

DATE July 14, 2017**PROJECT No.** 1651997**TO** Jason Wright, P.Eng.
AECOM**CC** Kyle Hampton, P.Eng.**FROM** Sarah Poot, P.Eng.**EMAIL** Sarah_Poot@golder.com

**GEOCRES NO. 31E-380
ASSIGNMENT 5015-E-0045 – WORK ORDER 1
CULVERT AT HIGHWAY 11 / HIGHWAY 117 INTERCHANGE
HIGHWAY 11 STATION 16+312, SITE 42-194
BRACEBRIDGE, ONTARIO**

Golder Associates Ltd. (Golder) has been retained by AECOM on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the culvert replacement at approximately Station 16+312 on Highway 11 (Site 42-194) near the Highway 11/117 interchange, as part of MTO Assignment No. 5015-E-0045. This memorandum provides a summary of the subsurface conditions from the borehole investigation, and preliminary geotechnical discussion and recommendations for geotechnical/foundations aspects of the culvert replacement, including consideration of trenchless and open-cut alternatives for installation.

1.0 PROJECT DESCRIPTION

The culvert is located on Highway 11, approximately 200 m south of the Highway 117 overpass in Bracebridge, Ontario as shown in the Key Plan on Drawing 1. Highway 11 at the culvert site is a four-lane divided highway with paved shoulders and a posted speed limit of 100 km/hr. The existing embankments for the northbound and southbound lanes (NBL and SBL) are about 8 m high relative to the original ground. Exposed bedrock was observed in the general site vicinity.

We understand the existing approximately 3 m wide cast-in-place reinforced concrete box culvert was originally constructed in the 1960s, then extended in 1973 as part of the highway widening, resulting in a total length of approximately 76 m. The culvert is to be replaced due to its poor condition. The preferred alternatives to be considered for the culvert replacement are as follows:

- Replace the culvert on the existing alignment by spanning over the existing culvert with an open frame structure and the use of either median crossovers or Temporary Modular Bridges (TMBs); or
- Realign the creek and construct a replacement culvert 18 m to the north using a trenchless method of installation, if subsurface conditions warrant.

The purpose of this investigation is to evaluate the subsurface fill, soil and bedrock conditions at the existing and potential culvert locations and determine the feasibility of conventional open-cut methods or trenchless methods for the culvert replacement.

Background documentation used in preparation of this memorandum include the following:

- Structural Design Memorandum (Preliminary for Discussion) by Morrison Hershfield, dated August 17, 2015;
- Contract 2007-5024, Highway 11/117 IC, Highway 11, Culvert No. 2 Rehabilitation drawings; and
- GEOCRE 31E-87, Foundation Investigation Report for Proposed Underpass Interchange at N. Jct. Hwy. #11 & Hwy #117, 3.0 miles North of Bracebridge, Hwy. #11, Site 42-174, W.P. 32-77-02, District 11.

2.0 INVESTIGATION PROCEDURES

The field work for this investigation was carried out between February 27 and March 8, 2017. A total of five boreholes were advanced using hollow stem augers with a truck-mounted drill rig supplied and operated by Downing George Estate Drilling Ltd. of Grenville-sur-la-Rouge, Quebec. Bedrock and rock fill were cored using rotary diamond drilling techniques while retrieving HQ-sized core for rock fill and NQ-sized core for bedrock.

Standard Penetration Testing (SPT) and sampling were carried out at regular intervals of depth in the boreholes, using conventional 35 mm internal diameter split-spoon sampling equipment advanced using an automatic hammer in accordance with ASTM D1586. The results of the in-situ field tests (i.e., SPT 'N'-values) as presented on the borehole records are uncorrected.

The boreholes were surveyed using a Trimble Geo7 GPS survey unit. The locations of the boreholes are shown on Drawing 1. A summary of the borehole locations (northing and easting given relative to NAD83 MTM Zone 10, as well as latitude and longitude) and geodetic elevations are provided on the borehole records and summarized in Table 1.

Table 1 – Summary of Borehole Locations

Borehole	Northing	Easting	Latitude	Longitude	Elevation	Location
17-1	4,993,667.2	320,702.6	45.084815	-79.297809	280.9 m	SBL, north of side of existing culvert
17-2	4,993,666.5	320,736.3	45.084808	-79.297382	282.0 m	NBL, drilled at existing culvert
17-2B	4,993,660.2	320,739.0	45.084752	-79.297347	282.1 m	NBL, south side of existing culvert
17-3	4,993,676.9	320,698.4	45.084903	-79.297863	280.7 m	SBL north side of proposed culvert
17-4	4,993,677.7	320,731.4	45.084909	-79.297443	281.6 m	NBL, south side of existing culvert

3.0 SUBSURFACE CONDITIONS

The detailed subsurface and soil and groundwater conditions encountered in the boreholes and the results of geotechnical laboratory testing are given on the borehole records. The results of geotechnical laboratory testing are also presented on Figures 1 to 5. The stratigraphic boundaries shown on the borehole records and on the interpreted stratigraphic sections on Drawing 1 are inferred from non-continuous sampling and represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the boreholes.

3.1 Asphalt

All boreholes were advanced through asphalt at the edge of the pavement or in the shoulders. The thickness of the asphalt ranges from 110 mm to 200 mm.

3.2 Fill

Fill of variable composition and thickness was encountered at all borehole locations. The elevations of the surface and base of the fill and the layer thickness of the fill materials as encountered in the boreholes are summarized in Table 2.

Table 2 – Summary of Fill Depth/Elevation/Thickness

Borehole No.	Depth to Surface of Fill (m)	Fill Surface Elevation (m)	Base of Fill Elevation (m)	Fill Thickness (m)
17-1	0.2	280.7	272.3	8.4
17-2	0.2	282.0	273.8*	8.2*
17-2B	0.1	282.0	272.0	10.0
17-3	0.1	280.6	272.1	8.5
17-4	0.1	281.5	274.3	7.2

* Top of box culvert encountered at this elevation/depth.

The fill materials vary in composition from moist, brown sand and gravel, to sand, to silty sand, to silt and sand. Zones of rock fill were encountered in Boreholes 17-2 and 17-2B. In Borehole 17-2, 1.7 m and 1.6 m thick rock fill zones were encountered from 2.6 m to 4.3 m depth (Elevation 279.4 m to 277.7 m) and from 5.3 m to 6.9 m depth (Elevation 276.7 m to 275.1 m). In Borehole 17-2B, a 2.3 m thick rock fill zone was encountered from 3.5 m to 5.8 m depth (Elevation 278.6 m to 276.3 m). These zones required HQ coring techniques to advance the borehole. Occasional instances of auger grinding and bouncing or empty split-spoon samples were also noted in Boreholes 17-2, 17-2B and 17-4, and represent the potential presence of gravel, cobbles/boulders or rock fill.

The SPT "N"-values within the non-cohesive fill materials generally range from 0 (weight of hammer) to 61 blows per 0.3 m of penetration, indicating a variable, very loose to very dense relative density. In general, the fill is compact to dense with the very loose fill being near the base of the fill deposit in Boreholes 17-1 and 17-2B. Four split-spoon samples did not penetrate the full sampler depth likely as a result of the presence of gravel, cobbles or rock fill fragments within the fill, as noted on the borehole records.

The results of grain size distribution tests completed on nine selected samples of the fill from the investigation are shown on Figures 1 and 2. The water contents measured on samples of the fill deposit range from about 3 to 25 percent. One organic content test was carried out on the lowest fill sample in Borehole 17-3 and measured 1.2 percent (i.e., trace organics).

3.3 Silt and Sand

A deposit of non-cohesive silt and sand was encountered below the fill in Boreholes 17-1, 17-2B and 17-3. Traces of clay, gravel, wood fragments and rootlets as well as organic inclusions were observed within the silt and sand deposit. The approximate elevations of the surface and base of the silt and sand and the thickness of the deposit as encountered in the boreholes are summarized in Table 3:

Table 3 - Summary of Silt and Sand Deposit Depth/Elevation/Thickness

Borehole No.	Deposit Surface Depth (m)	Deposit Surface Elevation (m)	Deposit Base Elevation (m)	Deposit Thickness (m)
17-1	8.6	272.3	269.2	3.1
17-2B	10.1	272.0	267.4	4.6
17-3	8.6	272.1	266.0	6.1

The SPT “N”-values measured within the silt and sand deposit range from 0 (weight of hammer) to 10 blows per 0.3 m of penetration, indicating a very loose to compact relative density.

