



October 11, 2018

FOUNDATION INVESTIGATION AND DESIGN REPORT

**STRUCTURAL BUNDLE - 11 STRUCTURES ON HIGHWAYS 129, 532
AND 556**

**HIGHWAY 532 - DAM CREEK CULVERTS REPLACEMENT, 0.15 KM
NORTH OF HIGHWAY 556 (SITE NO. 38S-040C)**

LAT. 46.751027° ; LONG. -84.067082°

HODGINS TOWNSHIP, ALGOMA DISTRICT, ONTARIO

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 5378-11-00 ; WP 5261-13-01

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REPORT





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PART A

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1.0 INTRODUCTION

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 detail design of the replacement of twin culverts on Highway 532 (Site No. 38S-040C) in the Hodgins Township, Algoma District, Ontario.

The purpose of the field investigation is to establish the subsurface conditions at the location of the proposed replacement culverts by methods of borehole drilling, in-situ testing and laboratory testing on selected soil samples.

This report summarizes the factual results of field and laboratory work (including field investigation procedures, borehole stratigraphy, and geotechnical and analytical laboratory test results) as well as a description of the interpreted soil and groundwater conditions at the Dam Creek culverts site.

The Terms of Reference and Scope of Work for the foundation investigation are outlined in MTO's Request for Proposal dated May 2016 (Agreement No. 5016-E-0029) as well as change request letter dated April 24, 2018 which was approved by MTO on June 11, 2018 (Change Order No. CO-5016-E-0029-001). Golder's proposal for foundation engineering services is contained in Section 17.8 of AECOM's Technical Proposal for this assignment.

2.0 PROJECT AND SITE DESCRIPTION

2.1 Project Description

The existing twin culverts at the site convey the Dam Creek under Highway 532 in an east to west direction. The culverts were constructed in 1983, but there are no records of the culverts being rehabilitated since that time. It is understood that the existing culverts underwent a structural assessment in 2015 and were identified as being in poor structural condition with significant deterioration of several elements, including the culvert barrels and the structural steel coatings. The culverts are to be replaced with either a new single reinforced concrete box culvert or new twin Structural Plate Corrugated Steel Pipe (SPCSP) culverts.

2.2 Site Description

The site of the proposed twin culverts replacement is located about 0.15 km north of Highway 556 in the Hodgins Township, Algoma District, Ontario.

As noted above, the site consists of two culverts as follows:

- **Southern Culvert at about Station 13+096:** a Structural Plate Corrugated Steel Pipe (SPCSP) culvert with an approximately 2.40 m diameter and measuring about 18.5 m in length. It is understood that this is a secondary/overflow culvert that conveys Dam Creek under Highway 532 when the water level in the creek is high.
- **Northern Culvert at about Station 13+102:** a Structural Plate Corrugated Steel Pipe Arch (SPCSPA) culvert with an approximately 4.68 m span and 3.05 m rise and measuring about 18.9 m in length. This is the primary culvert that conveys Dam Creek under Highway 532.

The culverts are shown on Drawing 1 and on Photographs 1 to 3 (on the following page).

The Dam Creek at the location of the culverts is between approximately 10 m and 15 m wide and flows in a westerly direction. The downstream end of the Dam Creek flows into the Goulais River about 375 m southwest of the culverts.



Highway 532 at the location of the culverts consists of an approximately 5 m high earth fill embankment and carries one lane of traffic in each direction. The travelled portion of the highway consists of an asphalt surface which is at approximately Elevation 196 m in the vicinity of the existing culverts.



Photograph 1: Twin culverts at the Dam Creek site with Highway 532 above the culverts (looking southeast at the outlets)



Photograph 2: Outlet of the northern SPCSPA culvert on the west side of Highway 532 (looking southeast)



Photograph 3: Outlet of the southern SPCSP culvert on the west side of Highway 532 (looking east through the culvert)

An entrance to a residential dwelling and to a sand and gravel pit, owned by the Ontario Ministry of Transportation and Communications (as posted on a sign near the entrance to the pit), are located on the west side of Highway 532, approximately 50 m south and 60 m north of the existing culverts, respectively. Overhead electrical transmission lines run along the highway on the east side of Highway 532 (i.e., immediately east of the inlets). The overhead lines also cross the highway about 20 m north of the northern culvert.

The topography of the area in the immediate vicinity of the culverts is relatively flat to undulating, particularly on the west side of Highway 532, given that the site is located within the Goulais River valley. However, the natural ground surface rises significantly further east and west of the culverts. The presence of a ski resort near Searchmont, located about 3.5 km north of the site, is an indicator of the high relief and rugged topography. The natural ground surface in the immediate vicinity of the inlets and outlets of the existing culverts varies between about Elevations 191 m and 195 m. The site is vegetated with grasses and shrubs, as well as deciduous and coniferous trees.

3.0 FIELD INVESTIGATION PROCEDURES

The fieldwork at the site of the culverts was carried out over eight days between August 15 and September 7, 2017, during which time six boreholes (designated as Boreholes DCC-01 to DCC-06) were advanced near the existing culverts. Boreholes DCC-01 to DCC-04 were advanced near the inlets and outlets of the existing culverts. These four boreholes were advanced in the creek in areas where: i) access was not restricted; ii) the drilling platform could be safely tied-off; iii) the creek bed was not covered with large cobbles/boulders, and; iv) the current in the creek was not too fast. Boreholes DCC-05 and DCC-06 were advanced through the Highway 532 embankment on the northbound lane (south of the southern culvert) and southbound lane (north of the northern



culvert), respectively. During a subsequent 2018 field investigation, approved as part of the change request, one borehole (designated as Borehole DCC-07) was advanced through the Highway 532 embankment on August 10, 2018. Borehole DCC-07 was advanced at the site to collect Shelby tube samples of the thick cohesive deposit encountered during the 2017 investigation in order to carry out laboratory consolidation testing on specimens of the cohesive samples. The test results were evaluated in order to confirm the geotechnical soil parameters estimated for the cohesive deposit.

The subsurface soil conditions encountered in the boreholes are shown in detail on the Records of Boreholes in Appendix A. Lists of abbreviations and symbols are also provided in Appendix A to assist in the interpretation of the borehole records. The locations of the as-drilled boreholes are shown in plan on Drawing 1.

The boreholes were advanced using portable drilling equipment and a drill rig. Boreholes DCC-01 to DCC-04 were advanced using portable drilling equipment set up on a drilling platform in the Dam Creek near the inlets and outlets of the culverts. The portable drilling equipment was supplied and operated by Ohlmann Geotechnical Services (OGS) Inc. of Almonte, Ontario. These four boreholes were advanced through the overburden using 'BW' casing with wash boring techniques. Boreholes DCC-05 to DCC-07 were advanced using a CME-75 truck-mounted drill rig supplied and operated by Landcore Drilling Inc. of Chelmsford, Ontario. Boreholes DCC-05 and DCC-06 were advanced through the upper portion of the embankment fill using 152 mm outer diameter, continuous flight, solid-stem augers and the remainder of the boreholes were advanced using 'NW' casing with wash boring techniques; while Borehole DCC-07 was advanced using 210 mm outer diameter, continuous flight, hollow-stem augers.

In the four boreholes advanced near the inlets and outlets of the culverts, the soil samples were generally obtained continuously immediately below the creek bed followed by sampling at intervals of depth of about 1.5 m; while in the two boreholes advanced on Highway 532 (i.e., Boreholes DCC-05 and DCC-06), the soil samples were obtained at intervals of depth of about 0.75 m and 1.5 m. All soil samples were collected using a 50 mm outer diameter split-spoon sampler driven by a manual hammer (within Boreholes DCC-01 to DCC-04 advanced using the portable drilling equipment) or an automatic hammer (within Boreholes DCC-05 and DCC-06 advanced using the truck-mounted drill rig) in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586, *Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils*). Field vane shear tests were carried out in the cohesive soils for assessment of undrained shear strengths (ASTM D2573, *Standard Test Method for Field Vane Shear Strength Test in Cohesive Soil*) using MTO Standard 'N'-size vanes in the boreholes advanced using the drill rig and 'B'-size vanes in the smaller diameter boreholes advanced by portable equipment. Dynamic Cone Penetration Tests (DCPTs) were also carried out in Boreholes DCC-01 to DCC-06 following the soil sampling operation. In Borehole DCC-07, SPT was not carried out and three Shelby tube samples were collected in accordance with ASTM D1587, *Standard Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes*.

The boreholes, including the DCPTs, were advanced to depths ranging between about 18.3 m and 21.9 m below existing ground or water surface.

All six boreholes were backfilled upon completion of drilling in accordance with Ontario Regulation 903 (Wells) (as amended).

Prior to commencement of field work, Golder arranged for the clearance of underground utilities/services. The field work was observed on a full-time basis by a member of Golder's engineering staff who monitored the drilling and sampling operations, and logged the boreholes in the field. The soil samples were transported to Golder's



Mississauga geotechnical laboratory where the samples underwent further visual/tactile examination and geotechnical laboratory testing.

