DRAFT 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

19131600

February 2020

Distribution List

1 e-copy - City of Ottawa

1 e-copy - Golder

Table of Contents

FIGURES

APPENDICES

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 65 m by 140 m. It is assumed that below grade excavations would extend to approximately 1 m below the founding slab to a depth of 7 to 9 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 a more detailed overview of the subsurface conditions encountered in the boreholes advanced during the current investigation. It should be noted that the shallow subsurface conditions noted on the borehole logs from the previous investigations may have changed since the boreholes were drilled, as such only auger refusal/bedrock depths 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 x 10^{-5}
13-4	Fill/Glacial Till	--	--	February 22, 2013	6 x 10^{-5}
13-6	Bedrock	--	--	February 22, 2013	1 x 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 x 10^{-6}
W-060	Fill/Glacial Till	3.51	57.72	January 20, 2011	5 x 10^{-6}
W-062	Glacial Till	2.58	60.37	January 20, 2011	1 x 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). 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 is provided under separate cover.

5.1 Site Grading

It is understood that, as currently proposed, the design finished grades will generally remain unchanged.

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 7 to 9 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 55.0 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 total and differential settlement values of 25 and 19 mm, respectively.

It should be noted that 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 Steel H-Pile or Steel Pipe Pile Foundations

5.2.2.1 Founding Elevations

Should the above preliminary bearing resistance not be sufficient for the design of the structure, or should the structure not contain the deep underground parking, the proposed structure may be supported on closed-ended steel pipe piles or steel H-piles driven to refusal on the underlying bedrock.

Based on the borehole results from this investigation and previous studies, the following table provides an overview of the expected elevations of the bedrock surface within the vicinity of the building.

Approximate Location	Borehole Number	Approximate Bedrock Surface Elevation (m)
Northwest Corner of Building	W-062	57.1
Northeast Corner of Building	T-1	59.2
	T-2	58.7
	T-74	57.1
	W-062	57.1
Middle of Building	14-601	48.9
	14-602	51.7
	T-75	50.7
	13-6	50.8
	W-060	52.1
	13-5	51.3
Southwest Corner of Building	W-059	51.8
	13-4	51.6
	14-603	53.0

As an alternative to driven piles (i.e. H-piles and/or closed-ended pipe piles), the use of an open-ended drilled pile advanced into the bedrock could also be considered. This pile type requires a specialized contractor and is generally more expensive than driven piles, but the use of drilled piles greatly reduces the risk of pile deflections, pile damage and piles ‘hanging up’ in the glacial till. The drilled pipe piles should be advanced to a minimum embedment depth of 1.5 m into the bedrock.

5.2.2.2 Axial Geotechnical Resistance

For an HP 310x110 pile driven to found on the limestone bedrock, the factored axial geotechnical resistance at ULS may be taken as 1,800 kN. Serviceability Limit States (SLS) resistances do not apply to piles founded on the limestone bedrock, since the SLS resistance for 25 mm of settlement is greater than the factored axial geotechnical resistance at ULS. It should be noted that pre-drilling may be required to advance the piles through the lower, very dense portions of the till if piles driven to bedrock are considered.

The preliminary ULS pile capacities discussed herein have been based on semi-empirical analyses using laboratory and in-situ test data and incorporate a geotechnical resistance factor of 0.4. Higher resistance values (0.5 for Pile Driver Analyzer or 0.6 for static pile load test methods) can be used where a field testing program is completed.

Pile installation should be in accordance with OPSS 903 *(Construction Specification for Deep Foundations).* For driven piles, the drawings should incorporate the appropriate note stating that the piles (both H-piles and pipe piles) should be equipped with pile points (e.g. Titus Standard H Point, or similar) and should be driven to bedrock. The pile points will provide additional protection to the pile tips against damage from boulders during driving, and they will also provide some penetration into the underlying bedrock. For piles driven to refusal on bedrock, and as described in OPSS 903, it is a generally accepted practice to reduce the hammer energy after abrupt peaking is met on the bedrock surface, and to then gradually increase the energy over a series of blows to seat the pile.

As a result of the two levels of underground basement, it is possible that some of the piles will be very short (i.e., less than 3 m in length). The piles should be at least 3 m in length to provide sufficient lateral confinement from the surrounding soils. In areas where the bedrock is less than 3 m below the pile caps, the piles should be pre-drilled into the bedrock to provide at least 3 m in length, or a spread footing placed directly onto the glacial till or bedrock surface could be used at these locations.

5.3 Impacts to Existing Structures

It is understood that the existing CSST tunnel crosses beneath the proposed development. Detailed information regarding the CSST has not been provided as part of this assignment, however 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).

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 outlined by the CSST team which may be up to 10 metres from the side of the pipe to avoid additional stresses from the deep foundations being imposed onto the tunnel. 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 existing collector sewer.

It is also understood that 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 5.8 below.

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 2012 Ontario Building Code (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 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.

5.7 Garage Excavation and Groundwater Control

It is understood that the two levels of underground garage parking will extend about 7 to 9 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 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 (i.e. 3.8 mbgs). It is understood that the proposed excavation will be about 130 m by 50 m in plan and will be founded at an elevation of about 54.3 masl (i.e. about 8 m below the average ground surface). The hydraulic conductivity of the glacial till was determined to be as high as $6x10^{-7}$ m/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 m below ground surface (mbgs) and a glacial till hydraulic conductivity of $6x10^{-7}$ m/s. The rate of groundwater inflow into the proposed excavation is estimated to be between approximately 212,000 L/day and 32,000 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 15 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 650,000 litres of direct precipitation, assuming all overland flow is diverted 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. 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. Based on a conservative estimate of the cumulative daily groundwater and stormwater volumes to be managed during construction as described, EASR registration may be required.

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 5.8.

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.

5.8 Temporary Building Excavation Shoring

The excavation for the proposed structure will extend about 7 to 9 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 7 to 9 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 7 to 9 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.

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 light and heavy duty pavement designs are recommended for this project:

Material		Light Duty Pavement Thickness of Pavement Elements (mm)	Heavy Duty Pavement Thickness of Pavement Elements (mm)
Bituminous Concrete OPSS 1150	Superpave 12.5 mm	60	40
	Superpave 19.0 mm	-	50
Granular Material OPSS 1010	Granular A Base	150	150
	Granular B, Type II Subbase	300	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 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.

Sarah Ghadbane, P.Eng.	Chris Hendry, P.Eng.
Geotechnical Engineer	*Senior Geotechnical Engineer*

SG/hdw
https://golderassociates.sharepoint.com/sites/116386/project files/6 deliverables/19131600-001-r-rev0-central library draft geotechnical report-february 2020.docx

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

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

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client, **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.

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

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

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

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

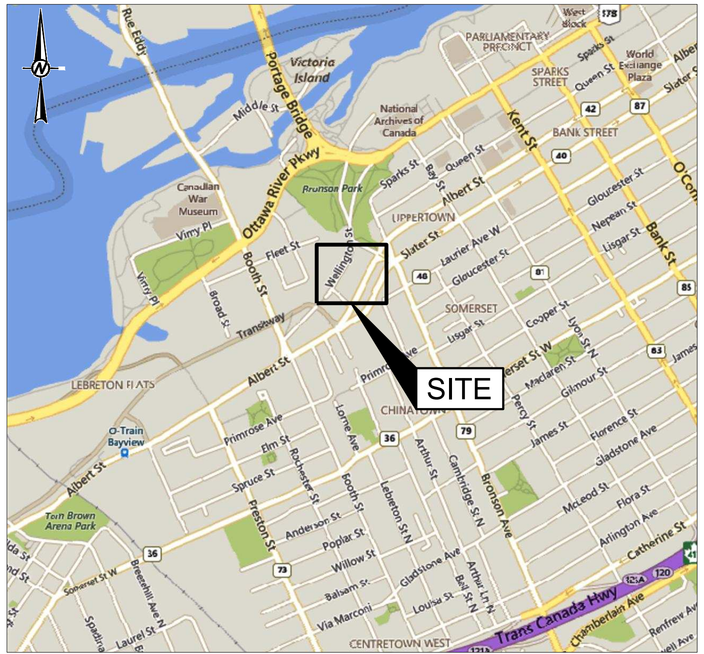
Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

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

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

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

KEY MAP



SCALE 1:25,000

LEGEND

⊕	APPROXIMATE BOREHOLE LOCATION, CURRENT INVESTIGATION
●	BOREHOLE LOCATION, PREVIOUS INVESTIGATIONS
▥	CSST ALIGNMENT
A/2	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

DRAFT

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	CRG
APPROVED	----

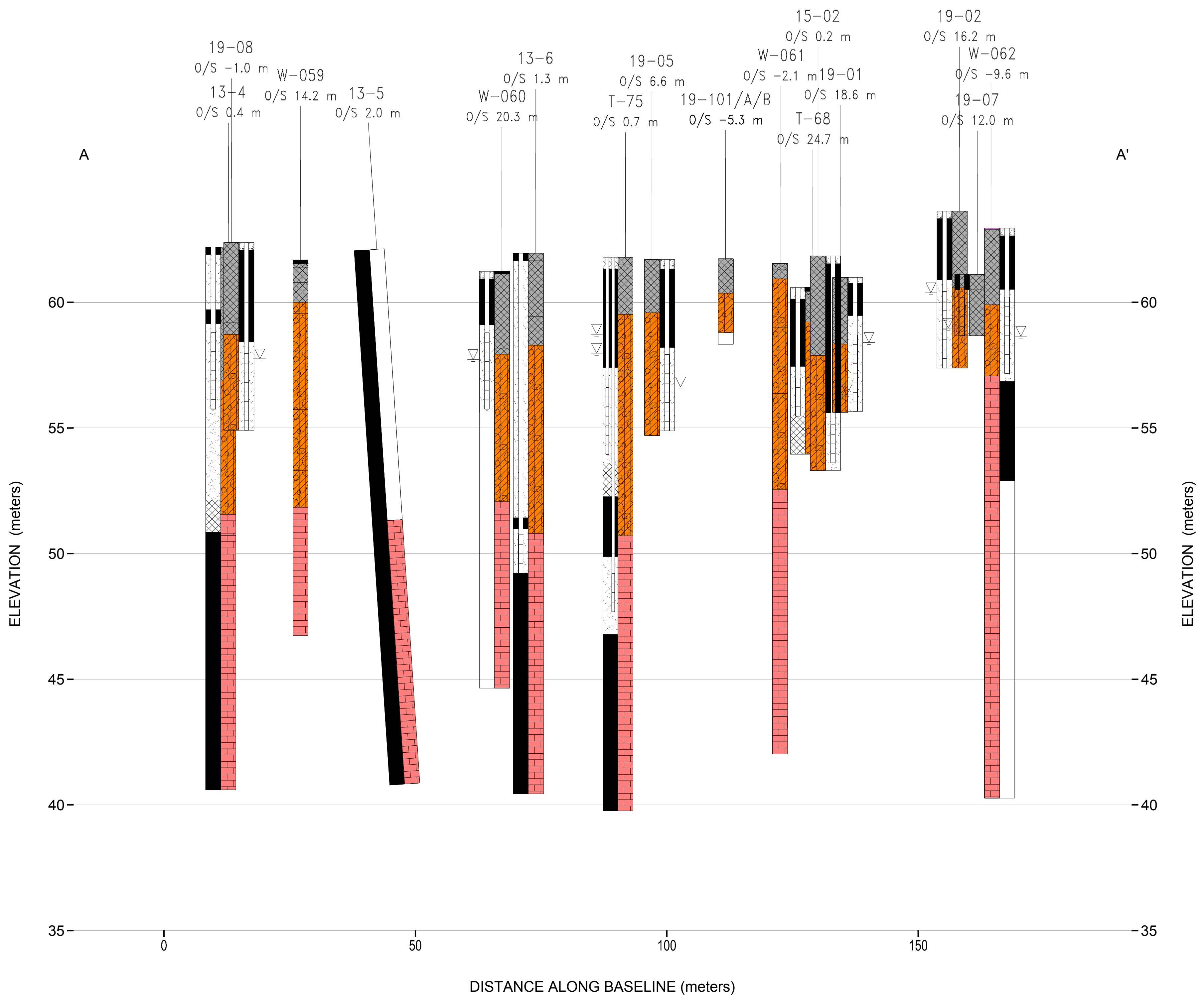
PROJECT NO.	CONTROL	REV.	FIGURE
19131600	0001	A	1

Path: \\golder.gds\gal\ottawa\Active\Spatial_IM\CityofOttawa\CentralLibrary\99_PROJ\19131600_CityofOttawa_Geotech\40_PROD\0001_GeotechInvestigation\ | File Name: 19131600-0001-BG-0001.dwg | Last Edited By: zsauve Date: 2020-01-23 Time:2:16:17 PM | Printed By: ZSauve Date: 2020-01-23 Time:2:16:28 PM

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25 mm

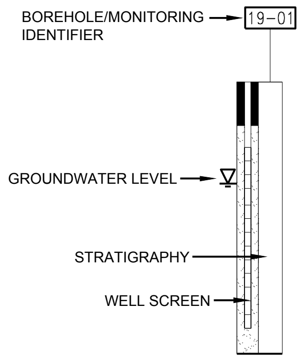
0



LEGEND

⊕ APPROXIMATE BOREHOLE LOCATION, CURRENT INVESTIGATION

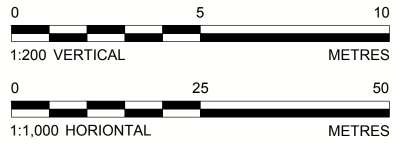
● BOREHOLE LOCATION, PREVIOUS INVESTIGATIONS



SUBSURFACE STRATIGRAPHY

■	ASPHALTIC CONCRETE	▨	GLACIAL TILL
▤	TOPSOIL	▦	LIMESTONE BEDROCK
▩	FILL		

DRAFT



CLIENT
CITY OF OTTAWA

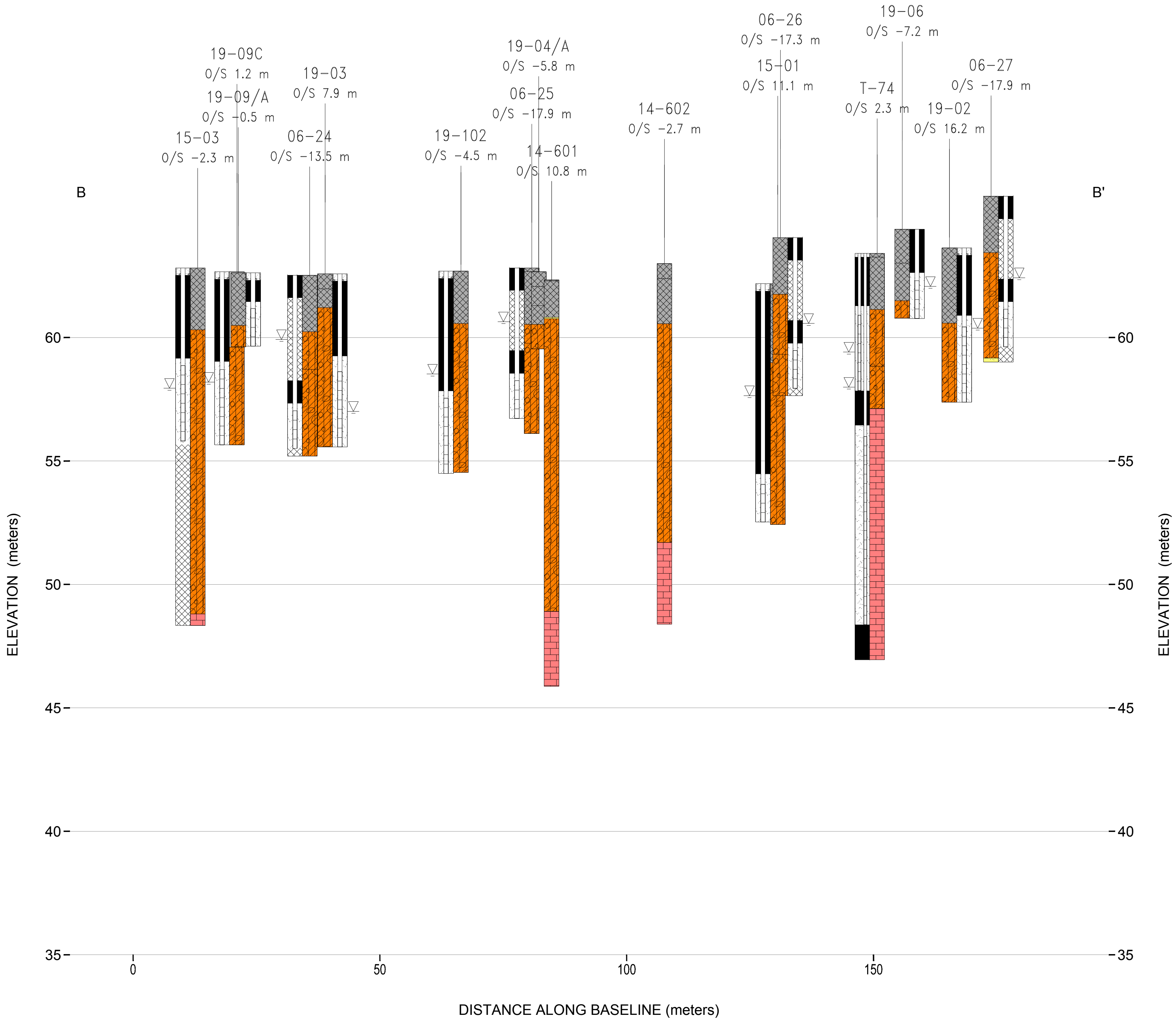
PROJECT
GEOTECHNICAL INVESTIGATION
CENTRAL LIBRARY
OTTAWA, ONTARIO

TITLE
CROSS-SECTION A-A'

CONSULTANT
GOLDER

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

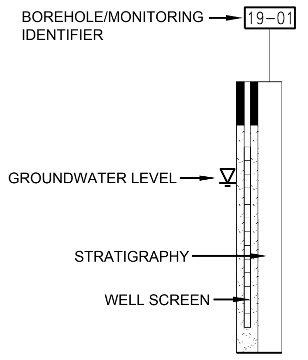
PROJECT NO.	CONTROL	REV.	FIGURE
19131600	0001	A	2



LEGEND

⊕ APPROXIMATE BOREHOLE LOCATION, CURRENT INVESTIGATION

● BOREHOLE LOCATION, PREVIOUS INVESTIGATIONS



SUBSURFACE STRATIGRAPHY

■	ASPHALTIC CONCRETE	▨	SAND
▨	TOPSOIL	▨	GLACIAL TILL
▨	FILL	▨	LIMESTONE BEDROCK

DRAFT

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

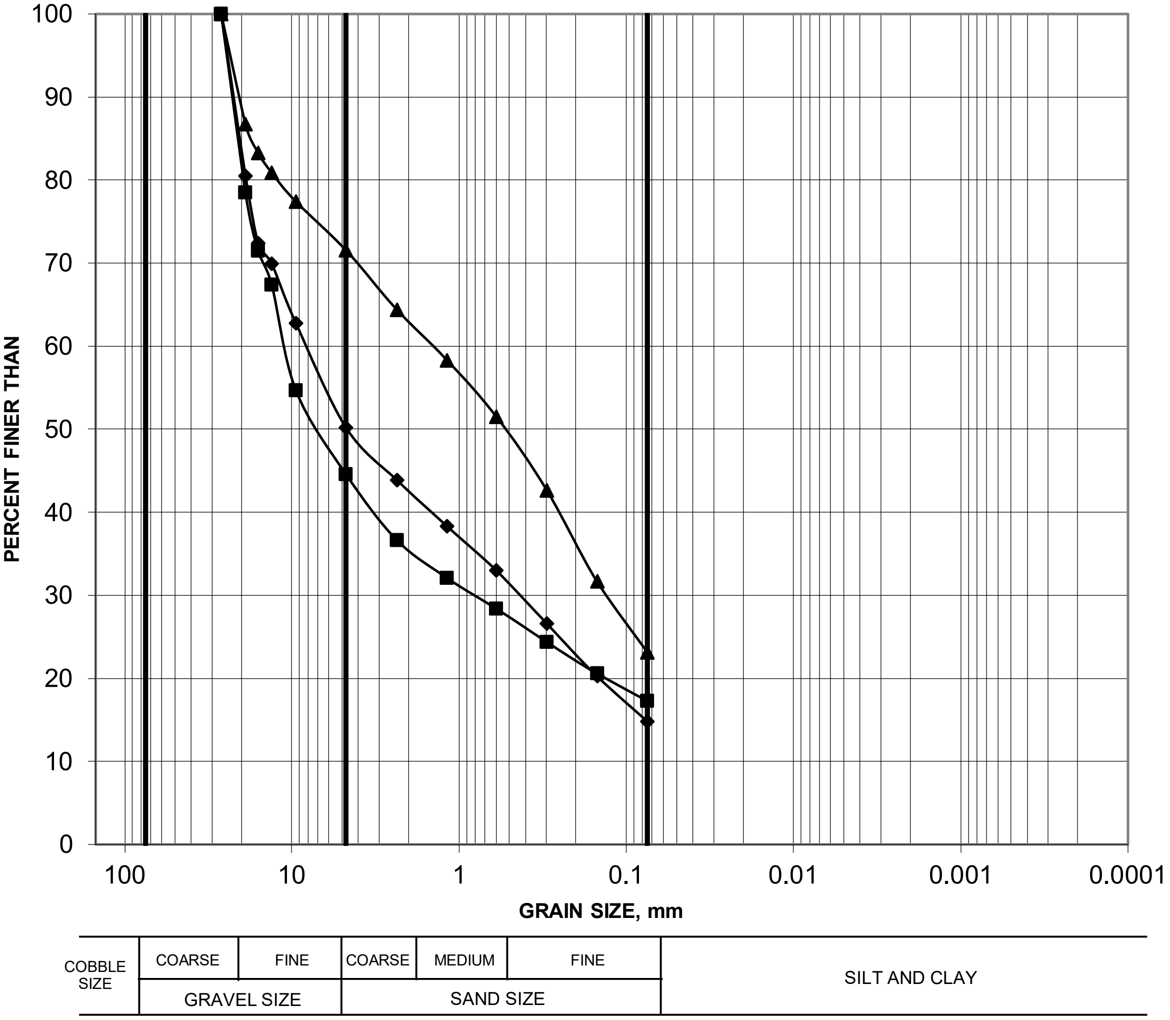
YYYY-MM-DD	2020-01-23
DESIGNED	----
PREPARED	ZS
REVIEWED	----
APPROVED	----

PROJECT NO.	CONTROL	REV.	FIGURE
19131600	0001	A	3

GRAIN SIZE DISTRIBUTION

FIGURE 4

FILL



			Constituents (%)			
Borehole	Sample	Depth (m)	Gravel	Sand	Silt	Clay
■ 19-01	1	0.00-0.61	55	28	17	
◆ 19-09	3	1.52-2.13	50	35	15	
▲ 19-102	2	0.76-1.37	28	49	23	