The results of grain size distribution tests completed on five selected samples of the silt and sand deposit are shown on Figure 3. Two Atterberg limits tests were conducted on selected samples of the silt and sand deposit and returned a non-plastic result. Two organic content tests were carried out on the upper sample of this deposit (just below the fill) and measured 3.3 and 3.6 percent (i.e., trace organics). The natural water contents measured on samples of the silt and sand deposit range from about 11 to 49 percent.

3.4 Sand

A deposit of non-cohesive sand was encountered below the silt and sand deposit in Boreholes 17-1, 17-2B and 17-3. Trace to some silt and trace to some gravel were encountered in some of the sand samples. The approximate elevations of the surface and base of the silt and sand and the thickness of the deposit as encountered in the boreholes are summarized in Table 4:

Table 4 - Summary of Sand Deposit Depth/Elevation/Thickness

Borehole No.	Deposit Surface Depth (m)	Deposit Surface Elevation (m)	Deposit Base Elevation (m)	Deposit Thickness* (m)
17-1	11.7	269.2	262.2	7.0
17-2B	14.7	267.4	263.2	4.2
17-3	14.7	266.0	265.0	1.0

* Note that Boreholes 17-1, 17-2B and 17-3 were terminated in the sand deposit and the actual thickness of the deposit is likely greater than noted.

Dynamic Cone Penetration Tests (DCPTs) were advanced from the base of sampled Boreholes 17-1, 17-2B and 17-3 to depths between 21.3 m and 24.4 m, likely terminated within the sand deposit.

The SPT “N”-values measured within the sand deposit range from 7 to 36 blows per 0.3 m of penetration, indicating a loose to dense relative density.

The results of grain size distribution tests completed on three selected samples of the silt and sand deposit are shown on Figure 4. The natural water contents measured on samples of the sand deposit range from about 18 to 33 percent.

3.5 Bedrock

Bedrock was encountered in Borehole 17-4 at a depth of 7.3 m below ground surface (Elevation 274.3 m). Bedrock was confirmed by coring for a length of 3.0 m. Knobs of bedrock were observed at the toe of the embankment slope adjacent to the location of Borehole 17-4, on the east side of the highway.

The bedrock core consists of slightly weathered, non-porous, light grey granite. The Rock Quality Designation (RQD) of the recovered core samples ranges from 86 percent to 100 percent. Unconfined Compressive Strength (UCS) testing on two selected bedrock core samples measured compressive strengths of about 52 MPa and 80 MPa, indicating the granite sample is strong, in accordance with the Canadian Foundations Engineering Manual (CFEM). Bedrock core photographs are shown on Figure 5.

3.6 Groundwater

Groundwater observations and measurements are shown in detail on the borehole records following the text of this report. The groundwater level was measured in Borehole 17-2B at a depth of 7.6 m (Elevation 274.6 m) upon completion of drilling, and in Borehole 17-4 at a depth of 7.3 m (Elevation 274.3 m). The groundwater level from previous information was measured at Elevation 272.5 m in September 2006.

It should be noted that the observations and readings shown on the Record of Borehole sheets reflect the groundwater conditions encountered in the boreholes during or shortly after the field investigation and some seasonal fluctuations should be anticipated.

3.7 Corrosivity Testing

The results of analytical tests on two soil samples at the culvert site are attached to this memorandum, and summarized in Table 5 below. The suite of parameters tested includes pH, sulphate, chloride, sulphide, resistivity, electrical conductivity and redox potential.

Table 5 - Summary of Analytical Test Results

Parameter	Units	BH 17-3 Sa 11		BH 17-2B Sa 12	
		Results	ANSI/AWWA Point Rating	Results	ANSI/AWWA Point Rating
Chloride (Cl)	mg/L	88	N/A	53	N/A
Sulphate (SO ₄)	mg/L	15	N/A	12	N/A
Sulphide	%	<0.05	0	<0.05	0
Conductivity (EC)	µS/cm	0.242	N/A	0.132	N/A
Resistivity	ohm-cm	4130	0	7580	0
pH	n/a	8.11	0	7.86	0
Redox Potential	mV	248	0	273	0

4.0 DISCUSSIONS AND PRELIMINARY GEOTECHNICAL RECOMMENDATIONS

4.1 Culvert Replacement Alternatives

It is our understanding that the existing structure consists of a cast-in-place reinforced concrete box culvert with a total width of 3.72 m (clear span of 3 m), a total height of 2.16 m (barrel height of 1.5 m), and a total length of approximately 76.3 m. The original culvert was constructed in the 1960s (49 m length under the existing SBL) and extended easterly in 1973 (27 m length under the NBL) to accommodate the eastward widening of Highway 11 at that time. The invert at the inlet (east end of culvert) and outlet (west end of culvert) is at approximately Elevation 272.59 m and Elevation 272.46 m, respectively. Between 7.7 m and 8.3 m of cover is estimated above the culvert at the centreline of the SBL and NBL, respectively.

We understand the culvert is to be replaced by a rigid frame open footing culvert using open cut excavations. Alternatively, trenchless methods could be used to install a circular pipe culvert along a new alignment; however, trenchless installation methods are typically not feasible in rock fill embankments. Based on background information, it was assumed that rock fill is present at the existing culvert location, but that earth fill is present some 18 m to the north (and hence, the location for investigation of the alternate culvert alignment).

Based on the results of the borehole investigation, rock fill was encountered in the vicinity of the existing culvert in the NBL embankment (Boreholes 17-2 and 17-2B). Rock fill was not encountered in Borehole 1 drilled through the SBL embankment, although this borehole was located about 7 m north of the existing culvert. The base of the fill was encountered between Elevation 272.0 m and 272.3 m in these boreholes, which corresponds to approximately just below the invert at the existing culvert location.

Earth fill was encountered in both the NBL and SBL embankments in Boreholes 17-3 and 17-4, which are located at the approximate culvert re-alignment location about 18 m north of the existing culvert. In Borehole 17-3, the granular fill extended to Elevation 272.1 m. In Borehole 17-4, bedrock was encountered at 7.3 m depth (Elevation 274.3 m), more than 2 m above the proposed culvert invert at this location.

4.1.1 Open-Cut Methods

Due to the approximately 8 m high embankments, in order to replace the culvert at the existing or re-aligned location using open-cut methods, the traffic would have to be staged to allow a minimum one-lane traffic flow in each direction. This could be accomplished by the use of single lane temporary modular bridges (TMB) or median crossovers. The temporary bridges could be founded on strip footings within the granular fill located a sufficient setback distance back from the open-cut excavation; otherwise vertical protection systems may be required. For median crossovers, the median swale would need to be filled in and traffic routed onto the opposing lanes during staging. Settlement of the underlying soils is not an issue for the median crossovers due to the granular nature of the fill and subsoils. Excavation and groundwater control for open-cut methods are discussed in Section 4.3 below.

4.1.2 Trenchless Methods

Typical trenchless methods for culvert installation include jacking and boring, pipe ramming, micro-tunnel boring machine (MTBM) and conventional tunnelling (hand mining). Horizontal directional drilling is typically not feasible for gravity culvert installations. Based on our investigations, trenchless methods for tunnelling are not recommended for the replacement of the culvert at the re-aligned location for the following reasons:

- Strong granite bedrock was encountered under the NBL embankment within the tunnel horizon, resulting in difficult mixed face conditions along the tunnel alignment. The advance of MTBMs and jack and bore equipment can be impacted by bedrock, with a high risk that the tunnelling equipment will be deflected upward along the interface with the strong granite bedrock.

- The diameter of the proposed culvert (assumed to be 3200 mm) exceeds the maximum tunnelling diameter that can be achieved using jack and bore and pipe ramming. Micro-tunnelling is also not recommended due to limited contractor experience with tunnelling of the proposed diameter, together with the risk associated with the mixed face conditions as noted above. Conventional tunnelling or hand mining may be feasible but may not be cost effective for one culvert. However, if multiple smaller pipes are utilized instead of one large pipe, then these methods may be feasible.
- The tunnel alignment may encounter very loose to compact granular fill and silt and sand deposits at or below the groundwater level, and perched water may also be encountered within granular fill materials. Jack and bore methods typically require groundwater level lowering to prevent loss of ground into the face in granular materials. It will be difficult to dewater the alignment across the full width of the Highway 11 platform from the surface.