Geotechnical index testing (i.e., water content, Atterberg limits and grain size distribution) was carried out on selected soil samples. In addition, two (2) one-dimensional consolidation (i.e., Oedometer) tests were carried out on select specimens of the cohesive samples. The results of the geotechnical laboratory testing are summarized on the borehole records in Appendix A and the results of the geotechnical laboratory testing are provided in Appendix B. All of the laboratory tests were carried out in accordance with MTO Laboratory and/or ASTM Standards, as appropriate.

Two soil samples were also collected from Boreholes DCC-01 (advanced near the outlet of the southern culvert) and DCC-04 (advanced near the inlet of the northern culvert) for corrosivity testing. The selected soil samples were submitted, under chain-of-custody procedures, to Maxxam Analytics of Mississauga, Ontario (a Standards Council of Canada accredited laboratory) for analysis of a suite of corrosivity parameters including pH, sulphate, sulphide, chloride and resistivity/conductivity.

Temporary benchmarks were established and surveyed near the existing Dam Creek culverts by Callon Dietz Inc. prior to the drilling crews mobilizing to site. Upon completion of drilling operations, borehole offsets and corresponding ground surface elevation differences were recorded and tied-in to the surveyed benchmark locations to determine the as-drilled borehole locations and ground surface elevations. The borehole survey information, including northing and easting coordinates (presented in the MTM NAD83 Zone 13 and latitude/longitude coordinate systems) and the ground surface elevations (referenced to Geodetic datum), are provided on the borehole records in Appendix A, presented on Drawing 1, and summarized below.

Borehole No.	Approximate Location	Coordinates (MTM NAD83 Zone 13)		Ground / Water ¹ Surface Elevation	Borehole Depth ⁴
		Northing (Latitude)	Easting (Longitude)		
DCC-01	Outlet of southern culvert; west of Highway 532	5179049.1 m (46.750998°)	299655.7 m (-84.067337°)	191.5 m ²	19.1 m ⁵
DCC-02	Outlet of northern culvert; west of Highway 532	5179057.6 m (46.751074°)	299662.8 m (-84.067245°)	191.3 m ²	19.2 m ⁵
DCC-03	Inlet of southern culvert; east of Highway 532	5179041.7 m (46.750931°)	299689.5 m (-84.066895°)	191.9 m ²	18.7 m ⁵
DCC-04	Inlet of northern culvert; east of Highway 532	5179050.0 m (46.751006°)	299693.3 m (-84.066846°)	191.8 m ²	18.3 m ⁵
DCC-05	Northbound lane of Highway 532; south of southern culvert	5179038.8 m (46.750905°)	299673.0 m (-84.067112°)	196.3 m ³	21.9 m
DCC-06	Southbound lane of Highway 532; north of northern culvert	5179063.3 m (46.751126°)	299675.1 m (-84.067084°)	196.0 m ³	21.6 m
DCC-07	Southbound lane of Highway 532; north of northern culvert	5179057.0 m (46.751061°)	299672.7 m (-84.067111°)	196.1 m ³	12.8 m

Notes:

1. Water surface refers to the top of the water in the Dam Creek at the time of the investigation.
2. Boreholes DCC-01 to DCC-04 were advanced using portable drilling equipment set up on a drilling platform in the Dam Creek near the inlets and outlets of the culverts.
3. Boreholes DCC-05 to DCC-07 were advanced using a truck-mounted drill rig through the Highway 532 embankment.
4. The borehole depth includes the DCPT carried out at the bottom of each open borehole.



Borehole No.	Approximate Location	Coordinates (MTM NAD83 Zone 13)		Ground / Water ¹ Surface Elevation	Borehole Depth ⁴
		Northing (Latitude)	Easting (Longitude)		

5. The termination depth of Boreholes DCC-01 to DCC-04 was measured from the water surface in the Dam Creek. The water depth in the creek at the time of drilling was measured at about 0.8 m, 0.9 m, 0.4 m and 0.6 m in the respective boreholes.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain (NOEGTS)¹ mapping, the Dam Creek culverts site is located within a valley train consisting primarily of gravelly and sandy soils which “are mainly confined to the larger river valleys and usually occur as flat, terraced landforms” (McQuay, 1980). The granular deposits are variable in thickness and are generally underlain by varved silt and clay to glacial till and bedrock. The valley train is bordered by bedrock knobs.

Based on geological mapping developed by the Ontario Ministry of Northern Development and Mines (MNDM)², the site is underlain by bedrock from the gneissic tonalite suite of rocks comprised of tonalite to granodiorite (foliated to gneissic) with minor supracrustal inclusions.

4.2 Overview of Local Subsurface Conditions

The subsurface soil and groundwater conditions encountered in the boreholes advanced at this site, together with the results of the in-situ and geotechnical/analytical laboratory testing, are presented on the borehole records (provided in Appendix A) and the laboratory test figures/sheets (provided in Appendices B and C). The results of the in-situ field tests (i.e., SPT ‘N’-values and field vane undrained shear strengths) as presented on the borehole records are uncorrected, and the ‘N’-values are based on SPT sampling procedures carried out with a manual hammer at the locations of Boreholes DCC-01 to DCC-04 and an automatic hammer at the locations of Boreholes DCC-05 and DCC-06. Borehole DCC-07 was advanced at the site to collect Shelby tube samples and SPT was not carried out.

The stratigraphic boundaries shown on the borehole records and on the soil strata profiles (i.e., Drawings 1 and 2) are inferred from observations of drilling progress, generally non-continuous sampling, and in-situ testing and therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations.

In general, the subsurface conditions encountered at the Dam Creek culverts site consist of embankment fill (associated with Highway 532) or water (associated with the Dam Creek) underlain by an extensive deposit of varved silt to clayey silt and silty clay. In places, deposits of cobbles and boulders are present on the creek bed and a thin deposit of gravelly sand to gravel or clayey silt with sand or silty clay is found immediately below the creek bed.

¹ Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41KNE, Study Number 91.

² Ontario Ministry of Northern Development of Mines. Bedrock Geology of Ontario – East Central Sheet, Ontario Geological Survey – Map 2544.



Detailed descriptions of the subsurface conditions encountered in the boreholes at this site are provided in the following subsections.

4.2.1 Water

Water was encountered above the creek bed in Boreholes DCC-01 to DCC-04 which were advanced in the Dam Creek near the inlets and outlets of the existing culverts. The water surface elevation and water depth at each borehole location is summarized below.

Borehole Designation	Approximate Location	Water Surface Elevation	Approximate Water Depth
DCC-01	About 9.4 m west of outlet of southern culvert	191.5 m	0.8 m
DCC-02	About 4.7 m west of outlet of northern culvert	191.3 m	0.9 m
DCC-03	About 6.7 m east of inlet of southern culvert	191.9 m	0.4 m
DCC-04	About 7.8 m east of inlet of northern culvert	191.8 m	0.6 m

As noted above, cobbles and boulders were observed on/above the creek bed near the inlets and outlets of culverts, especially at the smaller southern culvert (refer to Photograph 4 below).



Photograph 4: Cobbles and boulders at the outlet of the southern SPCSP culvert (looking west from top of Highway 532)

4.2.2 Asphalt

An approximately 40 mm thick layer of asphalt was encountered in Boreholes DCC-05 and DCC-06 which were advanced through the Highway 532 embankment on the northbound lane (south of the southern culvert) and southbound lane (north of the northern culvert), respectively. The top of the asphalt layer is at about Elevation 196.3 m and Elevation 196.0 m in the respective boreholes.



4.2.3 Silty Sand to Gravelly Sand to Sand and Gravel (Fill) / Sandy Clayey Silt (Fill) / Sandy Organic Silt (Fill)

An approximately 5.6 m thick layer of fill associated with the Highway 532 embankment was encountered below the asphalt in Boreholes DCC-05 and DCC-06. The fill is predominantly non-cohesive and is comprised of silty sand, some gravel, trace clay to gravelly sand, trace to some silt, trace clay to sand and gravel, trace to some silt, trace clay. However, an approximately 0.2 m thick layer of sandy organic silt and an approximately 0.6 m thick layer of sandy clayey silt, trace gravel was encountered interlayered within the non-cohesive fill at depths of about 2 m (corresponding to Elevation 194.3 m) and 0.8 m (corresponding to Elevation 195.2 m) below the existing ground surface in Boreholes DCC-05 and DCC-06, respectively. Clayey silt seams were encountered within the silty sand portion of the fill in Borehole DCC-05 between depths of about 3 m and 4.5 m below existing ground surface. Wood fragments and organics were encountered near the bottom portion of the embankment (i.e., at a depth of about 4.9 m below existing ground surface) in Borehole DCC-06. It is further noted that auger grinding was noted in Borehole DCC-06 between depths of about 2.7 m and 4.6 m below existing ground surface due to inferred cobbles. Difficulty with auger advancement was also encountered in the same borehole at a depth of about 5.2 m below existing ground surface due to presence of gravel and inferred cobbles.

The SPT 'N'-values measured within the non-cohesive portion of the fill range from 2 blows to 51 blows per 0.3 m of penetration, indicating a very loose to dense state of compactness. The lower SPT "N"-values (i.e., 8 blows or less) were encountered generally in the bottom half of the fill in Borehole DCC-05 and the very bottom of the fill in Borehole DCC-06. The SPT 'N'-value measured within the cohesive fill (i.e., the sandy clayey silt) is 20 blows per 0.3 m of penetration, suggesting a very stiff consistency.