GOLDER

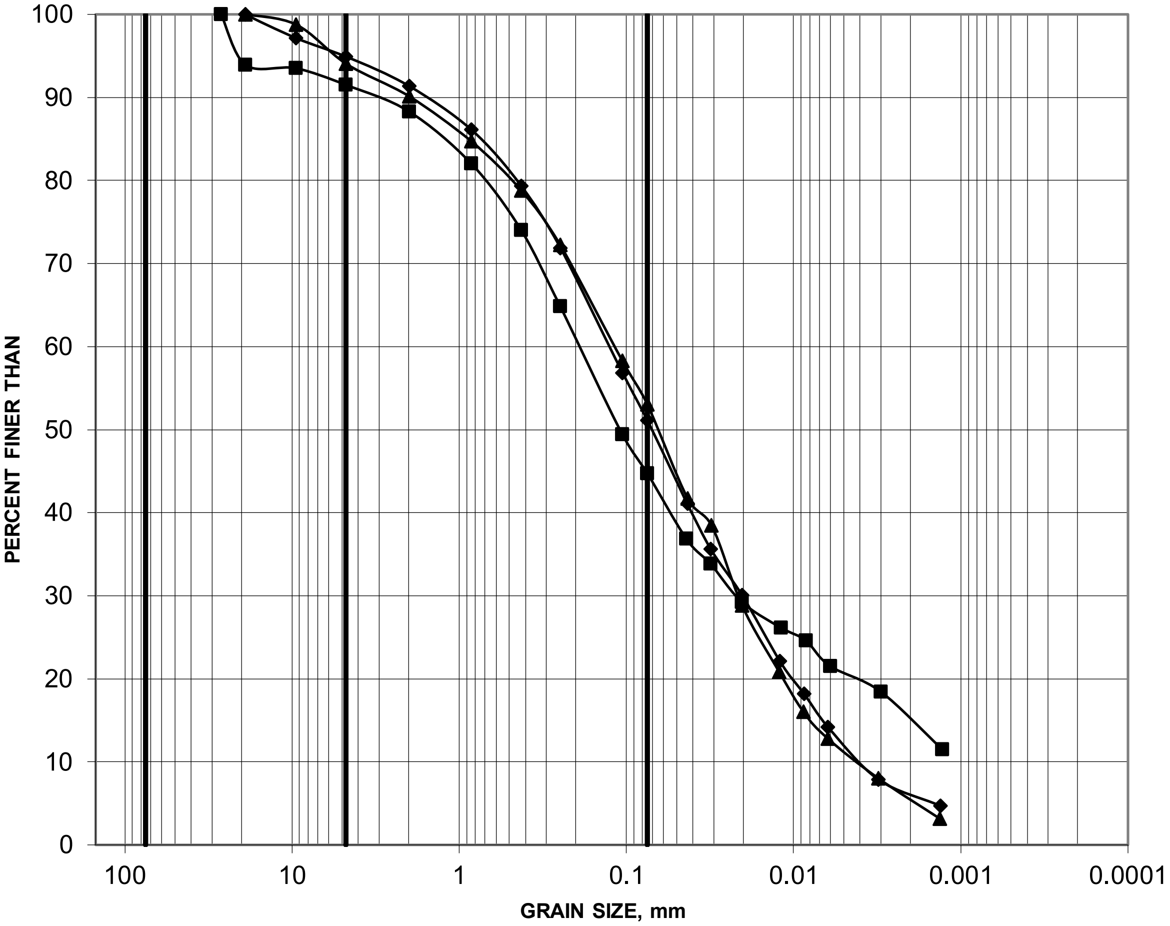
Project: 19131600

C:\Users\mireland\Golder Associates\Ottawa Geotech Lab - Documents\Active\2019\19131600\Figures\

Created by: MI
Checked by: GM

GRAIN SIZE DISTRIBUTION	FIGURE 5

GLACIAL TILL



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY
	GRAVEL SIZE		SAND SIZE			

				Constituents (%)			
Borehole		Sample	Depth (m)	Gravel	Sand	Silt	Clay
■	19-02	6	3.81-4.42	8	47	30	15
◆	19-03	5	2.50-3.05	5	44	45	6
▲	19-05	7	4.57-5.18	6	41	48	5

Project: 19131600

C:\Users\mireland\Golder Associates\Ottawa Geotech Lab - Documents\Active\2019\19131600\Figures\

Created by: MI

Checked by: GM

APPENDIX A

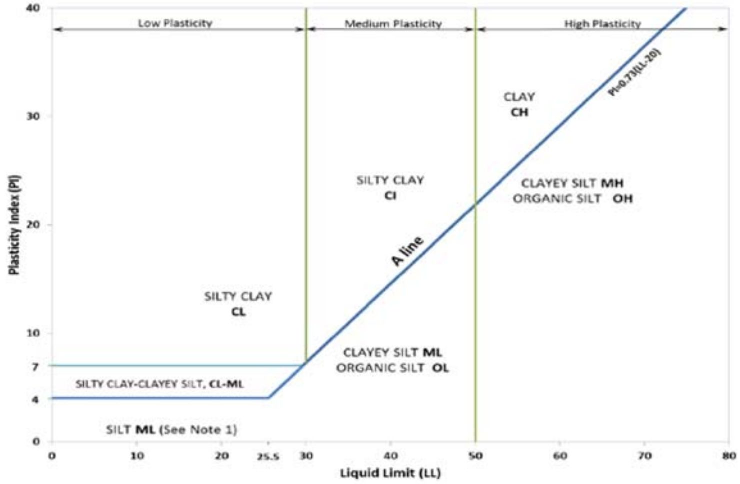
Borehole Logs – Current Investigation

METHOD OF SOIL CLASSIFICATION

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

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

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



Note 1 – Fine grained materials with PI and LL that plot in this area are named (ML) SILT with slight plasticity. Fine-grained materials which are non-plastic (i.e. a PL cannot be measured) are named SILT.
Note 2 – For soils with <5% organic content, include the descriptor "trace organics" for soils with between 5% and 30% organic content include the prefix "organic" before the Primary name.

Dual Symbol — A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC and CL-ML.
For non-cohesive soils, the dual symbols must be used when the soil has between 5% and 12% fines (i.e. to identify transitional material between "clean" and "dirty" sand or gravel.
For cohesive soils, the dual symbol must be used when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart (see Plasticity Chart at left).

Borderline Symbol — A borderline symbol is two symbols separated by a slash, for example, CL/CI, GM/SM, CL/ML.
A borderline symbol should be used to indicate that the soil has been identified as having properties that are on the transition between similar materials. In addition, a borderline symbol may be used to indicate a range of similar soil types within a stratum.

ABBREVIATIONS AND TERMS USED ON RECORDS OF BORHEOLES 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.).

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
FS	Foil sample
GS	Grab Sample
RC	Rock core
SC	Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size
TP	Thin-walled, piston – note size
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 - 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 overburden pressure effects.
2. Definition of compactness terms are based on SPT-'N' ranges as provided in Terzaghi, Peck and Mesri (1996) and correspond to typical average N_{60} values. Many factors affect the recorded SPT-'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), groundwater conditions, and grainsize. As such, the recorded SPT-'N' value(s) should be considered only an approximate guide to the compactness term. 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 = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

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

PROJECT: 19131600

RECORD OF BOREHOLE: 19-01

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)	SAMPLES NUMBER	SAMPLES 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
				4	SS	3		
		(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					
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								

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

PROJECT: 19131600

RECORD OF BOREHOLE: 19-02

SHEET 1 OF 1

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

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 METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE / SHEAR STRENGTH	HYDRAULIC CONDUCTIVITY / WATER CONTENT PERCENT	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				
					3	SS	11				Bentonite Seal
2					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				57.38 6.25	9	SS	>50				
		End of borehole Sampler Refusal									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

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 METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES 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		
1		(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 ▽
6				10	RC	DD		
				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								

DEPTH SCALE

1 : 50

GOLDER

LOGGED: DG

CHECKED: CRG

PROJECT: 19131600

RECORD OF BOREHOLE: 19-04

SHEET 1 OF 1

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	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m
		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
1		FILL - (SM) SILTY SAND, some gravel; grey, contains brick and ash; non-cohesive, moist, loose	▩	62.06 0.60	2	SS	7
		(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							

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

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

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

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

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE
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			SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3}	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.30m	SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80		
		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							
				61.97							
		End of Borehole Auger Refusal		0.69							
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

DEPTH SCALE

1 : 50

GOLDER

LOGGED: DG

CHECKED: CRG

PROJECT: 19131600

RECORD OF BOREHOLE: 19-04B

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

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 METRES	BORING METHOD	DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	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		
		End of Borehole Auger Refusal		59.00 3.66					

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: 19-05

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

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 METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
		GROUND SURFACE	61.71
0	Wash Boring HW Casing	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
2		(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
7		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	

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

PROJECT: 19131600

RECORD OF BOREHOLE: 19-06

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	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	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	3	SS	7	Silica Sand
2				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				WL in screen measured at 2.31 mbgs (Elev. 62.07) on Dec. 10, 2019
4							
5							
6							
7							
8							
9							
10							

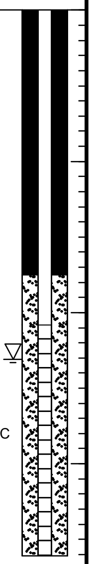
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

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

ADDITIONAL LAB. TESTING



DEPTH SCALE

1 : 50

GOLDER

LOGGED: DG

CHECKED: CRG

PROJECT: 19131600

RECORD OF BOREHOLE: 19-07

SHEET 1 OF 1

LOCATION: N 5030990.5 ;E 366645.3

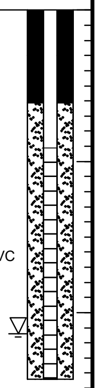
BORING DATE: December 2, 2019

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	SAMPLES TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		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					4	SS	>50				
		End of Borehole Auger Refusal		58.67 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

PROJECT: 19131600

RECORD OF BOREHOLE: 19-08

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

SOIL PROFILE

DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	62.38
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
FILL - (SP) SAND, fine to medium, some silt; brown; non-cohesive, moist, compact	59.18 3.20
(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
End of Borehole	54.91 7.47

SAMPLES

NUMBER	TYPE	BLOWS/0.3m
1	SS	55
2	SS	37
3	SS	29
4	SS	8
5	SS	13
6	SS	91
7	SS	>50
8	SS	>100
9	SS	91
10	SS	72

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

Flush Mount Casing

Bentontie Seal

Silica Sand

32 mm Diam. PVC #10 Slot Screen

WL in screen measured at 4.63 mbgs (Elev. 57.75) on Dec. 10, 2019

DEPTH SCALE
1 : 50

GOLDER

LOGGED: JS
CHECKED: CRG

PROJECT: 19131600

RECORD OF BOREHOLE: 19-09

SHEET 1 OF 1

LOCATION: N 5030839.9 ;E 366615.3

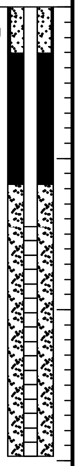
BORING DATE: November 20, 2019

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	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		62.62							
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				60.49 2.13							32 mm Diam. PVC #10 Slot Screen
		(SM) SILTY SAND, some gravel; grey brown, contains cobbles and boulders (GLACIAL TILL); non-cohesive, wet, very dense			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

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											
				60.79							
		End of Borehole Auger Refusal		1.83							
2											
3											
4											
5											
6											
7											
8											
9											
10											

MIS-BHS 001 19131600.GPJ GAL-MIS.GDT 20-2-18 ZS

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	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		62.62							
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

PROJECT: 19131600

RECORD OF BOREHOLE: 19-09C

SHEET 1 OF 1

LOCATION: N 5030840.5 ;E 366613.6

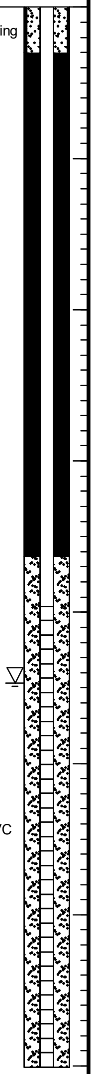
BORING DATE: November 27, 2019

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

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	Wash Boring HQ Casing	No Sampling - Alternate to 19-09 advanced to obtain samples below previous refusal		0.00							Flush Mount Casing
1											
2											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
4					3	SS	69				
					4	RC	DD				
5					5	SS	>50				32 mm Diam. PVC #10 Slot Screen
					6	SS	>50				
6					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
8											
9											
10											



DEPTH SCALE
1 : 50

GOLDER

LOGGED: DG
CHECKED: CRG

PROJECT: 19131600

RECORD OF BOREHOLE: 19-101

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	SAMPLES TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} / WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		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			SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH nat V. + Q - ● Cu, kPa rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.30m				
		GROUND SURFACE		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											

DEPTH SCALE

1 : 50

GOLDER

LOGGED: DG

CHECKED: CRG

PROJECT: 19131600

RECORD OF BOREHOLE: 19-101B

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	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		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							
1											
2											
3											
		End of Borehole Auger Refusal		58.33 3.40							
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

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

BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
	GROUND SURFACE	62.69					
Power Auger 200 mm Diam. (Hollow Stem)	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
			2	SS	10	M	
			3	SS	9		
	(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
			5	SS	68		
			6	SS	53		▽
			7	SS	59		Silica Sand
			8	SS	>100		
			9	SS	60		32 mm Diam. PVC #10 Slot Screen
			10	SS	65		
			11	SS	80		
	End of Borehole Auger Refusal	54.54 8.15					WL in screen measured at 4.17 mbgs (Elev. 58.52) on Dec. 10, 2019

DEPTH SCALE

1 : 50

GOLDER

LOGGED: DG

CHECKED: CRG

APPENDIX B

Borehole Logs and Results of UCS Testing - Previous Investigation

PROJECT: 10-1121-0068

RECORD OF DRILLHOLE: T-1

SHEET 1 OF 4

LOCATION: N 5030996.80 ;E 366695.16

INCLINATION: -68° AZIMUTH: 141°

DRILLING DATE: 03/05/2010

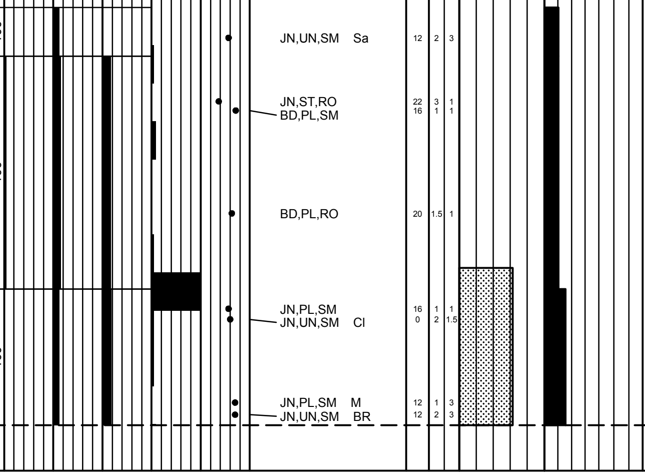
DRILL RIG: CME75

DRILLING CONTRACTOR: Downing

DATUM: Geodetic

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

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	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									
7	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		59.22 6.99							
					1	100	JN,UN,SM Sa	12	2	3	
8					2	100	JN,ST,RO BD,PL,SM	22 16	3 1	1 1	
							BD,PL,RO	20	1.5	1	
9					3	100	JN,PL,SM JN,UN,SM Cl	16 0	1 2	1 1.5	
							JN,PL,SM M JN,UN,SM BR	12 12	1 2	3 3	
10		CONTINUED NEXT PAGE									



DEPTH SCALE

1 : 50

Golder Associates

LOGGED: DWM/CP

CHECKED: MJT

PROJECT: 10-1121-0068

RECORD OF DRILLHOLE: T-1

SHEET 2 OF 4

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

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN
		--- *CONTINUED FROM PREVIOUS PAGE* ---			
10	Rotary Drill HQ Core			3	100
		Fresh to slightly weathered, medium bedded, fine grained, strong LIMESTONE	55.90 10.58		
11				4	100
12					
13				5	100
14				6	100
15					
16				7	100
17		- Clay gouge, soft clay with pieces of broken shale		8	100
18					
19				9	100
			47.36 19.79	10	100
20		*CONTINUED NEXT PAGE*			

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); HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8} 10^{-6} 10^{-4} 10^{-2}); WEATHERING INDEX (W1 W2 W3 W4 W5 W6); NOTES

DISCONTINUITY DATA

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			0.75
BD,PL,SM	20	1	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

1 : 50

Golder Associates

LOGGED: DWM/CP

CHECKED: MJT

PROJECT: 10-1121-0068

RECORD OF DRILLHOLE: T-1

SHEET 3 OF 4

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 %, SOLID CORE %; 80 60 40 20) | R.Q.D. % (80 60 40 20) | FRACT. INDEX PER 0.25m (5 10 15 20) | DISCONTINUITY DATA: DIP w.r.t. CORE AXIS (0 30 60 90), TYPE AND SURFACE DESCRIPTION, Jcon, Jr, Ja | HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8} 10^{-6} 10^{-4} 10^{-2}) | WEATHERING INDEX (W1 W2 W3 W4 W5 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
25	- Pyritization along calcite veins	
27.5	- 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			

30

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

LOGGED: DWM/CP
CHECKED: MJT

PROJECT: 10-1121-0068

RECORD OF DRILLHOLE: T-1

SHEET 4 OF 4

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

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	DISCONTINUITY DATA DIP w.r.t. CORE AXIS 0 30 60 90	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-8} 10^{-6} 10^{-4} 10^{-2}	WEATHERING INDEX W1 W2 W3 W4 W5 W6	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

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

PROJECT: 10-1121-0068

RECORD OF DRILLHOLE: T-2

SHEET 1 OF 4

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.	TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja
		GROUND SURFACE	66.32					
0	Wash Boring HW Casing	OVERBURDEN (no recovery)	0.00					
8	Rotary Drill HQ Core		58.72 8.09	1	HVN,, Ca			0.75
					JN,UN,SM		2	1
					BD,UN,SM Cl	12	2	3
					BD,UN,SM Cl	12	2	3
9				2	BD,PL,SM	16	1	1
					BD,UN,SM Ca		2	2
					JN,UN,SM Cl	12	2	3
					BD,CU,RO	22	3	1
10					BD,PL,SM	16	1	1

Column headings: 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; SYMBOLIC LOG; FLUSH RETURN; HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-8} 10^{-6} 10^{-4} 10^{-2}; WEATHERING INDEX W1 W2 W3 W4 W5 W6; NOTES

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

LOGGED: CP
CHECKED: MJT

PROJECT: 10-1121-0068

RECORD OF DRILLHOLE: T-2

SHEET 2 OF 4

LOCATION: N 5030988.22 ;E 366705.01

DRILLING DATE: 06/05/2010

DATUM: Geodetic

DRILL RIG: CME75

INCLINATION: -70° AZIMUTH: 270°

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 %, 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 W2 W3 W4 W5 W6) | NOTES

--- CONTINUED FROM PREVIOUS PAGE ---

Drilling record: Rotary Drill, HQ Core

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

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

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

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: CP
CHECKED: MJT

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

PROJECT: 10-1121-0068

RECORD OF DRILLHOLE: T-2

SHEET 3 OF 4

LOCATION: N 5030988.22 ;E 366705.01

DRILLING DATE: 06/05/2010

DATUM: Geodetic

DRILL RIG: CME75

INCLINATION: -70° AZIMUTH: 270°

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 % (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: 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

--- CONTINUED FROM PREVIOUS PAGE ---

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

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)

Flush return: 50 to 60

RUN No.	TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja
9	BD,UN,SM	20	2	1
	HVN,, Ca/Py			0.75
	BD,PL,RO Cl	12	1.5	3
	BD,PL,RO Cl	12	1.5	3
	BD,PL,RO Cl	12	1.5	3
10	BD,UN,SM	20	2	1
	BD,CU,RO	22	3	1
	BD,PL,RO	16	1.5	1
11	BD,UN,SM Py	16	2	2
	BD,CU,RO Py	20	3	2
	BD,PL,RO	16	1.5	1
	BD,PL,RO	16	1.5	1
12	BD,ST,SM	20	2	1
	BD,CU,SM	20	2	1
13	BD,UN,RO	22	3	1
	JN,CU,SM	20	2	1
	BD,PL,RO	16	1.5	1
14	BD,PL,RO Ca	12	1.5	2
	BD,PL,RO	16	1.5	1
	HVN,, Ca			0.75
15	BD,UN,SM	20	2	1
	BD,PL,RO	16	1.5	1

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: CP
CHECKED: MJT

PROJECT: 10-1121-0068

RECORD OF DRILLHOLE: T-2

SHEET 4 OF 4

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	Fresh, thinly bedded, grey, fine to medium grained, strong to very strong LIMESTONE interbedded with shale seams (2 to 40mm thick)	37.98 30.16	15						
						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										

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); HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8} 10^{-6} 10^{-4} 10^{-2}); WEATH-ERING INDEX (W1 W2 W3 W4 W5 W6)