At the existing culvert location, rock fill was encountered which typically negates the use of trenchless methods. However, given that the rock fill was limited to specific zones within the embankment (i.e. the embankment was not constructed entirely of rock fill based on the borehole results), and given that the rock fill zone in Boreholes 17-2 and 17-2B was not encountered at the approximate culvert invert, it may be possible to utilize trenchless methods at a location closer to the existing culvert location. However, the same risks with respect to tunnel size and groundwater levels noted above would apply for the realigned culvert in the granular deposits.

Therefore, the most feasible trenchless methods of installing the replacement culvert for the large size diameter culvert are hand mining/mechanically assisted excavation within a shield with proper dewatering, and, to a lesser degree, conventional tunneling with an appropriately designed and operated TBM that is selected recognizing the risk of bedrock at the re-aligned location or the presence of rock fill fragments (i.e. similar to cobbles and boulders) at the existing location. These two methods are less risky than microtunnelling since person-entry is possible to facilitate removal of obstructions, provided that the groundwater is adequately controlled.

Given the risks associated with the large culvert size and the presence of rock fill and bedrock, we recommend that the culvert be replaced via open-cut excavation. If the culvert could be sized such that the pipe diameters are less than about 1.5 m, then trenchless replacement immediately adjacent to the existing culvert location may also be feasible, as discussed above.

4.2 Culvert Foundations

4.2.1 Foundations Elevations and Frost Protection

It is not necessary to found box or pipe culverts at the standard depth for frost protection purposes, as a box structure is tolerant of small magnitudes of movement related to freeze-thaw cycle, should these occur. Open rigid frame culvert strip footings placed on the properly prepared subgrade should be placed below the frost depth of 1.7 m. Thus box or pipe culverts can be founded in the native very loose to compact silt and sand deposits at or below Elevation 272 m. Strip footings can be founded in the same deposit at or below Elevation 270.3 m.

4.2.2 Geotechnical Resistances

A box culvert of about 3.7 m total width (including 0.35 m thick side walls) may be designed using an estimated factored ultimate geotechnical resistance of 125 kPa and factored serviceability geotechnical resistance of 75 kPa (for a total settlement of 25 mm). For 0.6 m wide strip footings at the required depth, a factored ultimate geotechnical resistance of 150 kPa and factored serviceability geotechnical resistance of 100 kPa (for a total settlement of 25 mm) may be used.

The factored geotechnical axial resistances given above are in accordance with Canadian Highway Bridge Design Code (CHBDC) CSA S6-14, and are based on loading applied perpendicular to the base of the culvert box or footing. Where applicable, the inclination of the load should be taken into account.

4.2.3 Stability and Settlement

Given that both the embankment and subsoils consist of granular material, it is anticipated that global stability will not be a concern. However, global stability should be assessed during detailed design if there are grade raises or widening as part of the culvert replacement, as well as for any temporary/interim conditions associated with construction staging. Settlement of the granular soils after embankment reconstruction is expected to occur during construction.

4.2.4 Excavation and Replacement Fill Below Culvert

Prior to placement of any concrete and bedding material, any organics or deleterious materials should be sub-excavated from below the plan limits of the proposed works to the founding levels. The sub-excavated areas should be backfilled with granular material, meeting the requirements of OPSS.PROV 1010 (Aggregates) for Granular 'A' or Granular 'B' Type I, II or III that is placed and compacted in accordance with OPSS.PROV 501 (Compacting). The use of Granular 'B' Type II is recommended in wet ground conditions or below the groundwater table.

4.2.5 Culvert Bedding, Cover and Backfill

The bedding and levelling pad requirements will depend upon the type of culvert selected (i.e. box, rigid frame or pipe culvert) and the appropriate OPSS should be followed. Given the potential for surface water flow and some groundwater seepage through the adjacent granular fill and relatively permeable native soils at this site, a minimum 300 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular 'B' Type II material is recommended for bedding purposes. The granular bedding should be placed in maximum 200 mm thick loose lifts and be compacted to 98 percent of Standard Proctor Maximum Dry Density (SPMDD) as specified in OPSS.PROV 501 (Compacting). The Granular 'B' Type II could also be placed sub-aqueously with only surface compaction (i.e. above the water level), if required. In addition, a 75 mm thick un-compacted levelling pad consisting of OPSS.PROV 1010 Granular 'A' or fine concrete aggregate should be provided. A geotextile is not required between the granular bedding (based on the OPSS.PROV 1010 materials given above) and the native subsoils.

Backfill behind the culvert walls should consist of granular fill meeting the specifications for OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type I, II or III. The granular backfill should be placed and compacted in accordance with OPSS.PROV 501 (Compacting). The fill should also be placed concurrently on both sides of the culvert, ensuring that the backfill depth on one side does not exceed the other side by more than 400 mm.

Backfill placement for reconstruction of the roadway embankments along and over the culvert should be carried out as per OPSD 208.010 (Benching of Earth Slopes) to integrate the existing embankment fill and new fill along the cut faces.

Reuse of existing embankment fill as backfill above the culvert must be approved by a geotechnical engineer prior to placement. In this regard, excavated embankment fill from the site, free of significant amounts of deleterious materials, may be reused as engineered fill. Based on the measured natural water contents, the majority of the native non-cohesive sandy/silty soils are generally near or above their estimated laboratory optimum moisture contents for compaction and may require some drying prior to placement. It should also be noted that the workability of the excavated embankment fill may be sensitive to moisture conditions and some difficulty should be expected in achieving adequate compaction during wet weather. Existing rock fill fragments can also be

incorporated into the embankment fill above the culvert as per OPSS.PROV 206 (*Grading*) and OPSS.PROV 501 (*Compacting*).

4.2.6 Analytical Testing for Construction Materials

The analytical test results were compared to CSA A23.1-14 Table 3 (*"Additional requirements for concrete subjected to sulphate attack"*) for potential sulphate attack on concrete. The measured sulphate concentrations were less than 15 mg/L, which is below the exposure class of S-3 (Moderate). Therefore, when designing the concrete, the effects of sulphates from within the soils/groundwater around the culvert may not need to be considered.

The soil samples tested exhibited a pH of 7.86 to 8.11, and a resistivity of 4,130 and 7,580 ohm-cm. According to the MTO Gravity Pipe Design Guidelines (2014), the pH is not considered detrimental to culvert durability as it is less than a pH of 8.5. Based on the resistivity, the soil corrosiveness is considered low to moderate, as per Table 3.2 of the MTO Gravity Pipe Design Guidelines (2014). However, the culvert will be exposed to roadway de-icing salt. Therefore, it is recommended that concrete be designed for a "C" type exposure class as defined by CSA A23.1-14 Table 1 and consideration should be given to providing corrosion protection to reinforcing elements. All culverts should be designed with consideration given to Table 7.1 of the MTO Gravity Pipe Design Guidelines (2014). These recommendations are provided as guidance only; the structural designer should take the results of the laboratory testing, the potential for corrosion and the ultimate selection of materials into consideration.

4.3 Excavations and Groundwater Control

Temporary excavations for the culvert replacement at the existing or re-aligned locations will be made through the existing embankment fill consisting of very loose to very dense sand and gravel, sand, silty sand to silt and sand and rock fill as well as the very loose to compact silt and sand deposit. Excavations would extend to about Elevation 272 m or 270 m, resulting in excavations between 9 and 12 m deep below the highway grade, and up to about 2 m below the ground surface at the toe of slope near the culvert ends. All excavations must be carried out in accordance with Ontario Regulation 213, Ontario Occupational Health and Safety Act for Construction Projects (as amended). The granular fills are considered to be Type 3 soil while the native silt and sand material is considered Type 4 soil. Temporary open-cut excavations in Type 3 soils should remain stable provided that side slopes are formed no steeper than 1 horizontal to 1 vertical (1H:1V). In Type 4 soils, the side slopes should be formed no steeper than 3H:1V, unless appropriate groundwater control is implemented.

As the groundwater level is likely at or just above the invert of the culvert, dewatering will be required if carried out in open-cut excavation. Assuming adequate watercourse diversion is provided and the culvert is installed in short sections, then localized dewatering to the foundation level of the rigid frame footings could consist of pumping from several properly filter sump pumps at the base of the excavation in each section. If more sustained dewatering for open-cut excavation is required for a longer period of time and/or depending what trenchless method is selected which may require dewatering, then active dewatering consisting of well points or eductors may be required. It is recommended that piezometers be installed during detailed design to measure the stabilized groundwater levels, and provide further information for a more detailed assessment of dewatering volumes. Registration of the construction dewatering in the Environment Activity Section Registry (EASR) would be required if construction dewatering volumes exceed 50,000 L/day. A Permit to Take Water (PTTW) would be required for dewatering volumes greater than 400,000 L/day.