The water content measured on eight samples of the non-cohesive fill ranges between approximately 3% and 17%. The water content measured on a sample of the sandy organic silt fill and the sandy clayey silt fill is approximately 30% and 16%, respectively.

The results of a grain size distribution test carried out on a sample recovered from the sandy clayey silt fill are shown on Figure B1 in Appendix B. An Atterberg limits test carried out on a sample of the cohesive fill measured a liquid limit of about 22%, a plastic limit of about 16%, and a corresponding plasticity index of about 6%. The results of this Atterberg limits test are shown on the plasticity chart on Figure B2 in Appendix B, and indicate that the material is classified as a clayey silt of low plasticity.

The results of a grain size distribution test carried out on a sample recovered from the sandy organic silt fill are shown on Figure B3 in Appendix B. An Atterberg limits test carried out on a sample of this fill layer measured a liquid limit of about 34%, a plastic limit of about 29%, and a corresponding plasticity index of about 5%. The results of this Atterberg limits test are shown on the plasticity chart on Figure B4 in Appendix B, and indicate that the fines portion of the material is classified as an organic silt.

The results of grain size distribution tests carried out on two samples recovered from the silty sand fill and gravelly sand fill are shown on Figures B5 and B6, respectively, in Appendix B. An Atterberg limits test was also carried out on a sample of the silty sand fill deposit, but the results indicate that the material is non-plastic.

4.2.4 Gravelly Sand to Gravel

An approximately 1.2 m thick granular deposit comprised of gravelly sand, trace silt to gravel, some sand, trace silt, trace organics was encountered at the creek bed in Borehole DCC-03. The top of this deposit is at about Elevation 191.5 m.



The SPT 'N'-values measured within this granular deposit are 3 blows and 6 blows per 0.3 m of penetration, indicating a very loose and loose state of compactness.

The water content measured on a sample of the gravelly sand portion of the granular deposit is approximately 20%.

4.2.5 Clayey Silt with Sand to Silty Clay

A cohesive deposit of clayey silt with sand, some gravel to silty clay, some gravel, trace to some sand was encountered at the creek bed in Boreholes DCC-01 and DCC-04, respectively. In Borehole DCC-01 the deposit was encountered at about Elevation 190.7 m and is approximately 0.7 m thick. In Borehole DCC-04 the deposit was encountered at about Elevation 191.2 m and is approximately 0.6 m thick.

The SPT 'N'-values measured within the clayey silt with sand to silty clay deposit are 7 blows and 2 blows per 0.3 m of penetration, respectively, suggesting a firm and very soft to soft consistency.

The water contents measured on two samples of this deposit are about 39% and 42%.

The results of a grain size distribution test carried out on a sample of the clayey silt with sand portion of the cohesive deposit recovered from Borehole DCC-01 are shown on Figure B7 in Appendix B. The results of a grain size distribution test carried out on a sample of the silty clay portion of the cohesive deposit recovered from Borehole DCC-04 are shown on Figure B8 in Appendix B. An Atterberg limits test carried out on the sample recovered from Borehole DCC-04 measured a liquid limit of about 39%, a plastic limit of about 20%, and a corresponding plasticity index of about 19%. The results of this Atterberg limits test are shown on the plasticity chart on Figure B9 in Appendix B, and indicate that the material is classified as a silty clay of intermediate plasticity.

4.2.6 Varved Silt to Clayey Silt and Silty Clay

An extensive varved deposit comprised of silt to clayey silt laminae and silty clay laminae was encountered below the clayey silt with sand deposit in Borehole DCC-01, at the creek bed in Borehole DCC-02, below the gravelly sand deposit in Borehole DCC-03, below the silty clay deposit in Borehole DCC-04, and below the embankment fill in Boreholes DCC-05 and DCC-06. The two types of laminae are shown on Photograph 4 (below).



Photograph 5: Silt to clayey silt laminae (light grey colour) and silty clay laminae (dark grey colour)



Additional photographs of the laminae (obtained from the three Shelby tube samples) are shown on Figure B10 in Appendix B. The top of the varved deposit ranges between about Elevations 190.7 m and 190.0 m. All six boreholes were terminated within this deposit between about Elevations 181.7 m and 180.2 m. The thickness of the sampled portion of the varved silt to clayey silt and silty clay deposit ranges from approximately 8.6 m to 10.3 m. DCPTs were also carried out at the bottom of each open borehole (i.e., below the last collected soil sample). The DCPTs were terminated at elevations ranging between about 174.4 m and 172.1 m. The blow counts at these elevations generally range between 25 blows and 100 blows per 0.3 m of penetration.

The SPT 'N'-values measured within the varved clayey deposit range between 1 blow and 8 blows per 0.3 m of penetration. In-situ vane tests carried out within this deposit measured undrained shear strength ranging from about 29 kPa to greater than 96 kPa. The measured (uncorrected) undrained shear strengths below the Highway 532 embankment are greater than 96 kPa, and generally range between about 52 kPa and 92 kPa near the inlets and outlets of the culverts. The sensitivity (defined as the quotient between the undisturbed shear strength and the remoulded shear strength) ranges between about 2 and 11, but typically varies from 2 to 5. The higher sensitivities (i.e., greater than 6) were recorded in Boreholes DCC-03 and DCC-04. The in-situ field vanes tests results indicate that the varved deposit has a predominantly stiff to very stiff consistency. However, given the presence of generally stronger/stiffer silt to clayey silt laminae, the measured undrained shear strengths may not be representative of the operative shear strength of the varved deposit or of the weaker silty clay laminae. In fact, the undrained shear strength of 29 kPa measured at the bottom of Borehole DCC-01, suggesting a firm consistency, may be more representative of the strength of the silty clay laminae.

The water content measured on 29 samples of this deposit ranges between about 40% and 49%.

The results of grain size distribution tests carried out on three samples of the silty clay laminae from the varved deposit are shown on Figure B11 in Appendix B. Atterberg limits tests were carried out on 19 samples of the clayey silt laminae and silty clay laminae of the varved deposit. The tests measured liquid limits between about 34% and 41%, plastic limits between about 20% and 24%, and plasticity indices between about 13% and 21%. The results of the Atterberg limits tests are shown on the plasticity chart on Figure B12 in Appendix B, and indicate that the laminae are classified as clayey silt of low plasticity and silty clay of intermediate plasticity. The results also suggest that the laminae consist predominantly of silty clay, but this may not be a true representation of the overall varved deposit. The results can be attributed to the difficulty in separating the two types of laminae in a laboratory environment. The silt to clayey silt laminae, which were identified in the field and the laboratory based on tactile examination, may have been mixed with portions of the more plastic laminae, yielding Atterberg limits indicative of a cohesive material of intermediate plasticity.

Laboratory consolidation tests were also carried out on two specimens of the varved cohesive deposit obtained from the Shelby tube samples recovered from Borehole DCC-07. The preconsolidation stress was estimated for each specimen from the respective void ratio versus logarithmic pressure plot and from total work versus pressure plot. Details of the test results are shown on Figures B13 and B14 in Appendix B and the test results are summarized below.



Borehole/ Sample No.	Sample Depth (Elevation)	γ (kN/m ³) (G _s)	σ'_{vo} (kPa)	σ'_p (kPa)	$\sigma'_{vo} - \sigma'_p$ (kPa)	OCR	C _c	C _r	e _o	c _v ¹ (cm ² /s)
DCC-07 SA 1	6.4 m (189.7 m)	17.1 (2.75)	125	450	325	3.6	0.91	0.042	1.34	1.2 x 10 ⁻²
DCC-07 SA 2	9.4 m (186.7 m)	17.1 (2.71)	145	490	345	3.3	0.72	0.038	2.56	1.3 x 10 ⁻²

Note:

1. The coefficient of consolidation is based on a stress range between the existing in-situ effective overburden stress and the stress increase due to an up to about 5.5 m high embankment widening. The final stress is estimated to be less than the preconsolidation stress and within the over-consolidated stress range.

where: γ is the bulk unit weight in kN/m³

G_s is the specific gravity

σ'_{vo} is the effective overburden stress in kPa

σ'_p is the preconsolidation stress in kPa

OCR is the overconsolidation ratio

C_c is the compression index

C_r is the recompression index

e_o is the initial void ratio

c_v is the coefficient of consolidation in cm²/s

4.3 Groundwater Conditions

Given the presence of the Dam Creek, the groundwater level is anticipated to be at or near the creek surface. The water level in Boreholes DCC-05 and DCC-06 (advanced from the top of the Highway 532 embankment) was not recorded due to introduction of drilling water at depths of about 4.6 m and 5.2 m below the asphalt surface, respectively, to accommodate wash boring techniques. However, above these depths, the boreholes were advanced using solid stem augers and the embankment fill was observed to be moist and no signs of water seepage were recorded.

The water level surveyed at the surface of the Dam Creek during the field investigation is summarized below.