DEPTH SCALE

1 : 50

LOGGED: CP

CHECKED: MJT

PROJECT: 10-1121-0222

RECORD OF BOREHOLE: T-68

SHEET 1 OF 1

LOCATION: N 5030967.29 ;E 366619.07

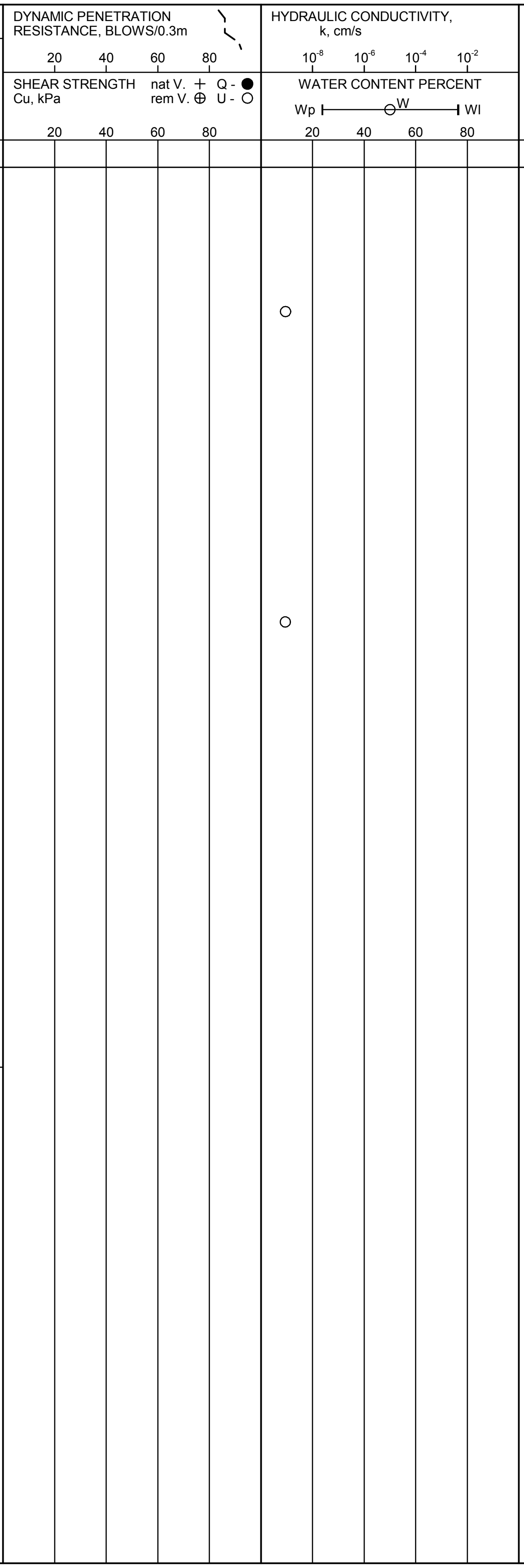
BORING DATE: September 1, 2011

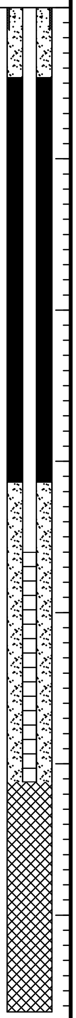
DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
		GROUND SURFACE	60.59				
0	Power Auger 200mm Diam. (Hollow Stem)	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				
1				1	50 DO	100	M
		Dense to very dense brown to grey brown SILTY SAND, some gravel, trace clay, with cobbles and boulders (GLACIAL TILL)	59.22 1.37				
				2	50 DO	43	
2							
				3	50 DO	47	
3							
				4	50 DO	54	MH
4				5	50 DO	>50	
				6	50 DO	>50	
5							
				7	50 DO	>50	
6				8	50 DO	>50	
				9	50 DO	>50	
		End of Borehole Auger Refusal	53.95 6.64				
7							
8							
9							
10							





DEPTH SCALE
1 : 50

Golder Associates

LOGGED: KS
CHECKED: SD

PROJECT: 10-1121-0222

RECORD OF BOREHOLE: T-74

SHEET 1 OF 1

LOCATION: N 5030956.27 ;E 366672.13

BORING DATE: April 4, 2011

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

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

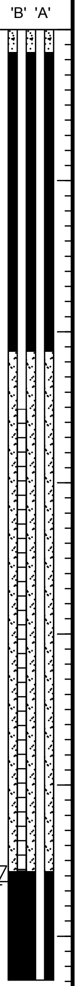
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

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

SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	WATER CONTENT	ADDITIONAL LAB. TESTING
GROUND SURFACE	63.41					
Grey crushed stone (FILL)	0.00					
Compact to dense brown sandy silt, trace gravel and clay (FILL)	0.15	1	A.S.			
		2	50 DO	20		
		3	50 DO	41		
Very dense brown SANDY SILT, trace gravel, with cobbles and sand layers (GLACIAL TILL)	61.13 2.28	4	50 DO	59		
		5	50 DO	55	○	MH
		6	50 DO	>100		
Very dense dark grey SANDY SILT, some gravel, trace clay, with cobbles (GLACIAL TILL)	58.84 4.57	7	50 DO	55		
		8	50 DO	57	○	MH
Borehole continued on RECORD OF DRILLHOLE T-74	57.12					



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

PROJECT: 10-1121-0222

RECORD OF DRILLHOLE: T-74

SHEET 1 OF 2

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), SOLID CORE % (80 60 40 20) | R.Q.D. % (80 60 40 20) | FRACT. INDEX PER 0.25m (5 10 15 20) | DISCONTINUITY DATA: DIP w.r.t. CORE AXIS (0 30 60 90), TYPE AND SURFACE DESCRIPTION, Jcon, Jr, Ja | HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8} 10^{-6} 10^{-4} 10^{-2}) | WEATHERING INDEX (W1 W2 W3 W4 W5 W6) | NOTES

Drilling record: Rotary Drill, HQ Core

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

BEDROCK SURFACE — 57.12

Elev./Depth: 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

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

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

LOGGED: JMR/DAC
CHECKED: MRR

PROJECT: 10-1121-0222

RECORD OF DRILLHOLE: T-74

SHEET 2 OF 2

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 'B' 'A'
		--- *CONTINUED FROM PREVIOUS PAGE* ---																
				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

OLRT-ROCK 1011210222-1300.GPJ GAL-MISS.GDT 12/16/11 JEM/JM

PROJECT: 10-1121-0222

RECORD OF BOREHOLE: T-75

SHEET 1 OF 2

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 | SAMPLES | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80) | HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-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: 0 to ~8.8 m Power Auger, 200mm Diam. (Hollow Stem); ~8.8 to 10 m Rotary Drill, HQ Core

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

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:

Flush mount protective casing set in Bentonite

Native Backfill

Bentonite Seal

▽

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

SHEET 2 OF 2

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	'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)	▨	50.71	14	50 DO	>50				W.L. in Screen at Elev. 58.73m on June 28, 2011
11		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

SHEET 1 OF 2

LOCATION: N 5030923.18 ;E 366623.23

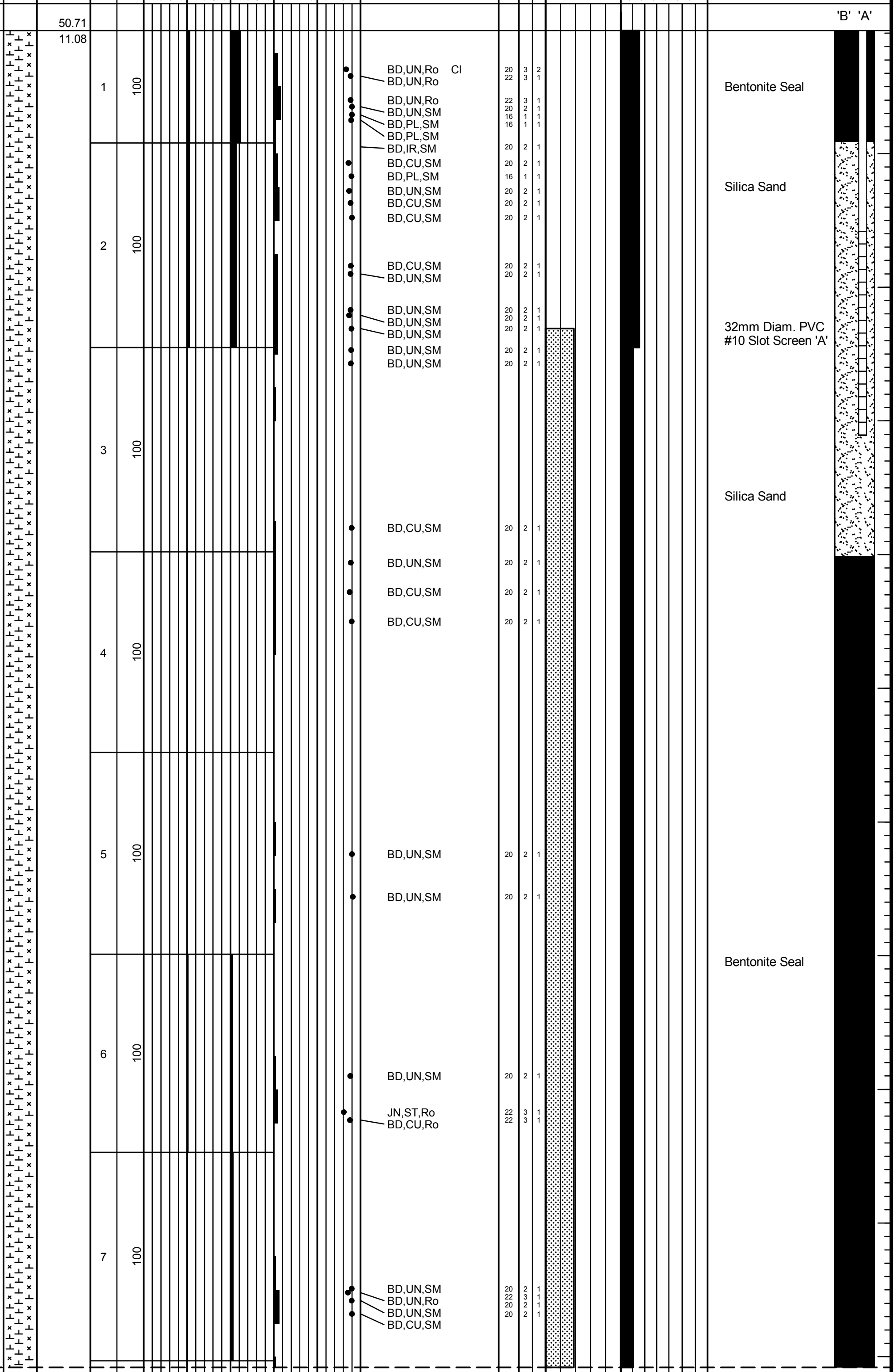
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: March 23-24, 2011
DRILL RIG: CME 75
DRILLING CONTRACTOR: Downing

DATUM: Geodetic

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

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: 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 — 50.71

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

Rotary Drill
HQ Core

RUN No.	FLUSH RETURN
1	100
2	100
3	100
4	100
5	100
6	100
7	100

TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja
BD,UN,Ro Cl	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

'B' 'A'

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

SHEET 2 OF 2

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

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	DISCONTINUITY DATA DIP w.r.t. CORE AXIS 0 30 60 90	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-8} 10^{-6} 10^{-4} 10^{-2}	WEATH-ERING INDEX W1 W2 W3 W4 W5 W6	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

PROJECT: 10-1121-0222

RECORD OF BOREHOLE: W-058

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

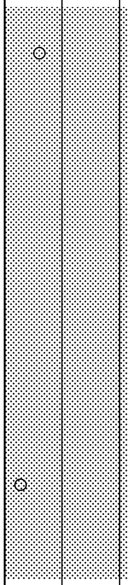
DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	ADDITIONAL LAB. TESTING	
		GROUND SURFACE		61.40					
0	Power Auger 200 mm Diam. (Hollow Stem)	Dense to very loose brown to grey to black silty sand, some gravel, trace to some reddish brick fragments, trace black cinders/asphalt, trace ash (FILL)	▨	0.00					Flush Mount Protective Casing set in Bentonite
1					1	50 DO	34		
2					2	50 DO	8		Bentonite Seal
					3	50 DO	7		
3		Compact to very dense brown to grey SANDY SILT, trace to some gravel, trace clay (GLACIAL TILL)		58.35 3.05	4	50 DO	18	M	Silica Sand
4					5	50 DO	81		
5					6	50 DO	50		
					7	50 DO	50		32mm Diam. PVC #10 Slot Screen
6					8	50 DO	50	MH	
				54.56	9	50 DO	50		W.L. in Screen at Elev. 57.69m on Jan. 20, 2011
7		Borehole continued on RECORD OF DRILLHOLE W-058							
8									
9									
10									

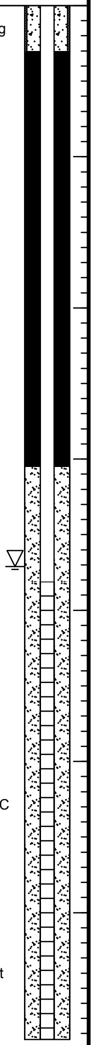
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

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

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

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





DEPTH SCALE

1 : 50

LOGGED: JC

CHECKED: MRR

PROJECT: 10-1121-0222

RECORD OF DRILLHOLE: W-058

SHEET 1 OF 1

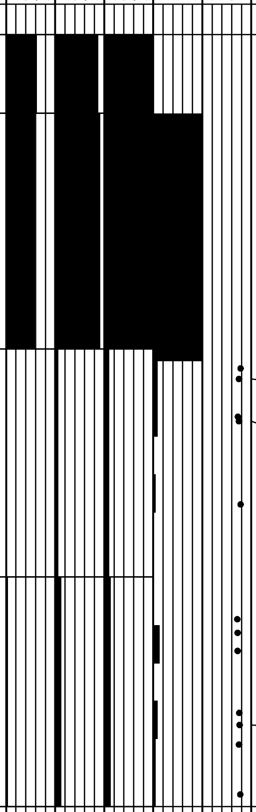
LOCATION: N 5030845.23 ;E 366541.33
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: October 18, 2010
DRILL RIG: CME 75
DRILLING CONTRACTOR: Downing

DATUM: Geodetic

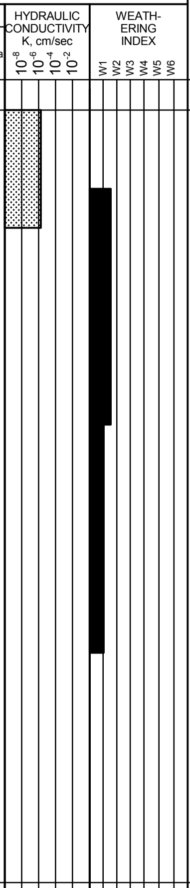
JN - Joint	BD - Bedding	PL - Planar	PO - Polished	BR - Broken Rock
FLT - Fault	FO - Foliation	CU - Curved	K - Slickensided	**NOTE:** For additional abbreviations refer to list of abbreviations & symbols.
SH - Shear	CO - Contact	UN - Undulating	SM - Smooth	
VN - Vein	OR - Orthogonal	ST - Stepped	RO -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

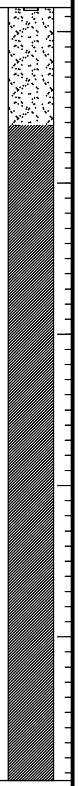
DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	NOTES
		BEDROCK SURFACE	54.56		
7	Rotary Drill HQ Core	Quartz (Boulder) - No recovery from 7.04m to 7.36m	6.84 54.04	C1	32mm Diam. PVC #10 Slot Screen Silica Sand
8		Fresh, medium bedded to irregular laminated, grey to dark grey, fine to medium grained, slightly porous, medium strong to strong LIMESTONE BEDROCK, interbedded with shale - Broken core from 7.36m to 8.02m - No recovery from 8.02m to 8.92m	7.36	C2	
9–10				C3	Grout
11		- Broken core from 11.33m to 11.44m	49.45	C4	
12		End of Drillhole	11.95		W.L. in Screen at Elev. 57.69m on Jan. 20, 2011



DISCONTINUITY DATA

TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja
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
JN,PL,SM	16	1	1
JN,CU,RO	22	3	1
JN,CU,RO	22	3	1
JN,CU,RO	22	3	1
JN,CU,SM Shale	20	2	2
JN,UN,RO Br	20	3	2
JN,PL,RO Br	16	1.5	2





DEPTH SCALE
1 : 50

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)

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

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	WATER CONTENT PERCENT	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						

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RI

CHECKED: MRR

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

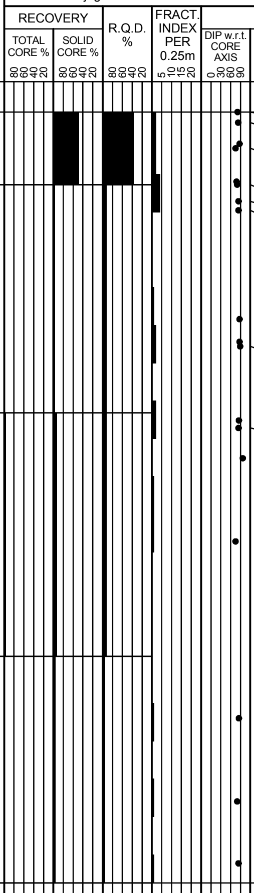
NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)
		BEDROCK SURFACE	51.84
10	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	9.84
			46.74 14.94
15		End of Drillhole	

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

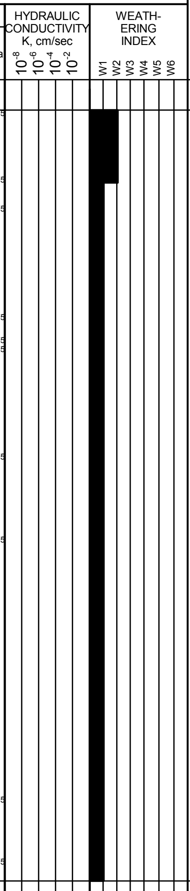
SYMBOLIC LOG

FLUSH RETURN



DISCONTINUITY DATA

RUN No.	TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja
1	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
2	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
3	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
4	BD,CU,SM Cl	12	1	3
	BD,CU,Ro/Sm	22	2	0.75
	BD,ST,Ro	22	3	0.75



NOTES

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

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

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

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	
	GROUND SURFACE	61.23					
0	ASPHALTIC CONCRETE	0.00					Flush Mount Protective Casing set in Bentonite
	Loose to dense brown sandy silt, trace medium sand layers (FILL)	0.10					
1			1	50 DO	9		Bentonite Seal
2			2	50 DO	35		
			3	50 DO	44		Silica Sand
3	Grey brown silty sand, trace gravel, some pieces of wood (FILL)	58.18 3.05	4	50 DO	>100		
	Very dense grey brown SILTY fine SAND, trace gravel (GLACIAL TILL)	57.93 3.30					∇
4			5	50 DO	78	MH	32mm Diam. PVC #10 Slot Screen
			6	50 DO	97		
5			7	50 DO	>100		Silica Sand
6			8	50 DO	>100		
7			9	50 DO	>100		
			10	50 DO	>100		Grout
8							
9							W.L. in Screen at Elev. 57.72m on Jan. 20, 2011
	Borehole continued on RECORD OF DRILLHOLE W-060	52.06					
10							

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: JD

CHECKED: MRR

PROJECT: 10-1121-0222

RECORD OF DRILLHOLE: W-060

SHEET 1 OF 1

LOCATION: N 5030910.36 ;E 366594.56

INCLINATION: -90° AZIMUTH: ---

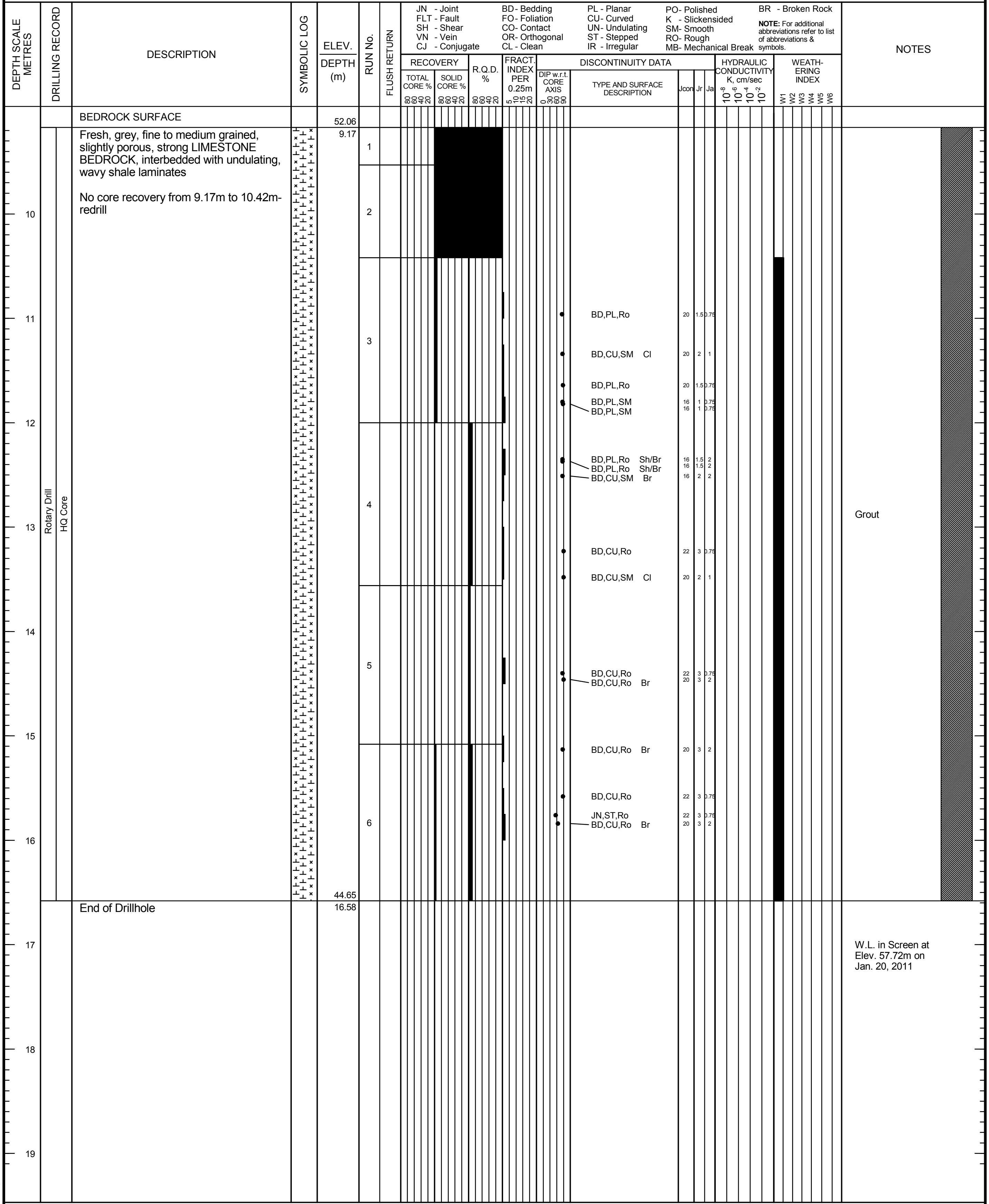
DRILLING DATE: November 24, 2010

DRILL RIG: CME 75

DRILLING CONTRACTOR: Downing

DATUM: Geodetic

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



DESCRIPTION	ELEV. DEPTH (m)
BEDROCK SURFACE	52.06
Fresh, grey, fine to medium grained, slightly porous, strong LIMESTONE BEDROCK, interbedded with undulating, wavy shale laminates No core recovery from 9.17m to 10.42m-redrill	9.17
	44.65
End of Drillhole	16.58

TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja
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
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
BD,CU,Ro	22	3	0.75
BD,CU,SM Cl	20	2	1
BD,CU,Ro	22	3	0.75
BD,CU,Ro Br	20	3	2
BD,CU,Ro Br	20	3	2
BD,CU,Ro	22	3	0.75
JN,ST,Ro	22	3	0.75
BD,CU,Ro Br	20	3	2

NOTES

Grout

W.L. in Screen at Elev. 57.72m on Jan. 20, 2011

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: JD

CHECKED: MRR

PROJECT: 10-1121-0222

RECORD OF BOREHOLE: W-061

SHEET 1 OF 1

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)

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 METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
0	GROUND SURFACE	61.55
	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
	Dense brown to grey brown SILTY SAND, some gravel, trace clay, with cobbles and sand seams (GLACIAL TILL) - Layer of cobbles at 1.22m	60.94 0.61
	Very dense grey brown to grey SILTY SAND, some gravel, trace clay, with cobbles and sand seams (GLACIAL TILL)	59.01 2.54
	Very dense grey SILTY SAND, some gravel, trace clay, with cobbles (GLACIAL TILL)	56.37 5.18
9	Borehole continued on RECORD OF DRILLHOLE W-061	52.54

SAMPLES NUMBER	TYPE	BLOWS/0.3m	HYDRAULIC CONDUCTIVITY	ADDITIONAL LAB. TESTING
3	GRAB	-		
1	50 DO	32		
2	50 DO	41		
4	50 DO	37		
5	50 DO	60		
6	50 DO	26	○	MH
7	50 DO	92		
8	50 DO	80		
9	50 DO	51	○	MH
10	50 DO	55		

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RI

CHECKED: MRR

PROJECT: 10-1121-0222

RECORD OF DRILLHOLE: W-061

SHEET 1 OF 2

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

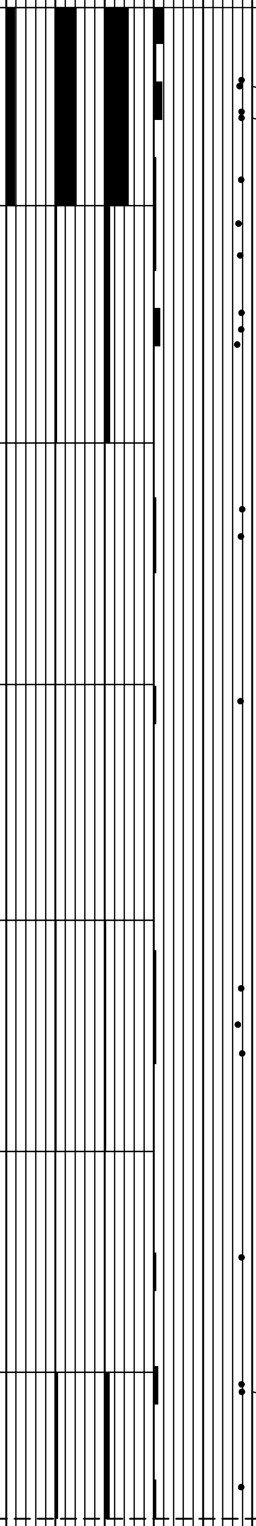
PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular

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

BR - Broken Rock

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

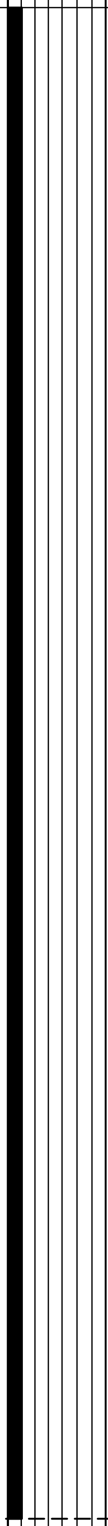
DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)
		BEDROCK SURFACE	52.54
	Rotary Drill HQ Core	Fresh to slightly weathered, medium brownish grey, fine to medium grained crystalline, non porous, thinly to medium bedded, strong, CALCARENITIC LIMESTONE, subordinate nodular limestone, minor 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
10			
11			
12			
13			
14			
15			
16			
17			
18		Fresh, medium to thickly bedded, grey, fine to medium grained, medium strong LIMESTONE BEDROCK, with thinly laminated black shale layers	43.51 18.04
19			
		CONTINUED NEXT PAGE	



DISCONTINUITY DATA

RUN No.	FLUSH RETURN	TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja
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
		BD,CU,RO Cl	12	1	4
C2		BD,CU,SM Cl	12	1	4
		BD,CU,SM Cl	12	1	4
		BD,CU,RO Ca	20	3	3
		BD,CU,SM Cl	12	1	4
		BD,CU,RO Cl	12	1	4
C3		BD,PL,RO Ca	16	1.5	2
		BD,UN,SM	20	2	1
C4		BD,UN,SM Fossils	16	2	2
C5		BD,UN,RO Br	20	3	0.75
		BD,UN,RO Br	20	3	0.75
		BD,PL,RO Cl	12	1	4
C6		BD,UN,SM	16	2	1
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

HYDRAULIC CONDUCTIVITY K, cm/sec
10^{-8} 10^{-6} 10^{-4} 10^{-2}



NOTES

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: RI
CHECKED: MRR

PROJECT: 10-1121-0222

RECORD OF DRILLHOLE: W-061

SHEET 2 OF 2

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)	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 ---																
	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	C7		■	■									■ W1	
		End of Drillhole		19.53														
20																		
21																		
22																		
23																		
24																		
25																		
26																		
27																		
28																		
29																		

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: RI
CHECKED: MRR

PROJECT: 10-1121-0222

RECORD OF BOREHOLE: W-062

SHEET 1 OF 1

LOCATION: N 5030983.21 ;E 366665.88

BORING DATE: October 19, 2010

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

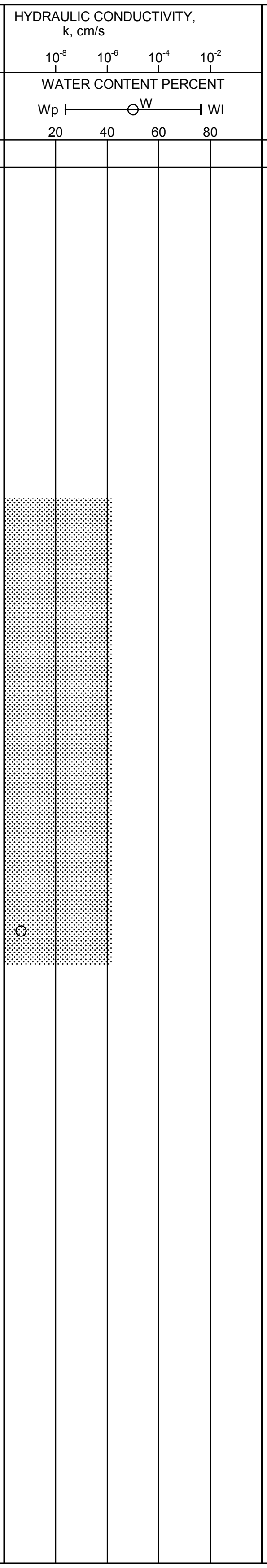
BORING METHOD: Power Auger 200 mm Diam. (Hollow Stem)

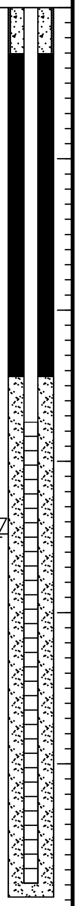
DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
	GROUND SURFACE	62.95
0	Black organic TOPSOIL	0.00
	Loose to dense miscellaneous red brick, broken cement (FILL)	0.05
3	Compact to very dense fine grey SILTY SAND, some gravel, trace clay (GLACIAL TILL)	59.90 3.05
		57.07
6	Borehole continued on RECORD OF DRILLHOLE W-062	

SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
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	MH

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

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




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

LOGGED: CC

CHECKED: MRR

PROJECT: 10-1121-0222

RECORD OF DRILLHOLE: W-062

SHEET 1 OF 2

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 | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH RETURN | RECOVERY: TOTAL CORE % / SOLID CORE % | R.Q.D. % | FRACT. INDEX PER 0.25m | DISCONTINUITY DATA | HYDRAULIC CONDUCTIVITY K, cm/sec | WEATHERING INDEX | NOTES

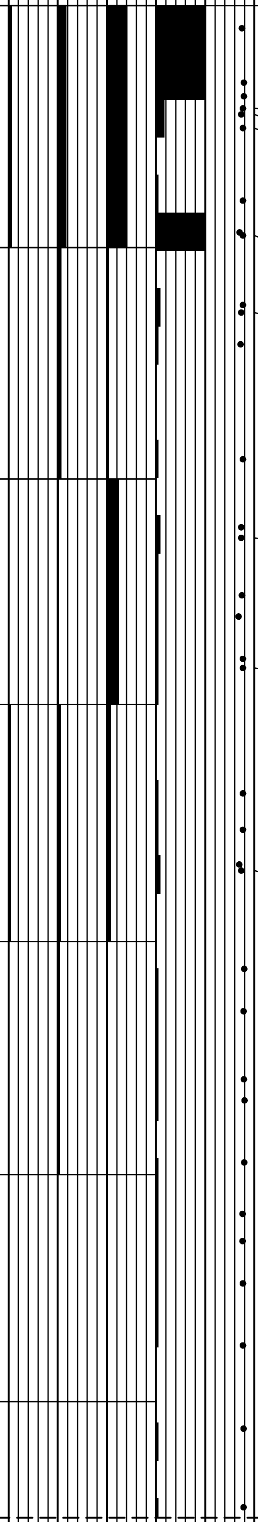
BEDROCK SURFACE — 57.07

5.88

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

Drilling record: Rotary Drill, HQ Core

Runs: C1, C2, C3, C4, C5, C6, C7



TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja
BD,CU,RO	20	3	1
BD,PL,RO	20	1.5	1
BD,CU,SM Cl	12	2	4
BD,CU,SM Cl	12	2	4
BD,ST,RO Br	20	3	2
BD,PL,RO Cl	12	1.5	4
BD,PL,SM Br	12	1	2
JN,ST,RO Cl/Sa	6	1	8
BD,PL,SM	12	1	1
BD,CU,RO	20	2	1
BD,PL,SM	12	1	1
BD,UN,RO	20	2	1
BD,PL,SM	16	1	3
BD,PL,RO	20	1.5	3
BD,PL,RO	12	1.5	1
BD,ST,RO	20	3	1
JN,CU,SM Ca	12	2	3
BD,CU,RO	20	3	2
BD,PL,SM Br	12	1	2
BD,PL,SM Br	12	1	2
BD,CU,RO	20	3	2
JN,CU,RO	20	3	2
BD,ST,RO	20	3	2
BD,PL,RO Br	12	1.5	2
BD,PL,RO Br	12	1.5	2
BD,CU,RO Ca	12	3	3
BD,PL,RO Br	16	1.5	2
BD,PL,SM Br	12	1	2
JN,CU,SM Br	16	2	2
BD,CU,SM	20	2	2
BD,PL,SM Br	12	1	2
BD,UN,RO Br	20	3	2
BD,PL,SM Br	12	1	2
BD,CU,SM Br	16	2	2

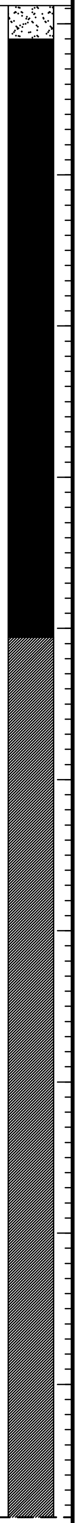
10^{-8} 10^{-6} 10^{-4} 10^{-2}

W1 W2 W3 W4 W5 W6

Silica Sand

Bentonite Seal

Grout



CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

LOGGED: CC
CHECKED: MRR

PROJECT: 10-1121-0222

RECORD OF DRILLHOLE: W-062

SHEET 2 OF 2

LOCATION: N 5030983.21 ;E 366665.88

DRILLING DATE: October 19, 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 % 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: 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

--- CONTINUED FROM PREVIOUS PAGE ---

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

Rotary Drill

HQ Core

RUN No.	TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja
C7	BD,PL,SM Br	12	1	2
	BD,PL,RO	16	1.5	2
C8	BD,PL,RO	16	1.5	1
	BD,CU,RO	16	3	1
	BD,CU,RO	20	3	1
	BD,CU,SM	16	2	1
	BD,PL,RO	16	2	1
C9	BD,UN,RO Br			
	BD,PL,SM Br	12	1	1
	BD,CU,RO Br	16	3	1
C10	BD,PL,SM Br	12	1	2
	BD,UN,RO	20	3	2
	BD,PL,RO Br	16	1.5	1
C11	BD,PL,SM Br	12	1	2

Grout

40.27
22.68

End of Drillhole

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

16
17
18
19
20
21
22
23
24
25

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: CC
CHECKED: MRR

PROJECT: 13-1121-0143

RECORD OF BOREHOLE: 13-3

SHEET 1 OF 4

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)

DESCRIPTION	ELEV. / DEPTH (m)
GROUND SURFACE	62.49
(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 - Becoming wet at 3.51 m depth - Becoming grey	60.97 1.52
(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

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

CONTINUED NEXT PAGE

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

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: KE
CHECKED: WAM/AJS

PROJECT: 13-1121-0143

RECORD OF BOREHOLE: 13-3

SHEET 2 OF 4

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

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: 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

PROJECT: 13-1121-0143

RECORD OF DRILLHOLE: 13-3

SHEET 3 OF 4

LOCATION: N 5030826.51 ;E 366567.39

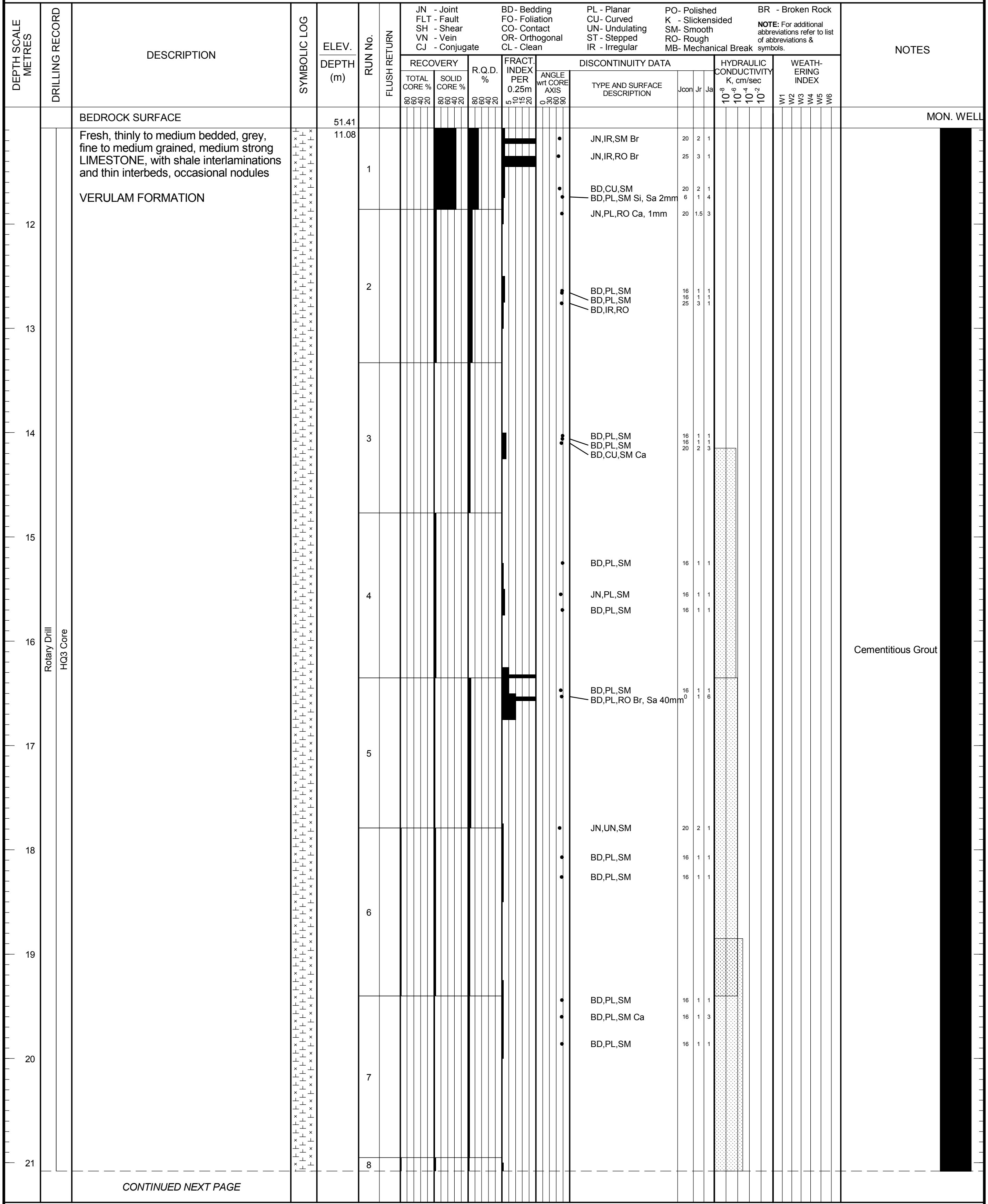
INCLINATION: -90° AZIMUTH: ---

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.



BEDROCK SURFACE — 51.41

11.08 — Fresh, thinly to medium bedded, grey, fine to medium grained, medium strong LIMESTONE, with shale interlaminations and thin interbeds, occasional nodules

VERULAM FORMATION

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

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: KE
CHECKED: WAM/AJS

PROJECT: 13-1121-0143

RECORD OF DRILLHOLE: 13-3

SHEET 4 OF 4

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 % 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	DISCONTINUITY DATA ANGLE wrt 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}	WEATH-ERING INDEX W1 W2 W3 W4 W5 W6	NOTES MON. WELL
		--- CONTINUED FROM PREVIOUS PAGE ---																
	Rotary Drill HQ3 Core			40.91	8						●	BD,PL,SM CL 2mm	6	1	8			Cementitious Grout
		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.		21.58														
22																		
23																		
24																		
25																		
26																		
27																		
28																		
29																		
30																		
31																		

DEPTH SCALE
1 : 50

LOGGED: KE
CHECKED: WAM/AJS

PROJECT: 13-1121-0143

RECORD OF BOREHOLE: 13-4

SHEET 1 OF 4

LOCATION: N 5030852.88 ;E 366587.26

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

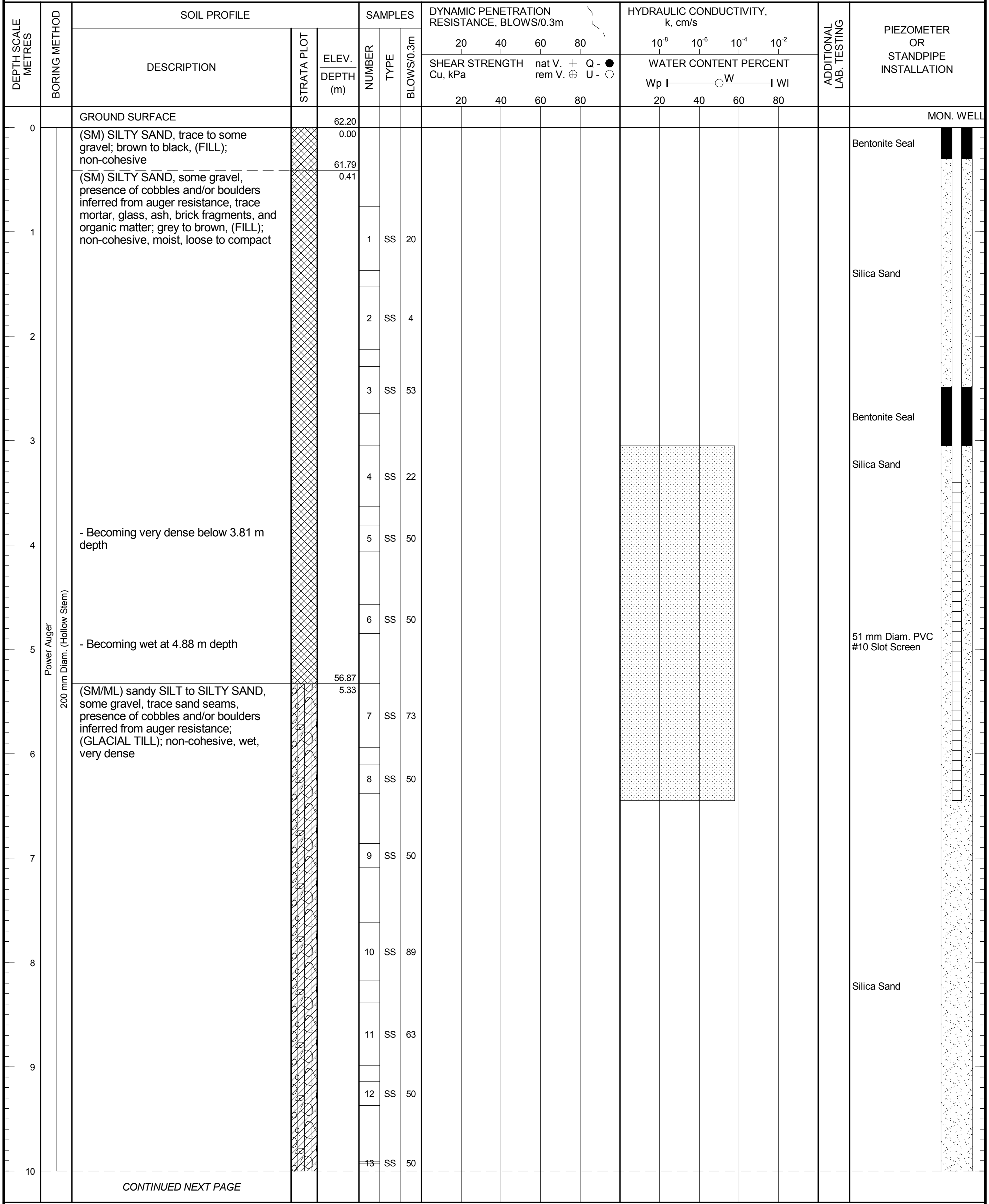
DRILLING DATE: February 4, 2013

DRILL RIG: CME-75

DRILLING CONTRACTOR: Downing Drilling

DATUM: CGVD1928

PENETRATION TEST HAMMER, 64kg; DROP, 760mm



DESCRIPTION	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m
GROUND SURFACE	62.20			
(SM) SILTY SAND, trace to some gravel; brown to black, (FILL); non-cohesive	0.00			
(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	61.79 0.41	1	SS	20
		2	SS	4
		3	SS	53
		4	SS	22
- Becoming very dense below 3.81 m depth		5	SS	50
		6	SS	50
- Becoming wet at 4.88 m depth				
(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	56.87 5.33	7	SS	73
		8	SS	50
		9	SS	50
		10	SS	89
		11	SS	63
		12	SS	50
		13	SS	50