If required depending on the staging option chosen, temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). Temporary excavation support systems should be designed to Performance Level 2 for any excavation adjacent to the existing roadways.

It is likely that sheet piles cannot be utilized for shoring at this location due to the presence of rock fill. As such, soldier pile and lagging protection systems will likely be required.

4.4 Recommendations for Further Work During Detail Design

During the detail design phase, additional field investigation and testing will be required, based on the final configuration and/ or alignment of the culvert and the replacement strategy (i.e., type of culvert and construction staging). The scope and results of this investigation must be reviewed at the time of the detail design to determine if they meet the then-current MTO requirements for the culvert type or staging strategy under consideration, and if additional investigation and analysis is necessary. This includes investigations for culvert foundations, temporary shoring and cofferdams (if required), temporary modular bridge foundations, embankment widening/grade raising (if implemented) and trenchless installation. Further, the need for an application for a PTTW should be defined early in the detail design phase of the project as not to delay the start of construction.

5.0 CLOSURE

We trust that the preliminary geotechnical information presented in this Technical Memorandum is sufficient for your immediate needs. If any clarification is required, please do not hesitate to contact this office.

Yours truly,

GOLDER ASSOCIATES LTD.



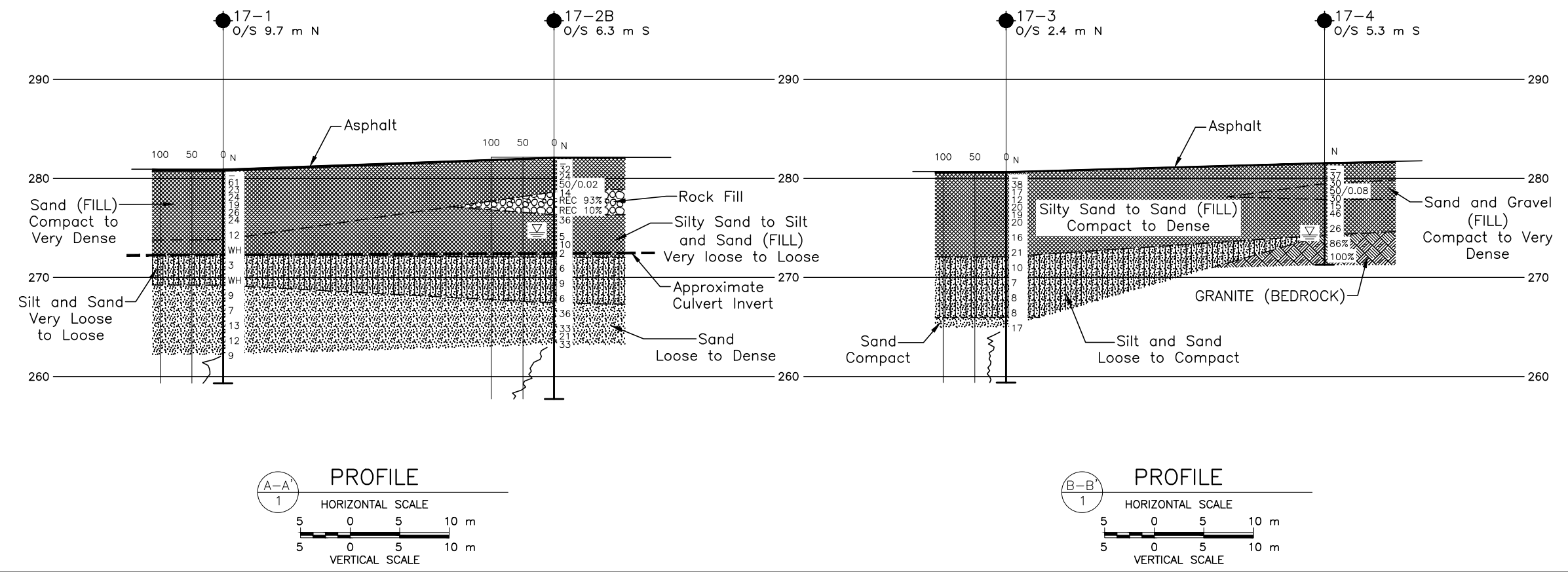
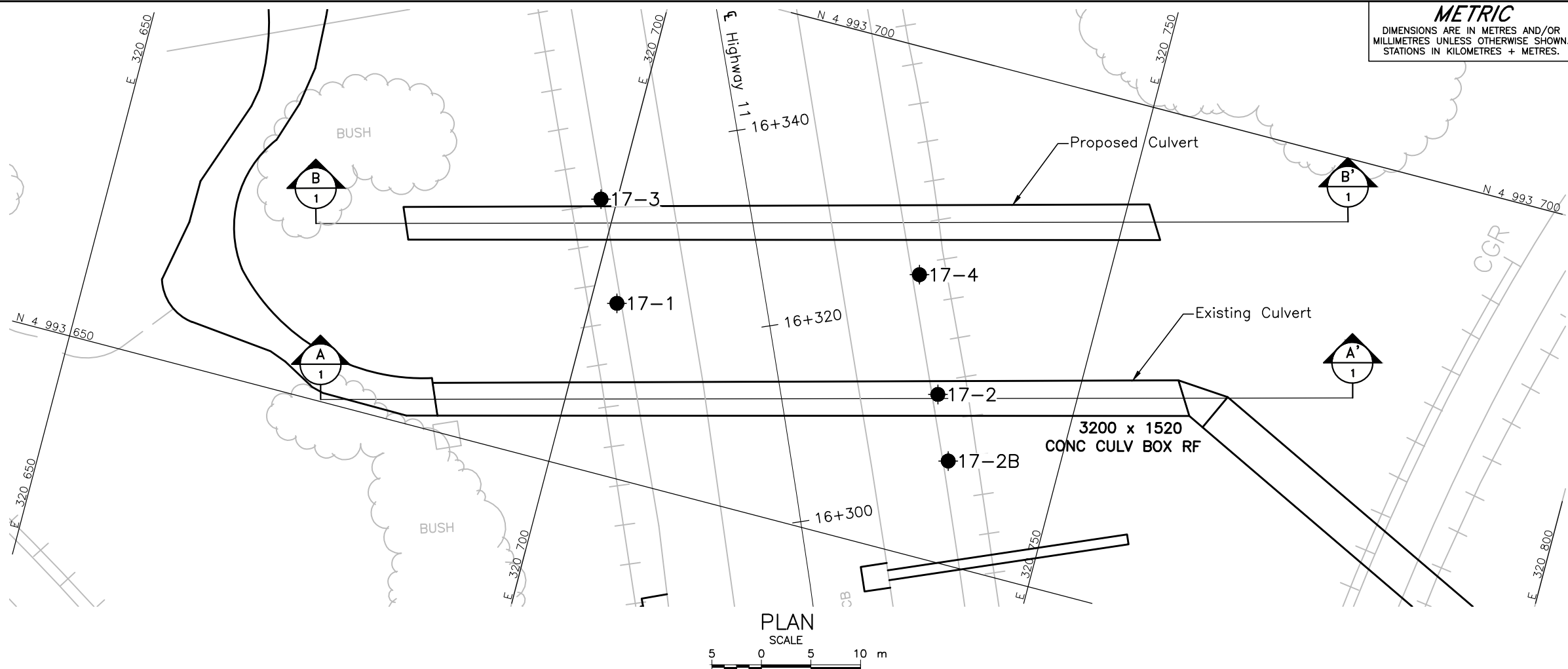
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Lisa C. Coyne, P.Eng.
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IK/SEMP/LCC/nh

Enclosures: Drawing 1 – Borehole Locations and Soil Strata
 Lists of Abbreviations and Symbols
 Lithological and Geotechnical Rock Description Terminology
 Record of Boreholes 17-1, 17-2, 17-2B, 17-3 and 7-4
 Record of Drillhole 17-4
 Figure 1 – Grain Size Analysis – Silt and Sand Silty Sand, Sand (Fill)
 Figure 2 – Grain Size Analysis – Sand and Gravel (Fill)
 Figure 3 – Grain Size Analysis – Silt and Sand
 Figure 4 – Grain Size Analysis – Sand
 Figure 5 – Bedrock Core Photographs
 Summary of Analytical Soil Testing

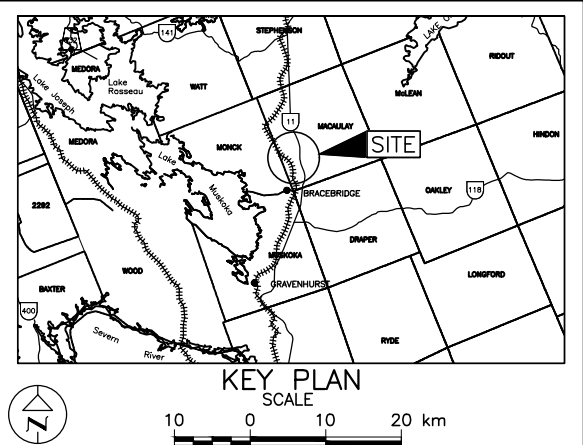


METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.