Borehole Designation	Approximate Location	Water Surface Elevation	Date
DCC-01	About 9.4 m west of outlet of southern culvert	191.5 m	August 23, 2017
DCC-02	About 4.7 m west of outlet of northern culvert	191.3 m	August 16, 2017
DCC-03	About 6.7 m east of inlet of southern culvert	191.9 m	August 25, 2017
DCC-04	About 7.8 m east of inlet of northern culvert	191.8 m	August 26, 2017

The water level in the creek and the degree of saturation of the embankment fill (or the potential presence of a perched water table within the fill) is subject to seasonal fluctuations and precipitation events. Water levels in the creek and within the fill are expected to be higher during wet seasons and sustained periods of precipitation.

4.4 Analytical Testing of Soil

Two soil samples were selected from Boreholes DCC-01 (advanced near the outlet of the southern culvert) and DCC-04 (advanced near the inlet of the northern culvert) and submitted to Maxxam Analytics Ontario for corrosivity testing. The analytical laboratory test results are provided on the Certificates of Analysis presented in Appendix C, and summarized below.



Borehole Designation	Sample No.	Average Approx. Sample Depth ² (m)	Average Approx. Sample Elevation (m)	Material Type	Resistivity (ohm-cm)	Conductivity (μohm/cm)	pH	Chloride (Cl) Content (ppm or μg/g)	Sulphate (SO ₄) Content (ppm or μg/g)
DCC-01 ¹	SA 2	1.1	189.6	Varved Silt to Clayey Silt and Silty Clay	2,200	450	8.2	190	<20 ³
DCC-04 ¹	SA 2	0.9	190.3		5,100	198	8.0	<20 ³	39

Notes:

1. It is noted that corrosivity test results associated with soil samples recovered from boreholes that were advanced at other sites associated with this project are also presented on the Certificates of Analysis.
2. Sample depth measured from the bottom of the creek bed.
3. The sulphate and chloride concentrations measured on samples recovered from Boreholes DCC-01 and DCC-04, respectively, are below the reportable detection limit of 20 μg/g.

It is noted that the sulphide concentration measured on soil samples recovered from Boreholes DCC-01 and DCC-04 was also analyzed and is approximately 0.68 μg/g and 0.92 μg/g, respectively.

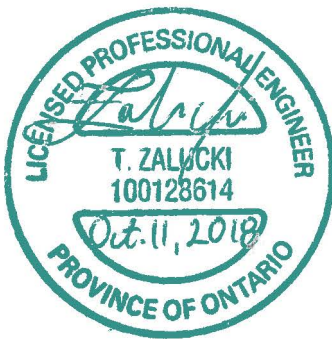
5.0 CLOSURE

The field work for this investigation was supervised by Ms. Alysha Kobylinski, B.A.Sc. and Ms. Amelia Jewison, B.A.Sc. The Foundation Investigation Report was prepared by Mr. Tomasz Zalucki, P.Eng., a geotechnical engineer with Golder. Mr. Paul Dittrich, P.Eng., a Principal and MTO Foundations Designated Contact for Golder, conducted an independent quality control review of the report.



Report Signature Page

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PART B

FOUNDATION DESIGN REPORT

STRUCTURAL BUNDLE – 11 STRUCTURES ON HIGHWAYS 129, 532 AND 556

HIGHWAY 532 – DAM CREEK CULVERTS REPLACEMENT, 0.15 KM
NORTH OF HIGHWAY 556 (SITE NO. 38S-040C)

LAT. 46.751027° ; LONG. -84.067082°

HODGINS TOWNSHIP, ALGOMA DISTRICT, ONTARIO

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 5378-11-00 ; WP 5261-13-01



6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the replacement of the Dam Creek culverts under Highway 532 (Site No. 38S-040C). These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the field investigation. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and carry out the design of the culvert foundations. The foundation investigation report, discussion and recommendations are intended for the use of MTO and its designers and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor.

Contractors must make their own interpretation based on the factual data presented in the Foundation Investigation Report (Part A of this report). Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project and for which special provisions may be required in the Contract Documents. Those requiring information on aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 General

It is understood that the existing twin culverts (i.e., the Structural Plate Corrugated Steel Pipe Arch (SPCSPA) culvert with a 4.68 m span and 3.05 m rise as well as the 2.4 m diameter Structural Plate Corrugated Steel Pipe (SPCSP) culvert) at Dam Creek are in poor structural condition and will be replaced.

It is further understood that the construction works will involve a platform widening of the existing Highway 532 embankment in the vicinity of the Dam Creek culverts to facilitate construction staging, but no raising of the existing highway grade. The platform widening is anticipated to occur on both sides of the highway embankment between approximately Stations 13+020 and 13+160. The total width of the new highway platform is to be most pronounced in the vicinity of the existing culverts where it is proposed to be about 12 m wide. In comparison, the current highway platform is about 8 m to 9 m wide. The side slopes of the platform widening are expected to be constructed at an inclination of 2 horizontal to 1 vertical (2H:1V). The platform widening will likely be a permanent feature at this site.

Moreover, given that Dam Creek is categorized as a “coldwater stream”, any in-water work, including fill placement and culvert construction, must be carried out between approximately July 16 and August 31. The restricted activity timing windows are enforced to protect fish and fish habitat and are based on:

- i) the species of fish present in the watercourse/waterbody;
- ii) when the fish spawning season occurs, and,
- iii) the geographic location of the watercourse/waterbody.

6.2 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the 2014 *Canadian Highway Bridge Design Code* (CHBDC 2014) and its *Commentary*, the proposed culvert(s) and its foundation system is expected to carry low to medium traffic volumes, but its performance will have potential impacts on other transportation corridors, hence having a “typical consequence level” associated with exceeding limits states design. In addition, given the typical project-specific foundation investigation carried out at this site (as presented in Foundation Investigation Report (i.e., Part A)), in comparison to the degree of site understanding in Section 6.5 of *CHBDC (2014)*, the level of confidence for design



is considered to be a “typical degree of site and prediction model understanding.” Accordingly, the appropriate corresponding ULS and SLS consequence factor, Ψ , and geotechnical resistance factors, ϕ_{gu} and ϕ_{gs} , from Tables 6.1 and 6.2 of the CHBDC have been used for design.

6.3 Culvert Replacement Options

Based on discussions with AECOM, it is understood that four culvert replacement strategies are being considered as follows:

- **Option No. 1:** replace the existing SPCSPA culvert with a 5.7 m wide by 4.3 m high precast (outer dimensions; wall/slab thickness of 350 mm) concrete box culvert founded at approximately Elevations 190.8 m (inlet) and 190.0 m (outlet).
- **Option No. 2:** replace the existing SPCSPA culvert with a 4.2 m wide by 4.2 m high precast (outer dimensions; wall/slab thickness of 300 mm) concrete box culvert founded at approximately Elevations 190.85 m (inlet) and 190.05 m (outlet).
- **Option No. 3:** replace the existing SPCSPA with a single 3.99 m diameter SPCSP culvert founded at approximately Elevations 191.15 m (inlet) and 190.35 m (outlets).
- **Option No. 4:** replace both the existing SPCSPA and SPCSP culverts with twin 3.6 m diameter SPCSP culverts founded at approximately Elevations 191.15 m (inlet) and 190.35 m (outlets). The new SPCSP culverts would be installed about 1 m to 2 m apart.

It is further understood that the following details apply to all four options:

- The new culvert(s) will be approximately 32 m long.
- The new culvert(s) will be countersunk (i.e., embedded below the creek bed).
- The existing southern SPCSP culvert would most likely be used to divert Dam Creek during the installation phase of the new culvert.
- The selected replacement strategy would most likely involve a complete removal of the existing southern SPCSP culvert. However, the option of leaving the existing SPCSP culvert (and likely rehabilitating it) to act as an overflow culvert is still being considered.

6.3.1 Factored Geotechnical Resistances

As noted above, either a precast concrete box culvert founded between approximately Elevations 190.0 m and 190.85 m or a SPCSP culvert(s) founded between approximately Elevations 190.35 m and 191.15 m will be constructed as part of the replacement strategy at the Dam Creek site. It is not necessary to found the proposed precast box culvert or SPCSP culvert(s) at or below the standard depth (i.e., 2.0 m in this area) for frost protection purposes, as these types of culverts are tolerant of small magnitudes of movement related to freeze-thaw cycles. The factored ultimate and serviceability geotechnical resistances for the precast box culvert options as well as the SPCSP culverts options founded on a 0.3 m thick bedding layer placed on properly prepared subgrade are as follows:



Culvert Type	Culvert Size	Founding Soils	Factored Ultimate Geotechnical Resistance	Factored Serviceability Geotechnical Resistance for 50 mm of Settlement	Factored Serviceability Geotechnical Resistance for 75 mm of Settlement
Precast Concrete Box	5.7 m wide by 4.3 m high	0.3 m of compacted Granular 'A' material over generally firm to very stiff clayey silt with sand to silty clay to varved clayey silt and silty clay	145 kPa	55 kPa ¹	80 kPa ²
	4.2 m wide by 4.2 m high		130 kPa	55 kPa ¹	80 kPa ²
SPCSP	3.99 m diameter		130 kPa	55 kPa ¹	80 kPa ²
	3.6 m diameter (twin culverts)		125 kPa	55 kPa ¹	80 kPa ²

Notes:

1. The differential settlement along the length of the culverts is estimated to range between about 10 mm and 20 mm as summarized in Section 6.7 for each culvert type. If the precast concrete box culverts, the 3.99 m diameter SPCSP culvert, and twin SPCSP culverts can tolerate a maximum factored settlement of 55 mm, 30 mm, and 55 mm, respectively, and a differential settlement between about 10 mm and 20 mm, the factored serviceability geotechnical resistances will not govern and the design of the culvert(s) can be based on the factored ultimate geotechnical resistances as presented above.