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 50

LOGGED: KE

CHECKED: WAM/AJS

PROJECT: 13-1121-0143

RECORD OF BOREHOLE: 13-4

SHEET 2 OF 4

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	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: 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

PROJECT: 13-1121-0143

RECORD OF DRILLHOLE: 13-4

SHEET 3 OF 4

LOCATION: N 5030852.88 ;E 366587.26

DRILLING DATE: February 4, 2013

DATUM: CGVD1928

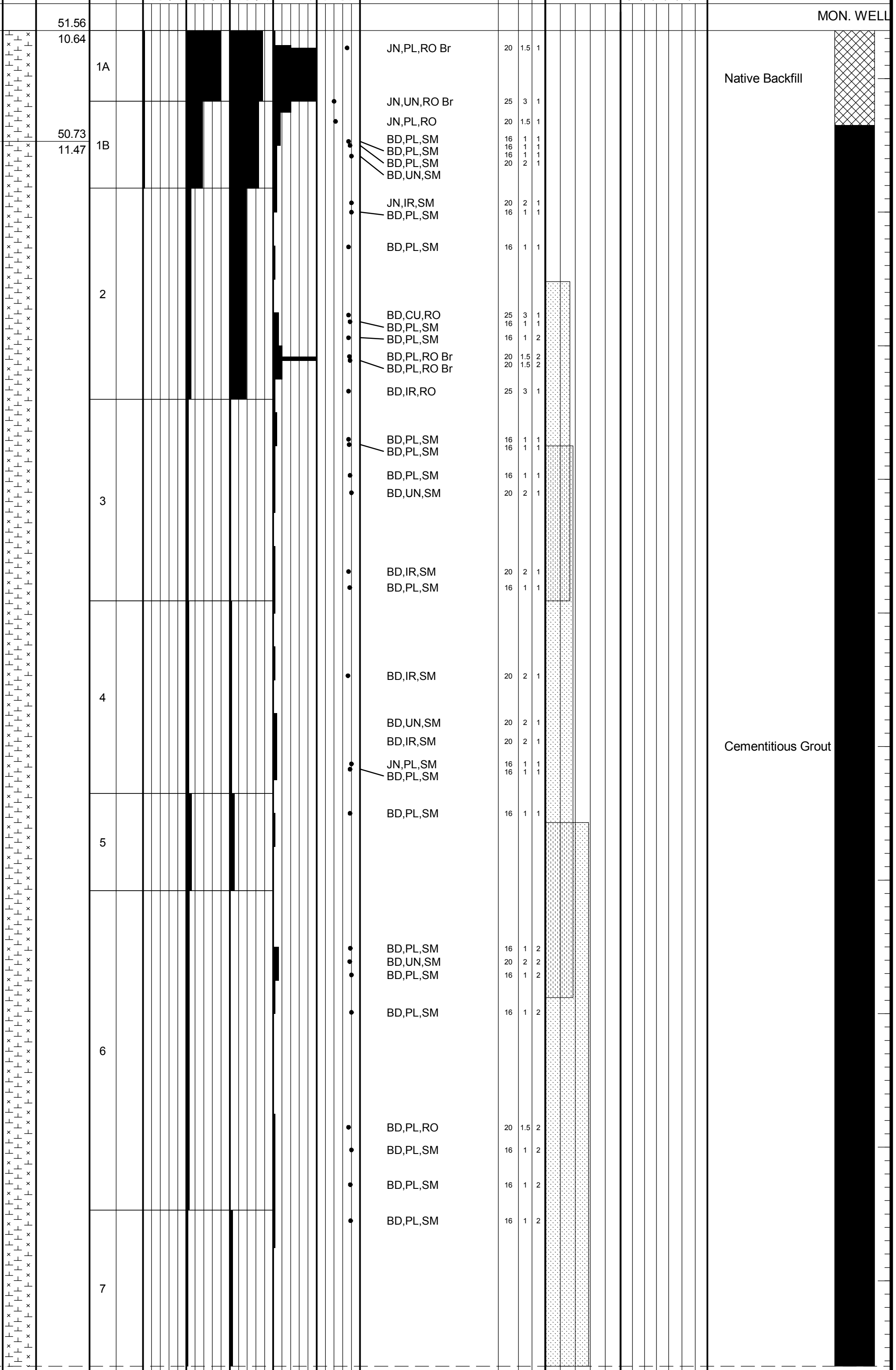
DRILL RIG: CME-75

INCLINATION: -90° AZIMUTH: ---

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.



DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)
		BEDROCK SURFACE	51.56
11	Rotary Drill HQ3 Core	Slightly weathered, thinly to medium bedded, grey, fine to medium grained, non-porous, medium strong LIMESTONE, with thin shale laminates VERULAM FORMATION	10.64
12–20		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	50.73 11.47

TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja
JN,PL,RO Br	20	1.5	1
JN,UN,RO Br	25	3	1
JN,PL,RO	20	1.5	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,UN,SM	20	2	1
JN,IR,SM	20	2	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,CU,RO	25	3	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	2
BD,PL,RO Br	20	1.5	2
BD,PL,RO Br	20	1.5	2
BD,IR,RO	25	3	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,UN,SM	20	2	1
BD,IR,SM	20	2	1
BD,PL,SM	16	1	1
BD,IR,SM	20	2	1
BD,UN,SM	20	2	1
BD,IR,SM	20	2	1
JN,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	2
BD,UN,SM	20	2	2
BD,PL,SM	16	1	2
BD,PL,SM	16	1	2
BD,PL,RO	20	1.5	2
BD,PL,SM	16	1	2
BD,PL,SM	16	1	2
BD,PL,SM	16	1	2

NOTES

Native Backfill

Cementitious Grout

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 50

LOGGED: KE

CHECKED: WAM/AJS

PROJECT: 13-1121-0143

RECORD OF DRILLHOLE: 13-4

SHEET 4 OF 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.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	NOTES
		--- CONTINUED FROM PREVIOUS PAGE ---							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	
22		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.							
23									
24									
25									
26									
27									
28									
29									
30									

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: KE

CHECKED: WAM/AJS

PROJECT: 13-1121-0143

RECORD OF BOREHOLE: 13-5

SHEET 1 OF 4

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	SAMPLES TYPE	SAMPLES 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

SHEET 2 OF 4

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	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: 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											

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: HEC
CHECKED: WAM/AJS

PROJECT: 13-1121-0143

RECORD OF DRILLHOLE: 13-5

SHEET 3 OF 4

LOCATION: N 5030879.81 ;E 366599.42

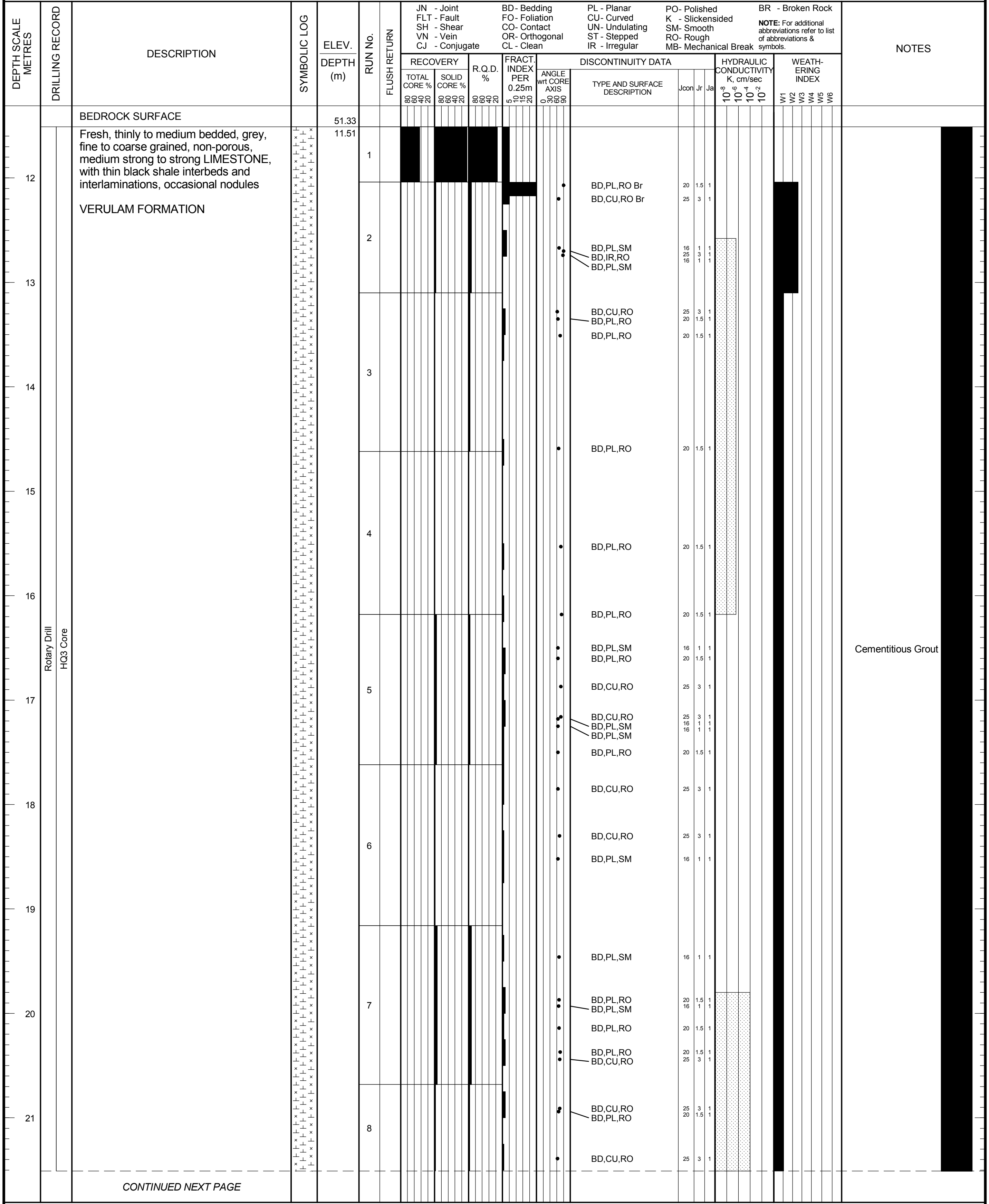
INCLINATION: -69.5° AZIMUTH: 203°

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.



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

TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja
BD,PL,RO Br	20	1.5	1
BD,CU,RO Br	25	3	1
BD,PL,SM	16	1	1
BD,IR,RO	25	3	1
BD,PL,SM	16	1	1
BD,CU,RO	25	3	1
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
BD,PL,RO	20	1.5	1
BD,PL,SM	16	1	1
BD,PL,RO	20	1.5	1
BD,CU,RO	25	3	1
BD,CU,RO	25	3	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,RO	20	1.5	1
BD,CU,RO	25	3	1
BD,CU,RO	25	3	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,RO	20	1.5	1
BD,PL,SM	16	1	1
BD,PL,RO	20	1.5	1
BD,PL,RO	20	1.5	1
BD,CU,RO	25	3	1
BD,CU,RO	25	3	1
BD,PL,RO	20	1.5	1
BD,CU,RO	25	3	1

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: HEC
CHECKED: WAM/AJS

PROJECT: 13-1121-0143

RECORD OF DRILLHOLE: 13-5

SHEET 4 OF 4

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	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	DISCONTINUITY DATA ANGLE wrt 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 ---																
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 24 25 26 27 28 29 30 31		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.																

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: HEC
CHECKED: WAM/AJS

PROJECT: 13-1121-0143

RECORD OF BOREHOLE: 13-6

SHEET 1 OF 4

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

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

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

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-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

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	PIEZOMETER OR STANDPIPE INSTALLATION
	GROUND SURFACE	61.95				
0	(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

DEPTH SCALE
1 : 50

LOGGED: KE
CHECKED: WAM/AJS

PROJECT: 13-1121-0143

RECORD OF BOREHOLE: 13-6

SHEET 2 OF 4

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

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

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m	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

PROJECT: 13-1121-0143

RECORD OF DRILLHOLE: 13-6

SHEET 3 OF 4

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 % 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

BEDROCK SURFACE 50.80

11.15

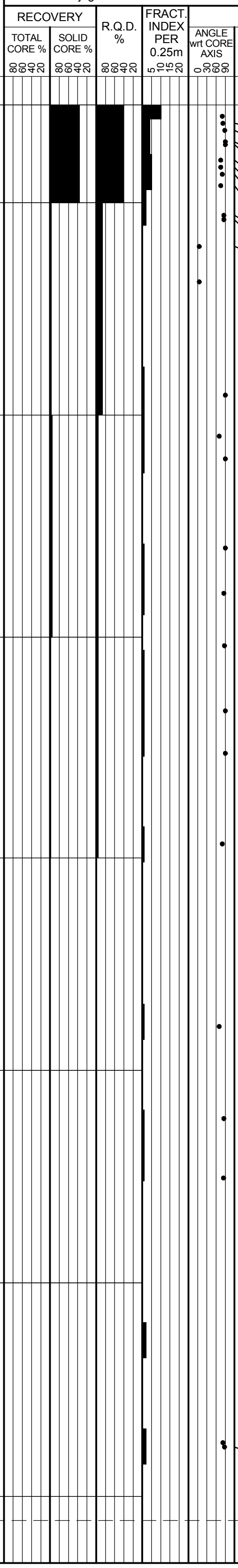
Fresh, thinly to medium bedded, grey, non-porous, medium strong to strong, fossiliferous LIMESTONE, with thin shale interbeds and interlaminations, occasional nodules

VERULAM FORMATION

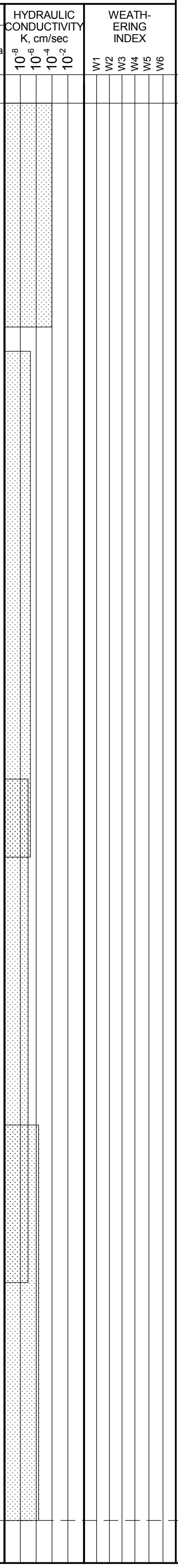
Depth scale: 12, 13, 14, 15, 16, 17, 18, 19, 20, 21

Drilling record: Rotary Drill, HQ3 Core

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

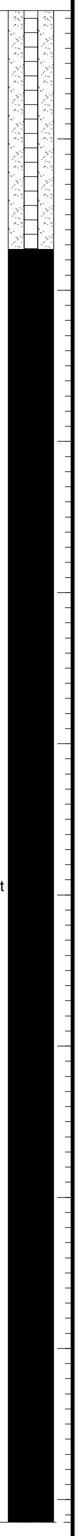


TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja
BD,IR,RO	25	3	1
BD,IR,SM	20	2	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,CU,SM	20	2	1
BD,CU,SM	20	2	1
BD,PL,SM	16	1	1
BD,UN,SM	20	2	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
JN,PL,RO	20	1.5	1
JN,PL,RO	20	1.5	1
BD,PL,SM	16	1	1
BD,IR,RO	25	3	1
BD,CU,SM	20	2	1
BD,PL,SM	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

PROJECT: 13-1121-0143

RECORD OF DRILLHOLE: 13-6

SHEET 4 OF 4

LOCATION: N 5030907.61 ;E 366614.54

DRILLING DATE: February 8, 2013

DATUM: CGVD1928

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME-75

DRILLING CONTRACTOR: Downing Drilling

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

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	DISCONTINUITY DATA ANGLE wrt 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 ---																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																		

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

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: KE

CHECKED: WAM/AJS

Queen's
UNIVERSITY

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 ± 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

Photographs of Pre-Test Samples


GOLDER (DUNLOP)
BH 13-4
(12.42)
UCS
GOLDER (DUNLOP)
BH 13-4
(12.42)
BRAZ
3
2
1
5
4


GOLDER (DUNLOP
BH 13-4
(14.10)
UCS
14.10
13-1121
UCS
BH
GOLDER (DUNLOP)
BH 13-4
(14.10)
BRAZ
3
2
1
6
5
4


GOLDER (DUNLOP)
BH 13-4
(16.53)
UCS
GOLDER (DUNLOP)
BH 13-4
(16.53)
BRAZ
3
2
1
6
5
4

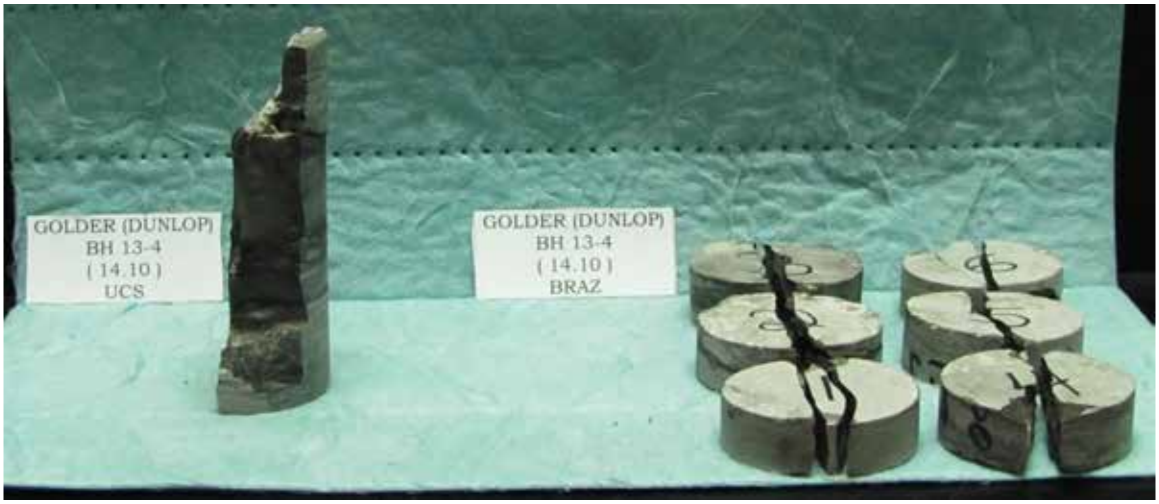

GOLDER (DUNLOP)
BH 13-6
(12.11)
UCS
BH13-6
GOLDER (DUNLOP)
BH 13-6
(12.11)
BRAZ
3
6
2
5
1
4

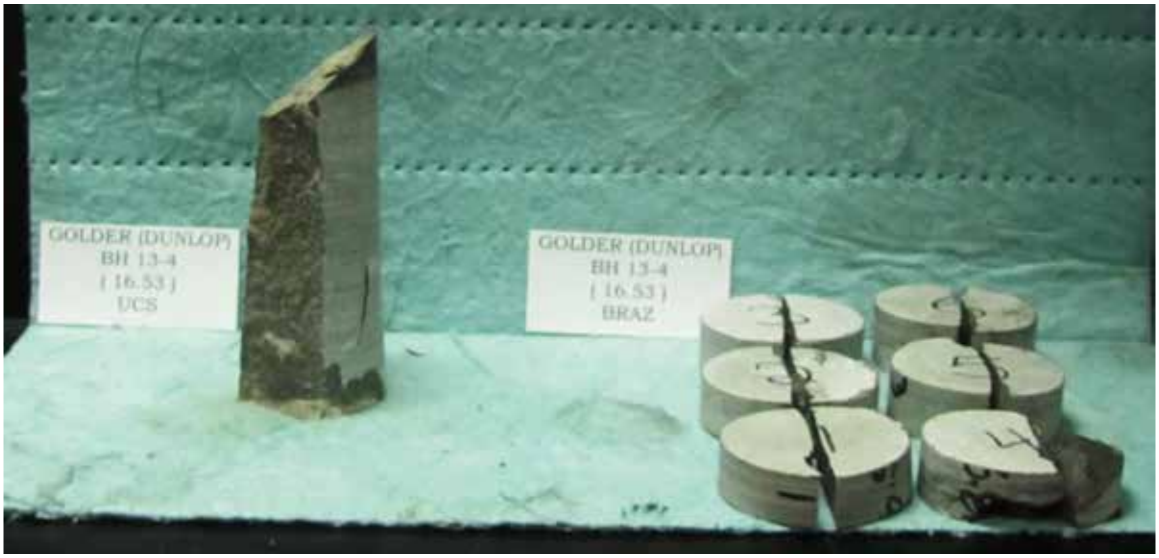

GOLDER (DUNLOP)
BH 13-6
(14.97)
UCS
UCS
13-1121-0005
GOLDER (DUNLOP)
BH 13-6
(14.97)
BRAZ
3
2
1
5
4


GOLDER (DUNLOP
BH 13-6
(16.47)
UCS
GOLDER (DUNLOP)
BH 13-6
(16.47)
BRAZ
3
6
2
5
1
4

Photographs of Post-Test Samples


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


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

SHEET 1 OF 3

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

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

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
		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
		(SM) SILTY SAND, fine; dark brown (BURIED TOPSOIL); non-cohesive, moist	60.82 1.58
		(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	
5	Wash Boring HW Casing		
10		CONTINUED NEXT PAGE	