HIGHWAY 11
BRACEBRIDGE CULVERT STA 16+312
BOREHOLE LOCATIONS AND SOIL
STRATA

SHEET



LEGEND			
	Borehole		
N	Standard Penetration Test Value		
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)		
REC	Recovery (%)		
100%	Rock Quality Designation (RQD)		
	WL upon completion of drilling		

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
17-1	280.9	4993667.2	320702.6
17-2	282.0	4993666.5	320736.3
17-2B	282.1	4993660.2	320739.0
17-3	280.7	4993676.9	320698.4
17-4	281.6	4993677.7	320731.4

NOTES
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

REFERENCE
Base plans provided in digital format by Morrison Hershfield, drawing file no. Hwy 11 - Bracebridge Culvert.dwg, received JAN 05, 2017.



NO.	DATE	BY	REVISION
Geocres No. 31E-380			
HWY. 11	PROJECT NO. 1651997		DIST. .
SUBM'D.	CHKD. IK	DATE: 7/12/2017	SITE: 42-194
DRAWN: TB	CHKD. SEMP	APPD. LCC	DWG. 1



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
FoS	factor of safety

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
ν	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

(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

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

Notes: 1
2

$$\tau = c' + \sigma' \tan \phi'$$
$$\text{shear strength} = (\text{compressive strength})/2$$



LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. 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.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; 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

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils Consistency

	C_u, S_u	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
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, G_s)
DS	direct shear test
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	field vane (LV-laboratory vane test)
γ	unit weight

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

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand



LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERINGS STATE

Fresh: no visible sign of weathering

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

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

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

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

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

BEDDING THICKNESS

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

JOINT OR FOLIATION SPACING

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

GRAIN SIZE

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

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

CORE CONDITION

Total Core Recovery (TCR)

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

Solid Core Recovery (SCR)

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

Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

DISCONTINUITY DATA

Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to Core Axis

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

Description and Notes

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

Abbreviations

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

CSUD-MTO 001 LAT/LONG 165.1997.GPJ GAL-MISS.GDT 07/04/17 DATA INPUT:

+³, ×³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE

PROJECT 1651997		RECORD OF BOREHOLE No 17-1				2 OF 2 METRIC							
W.P. _____		LOCATION N 4993667.2; E 320702.6 (LAT. 45.084815; LONG. -79.297809)				ORIGINATED BY IK							
DIST _____ HWY 11 (SBL)		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers				COMPILED BY TB							
DATUM GEODETIC		DATE February 27, 2017				CHECKED BY SEMP							
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					
	--- CONTINUED FROM PREVIOUS PAGE ---						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED	20 40 60					
262.2	SAND, trace to some gravel, trace to some silt Loose to compact Brown Wet		12	SS	9								19 75 (6)
						268							
			13	SS	7								
						267							
						266							
			14	SS	13								
						265							
						264							
			15	SS	12								
						263							
						262							
18.7	END OF BOREHOLE START OF DCPT		16	SS	9								
259.3	END OF DCPT												
21.6	Note: 1. Groundwater level not recorded due to water introduced during drilling to mitigate heaving sand.												

SUD-MTO 001 LAT/LONG 1651997.GPJ GAL-MISS.GDT 07/04/17 DATA INPUT:





PROJECT <u>1651997</u>		RECORD OF BOREHOLE No 17-2		1 OF 1 METRIC	
W.P. _____		LOCATION <u>N 4993666.5; E 320736.3 (LAT. 45.084808; LONG. -79.297382)</u>		ORIGINATED BY <u>IK</u>	
DIST _____ HWY <u>11 (NBL)</u>		BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Augers and HQ Casing/Coring</u>		COMPILED BY <u>TB</u>	
DATUM <u>GEODETIC</u>		DATE <u>February 28, 2017</u>		CHECKED BY <u>SEMP</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
								<div><div></div><div></div><div></div><div></div><div></div></div> <div>20 40 60 80 100</div>					<div><div></div><div></div><div></div></div> <div>W_p W W_L</div>				
282.0	GROUND SURFACE																
0.0	ASPHALT (200 mm)																
0.2	Sand, some gravel, trace silt (FILL) Compact to very dense Brown Moist		1	AS	-												
			2	SS	44												
			3	SS	24												
			4	SS	50/0.05												
279.4	Auger grinding from 2.5 m to 2.6 m depth.																
2.6	ROCK FILL		R1	RC	REC 58%												
277.7																	
4.3	Sand, some silt, some gravel (FILL) Compact Brown Moist		5A	SS	29												
276.7																	
5.3	ROCK FILL		R2	RC	REC 7%												
			5B	SS	44												
			R3	RC	REC 0%												
275.1	No recovery in Sample 5B.																
6.9	Silty sand and gravel (FILL) Very dense Brown Moist																
			6	SS	50/0.13												
273.8																	
8.2	END OF BOREHOLE																
	Note: 1. Cored through existing culvert at 8.2 m depth. Culvert obvert plugged and borehole backfilled.																

SUD-MTO 001 LATILONG 1651997.GPJ GAL-MISS.GDT 07/04/17 DATA INPUT:

+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

USUD-MTO 001 LAT/LONG 1651997.GPJ GAL-MISS.GDT 07/04/17 DATA INPUT:

PROJECT <u>1651997</u>				RECORD OF BOREHOLE No 17-2B				2 OF 3 METRIC										
W.P. _____				LOCATION <u>N 4993660.2; E 320739.0 (LAT. 45.084752; LONG. -79.297347)</u>				ORIGINATED BY <u>IK</u>										
DIST _____ HWY <u>11 (NBL)</u>				BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Augers and HQ Casing/Coring</u>				COMPILED BY <u>TB</u>										
DATUM <u>GEODETIC</u>				DATE <u>February 28 and March 8, 2017</u>				CHECKED BY <u>SEMP</u>										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED									WATER CONTENT (%)	
--- CONTINUED FROM PREVIOUS PAGE ---																		
267.4	SILT and SAND, trace clay, trace organics, trace rootlets Loose Black Moist		11	SS	9		270											
14.7	SAND, some silt Compact to dense Brown Wet		12	SS	6		269									0 60 39 1		
									268									
									267									
									266									
									265									
263.2	END OF BOREHOLE START OF DCPT		13	SS	36		267									0 85 14 1		
18.9							266											
									265									
									264									
									263									
						262												
						261												
						260												
						259												

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

SUD-MTO 001 LATILONG 1651997.GPJ GAL-MISS.GDT 07/04/17 DATA INPUT:

PROJECT <u>1651997</u>		RECORD OF BOREHOLE No 17-2B		3 OF 3 METRIC	
W.P. _____		LOCATION <u>N 4993660.2; E 320739.0 (LAT. 45.084752; LONG. -79.297347)</u>		ORIGINATED BY <u>IK</u>	
DIST _____ HWY <u>11 (NBL)</u>		BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Augers and HQ Casing/Coring</u>		COMPILED BY <u>TB</u>	
DATUM <u>GEODETIC</u>		DATE <u>February 28 and March 8, 2017</u>		CHECKED BY <u>SEMP</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W _p	W	W _L		WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED												
	--- CONTINUED FROM PREVIOUS PAGE ---						258	20	40	60	80	100	20	40	60		GR	SA	SI	CL
257.7																				
24.4	END OF DCPT																			
	Note:																			
	1. Water level at a depth of 7.6 m below ground surface (Elev. 274.5) upon completion of drilling.																			