2. If the precast concrete box culverts, the 3.99 m diameter SPCSP culvert, and twin SPCSP culverts can tolerate a maximum factored settlement of 75 mm, 40 mm, and 75 mm, respectively, and a differential settlement between about 20 mm and 40 mm, the factored serviceability geotechnical resistances will not govern and the design of the culvert(s) can be based on the factored ultimate geotechnical resistances as presented above.

The factored ultimate resistances presented above are based on loading applied perpendicular to the top surface slab of the culvert. Where the load is not applied perpendicular to the top surface slab of the culvert, inclination of the load should be taken into account in accordance with Section 6.10.4 and Section C6.10.4 of the CHBDC (2014) and its *Commentary*.

6.3.2 Resistance to Lateral Loads / Sliding Resistance

Resistance to lateral forces/sliding resistance between a precast concrete box culvert or a SPCSP culvert and granular bedding as well as between the granular bedding and the native subgrade soils shall be calculated in accordance with Section 6.10.5 of the CHBDC (2014). The unfactored coefficient of friction ($\tan \delta$) and effective cohesion (where applicable) between the various interface materials is summarized below.

Interface Materials	Unfactored Coefficient of Friction ($\tan \delta$)	Effective Cohesion, c'
Precast concrete box culvert on Granular 'A' material	0.45	0 kPa
Corrugated Steel Pipe culvert on Granular 'A' material	0.40	0 kPa
Granular 'A' material on gravelly sand subgrade	0.58	0 kPa
Granular 'A' material on clayey silt with sand to silty clay to varved silt to clayey silt and silty clay	0.49 (long-term)	70 kPa (short-term)



6.4 Lateral Earth Pressures

The lateral earth pressures acting on the walls of the culvert (assuming the existing SPCSPA culvert will be replaced with precast concrete box culvert) will depend on the type and method of placement of the backfill material, the nature of the soils/embankment fill behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the walls.

The following recommendations are made concerning the design of the culvert walls. These design recommendations and parameters assume level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- Select, free draining granular fill meeting the specifications of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II should be used as backfill behind the walls and on top of the culvert for a thickness not less than 300 mm. Backfill should be placed in a maximum 200 mm loose lift thickness and nominally compacted. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (Compacting).
- Surcharge loadings should be accounted for in the design as required.
- For restrained structures, granular fill should be placed in a zone with the width equal to at least 2.0 m behind the back of the wall (in accordance with Figure C6.20(a) of the *Commentary* to the CHBDC, 2014). For unrestrained structures, fill should be placed within a 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 a footing or bottom of a structure (in accordance with Figure C6.20(b) of the *Commentary* to the CHBDC, 2014). The lateral pressures should be based on the proposed embankment fill/backfill and existing soils/fill, where applicable, and the following parameters (unfactored) may be used:

Fill Type	Soil Unit Weight	Coefficients of Static Lateral Earth Pressure	
		At-Rest, K_o	Active, K_a
New Granular 'A'	22 kN/m ³	0.43	0.27
New Granular 'B' Type II	21 kN/m ³	0.43	0.27
Generally Compact Gravelly Sand to Sand and Gravel (Fill)	22 kN/m ³	0.47	0.31
Very Stiff Sandy Clayey Silt (Fill)	19 kN/m ³	0.47	0.31
Generally Very Loose to Loose to Silty Sand and Gravelly Sand (Fill)	19 kN/m ³	0.53	0.36

If the culvert design does not allow lateral yielding of the culvert walls (e.g., a rigid box culvert), at-rest earth pressures should be assumed for the geotechnical design. Where the culvert design does allow lateral yielding of the walls, active earth pressures should be used in the geotechnical design of the wall structure(s). The movement required to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure for design, should be calculated in accordance with Section C6.12.1 and Table C6.6 of the *Commentary* to the CHBDC, 2014.



6.5 Platform Widening – Embankment Stability and Settlement

As noted in Section 6.1, it is understood that no grade raise is required along Highway 532 as part of the culvert replacement construction; however, platform widening is required in the vicinity of the culverts to facilitate construction staging. The platform widening is expected to extend on both sides of the highway embankment between approximately Stations 13+020 and 13+160, but it will be most prominent near Dam Creek where the platform is proposed to be about 12 m in width. The side slopes of the platform widening are expected to be constructed at an inclination of 2 horizontal to 1 vertical (2H:1V). It is further understood that the platform widening will likely be a permanent feature in order to:

- i) avoid double-handling of the fill material;
- ii) ensure that the construction operation is completed on schedule due to a restricted in-water work timeframe;
- iii) increase the width of the essentially non-existent shoulders near Dam Creek;
- iv) ensure that future culvert rehabilitation works can be completed without re-constructing a temporary platform, and;
- v) improve the stability of the existing embankment side slopes which are in some places inclined at 1H:1V (or steeper) and are showing signs of surficial erosion.

Slope stability and settlement analyses associated with the proposed platform widening are addressed herein.

6.5.1 Global Slope Stability

The following sections outline the method used to evaluate static global stability of the new highway embankment as a result of the proposed platform widening. The geotechnical soil parameters used in the analyses are also presented. The results of the stability analyses are presented in Section 6.7 where they are discussed together with the results of the settlement analyses.

6.5.1.1 Method of Analysis

Given the presence of an extensive varved silt to clayey silt and silty clay deposit encountered within the project limits, stability analyses were carried out at one critical section corresponding to the greatest volume of fill being placed as part of the platform widening. The critical section was identified at approximately Station 13+100 (i.e., between the two existing culverts) and was analyzed using limit equilibrium methods.

Two-dimensional limit equilibrium slope stability analyses were performed using the commercially available program Slide (Version 6.0), developed by Rocscience Inc., employing the Morgenstern-Price method of analysis. Morgenstern-Price is a general method of slices which is based on equilibrium of forces and moments acting on each slice of soil mass above the potential failure surface. For all analyses, the Factors of Safety of numerous potential failure surfaces were computed in order to establish the minimum Factor of Safety. The Factor of Safety is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause failure. For the purpose of the stability analysis, the Factor of Safety is equal to the inverse of the product of the consequence factor, Ψ , and the geotechnical resistance factor, ϕ_{gu} . (i.e., $FoS = 1/(\Psi \cdot \phi_{gu})$). Accordingly, minimum Factors of Safety of 1.3 and 1.5 have been used for the design of the embankment slopes for the short-term/temporary and long-term/permanent conditions, respectively, as per Table 6.2 of CHBDC (2014).



6.5.1.2 Parameter Selection

The simplified stratigraphy together with the foundation engineering parameters employed for the different soils types encountered at the site are summarized in Table 1. The following is a summary of the embankment slope inclination, unit weight and effective friction angle for the new granular fill (Granular 'A' or Granular 'B' Type II material satisfying OPSS.PROV 1010 requirements) modelled in the slope stability analyses.

Fill Type	Recommended Slope Inclination	Bulk Unit Weight, γ	Effective Friction Angle, ϕ'	Cohesion, c'
New Granular Fill	2H:1V	21 kN/m ³	37°	0 kPa

For the non-cohesive soils/fills present at this site, the effective stress parameters employed in the analysis were estimated from empirical correlations based on the results of the in-situ Standard Penetration Tests (SPT). The correlations proposed by Peck et al. (1974) and U.S. Navy (1986) were also employed and the results were adjusted using engineering judgment based on precedent experience in similar soil conditions.

For cohesive deposits, total stress parameters were employed in the analyses for the short-term, undrained conditions (i.e., temporary conditions). The total stress parameters (i.e., average mobilized undrained shear strength, s_u) for the cohesive soils were assessed based on the results of in-situ field vane shear tests.

Where appropriate, Bjerrum's correction factor was employed to estimate the average mobilized undrained shear strength from the results of the in-situ field vane tests as follows:

$$s_{u(mob)} = \mu s_{u(FV)} \quad (\text{after Bjerrum, 1973})$$

where,

$$\begin{aligned} s_{u(mob)} &= \text{average mobilized undrained shear strength (kPa)} \\ s_{u(FV)} &= \text{undrained shear strength from field vane test (kPa)} \\ \mu &= \text{Bjerrum's correction factor based on plasticity index} \end{aligned}$$

For the extensive varved silt to clayey silt and silt clay deposit at this site, an additional reduction factor of 25% was employed to account for the angle of minimum shearing resistance (as described in Lo and Milligan, 1967). A plot of the corrected undrained shear strengths versus elevation (along with other index and compressibility parameters for the varved silt to clayey silt and silty clay deposit) is shown on Figure 1. It is noted that with Bjerrum's correction factor and the additional reduction factor of 25%, the corrected undrained shear strength of the varved clayey deposit generally varies between about 47 kPa and 72 kPa. It is further noted that the lower shear strengths were measured in the boreholes advanced near the toes of the existing embankment, while the higher shear strengths were measured in the boreholes advanced near the centreline of the existing embankment. As such, for slope stability purposes, the lower bound of the undrained shear strengths of 55 kPa (above Elevation 182.0 m) and 30 kPa (below Elevation 182.0 m) was utilized, as shown in the design line on Figure 1, was assigned to the varved clay deposit.