SAMPLE NUMBER	TYPE	BLOWS/0.3m
1	SS	22
2	SS	13
3	SS	>50
4	SS	78
5	SS	>50
6	SS	>50
7	SS	>50
8	SS	>50
9	SS	>50

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: HEC
CHECKED: SD

PROJECT: 13-1121-0143

RECORD OF BOREHOLE: 14-601

SHEET 2 OF 3

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
		--- CONTINUED FROM PREVIOUS PAGE ---									
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											
15											
16											
17											
18											
19											
20											

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: HEC
CHECKED: SD

PROJECT: 13-1121-0143

RECORD OF DRILLHOLE: 14-601

SHEET 3 OF 3

LOCATION: N 5030901.52 ;E 366634.38

INCLINATION: -90° AZIMUTH: ---

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

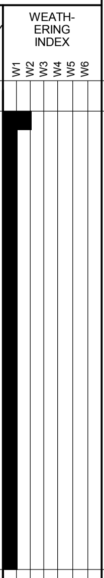
NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	NOTES
		BEDROCK SURFACE		48.91			
	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		13.43			
14					1	100	
15					2	100	
16		- 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		45.88 16.46			
		End of Drillhole					
17							
18							
19							
20							
21							
22							
23							

DISCONTINUITY DATA

TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja
JN,PL,RO	20	1.5	1
BD,IR,RO	25	3	1
BD,PL,RO	20	1.5	1
BD,PL,RO	20	1.5	1
BD,UN,SM	20	2	1
BD,PL,RO	20	1.5	1
BD,PL,RO	20	1.5	1
BD,PL,SM	16	1	1
BD,IR,RO	25	3	1
BD,IR,SM	20	2	1
JN,CU,SM	20	2	1
BD,PL,RO	20	1.5	1
BD,PL,SM	16	1	1
JN,CU,RO	25	3	1
BD,IR,RO	25	3	1
BD,PL,RO	20	1.5	1
BD,CU,RO	25	3	1
BD,CU,RO	25	3	1
JN,PL,RO	20	1.5	1
BD,PL,RO	20	1.5	1
BD,CU,RO	25	3	1
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
JN,UN,RO	25	3	1
JN,UN,RO	25	3	1
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
BD,PL,RO	20	1.5	1

HYDRAULIC CONDUCTIVITY K, cm/sec
10^{-8} 10^{-6} 10^{-4} 10^{-2}



DEPTH SCALE
1 : 50

Golder Associates

LOGGED: HEC
CHECKED: AJS

PROJECT: 13-1121-0143

RECORD OF BOREHOLE: 14-602

SHEET 1 OF 3

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 | SAMPLES | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80) | SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20, 40, 60, 80) | HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}) | WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (20, 40, 60, 80) | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

BORING METHOD: Portable Drill - Wash Boring; NW Casing

DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)
GROUND SURFACE		63.00
FILL - (SP) SAND, some gravel; brown, with cobbles; non-cohesive, moist, compact	▨	0.00
FILL - (SM) SILTY SAND, some gravel; brown, with mica, organic matter and cobbles; non-cohesive, moist, compact	▨	62.39 0.61
(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

NUMBER	TYPE	BLOWS/0.3m
1	SS	29
2	SS	10
3	SS	11
4	SS	19
5	SS	>50
6	SS	52
7	RC	DD
8	SS	>50
9	RC	DD
10	RC	DD
11	RC	DD
12	RC	DD
13	SS	>50

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

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

LOGGED: HEC
CHECKED: SD

PROJECT: 13-1121-0143

RECORD OF BOREHOLE: 14-602

SHEET 2 OF 3

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

PROJECT: 13-1121-0143

RECORD OF DRILLHOLE: 14-602

SHEET 3 OF 3

LOCATION: N 5030915.66 ;E 366656.86

DRILLING DATE: November 28 - December 3, 2014

DATUM: CGVD1928

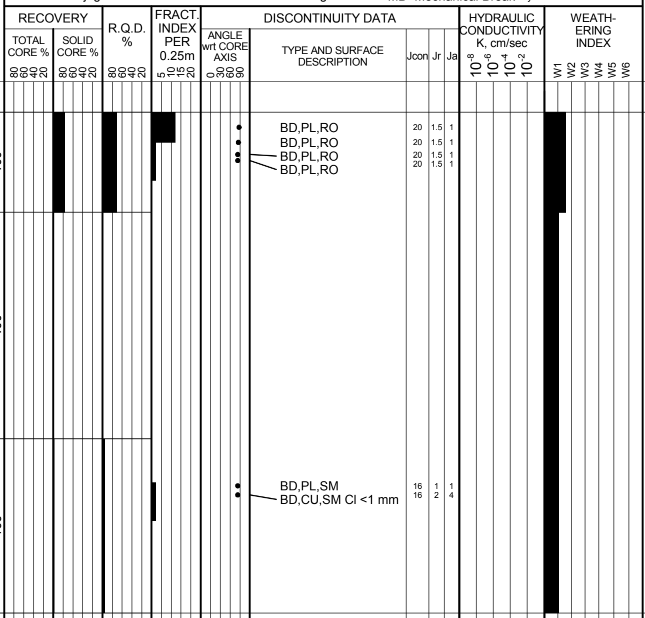
INCLINATION: -90° AZIMUTH: ---

DRILL RIG: Portable Drill

DRILLING CONTRACTOR: Marathon Drilling

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

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	NOTES
		BEDROCK SURFACE		51.70			
12 13 14	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) VERULAM FORMATION - Broken core from 11.40 m to 11.50 m		11.30	1	100	
					2	100	
				48.39 14.61	3	100	
15 16 17 18 19 20 21		End of Drillhole					



DISCONTINUITY DATA

TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja
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
BD,PL,SM	16	1	1
BD,CU,SM Cl <1 mm	16	2	4

DEPTH SCALE

1 : 50

LOGGED: HEC

CHECKED: AJS

PROJECT: 13-1121-0143

RECORD OF BOREHOLE: 14-603

SHEET 1 OF 2

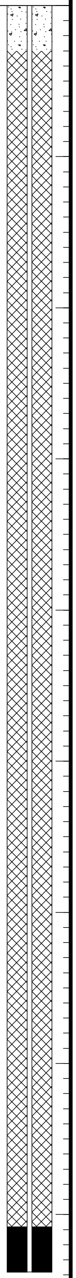
LOCATION: N 5030855.87 ;E 366544.85
INCLINATION: -90° AZIMUTH: ---
SAMPLER HAMMER, 64kg; DROP, 760mm

DRILLING DATE: January 13, 2015
DRILL RIG: CME 55
DRILLING CONTRACTOR: Marathon Drilling

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

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

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	61.41				MON. WELL
0	Power Auger 200 mm Diam. (Hollow Stem)	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	
1							
		FILL - (SM) gravelly SILTY SAND; dark brown, with cobbles; moist, compact RDR = 2	59.89 1.52	3	SS	18	
2				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	
3							
		(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
4				7	SS	56	
5				8	SS	65	
6		(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	
7				10	SS	>50	
				11	SS	>50	
8			53.03				Bentonite Seal
		Borehole continued on RECORD OF DRILLHOLE 14-603					
9							
10							



DEPTH SCALE
1 : 50

LOGGED: HEC
CHECKED: SD

PROJECT: 13-1121-0143

RECORD OF DRILLHOLE: 14-603

SHEET 2 OF 2

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

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

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

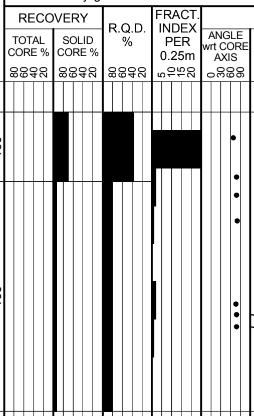
PL - Planar
CU- Curved
UN- Undulating
ST - Stepped
IR - Irregular

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

BR - Broken Rock

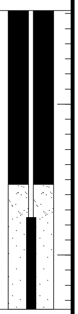
NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	NOTES
		BEDROCK SURFACE	53.03							MON. WELL
9 10	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	8.38	1	100	JN,PL,RO	20	1.5	1	
						BD,PL,SM	16	1	1	
						BD,PL,SM	16	1	1	
				2	100	BD,PL,VR	22	1.5	1	Bentonite Seal
						BD,PL,RO	20	1.5	1	Silica Sand
						BD,PL,RO	20	1.5	1	
			51.05 10.36			BD,PL,RO	20	1.5	1	19 mm Diam. PVC Standpipe
11 12 13 14 15 16 17 18		End of Drillhole								



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: AJS

CSST-ROCK 1311210143.GPJ GAL-MISS.GDT 07/17/15 JM

PROJECT: 13-1121-0143

RECORD OF BOREHOLE: 14-604

SHEET 1 OF 2

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	ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: 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	SS	5				
2										
				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

SHEET 2 OF 2

LOCATION: N 5030851.90 ;E 366526.55

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: January 15, 2015

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon 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.	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 50.66	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	
						BD,PL,SM	16	1	1	
6		End of Drillhole	5.78							
7										
8										
9										
10										
11										
12										
13										
14										

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); ANGLE wrt CORE AXIS (0 30 60 90); 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: AJS

PROJECT: 1522242-3000

RECORD OF BOREHOLE: 15-01

SHEET 1 OF 1

LOCATION: See Site Plan

BORING DATE: February 28, 2015

DATUM: Geodetic

BORING METHOD: Percussion Drill, 105 mm Diam. Casing

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)

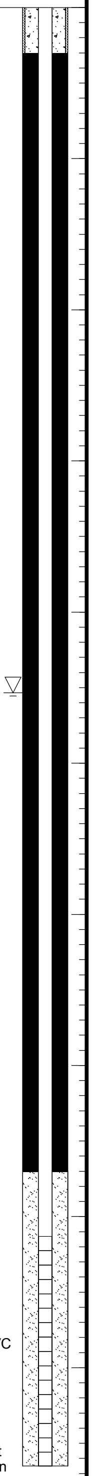
SOIL PROFILE

DESCRIPTION	ELEV. / 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	ADDITIONAL LAB. TESTING
1	SS			CHEM
2	SS		⊕□ ND	
3	SS		⊕ □ ND	CHEM
3A	SS			CHEM
4	SS		⊕ □	
5	SS		⊕ □	
6	SS		⊕□	

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

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

PROJECT: 1522242-3000

RECORD OF BOREHOLE: 15-02

SHEET 1 OF 1

LOCATION: See Site Plan

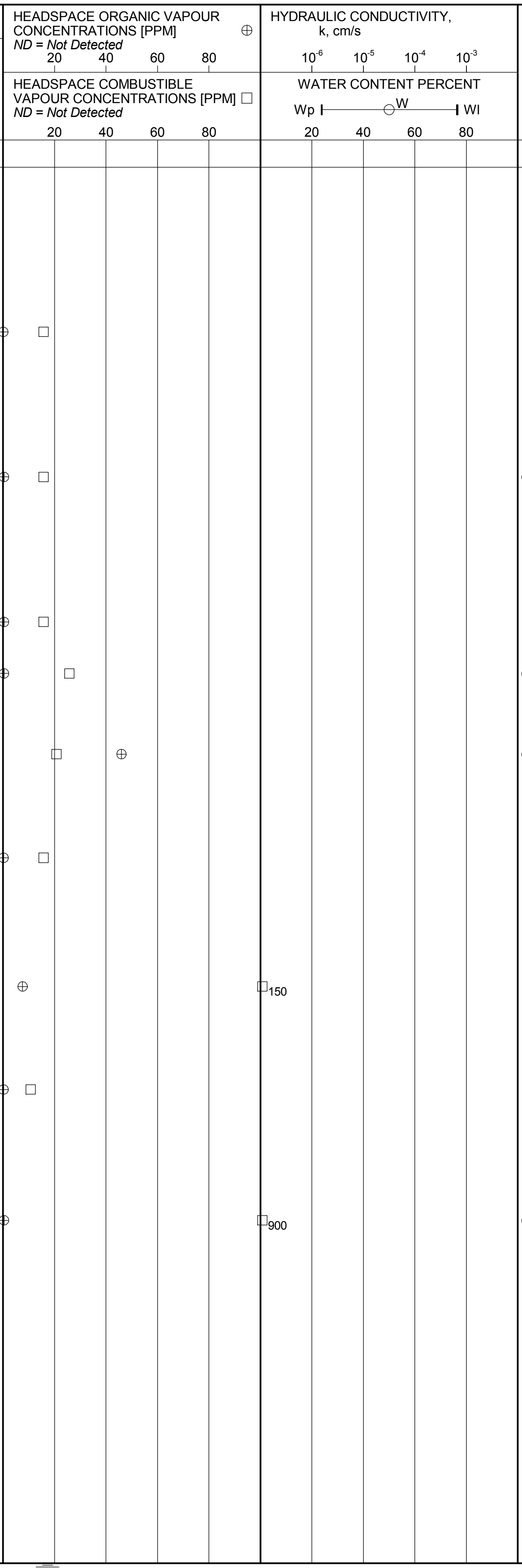
BORING DATE: February 28, 2015

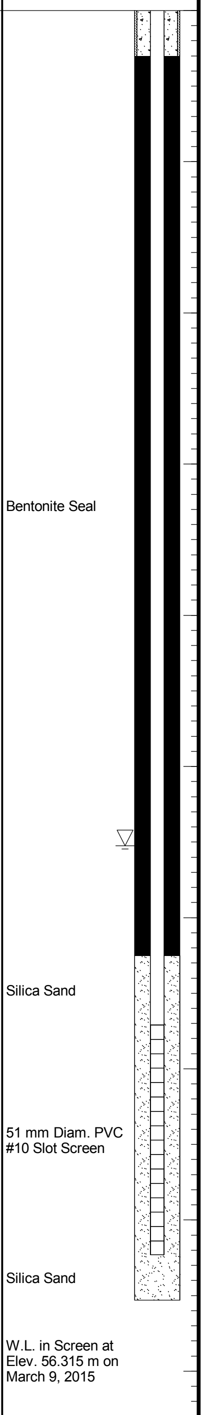
DATUM: Geodetic

BORING METHOD: Percussion Drill, 105 mm Diam. Casing

SOIL PROFILE – DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	61.84
FILL - (SW) gravelly SAND, angular; grey	0.00
FILL - (SP) SAND, fine; brown; non-cohesive, moist	60.32 1.52
FILL - Mixture of fine SAND, orange brick; hydro carbon odour, black staining	58.18 3.66
(SM) SILTY SAND, some gravel; grey (GLACIAL TILL); non-cohesive, moist	57.88 3.96
(SM) SILTY SAND, trace gravel, trace coarse sand; (GLACIAL TILL); non-cohesive, moist to wet	55.21 6.63
End of Borehole	53.31 8.53

SAMPLES NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING
1	SS		
2	SS		CHEM
3	SS		
3A	SS		CHEM
4	SS		CHEM
4A	SS		
5	SS		
5A	SS		
6	SS		CHEM





W.L. in Screen at Elev. 56.315 m on March 9, 2015

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: HEC
CHECKED: AC

PROJECT: 1522242-3000

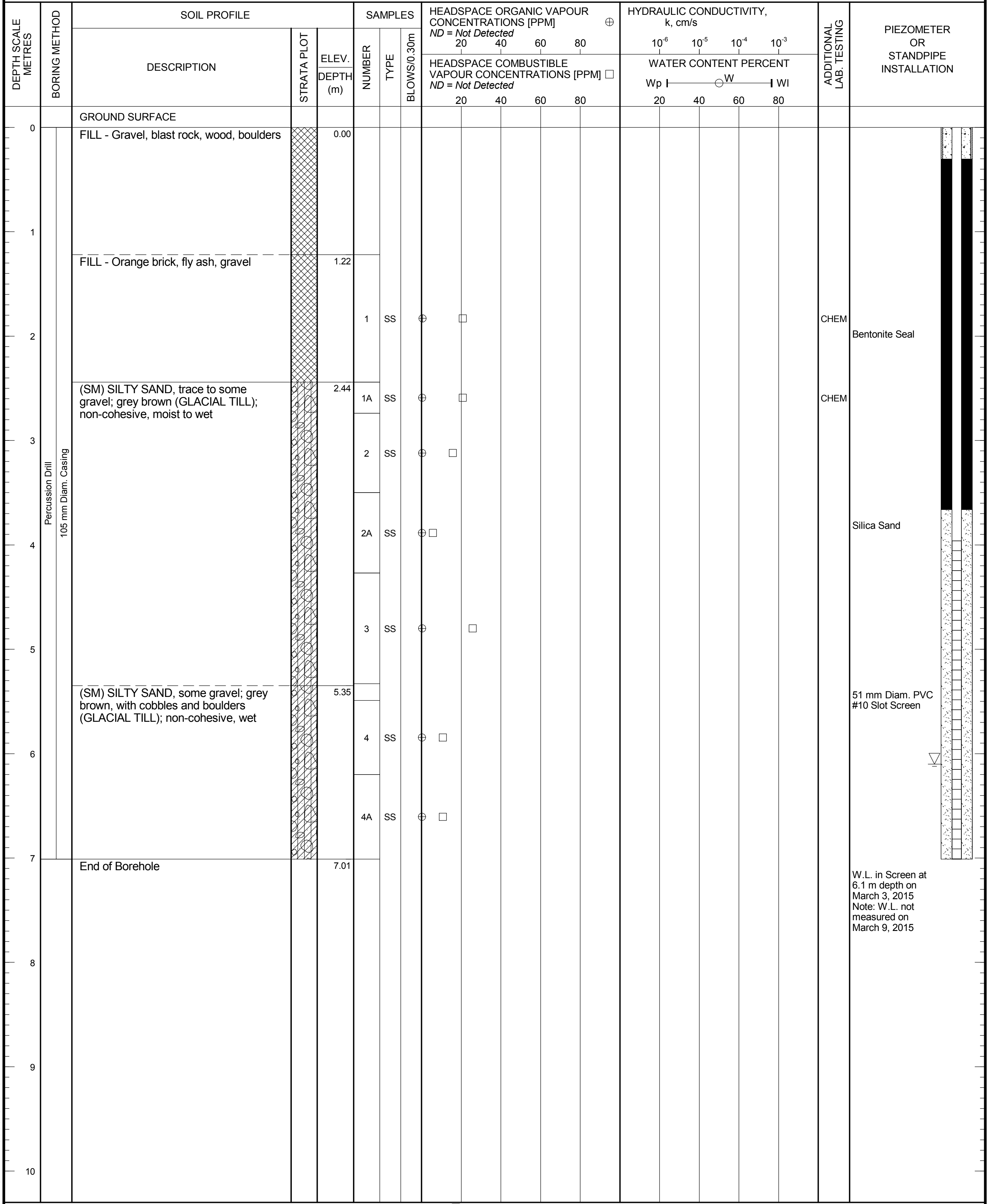
RECORD OF BOREHOLE: 15-04

SHEET 1 OF 1

LOCATION: See Site Plan

BORING DATE: March 1, 2015

DATUM: Geodetic



Boring method: Percussion Drill, 105 mm Diam. Casing

DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	
FILL - Gravel, blast rock, wood, boulders	0.00
FILL - Orange brick, fly ash, gravel	1.22
(SM) SILTY SAND, trace to some gravel; grey brown (GLACIAL TILL); non-cohesive, moist to wet	2.44
(SM) SILTY SAND, some gravel; grey brown, with cobbles and boulders (GLACIAL TILL); non-cohesive, wet	5.35
End of Borehole	7.01

NUMBER	TYPE	ADDITIONAL LAB. TESTING
1	SS	CHEM
1A	SS	CHEM
2	SS	
2A	SS	
3	SS	
4	SS	
4A	SS	

Bentonite Seal

Silica Sand

51 mm Diam. PVC
#10 Slot Screen

W.L. in Screen at
6.1 m depth on
March 3, 2015
Note: W.L. not
measured on
March 9, 2015

DEPTH SCALE
1 : 50

LOGGED: HEC
CHECKED: AC

PROJECT: 06-1120-331

RECORD OF BOREHOLE: BH 06-24

SHEET 1 OF 1

LOCATION: See Site Plan

BORING DATE: Nov. 6-7, 2006

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: ELEV. / DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	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^{-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		62.52							
0	Power Auger 200mm Diam. (Hollow Stem)	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
					7	50 DO	91				
6					8	50 DO	85				50mm Diam. PVC #10 Slot Screen
7					9	50 DO	>100				Native Backfill
		End of Borehole Sampler Refusal		55.20 7.32							Water level in screen at elev. 59.92m on Dec. 8, 2006
8											
9											
10											
11											
12											
13											
14											
15											

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

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

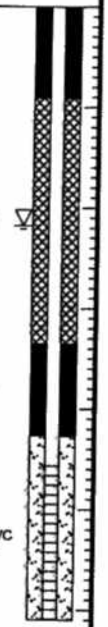
BORING DATE: Nov. 7, 2006

SHEET 1 OF 1

DATUM: Geodetic

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 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^{-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	62.82							
0	Power Auger 200mm Diam. (Hollow Stem)	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				
		Very dense brown SANDY SILT, some gravel, trace clay with cobbles and boulders (GLACIAL TILL)	60.53 2.29	3	50 DO	>100				Native Backfill ∇
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				
				7	50 DO	78				50mm Diam. PVC #10 Slot Screen
6				8	50 DO	66				Water level in screen at elev. 60.64m on Dec. 8, 2006
		End of Borehole	56.11 6.71							
7										
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 06-26

BORING DATE: Nov. 7-8, 2006

SHEET 1 OF 1

DATUM: Geodetic

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES | 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

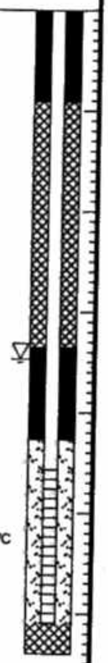
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

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

SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)
GROUND SURFACE	64.04
Dark grey sand with silt, gravel, brick, concrete, ash and coal (FILL)	0.00
Dense grey brown SANDY SILT, some gravel, trace clay with cobbles and boulders (GLACIAL TILL)	61.75 2.29
Very dense grey SANDY SILT, some gravel, trace clay with cobbles, boulders and sand layers (GLACIAL TILL)	59.32 4.72
End of Borehole Sampler Refusal	57.64 6.40

SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
1	50 DO	4	MH
2	50 DO	26	
3	50 DO	47	
4	50 DO	31	
5	50 DO	97	MH
6	50 DO	>100	
7	50 DO	62	
8	50 DO	>100	

PIEZOMETER OR STANDPIPE INSTALLATION



Flush mount casing set in bentonite

Native Backfill

Bentonite Seal

Silica Sand

50mm Diam. PVC #10 Slot Screen

Native Backfill

Water level in screen at elev. 60.57m on Dec. 8, 2006

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

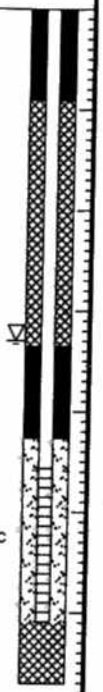
PROJECT: 06-1120-331
LOCATION: See Site Plan
SAMPLER HAMMER, 64kg; DROP, 760mm

RECORD OF BOREHOLE: BH 06-27

BORING DATE: Nov. 8, 2006

SHEET 1 OF 1
DATUM: Geodetic
PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	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^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
0		GROUND SURFACE	65.72							
	Power Auger 200mm Diam. (Hollow Stem)	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
5				6	50 DO	43				Silica Sand
				7	50 DO	62				50mm Diam. PVC #10 Slot Screen
6			59.17	8	50 DO	88				Native Backfill
		Brown fine SAND	6.55							
7		End of Borehole	6.71							Water level in screen at elev. 62.42m 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.