SUD-MTO 001 LATILONG 1651997.GPJ GAL-MISS.GDT 07/04/17 DATA INPUT:

1 OF 2 **METRIC**

W.P. _____	LOCATION	N 4993676.9; E 320698.4 (LAT. 45.084903; LONG. -79.297863)	ORIGINATED BY	IK
DIST _____ HWY 11 (SBL)	BOREHOLE TYPE	108 mm I.D. Hollow Stem Augers and NQ Casing/Coring	COMPILED BY	TB
DATUM GEODETIC	DATE	March 8, 2017	CHECKED BY	SEMP

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT 1651997				RECORD OF BOREHOLE No 17-3				2 OF 2 METRIC									
W.P. _____				LOCATION N 4993676.9; E 320698.4 (LAT. 45.084903; LONG. -79.297863)				ORIGINATED BY IK									
DIST _____ HWY 11 (SBL)				BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers and NQ Casing/Coring				COMPILED BY TB									
DATUM GEODETIC				DATE March 8, 2017				CHECKED BY SEMP									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	--- CONTINUED FROM PREVIOUS PAGE ---																
266.0	SILT and SAND, trace clay, trace gravel Loose to compact Grey to brown Moist to wet Seam of coarse sand encountered in Sample 12. 0.3 m of sand heaving in augers at 12.2 m depth.		12	SS	8		268										
							267										
			13	SS	8												
14.7	SAND, trace silt Compact Grey to brown Moist to wet						266										
265.0			14	SS	17												
15.7	END OF BOREHOLE START OF DCPT						265										
							264										
							263										
							262										
							261										
							260										
259.4																	
21.3	END OF DCPT																

SUD-MTO 001 LATILONG 1651997.GPJ GAL-MISS.GDT 07/04/17 DATA INPUT:

PROJECT 1651997				RECORD OF BOREHOLE No 17-4				1 OF 2 METRIC												
W.P. _____				LOCATION N 4993677.7; E 320731.4 (LAT. 45.084909; LONG. -79.297443)				ORIGINATED BY IK												
DIST _____ HWY 11 (NBL)				BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers				COMPILED BY TB												
DATUM GEODETIC				DATE March 8, 2017				CHECKED BY SEMP												
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								20	40	60	80	100						20	40	60
281.6	GROUND SURFACE																			
0.0	ASPHALT (120 mm)																			
0.1	Sand, trace to some silt, trace gravel (FILL) Dense Brown Moist		1	AS	-															
			2	SS	37															
			3	SS	30															
279.5																				
2.1	Sand and gravel, trace to some silt, containing cobbles (FILL) Dense to very dense Grey Moist		4	SS	50/0.08													2 92 (6)		
			5	SS	30															
277.9																				
3.7	Sand, trace to some silt, trace to some gravel (FILL) Compact to dense Brown Moist		6	SS	15															
	Auger grinding from 2.3 m to 5.3 m depth.		7	SS	46													54 36 (10)		
			8	SS	26															
274.3																				
7.3	GRANITE (BEDROCK) Bedrock cored from 7.3 m to 10.3 m depth. For coring details see Record of Drillhole 17-4.		1	RC	REC 95%													RQD = 86%		
			2	RC	REC 100%													RQD = 100%		
271.3																				
10.3	END OF BOREHOLE																			
	Note: 1. Water level at a depth of 7.3 m below ground surface (Elev. 274.3) upon completion of drilling.																			

SUD-MTO 001 LAT/LONG 1651997.GPJ GAL-MISS.GDT 07/04/17 DATA INPUT:

PROJECT: 1651997

RECORD OF DRILLHOLE: 17-4

SHEET 2 OF 2

LOCATION: N 4993677.7; E 320731.4 (LAT. 45.084909; LONG. -79.297443)

DRILLING DATE: March 8, 2017

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME 75

DRILLING CONTRACTOR: Downing Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	JN - Joint FLT - Fault SHR - Shear VN - Vein CJ - Conjugate BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular PO - Polished K - Slickensided SM - Smooth Ro - Rough MB - Mechanical Break BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.										Q AVG.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
							FLUSH	RECOVERY		R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA				ROCK STRENGTH INDEX		WEATH- ERING INDEX																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
								TOTAL CORE %	SOLID CORE %			B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja		Jn	R4	R3	R2	R1	W1	W2	W3	W4																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
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DEPTH SCALE