Effective stress parameters were also employed to evaluate the stability of the embankments based for the long-term, drained conditions (i.e., permanent conditions). The effective stress parameters (i.e., effective friction angle (ϕ') and effective cohesion (c')) for the cohesive deposits were estimated from empirical correlations based on the plasticity index. The correlations proposed by Mitchell (1993), Kulhawy and Mayne (1990), and Ladd et al. (1977) were employed and the results were adjusted by engineering judgment based on precedent experience in similar soil conditions.



For the purpose of the stability analysis, the groundwater level was assumed to be at creek surface.

6.5.2 Settlement

The following sections outline the method used to carry out the settlement analyses at the location of the platform widening near Dam Creek. The geotechnical soil compressibility parameters used in the analyses are also presented. The results of the analyses are presented in Section 6.7 where they are discussed together with the results of the slope stability analyses.

6.5.2.1 Method of Analysis

To estimate the magnitude of expected settlement, analyses were carried out at the location of the culvert and at the critical section of the proposed platform widening. The critical section corresponds to the greatest volume of fill being placed as part of the platform widening. The critical section was identified at approximately Station 13+100 (i.e., between the two existing culverts). The settlement analyses were carried out using the commercially available program Settle^{3D} (Version 4.0), developed by Rocscience Inc.

The sources of settlement are considered to include:

- Immediate settlement of the granular soils (short-term); and,
- Primary time-dependent consolidation of the cohesive deposits (using Terzaghi's one-dimensional consolidation theory – long-term)

Secondary time-dependent (creep) consolidation of the cohesive deposits (long-term) is considered to be negligible given that the final vertical effective stress as a result of the platform widening generally does not exceed the preconsolidation stress (which was estimated based on the undrained shear strength from the results of the in-situ field vane tests as described in Section 6.5.1.2 and confirmed by the results of Oedometer consolidation testing) as shown on Figure 1.

The thickness of the compressible foundation soils is relatively consistent at the site, however, the height (or thickness) of the embankment platform widening will vary along the culvert alignments, and as such the settlements along the length of a given culvert alignment will similarly vary. In addition, since no highway grade raise is proposed at the site, the majority of the filling (and the associated settlement) is anticipated to occur near the ends of the culverts. Given that the analyses were carried out at the critical section of embankment platform widening, the settlements estimated will generally represent the maximum estimated value along a given culvert alignment.

6.5.2.2 Parameter Selection

The simplified stratigraphy together with the deformation and time-rate consolidation parameters, where applicable, employed for the different soil types encountered at the site are summarized in Table 1. The parameters associated with the extensive varved silt to clayey silt and silty clay deposit encountered at the site are also presented on Figure 1.

The consolidation settlement of the varved cohesive deposit was assessed using the results of the laboratory oedometer testing along with the results of the in-situ field vane tests to estimate the deformation parameters and stress history of the varved cohesive deposit, respectively. In addition, the results of the laboratory index test were employed to further assess deformation soil parameters (i.e., compression and recompression indices) using



empirical correlations proposed in literature by Azzouz et al. (1976), Koppula (1986), Kulhawy and Mayne (1990), Nishida (1956) and Terzaghi and Peck (1967). The correlation by Koppula (1986) relating the natural water content (w_n) and liquid limit (w_L) to the compression index (i.e., $C_c = 0.009 \cdot w_n + 0.005 \cdot w_L$) is considered to be the most relevant based on our experience with similar soils in Northern Ontario. In addition, the correlation for soils with low plasticity (as referenced in Bowles, 1979) relating the void ratio (e_o) to the compression index (i.e., $C_c = 0.75 \cdot (e_o - 0.50)$) was also considered to be representative at this site. Although this correlation is generally applicable to soils with low plasticity, it is believed that the laminae with low plasticity (i.e., the silt to clayey silt laminae) have a considerable impact on the overall behaviour of the varved deposit. Based on the two aforementioned correlations, the range of compression indices is very narrow and the average compression index (C_c) has been estimated to be about 0.6. The compression index estimated from the results of the Oedometer consolidation tests is about 0.7 and 0.9; however, the varved cohesive deposit is over-consolidated (i.e., the OCR is approximately 3.5) and the compression index will not affect the estimated magnitude of settlement at the site as described in Section 6.7. The recompression index of clayey soils encountered in Northern Ontario typically varies between about 5% and 10% of the compression index. Given the presence of the stiffer silt to clayey silt laminae within the varved clayey stratum at this site, a value closer to the lower end of this range (i.e., of approximately 6.7%, or $C_r = (1/15) \cdot C_c$) was selected for design. The recompression index estimated from the results of the oedometer consolidation tests and the empirical correlations is in general agreement.

It is also noted that the selected values of C_c and C_r (described above) are similar to the findings of Quigley and Ogunbadejo (1972) (giving due consideration to stress levels and plasticity of the laminae) who carried out oedometer consolidation tests on varved sediments from New Liskeard located in Northern Ontario, some 350 km northeast of the Dam Creek site.

The following correlation relating in-situ undrained shear strength to preconsolidation stress (Mesri, 1975) was employed:

$$\sigma'_p = \frac{S_{u(mob)}}{0.22}$$

where,

$$\begin{aligned}\sigma'_p &= \text{preconsolidation stress (kPa); and,} \\ S_{u(mob)} &= \mu S_{u(FV)} \text{ (after Bjerrum, 1973), where,} \\ &\quad S_{u(mob)} = \text{average mobilized undrained shear strength (kPa)} \\ S_{u(FV)} &= \text{undrained shear strength from field vane test (kPa)} \\ \mu &= \text{Bjerrum's correction factor based on Plasticity Index}\end{aligned}$$

In order to carry out time-rate consolidation settlement analyses, the coefficient of consolidation, c_v (cm^2/s), and the overall thickness of the varved deposit are required. The coefficient of consolidation was established using the results of the oedometer consolidation tests and also estimated from the U.S. Navy (1986) correlation with liquid limit assuming over-consolidated soils.

The overall thickness of the varved deposit was estimated based on the DCPT carried out in each borehole advanced during the field investigation. The bottom of the varved deposit was inferred based on the DCPT data (i.e., blows per 0.3 m) as follows:



Boreholes Designation	Range of SPT 'N'-Values Within Varved Deposit	Range of DCPT Blow Counts Within Inferred Varved Deposit	Inferred Bottom Elevation of Varved Deposit	Inferred Overall Thickness of Varved Deposit ²
DCC-01	2 - 6 blows/0.3 m	2 - 10 blows/0.3 m	177.0 m	13.0 m
DCC-02	3 - 8 blows/0.3 m	1 - 13 blows/0.3 m	176.5 m	13.9 m
DCC-03	3 - 6 blows/0.3 m	4 - 13 blows/0.3 m	177.3 m	13.0 m
DCC-04	2 - 7 blows/0.3 m	4 - 14 blows/0.3 m	177.5 m	13.1 m
DCC-05	1 - 5 blows/0.3 m	1 - 14 blows/0.3 m	177.1 m	13.6 m
DCC-06	1 - 5 blows/0.3 m	1 - 14 blows/0.3 m ¹	177.4 m	13.0 m

Notes:

1. The blow counts at Elevations 177.4 m and 177.1 m were 17 blows and 16 blows per 0.3 m of penetration, respectively.
2. The average thickness of the varved cohesive deposit based on the six boreholes (Borehole DCC-07 was terminated within the varved cohesive deposit) is about 13.3 m.

The DCPTs were terminated within a deposit(s) (most likely a non-cohesive deposit(s) based on the regional geology) inferred to be competent (based on the measured blow counts typically ranging between 40 blows and 100 blows per 0.3 m of penetration) at elevations ranging between about 174.4 m and 172.1 m.

For the purpose of the settlement analysis, the groundwater level was assumed to be at the creek surface.

6.6 Settlement Performance Requirements

The settlement performance criterion for design of embankment widenings is outlined in MTO's Guideline titled, "Embankment Settlement Criteria for Design", dated July 2010. In general, embankment widenings not approaching a structural element are to be designed in accordance with Section 1.3 of MTO's Guideline as follows:

- Total settlement and differential settlement rate is not to exceed 50 mm and 200:1, respectively, over a 15-year period following completion of construction for a secondary highway (Highway 532 in this case).

However, where new embankments/widenings approach structural elements (such as culverts), a more stringent settlement criterion associated with such a transition point will apply in accordance with Section 1.2 of MTO's Guideline. In this case, the embankment widening will be carried out next to the proposed culvert(s). Consequently, any embankment widening 20 m away from the culvert(s) must satisfy a post-construction settlement criterion of 25 mm over a 15-year period following completion of construction.

6.7 Results of Analyses

The results of global slope stability and settlement analyses at the Dam Creek site are provided herein.

The global slope stability analyses indicate that the Highway 532 embankment will have a Factor of Safety of approximately 1.5 during the temporary/short-term and permanent/long-term conditions for deep-seated, global failure surfaces of the side slopes that would impact the operation of the highway (refer to Figures 2 and 3).