APPENDIX C

Results of Chemical Analysis

eurofins | Environment Testing

Certificate of Analysis

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

				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
Group	**Analyte**	**MRL**	**Units**	**Guideline**		
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

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

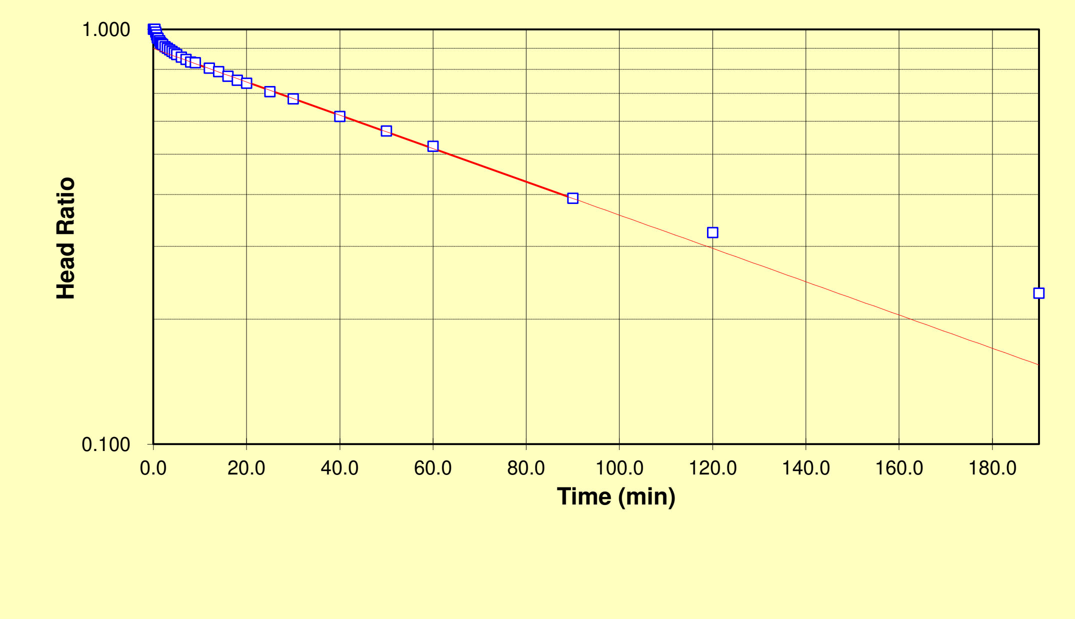
where:
r_c = casing radius (feet)
R_e = filter pack radius (feet)
L_e = length of screened interval (feet)
t = time (seconds)
h_t = head at time t (feet)

INPUT PARAMETERS

r_c = 0.05
R_e = 0.33
L_e = 12.9
t_1 = 480
t_2 = 5400
h_1/h_0 = 0.83
h_2/h_0 = 0.39

RESULTS

K= 2E-06 cm/sec
K= 5E-03 ft/day



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:

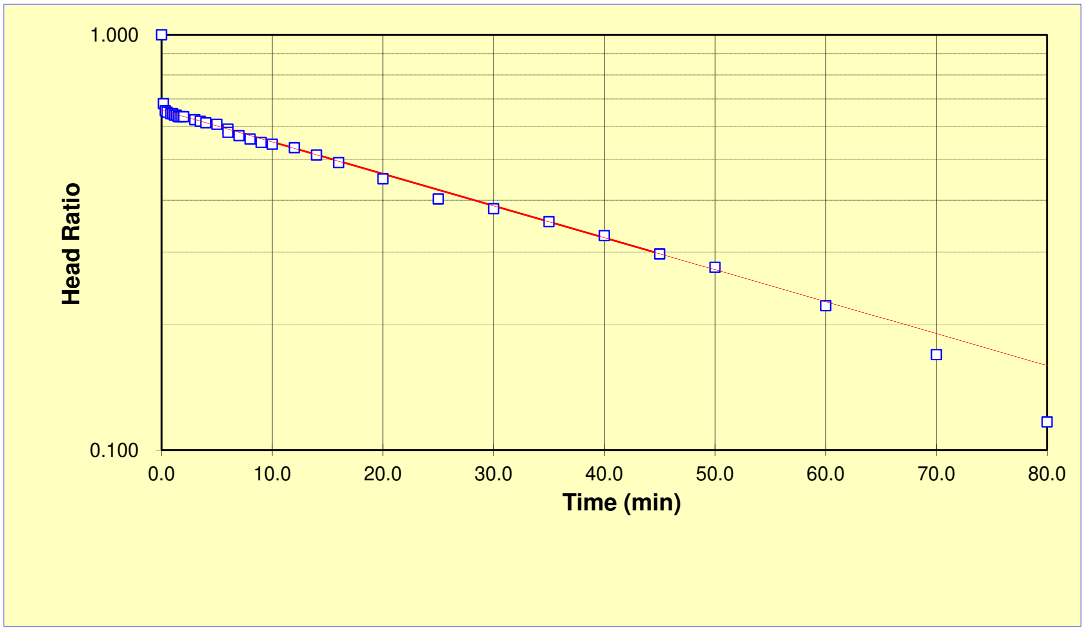
r_c = casing radius (feet)
R_e = filter pack radius (feet)
L_e = length of screened interval (feet)
t = time (seconds)
h_t = head at time t (feet)

INPUT PARAMETERS

r_c = 0.05
R_e = 0.33
L_e = 7.0
t_1 = 180
t_2 = 2700
h_1/h_0 = 0.63
h_2/h_0 = 0.30

RESULTS

K= 5E-06 cm/sec
K= 2E-02 ft/day



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:

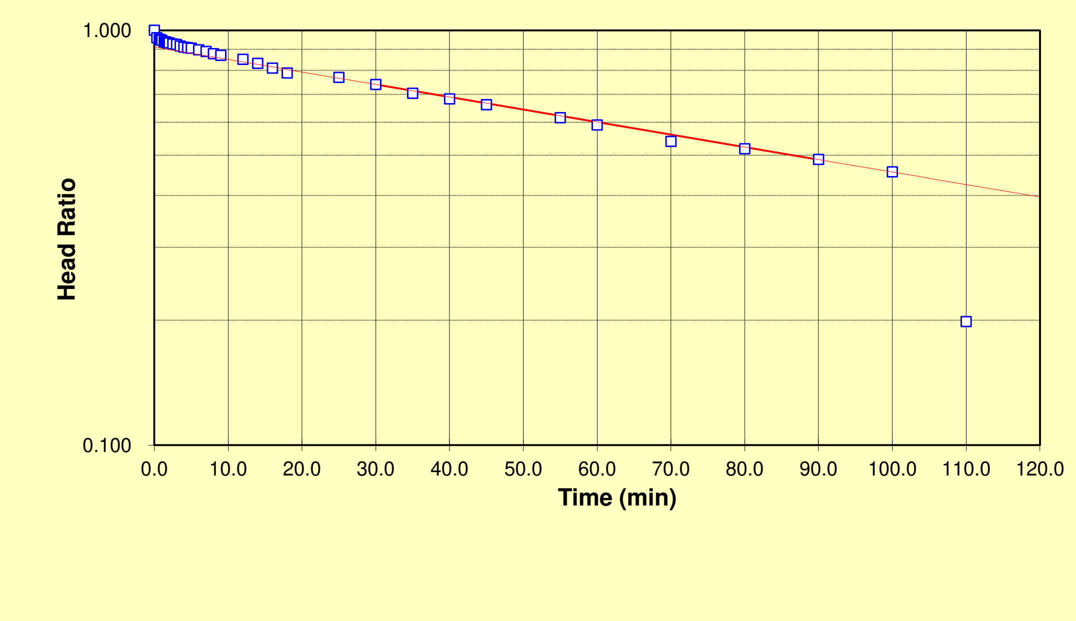
r_c = casing radius (feet)
R_e = filter pack radius (feet)
L_e = length of screened interval (feet)
t = time (seconds)
h_t = head at time t (feet)

INPUT PARAMETERS

r_c =	0.05
R_e =	0.33
L_e =	11.7
t_1 =	1800
t_2 =	5400
h_1/h_0 =	0.74
h_2/h_0 =	0.49

RESULTS

K=	1E-06	cm/sec
K=	4E-03	ft/day



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)

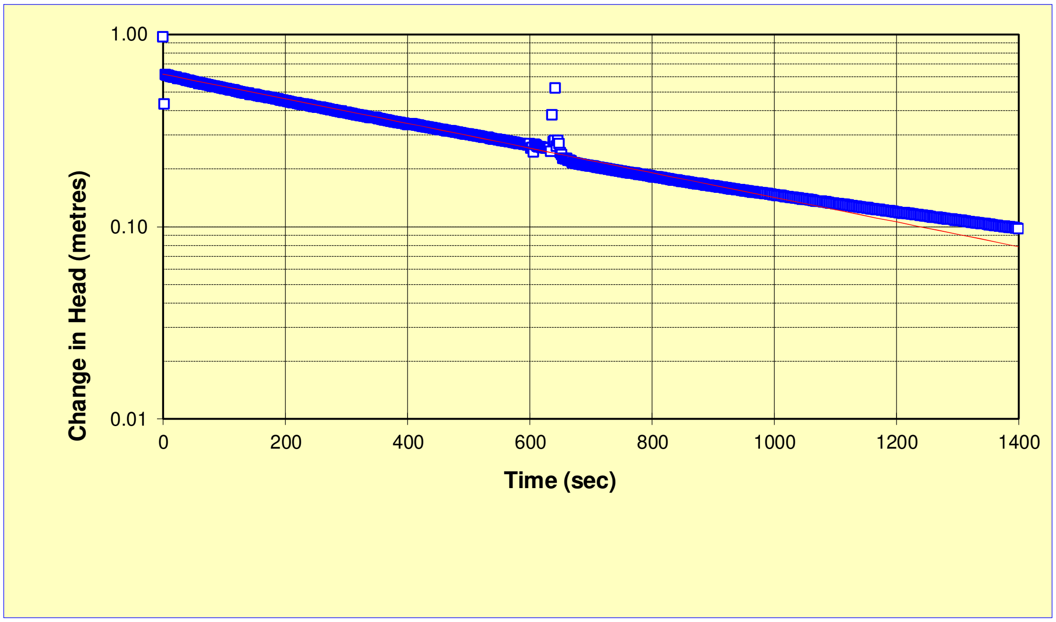
y_t = drawdown (metres) at time t (seconds)

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:

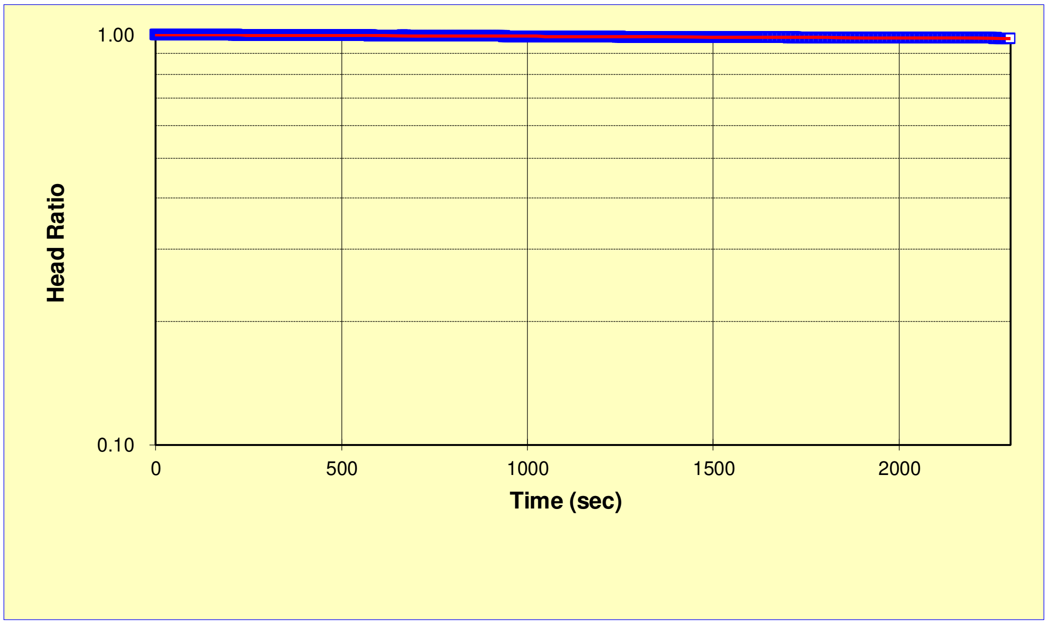
r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

INPUT PARAMETERS

r_c =	1.9E-02
R_e =	5.0E-02
L_e =	0.9
t_1 =	0
t_2 =	2500
Head Ratio $_1$ =	1.00
Head Ratio $_2$ =	0.98

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: 2/14/2013

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

Golder Associates Ltd.

HVORSLEV TEST ANALYSIS
FALLING HEAD TEST BH13-3 Test 2

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

where:

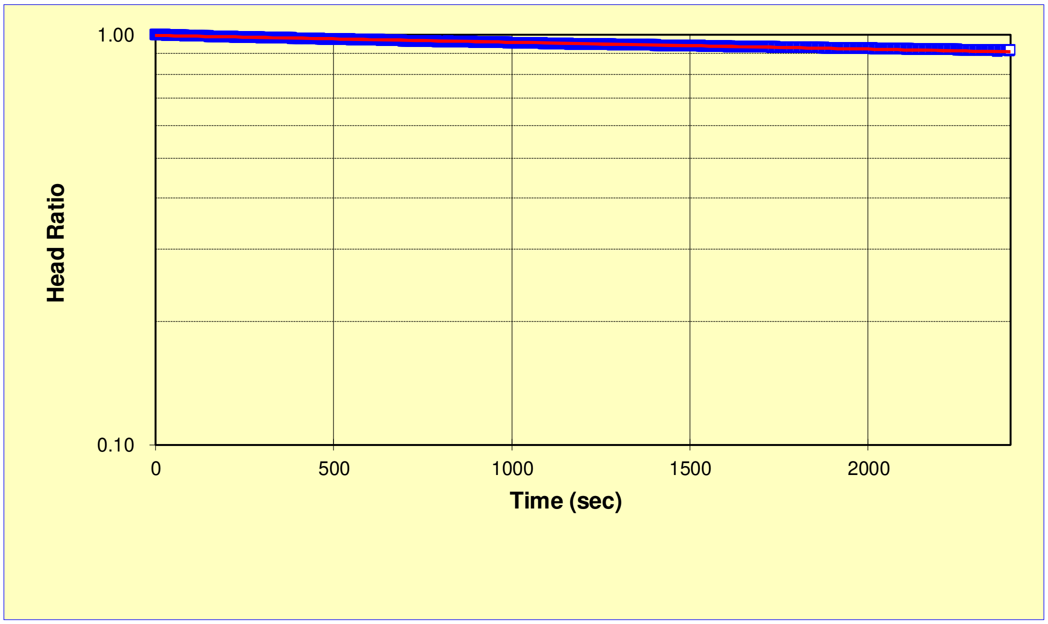
r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

INPUT PARAMETERS

r_c =	1.9E-02
R_e =	5.0E-02
L_e =	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:

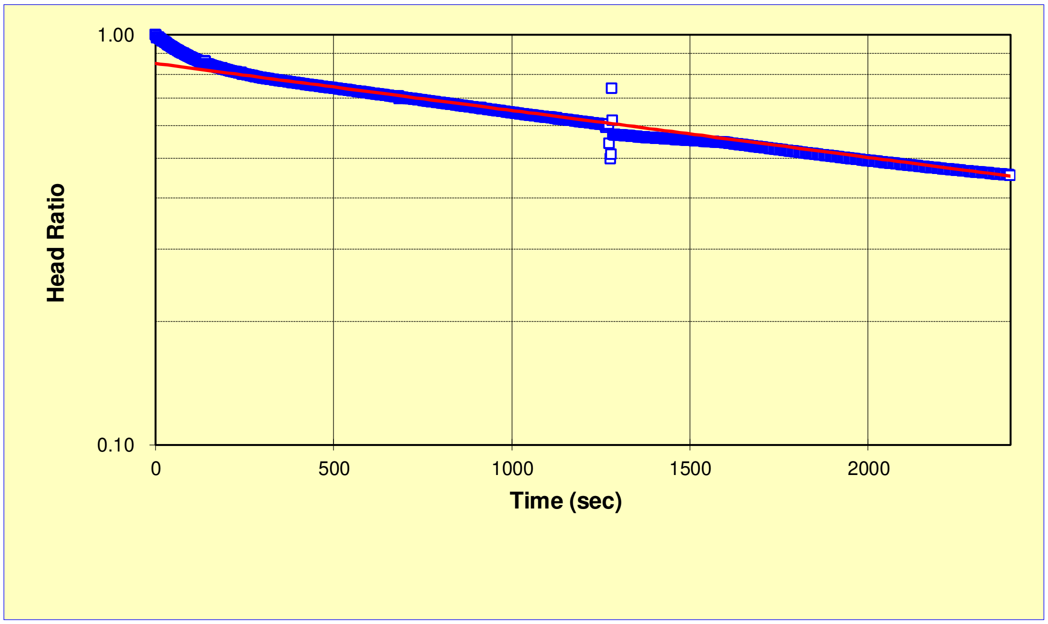
r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

INPUT PARAMETERS

r_c =	1.9E-02
R_e =	5.0E-02
L_e =	2.7
t_1 =	0
t_2 =	2500
Head Ratio $_1$ =	0.85
Head Ratio $_2$ =	0.44

RESULTS

K=	7E-08	m/sec
K=	7E-06	cm/sec



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.