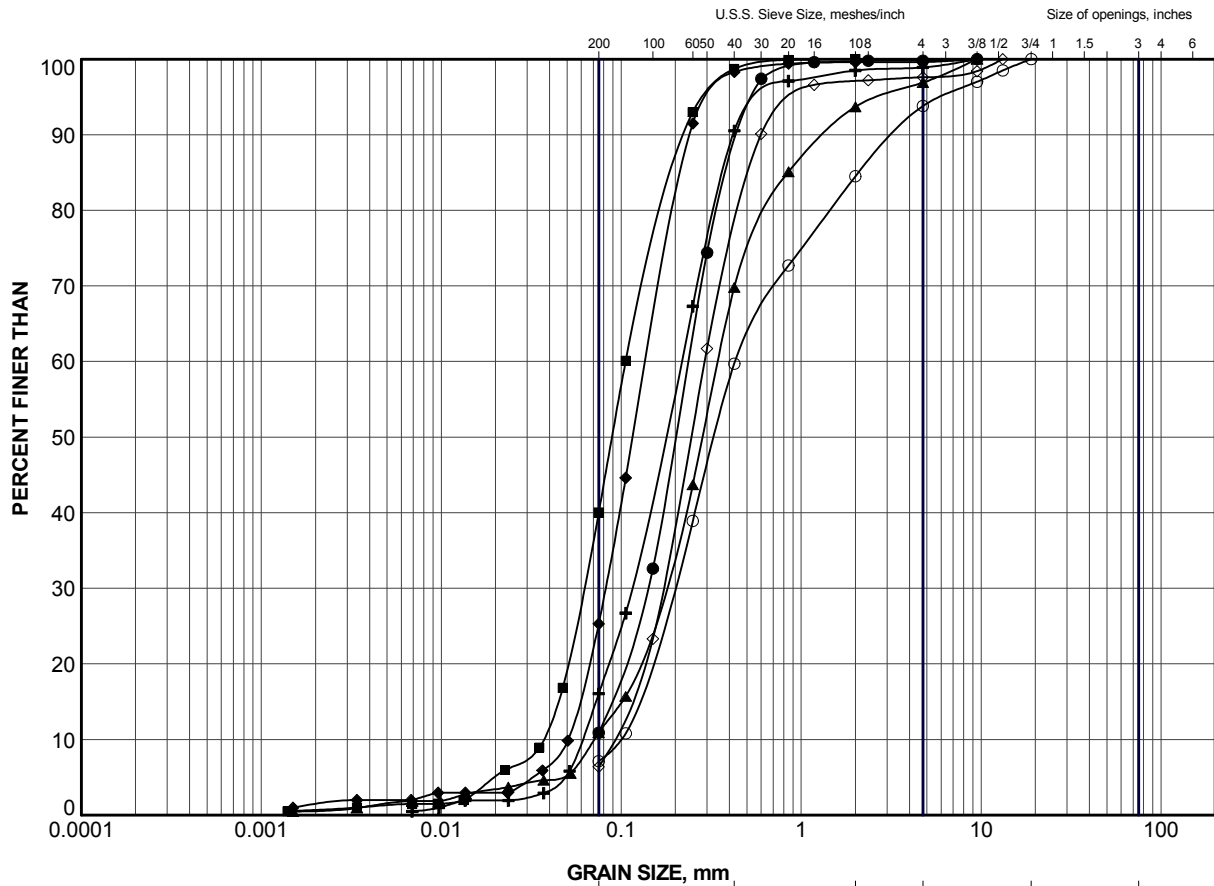
1 : 60

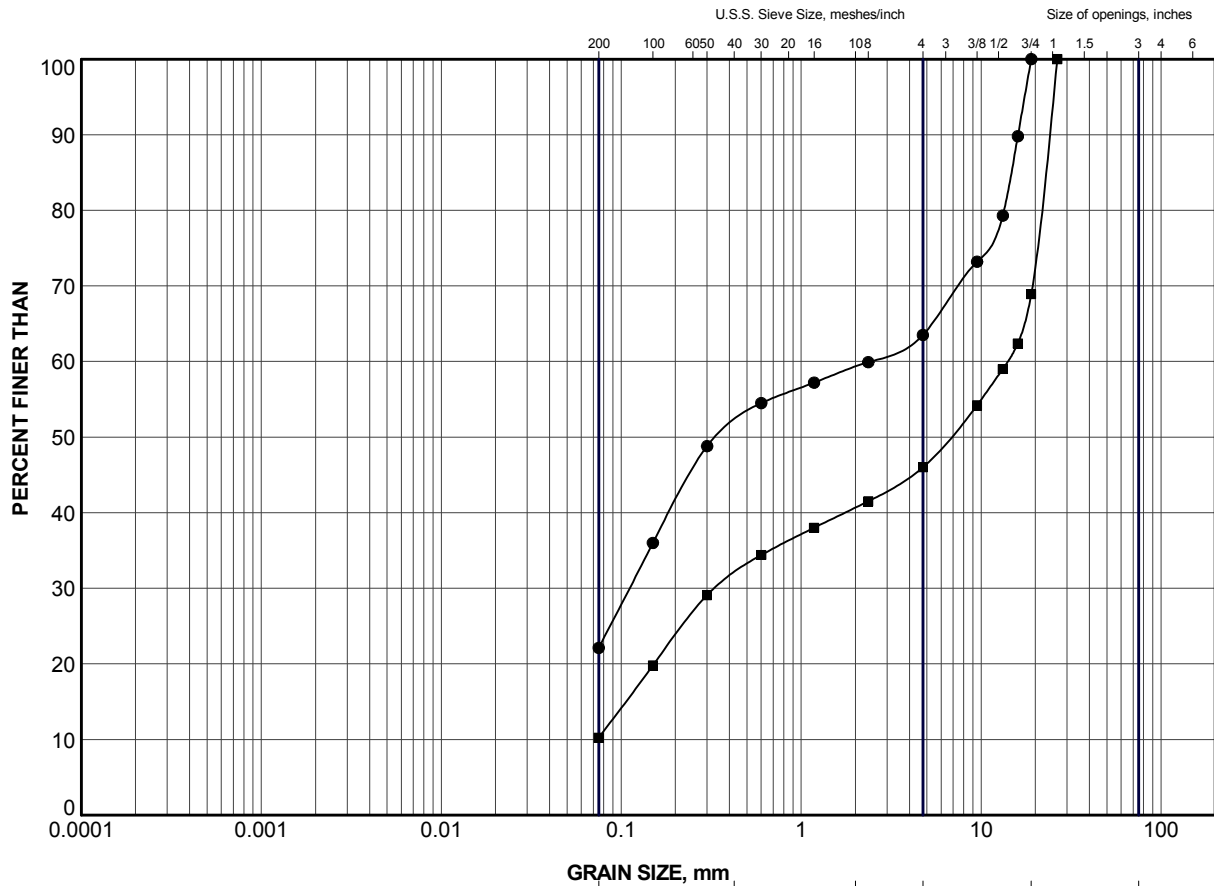


LOGGED: IK

CHECKED: SEMP

SUD-RCK (LAT/LONG) 1651997.GPJ GAL-MISS.GDT 31/03/17 DATA INPUT:





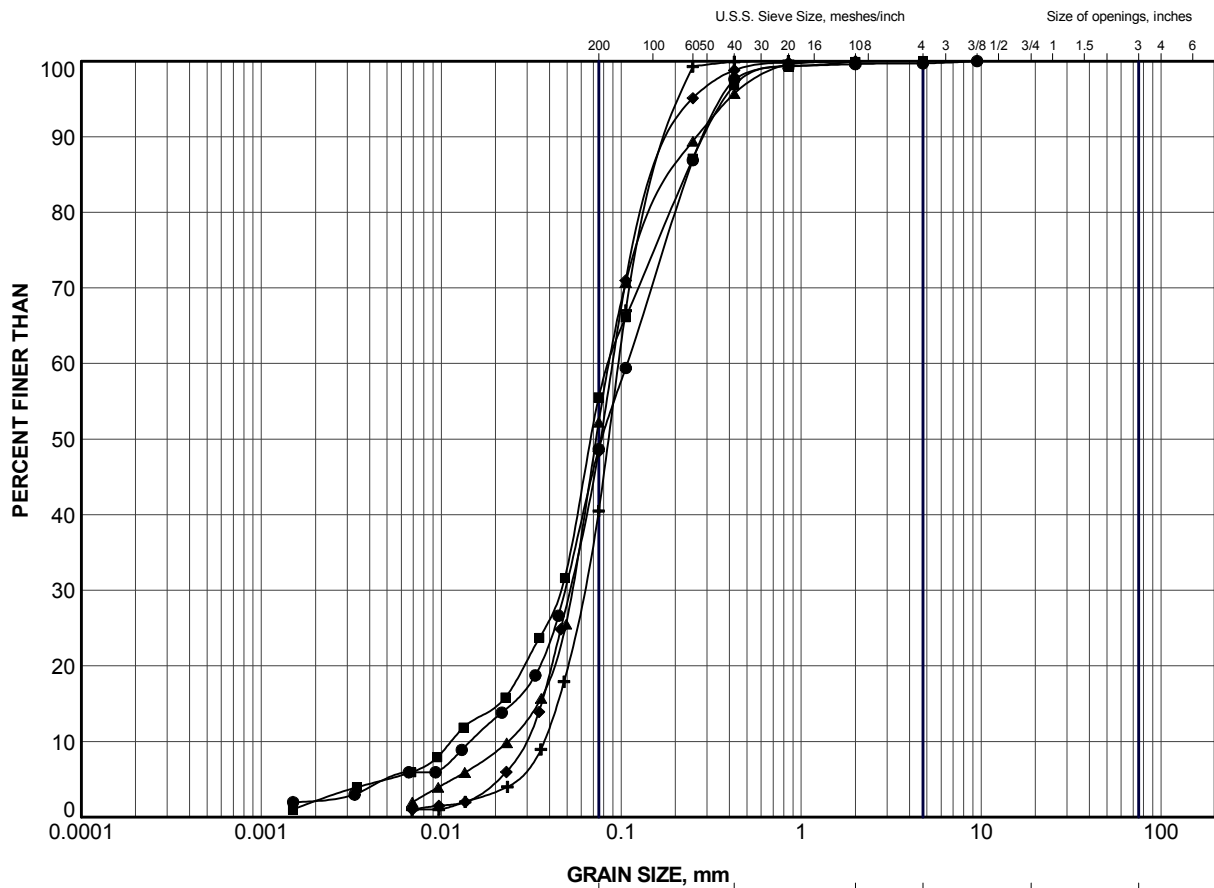
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	17-2	6	274.3
■	17-4	5	278.4

PROJECT						HIGHWAY 11 BRACEBRIDGE CULVERT STA 16+312					
TITLE						GRAIN SIZE DISTRIBUTION SAND and GRAVEL (FILL)					
PROJECT No.			1651997			FILE No.			1651997.GPJ		
DRAWN	TB	Mar 2017	SCALE	N/A	REV.						
CHECK	SEMP	Mar 2017									
APPR	LCC	Mar 2017									
						FIGURE 2					