The results of settlement analyses are summarized below. The estimated magnitudes of settlement correspond to the primary consolidation settlement of the varved silt to clayey silt and silty clay deposit. The estimated settlement corresponds to the maximum magnitude of settlement, unless stated otherwise, and is based on the loading imposed by platform widening, fill placement above/around new culverts, abandonment and backfilling of



existing culvert(s), where applicable, and construction of new culverts. In areas where the platform widening is proposed, the maximum settlement is anticipated to occur near the toes of the existing highway embankment where the maximum “wedge” of fill is proposed to be placed.

■ **Highway 532 Embankment after Platform Widening**

- The total factored settlement along the new roadway platform is expected to range from about 18 mm (at the centreline of the highway) to about 25 mm (near the new crests of the widened embankment).
- The total factored settlement at the critical section (i.e., near the toes of the existing embankment or about mid-slope of the new widening where the greatest height of new fill will be placed) is estimated to range between about 45 mm and 60 mm.
- The total factored settlement along the new highway platform is estimated to be about 25 mm or less and as such, the post-construction settlement criterion is not expected to be exceeded. Consequently, settlement mitigation measures are not required for the platform widening.

■ **New 3.99 m Diameter SPCSP Culvert**

- The total factored settlement along the culvert where fill will be in contact with the top of the culvert is estimated to range between about 25 mm and 30 mm, while the total factored settlement near the inlet and outlet of the culvert is estimated to range between about 15 mm and 20 mm.
- The differential settlement along the length of the new culvert is estimated to range between about 10 mm and 15 mm. Consequently, the new culvert can be constructed concurrently with embankment widening so long as the culvert structure can tolerate these differential settlements.

■ **New 3.6 m Diameter Twin SPCSP Culverts**

- The total factored settlement along the culverts where the embankment fill will be in contact with the top of the twin culverts is estimated to range between about 30 mm and 35 mm, while the total factored settlement near the inlets and outlets of the twin culverts is estimated to range between about 15 mm and 25 mm.
- The differential settlement along the length of the new culverts is estimated to range between about 15 mm and 20 mm. Consequently, the new culverts can be constructed concurrently with embankment widening so long as the culvert structure can tolerate these differential settlements.

■ **New Precast Box Culvert**

The following results of settlement analyses apply to both the 5.7 m wide and 4.2 m wide precast box culverts. The total load imposed below the footprint of these proposed culverts as a result of the deadweight of the respective culvert and the fill above the top slab of the culvert is essentially the same under both scenarios.

- The total factored settlement along the culvert where the embankment fill will be in contact with the top slab of the culvert is estimated to range between about 50 mm and 55 mm, while the total factored settlement near the inlet and outlet of the culvert is estimated to range between about 40 mm and 45 mm.
- The differential settlement along the length of the new culvert is estimated to range between about 10 mm and 15 mm. Consequently, the new culvert can be constructed concurrently with the proposed embankment widening so long as the culvert structure can tolerate these differential settlements.



■ **Existing Southern SPCSP Culvert – Abandoned and Backfilled**

- If a precast box culvert is constructed and the existing southern SPCSP is abandoned and backfilled, the total factored settlement is estimated to range between about 35 mm and 40 mm along the highway platform and between about 50 mm and 60 mm near the toes of the existing embankment.
- However, assuming a c_v of $1.25 \times 10^{-2} \text{ cm}^2/\text{sec}$, the post-construction settlement criterion of 25 mm over a 15-year period following construction can be achieved after a delay period of approximately 10 days. After 10 days, the total factored settlement is estimated to be about 20 mm along the highway platform and between about 20 mm and 25 mm near the toes of the existing embankment. It is recommended that a Special Provision be included in the contract documents to allow a 10-day delay period prior to placement of the granular base material and paving of the highway. If possible, the existing culvert should be backfilled as soon as possible while other construction works are being carried out to allow a large portion of the total estimated settlement to occur prior to paving the newly widened highway.

6.8 Construction Considerations

This section identifies key construction considerations that may impact the design and construction of the new culvert(s).

6.8.1 Temporary Open-Cut Excavations

It is expected that temporary excavations will extend to down to approximately Elevation 190.4 m in order to facilitate removal of the existing culverts and installation of a new precast box culvert or twin SPCSP culverts, including placement of granular bedding for the new culvert(s). As such, the excavation will extend through the existing highway embankment fill as well as deposits of gravelly sand to gravel, clayey silt with sand, silty clay, and varved silt to clayey silt with silty clay. The founding subgrade should be inspected to ensure that any organic soils or other unsuitable materials have been removed in accordance with OPSS.PROV 421 (*Pipe Culvert Installation in Open Cut*) for a SPCSP culvert or OPSS 422 (*Precast Reinforced Concrete Box Culverts*) for a precast concrete box culvert. Any sub-excavated areas should be backfilled with granular material meeting OPSS.PROV 1010 (*Aggregates*) Granular 'A' or Granular 'B' Type II and placed and compacted in accordance with OPSS.PROV 501 (*Compacting*).

All excavations must be carried out in accordance with Ontario Regulation 213 (*Ontario Occupation Health and Safety Act for Construction Projects*), as amended, and OPSS 902 (*Excavating and Backfilling – Structures*).

The existing embankment fill (assuming it is above the groundwater/perched water level as noted during the field investigation) can be classified as a Type 3 soil according to OHSA, except for the very loose portions of the non-cohesive fill, which are classified as Type 4 soils. The soils below the groundwater table/water in the creek (i.e., bottom portion of the embankment fill (gravelly sand to sand and gravel), gravelly sand to gravel, clayey silt with sand, silty clay, and varved silt to clayey silt with silty clay) would be classified as Type 4 soils; however, if dewatered, these soils can be classified as Type 3 soils. Temporary excavations in Type 3 soils should be made with side slopes no steeper than 1 horizontal to 1 vertical (1H:1V). Temporary excavations in Type 4 soils should be made with side slopes no steeper than 3H:1V.

Cobbles and boulders were observed at the surface of the creek bed near the inlets and outlets of the existing culverts, especially at the southern SPCSP culvert; cobbles were also inferred to be encountered within the



embankment fill. Consequently, construction equipment must be capable of excavating through these obstructions.

All temporary excavations should be observed by a qualified geotechnical engineer and reviewed during construction to confirm that the soil and groundwater conditions encountered are as anticipated in this document.

6.8.2 Temporary Cofferdams and Roadway Protection Systems

Temporary cofferdams near the inlets and outlets of the culverts and temporary roadway protection systems along Highway 532 in the vicinity of Dam Creek will be required to support the installation/construction of the new culvert(s) and allow vehicular traffic flow along the highway during excavation/construction operations, respectively.

Since the depth of water in the creek near the inlets and outlets of the culverts is relatively shallow (i.e. up to about 0.6 m and 0.9 m, respectively as measured during the field investigation), and considering that the excavations for the culvert bedding placement and construction will only penetrate between about 1 m below the creek bed near the inlets and 0.3 m below the creek bed near the outlets, it may be possible to construct the temporary cofferdams and divert the creek water using one of the following methods:

- Small inflatable bladder cofferdams;
- Water dams consisting of industrial grade, impermeable, composite fabrics formed into flexible tubes containing one or more chambers; or,
- Multiple rows of large sand bags ('super-bags' or 'bulk-bags') lined with an impermeable barrier (poly-material).

Further, given the relatively constrained access to the site, the use of smaller, and more modular or inflatable cofferdams may be preferred as these systems can be maneuvered by small equipment and/or by hand. However, the viability and effectiveness of such systems will depend on the creek water level at the time of construction as well as the available space between where the diversion structure(s)/temporary cofferdams will be located relative to the excavation for the new culvert(s). As noted in Section 6.8.1, the soils below the creek bed are considered Type 4 soils and as such, temporary unsupported excavations will have to be made with side slopes no steeper than 3H:1V. The spacing required to accommodate this slope, relative to the restrictions imposed by the Right-of-Way will need to be considered when determining if an unsupported excavation using one of the above methods is practical or not.

If water levels in the creek are high, if the working area is restricted and/or if deeper sub-excavation is required to remove weak/softened soils before bedding placement, it may be necessary to install a proper groundwater cut-off system (comprised of an interlocking steel sheet piles) to avoid excavation instability, a "boiling" or "quick" condition that would loosen/soften any of the cohesionless soils and/or cause disturbance of the foundation subgrade within the footprint(s) of the excavation area. If required, a more robust/watertight cofferdam system for this site would consist of steel sheet piles driven to a suitable depth.

For the temporary roadway protection system, consideration could be given to driven steel sheet piles or a soldier pile and lagging system whereby more rigid steel H-piles would be driven to a suitable depth and horizontal timber lagging installed between the H-piles as the excavation proceeds to retain the embankment fill. The latter system assumes that groundwater is not perched up in the highway embankment fill and that the lower portions of the



existing fill (i.e., below the creek water level) could be adequately retained and seepage would not be excessive. Otherwise, a perched water level in the embankment fill, or where the embankment fill exists below the creek level, could result in some water seepage/inflow into the excavation and may cause migration of fine-grained soil particles through the lagging boards (resulting in potential subsidence of the highway surface) which are not considered watertight.