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

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

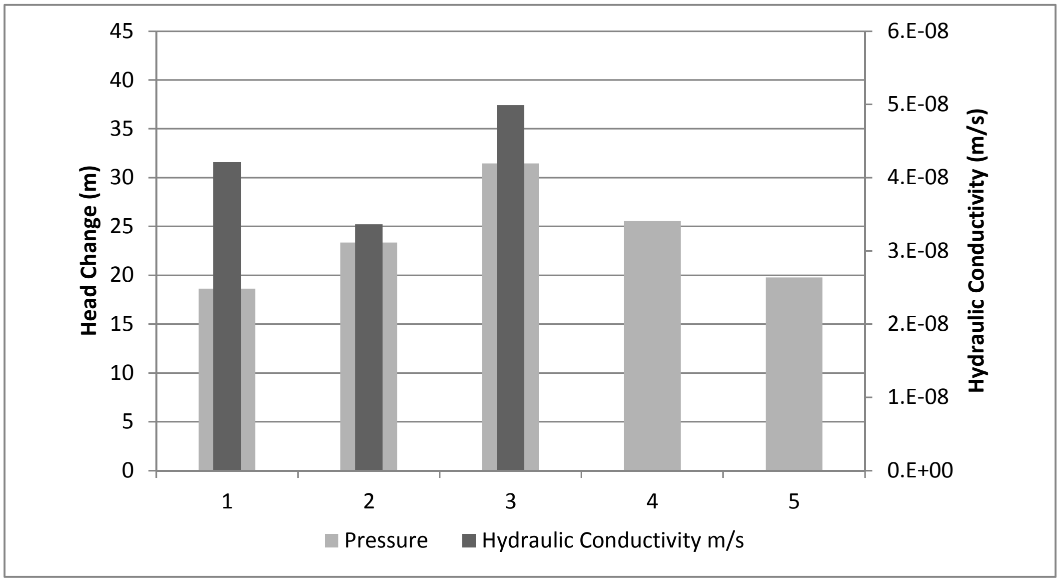
Steady State Equation:
K=[Q*ln(L/D)+sqrt(1+(L/D)^2)]/[2(PI)LP]
(Thiem 1906)

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**

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)

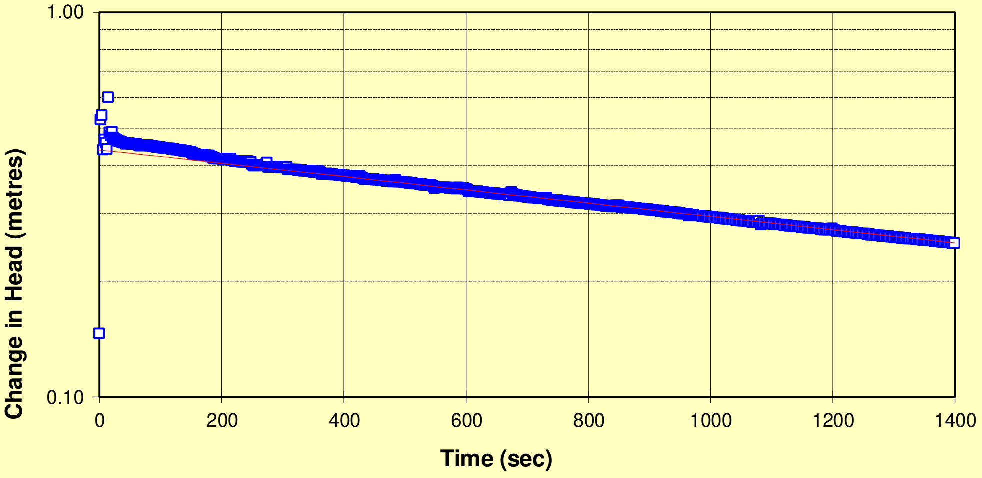
y_t = drawdown (metres) at time t (seconds)

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

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

where:

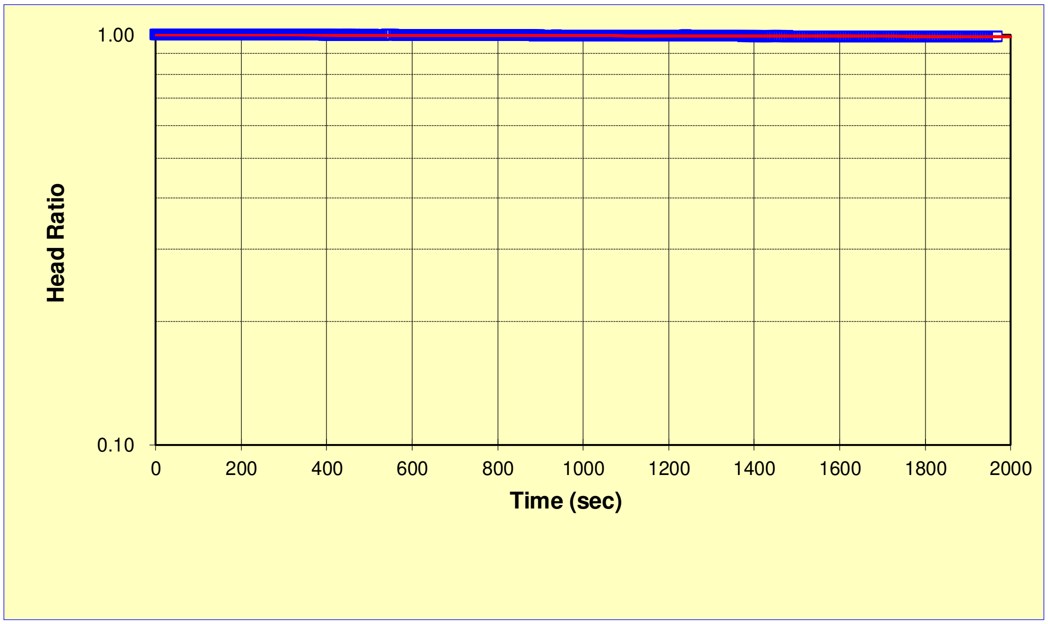
r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

INPUT PARAMETERS

r_c = 1.9E-02
R_e = 5.0E-02
L_e = 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:

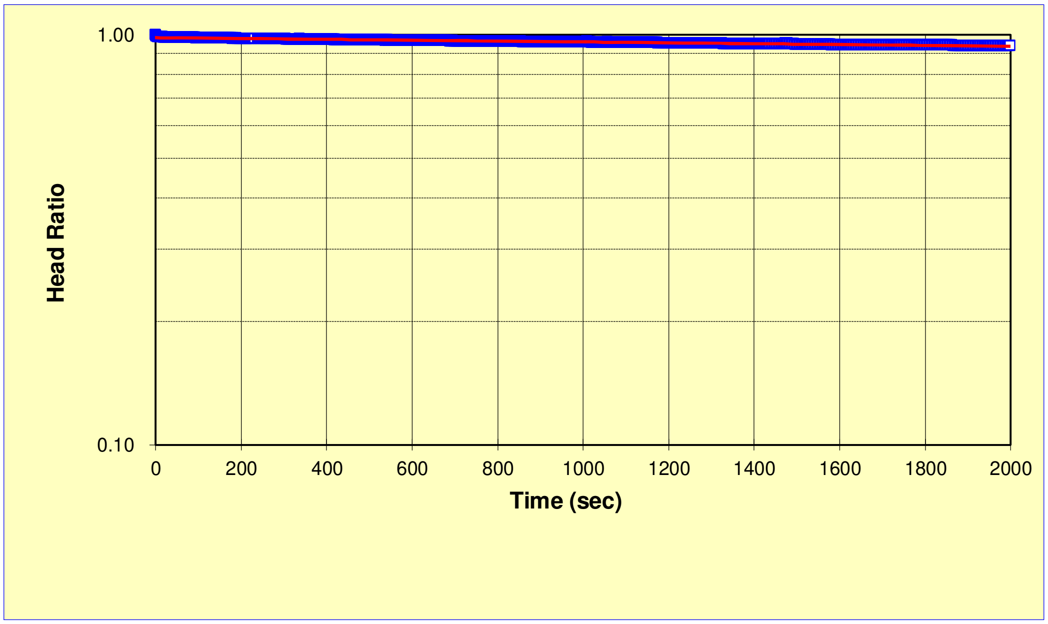
r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

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

Golder Associates Ltd.

HVORSLEV TEST ANALYSIS
FALLING HEAD TEST BH13-4 Test 4

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

where:

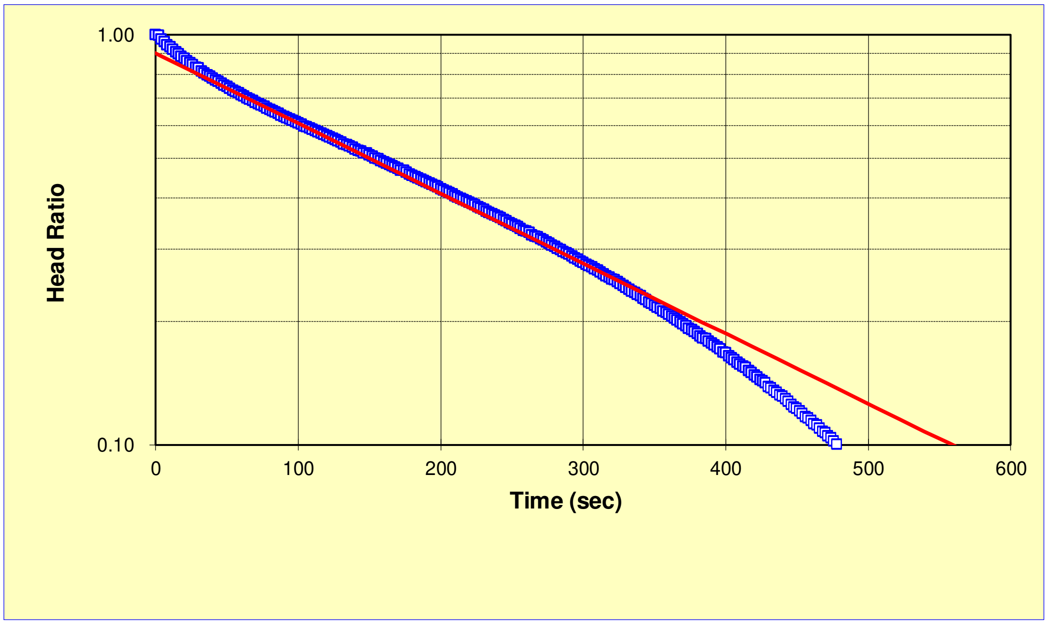
r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

INPUT PARAMETERS

r_c =	1.9E-02
R_e =	5.0E-02
L_e =	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

Golder Associates Ltd.

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

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

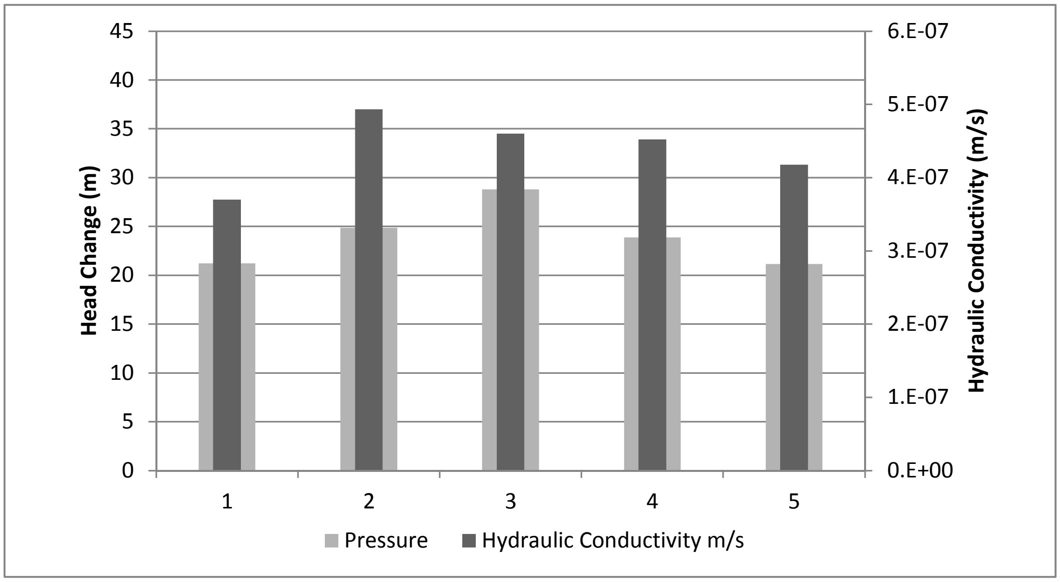
RESULTS:

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

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

Pressure and Hydraulic Conductivity



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

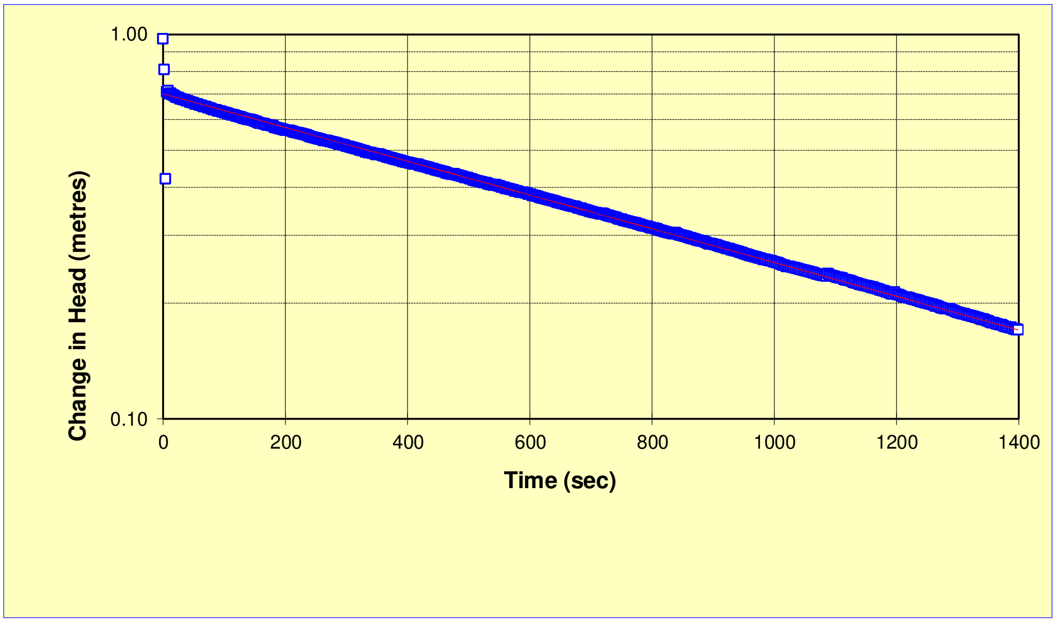
y_0 = 0.70

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	Analysis By:	DH
Project No.:	13-1121-0005	Checked By:	SRW
Test Date:	02/22/13	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:

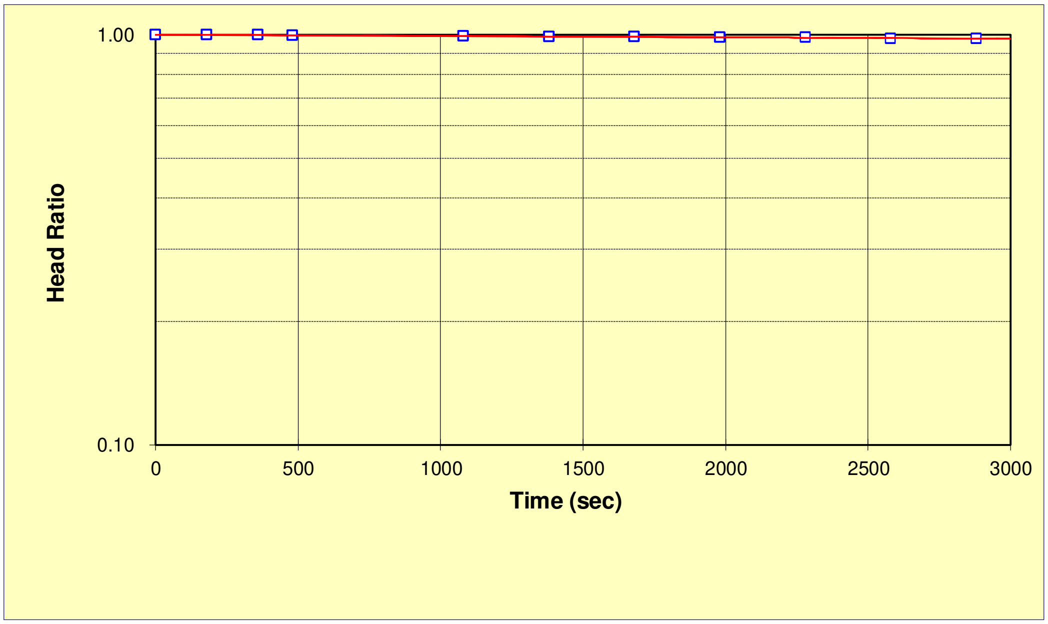
r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

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

Golder Associates Ltd.

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:

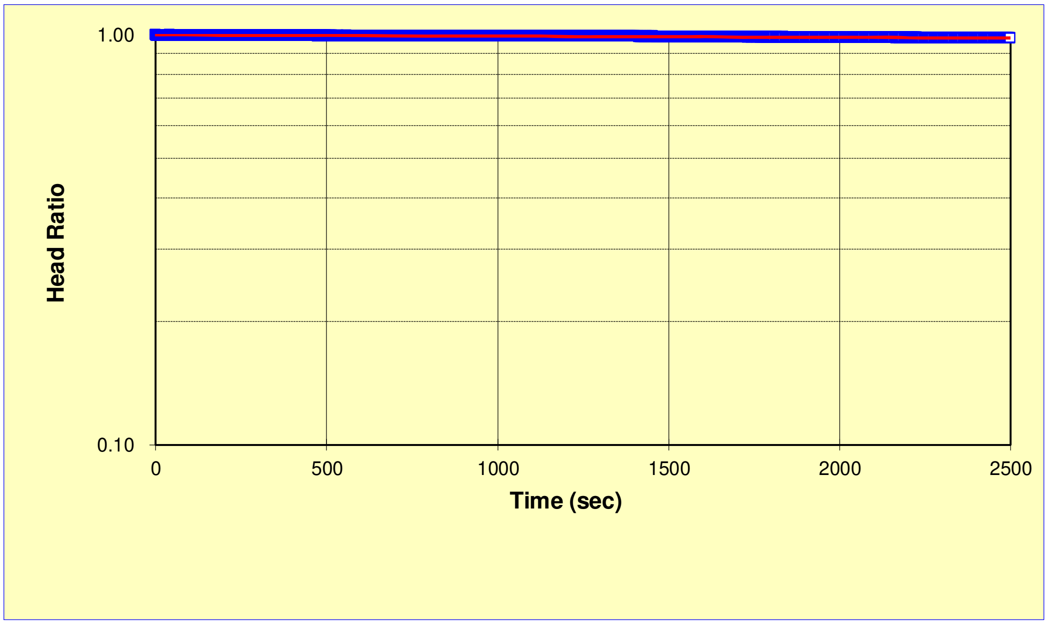
r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

INPUT PARAMETERS

r_c =	1.8E-02
R_e =	4.8E-02
L_e =	3.6
t_1 =	0
t_2 =	1000
Head Ratio $_1$ =	1.00
Head Ratio $_2$ =	0.99

RESULTS

K=	1E-09	m/sec
K=	1E-07	cm/sec



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

$$K = \frac{r_c^{\,2}}{2L_e} \ln\left[\frac{L_e}{2R_e} + \sqrt{1+\left(\frac{L_e}{2R_e}\right)^2}\right]\left[\frac{\ln\left(\frac{h_1}{h_2}\right)}{\left(t_2 - t_1\right)}\right]$$ 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 = 1.8E-02

R_e = 4.8E-02

L_e = 3.2

t_1 = 0

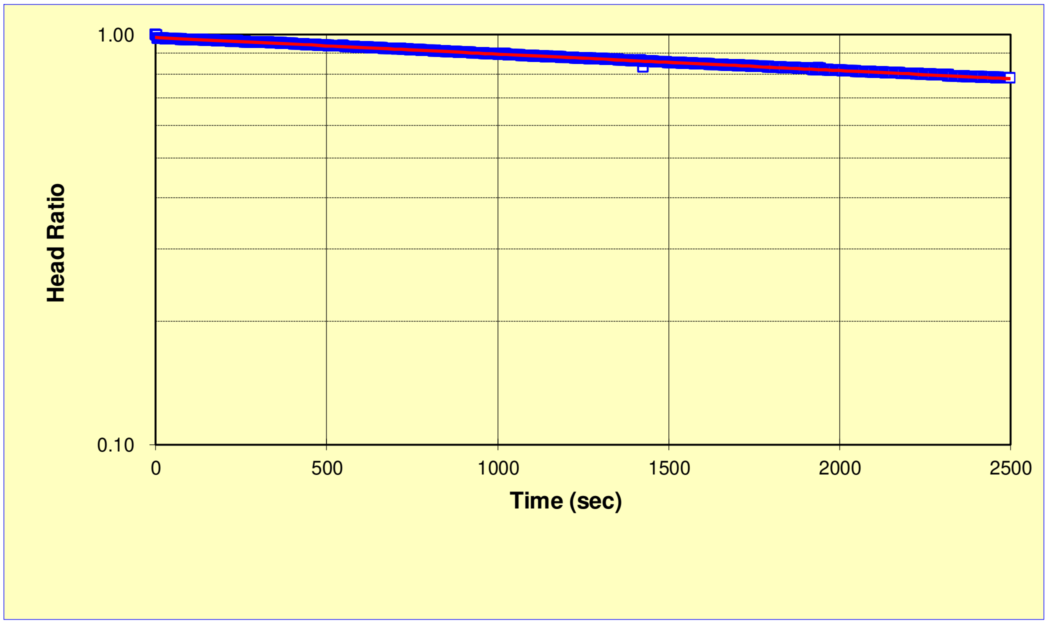
t_2 = 2000

Head Ratio $_1$ = 0.98

Head Ratio $_2$ = 0.82

RESULTS

K=	2E-08	m/sec
K=	2E-06	cm/sec



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

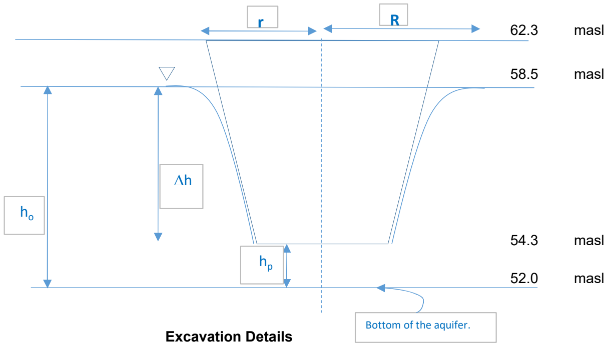
Groundwater Inflow

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_0 (m)	6.5	**r - radius of pit**
h_p (m)	2.3	**R - radius of influence**
r (m)	**45.5**	**SF - Safety Factor**
SF	**1.5**	

	Q	R	Rad of Inf. from edge	m^3/day	L/day
Initial*	2.4E-03	47	2	210	209,936
	1.0E-03	50	5	87	86,619
	5.3E-04	55	10	45	45,458
Steady-State**	3.7E-04	60	15	32	31,696
	2.9E-04	65	20	25	24,788
	2.1E-04	75	30	18	17,834
	1.7E-04	85	40	14	14,317
	1.4E-04	95	50	12	12,182
	1.2E-04	105	60	11	10,739
	1.0E-04	125	80	9	8,902
	9.0E-05	145	100	8	7,770
	7.2E-05	195	150	6	6,196
	6.2E-05	245	200	5	5,359

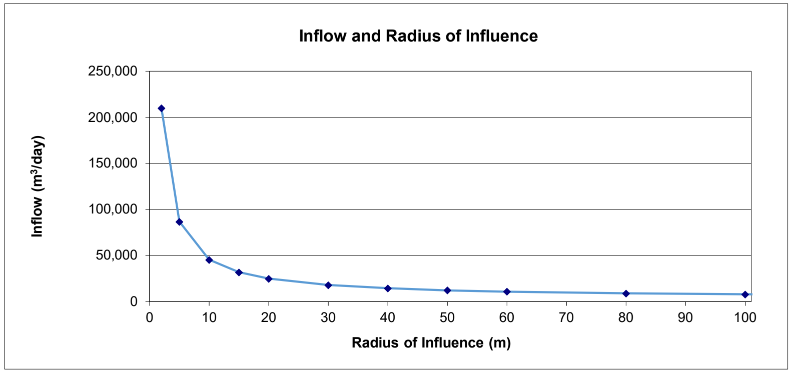


Excavation Details

Footprint Area (m2)	6500	
Ground 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, +0.2 masl for safety)
Average depth 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) 15



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)	6,500
10 year Rainfall event (m)	0.1
Max Vol Precipitation (L)	650,000

GOLDER

golder.com