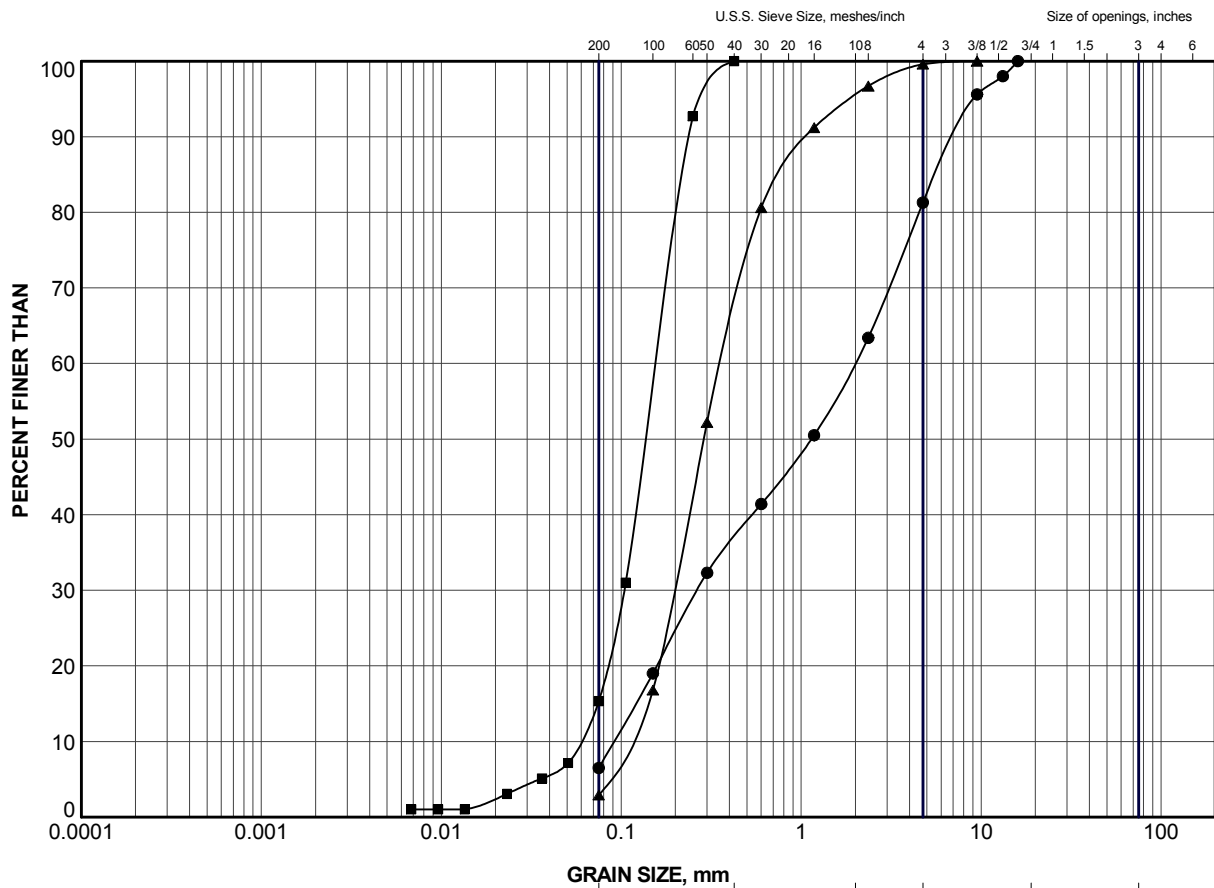
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	17-1	10	271.5
■	17-2B	10A	271.3
▲	17-2B	10B	271.1
+	17-2B	12	268.2
◆	17-3	10	271.3

PROJECT						HIGHWAY 11 BRACEBRIDGE CULVERT STA 16+312					
TITLE						GRAIN SIZE DISTRIBUTION SILT and SAND					
PROJECT No.			1651997			FILE No.			1651997.GPJ		
DRAWN	TB	Mar 2017	SCALE	N/A	REV.	FIGURE 3					
CHECK	SEMP	Mar 2017									
APPR	LCC	Mar 2017									





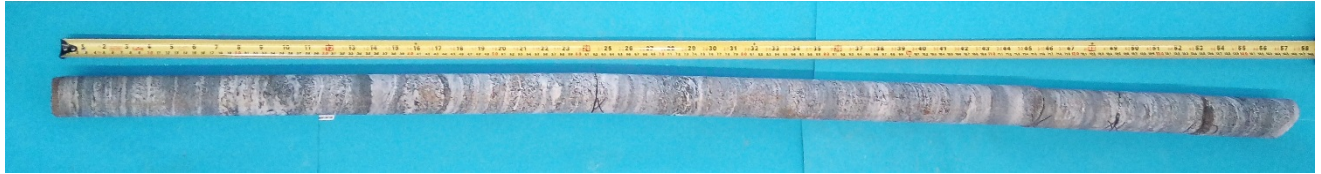
CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	17-1	12	268.5
■	17-2B	16	263.5
▲	17-3	14	265.2

PROJECT						HIGHWAY 11 BRACEBRIDGE CULVERT STA 16+312					
TITLE						GRAIN SIZE DISTRIBUTION SAND					
PROJECT No.			1651997			FILE No.			1651997.GPJ		
DRAWN	TB	Mar 2017	SCALE	N/A	REV.	FIGURE 4					
CHECK	SEMP	Mar 2017									
APPR	LCC	Mar 2017									

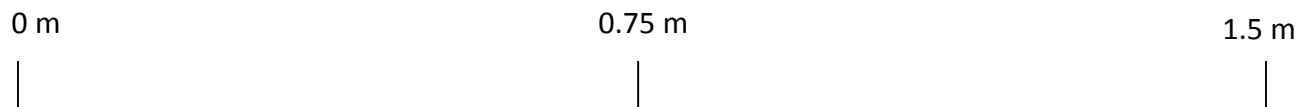





Borehole 17-4
Elevation 274.3 m to 272.8 m



Borehole 17-4
Elevation 272.8 m to 271.3 m



PROJECT		HIGHWAY 11 BRACEBRIDGE CULVERT STA 16+312			
TITLE		BEDROCK CORE PHOTOGRAPHS			
	PROJECT No.	1651997	FILE No. ----		
	DESIGN	IK	Mar. 2017	SCALE	AS SHOWN
	CADD	--		REV.	
	CHECK	SEMP	Mar. 2017	FIGURE 5	
	REVIEW	LCC	Mar. 2017		

**CLIENT NAME: GOLDER ASSOCIATES LTD.
100 SCOTIA COURT
WHITBY, ON L1N8Y6
(905) 723-2727**

ATTENTION TO: Imran Khalid

PROJECT: 1651997

AGAT WORK ORDER: 17T197482

SOIL ANALYSIS REVIEWED BY: Amanjot Bhela, Inorganic Coordinator

DATE REPORTED: Mar 24, 2017

PAGES (INCLUDING COVER): 5

VERSION*: 1

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

***NOTES**

All samples will be disposed of within 30 days following analysis. Please contact the lab if you require additional sample storage time.



AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 17T197482

PROJECT: 1651997

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
<http://www.agatlabs.com>

CLIENT NAME: GOLDER ASSOCIATES LTD.

SAMPLING SITE:

ATTENTION TO: Imran Khalid

SAMPLED BY:

Corrosivity Package

DATE RECEIVED: 2017-03-17

DATE REPORTED: 2017-03-24

		SAMPLE DESCRIPTION: BH 17-3 Sa 11		BH 17-2B Sa 12	
		SAMPLE TYPE: Soil		Soil	
		DATE SAMPLED: 2017-03-08		2017-02-28	
Parameter	Unit	G / S	RDL	8262194	8262195
*Sulphide	%		0.05	<0.05	<0.05
Chloride (2:1)	µg/g		2	88	53
Sulphate (2:1)	µg/g		2	15	12
pH (2:1)	pH Units		NA	8.11	7.86
Electrical Conductivity (2:1)	mS/cm		0.005	0.242	0.132
Resistivity (2:1)	ohm.cm		1	4130	7580
Redox Potential (2:1)	mV		5	248	273

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

8262194-8262195 EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil).

*Sulphide analyzed at AGAT Vancouver

Certified By:

Amanjot Bhela



Quality Assurance

CLIENT NAME: GOLDER ASSOCIATES LTD.

PROJECT: 1651997

SAMPLING SITE:

AGAT WORK ORDER: 17T197482

ATTENTION TO: Imran Khalid

SAMPLED BY:

Soil Analysis

RPT Date: Mar 24, 2017			DUPLICATE			Method Blank	REFERENCE MATERIAL		METHOD BLANK SPIKE		MATRIX SPIKE	
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper

Corrosivity Package

*Sulphide	8266038		<0.05	<0.05	NA	< 0.05	96%	80%	120%						
Chloride (2:1)	8257090		29	28	3.5%	< 2	99%	80%	120%	103%	80%	120%	101%	70%	130%
Sulphate (2:1)	8257090		190	187	1.6%	< 2	96%	80%	120%	103%	80%	120%	102%	70%	130%
pH (2:1)	8257928		8.07	8.11	0.5%	NA	100%	90%	110%	NA			NA		
Electrical Conductivity (2:1)	8265139		0.165	0.166	0.6%	< 0.005	95%	90%	110%	NA			NA		
Redox Potential (2:1)	8257928		257	261	1.5%	< 5	106%	70%	130%	NA			NA		

Comments: NA signifies Not Applicable.

Certified By:

Amanjot Bhela

Method Summary

CLIENT NAME: GOLDER ASSOCIATES LTD.

AGAT WORK ORDER: 17T197482

PROJECT: 1651997

ATTENTION TO: Imran Khalid

SAMPLING SITE:

SAMPLED BY:

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
*Sulphide	INOR-181-6027	modified from ASTM E1915-11	COMBUSTION
Chloride (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
Sulphate (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
pH (2:1)	INOR 93-6031	MSA part 3 & SM 4500-H+ B	PH METER
Electrical Conductivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B	EC METER
Resistivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B, SSA #5 Part 3	CALCULATION
Redox Potential (2:1)		McKeague 4.12 & SM 2510 B	REDOX POTENTIAL ELECTRODE