The temporary cofferdams and protection systems at this site should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*). The temporary protection systems extending through the highway embankment should be designed in accordance with Performance Level 2. The lateral movement of the temporary cofferdam system should include an evaluation of base stability, soil squeezing stability and hydraulic uplift as defined in the Canadian Foundation Engineering Manual (CFEM, 2006). The contractor is responsible for the design and construction of all temporary cofferdams and protection systems.

The temporary cofferdams and protection systems may be designed using the following parameters:

Fill / Soil Type	Bulk Unit Weight, γ	Internal Angle of Friction, ϕ'	Undrained Shear Strength, s_u	Lateral Earth Pressure Coefficients ¹		
				K_p (Passive) ²	K_o (At-Rest)	K_a (Active)
Generally Compact Gravelly Sand to Sand and Gravel (Fill)	22 kN/m ³	32°	--	3.25	0.47	0.31
Very Stiff Sandy Clayey Silt (Fill)	19 kN/m ³	32°	125 kPa ³	3.25	0.47	0.31
Generally Very Loose to Loose to Silty Sand and Gravelly Sand (Fill)	19 kN/m ³	28°	--	2.77	0.53	0.36
Very Loose to Loose Gravelly Sand to Gravel	22 kN/m ³	28°	--	2.77	0.53	0.36
Firm to Very Stiff Clayey Silt with Sand to Silty Clay to Varved Silt to Clayey Silt and Silty Clay	19 kN/m ³	26°	22 kPa to 72 kPa ³	2.56	0.56	0.39

Notes:

1. The lateral earth pressure coefficients presented above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are expected, the coefficients should be corrected accordingly.
2. The total passive resistance below the base of the excavation (i.e., within the sheet pile cofferdam or temporary protection system enclosure) may be calculated based on the values of K_p indicated above but reduced by an appropriate factor that considers the allowable wall movement in accordance with Figure C6.16 of the Canadian Highway Bridge Design Code (CHBDC, 2014) to account for the fact that a large strain would be required for mobilization of the full passive resistance.
3. For cohesive deposits, an assessment for both the drained (ϕ') and undrained (s_u) cases should be made to establish the more conservative earth pressure condition for design.

The installation of sheet piles for temporary cofferdams and roadway protection systems may be impeded by the presence of cobbles/boulders at the creek bed near the inlets and outlets of the culverts and potential presence of cobbles within the granular highway embankment. Given the presence of these obstructions, consideration should be given to protecting the tips of the sheet piles and/or the use of heavier sheet pile sections, assuming a sheet pile system is selected. Further, any cobbles and boulders on the creek bed within the footprint of the proposed cofferdams/protection systems should be removed prior to sheet driving.



6.8.3 Control of Groundwater and Surface Water

Although the excavations will extend into the varved cohesive deposit below the creek bed, the silty laminae are water bearing and more permeable than the silty clay laminae. In addition, the excavations will extend through the lower portion of the existing granular embankment fill below the creek level. As such, some form of groundwater control will be required to allow for construction to be carried out in-the-dry.

The method and extent of groundwater control required will ultimately depend on the type of temporary cofferdams and roadway protection selected by the contractor (described in Section 6.8.2). If temporary shoring is comprised of sheet pile cut-off walls, the requirements for groundwater control will be lessened. However, if temporary shoring is comprised of soldier pile and timber lagging (through the roadway embankment) and inflatable bladders, flexible tubes or sand bags (for cofferdams around the culvert inlet(s) and outlet(s)), the requirements for groundwater control could be more extensive. The contractor is responsible for the design and installation of all groundwater control measures giving due consideration to the type of temporary shoring selected as well as the requirements for maintaining the stability/integrity of the culvert foundation subgrade and for construction of the culvert and bedding in-the-dry.

Surface water should be directed away from the excavation area(s) to prevent ponding of water that could result in disturbance and loosening/softening of the foundation subgrade

Depending on the creek flow, surface water flow and groundwater levels at the time of construction, water flow could be diverted and/or pumped from behind a temporary cofferdam in accordance with MTO's Special Provision 517F01 (*Temporary Flow Passage System*). However, if construction water pumping volumes are anticipated to exceed 50 m³/day, an Environmental Activity Section Registry (EASR) will be required as per the recently introduced changes to the Environmental Protection Act by the Ontario Ministry of Environment and Climate Change (MOECC).

6.8.4 Obstructions

As described in Section 4.2.1, cobbles/boulders were noted at the surface of the creek bed; cobbles were also inferred to be encountered within the existing embankment fill as noted in Section 4.2.3. Consequently, construction equipment should be capable of excavating through such obstructions. It is recommended that a Non-Standard Special Provision be included in the contract documents to address obstructions (refer to Appendix D).

Equipment/tools used to install all temporary cofferdam and protection systems must also be capable of penetrating through such obstructions. A separate Non-Standard Special Provision for this item should be included in the contract documents (refer to Appendix D).

6.8.5 Culvert Bedding, Cover and Backfill

Culvert construction, including placement of bedding, cover and backfill should be in accordance with the relevant Ontario Provincial Standards for Roads and Public Works as summarized below.



Culvert Replacement Option	Ontario Provincial Standard Drawing: Bedding, Cover and Backfill	Ontario Provincial Standard Specification: Culvert Construction
Steep Plate Corrugated Steel Pipe (CPCSP)	OPSD 802.010 – Flexible Pipe Embedment and Backfill, Earth Excavation	OPSS.PROV 421 – Pipe Culvert Installation in Open Cut
Concrete Precast Box Culvert	OPSD 803.010 – Backfill and Cover for Concrete Culverts ¹	OPSS 422 – Precast Reinforced Concrete Box Culverts

Note:

1. OPSD 803.010 is applicable to concrete culverts with spans less than 3 m. However, the proposed 5.6 m wide precast box culvert should be constructed in general accordance with this specification.

Culvert bedding should be placed on properly prepared subgrade whether comprised of native soil or sub-excavation backfill. However, taking into consideration that the bedding will likely be placed on native fine-grained soils (i.e., clayey silt with sand to silty clay to varved silt to clayey silt and silty clay), it is recommended that a non-woven geotextile be placed between the subgrade soils and the bottom of the bedding. The geotextile should meet the specification for OPSS 1860 (*Geotextiles*) Class II and have a Filtration Opening Size (FOS) not greater than 212 µm. The bedding, cover and backfill should be placed in lifts not exceeding 200 mm in loose thickness, and compacted to at least 95% of the Standard Proctor maximum dry density of the material as specified in OPSS.PROV 501 (*Compacting*). If the subgrade is expected to be disturbed due to construction traffic and/or ponded water and the bedding cannot be placed in a timely manner, a concrete working slab will be required on the subgrade as outlined in Section 6.8.6.

The backfill behind the culvert walls should consist of granular fill meeting the specifications for OPSS.PROV 1010 Granular 'A' or Granular 'B' Type II material. The granular backfill should be placed and compacted in accordance with OPSS.PROV 501 (*Compacting*).

Backfill placement for the platform widening/reconstruction of the highway embankments along and over the culvert(s) should be carried out in accordance with OPSD 208.010 (*Benching of Earth Slopes*) to integrate the new fill with the existing embankment fill along the cut faces.

Inspection and field density testing should be carried out during all engineering fill placement operations to ensure that appropriate materials are used, and that adequate levels of compaction have been achieved.

Additional requirements/recommendations for culvert construction are provided below for each culvert replacement option.

6.8.5.1 Precast Box Culvert

The culvert bedding should be minimum 300 mm thick and consist of OPSS.PROV 1010 (*Aggregates*) Granular 'A' material, placed and compacted in-the-dry. In addition, a minimum 75 mm thick uncompacted levelling layer consisting of OPSS.PROV 1010 Granular 'A' material or concrete fine aggregate meeting the gradation requirements specified in OPSS.PROV 1002 (*Aggregates – Concrete*) should be provided as shown on OPSD 803.010 (*Backfill and Cover for Concrete Culverts*) for culvert construction.

Backfill should be placed concurrently on both sides of the culvert walls, ensuring that the backfill depth on one side does not exceed the other side by more than 400 mm as per OPSS 422 (*Precast Reinforced Concrete Box Culverts*).



6.8.5.2 SPCSP Culverts

The culvert bedding, cover and backfill for SPCSP culverts should satisfy the requirements outlined in the applicable 800 series Ontario Provincial Standard Drawings (OPSD's).

The culvert bedding should be minimum 300 mm thick and consist of OPSS.PROV 1010 (*Aggregates*) Granular 'A' material, placed and compacted in-the-dry. The bedding layer should be compacted in accordance with OPSS.PROV 501 (*Compacting*). The bedding should be pre-shaped in the transverse direction to the approximate profile of the bottom of the culvert. In all areas, the shaped portion of the bedding must be sufficiently wide to allow adequate compaction of the backfill under the remaining haunches of the culvert structure.

6.8.6 Subgrade Protection

The overburden soils exposed at the founding level, especially the silt to clayey silt laminae, will be susceptible to disturbance from construction traffic and/or ponded water. To limit the effect of this disturbance, a concrete working slab should be placed on the subgrade if the precast concrete box culvert (if selected as the preferred alternative) and associated bedding is not placed within four hours after preparation, inspection and approval of the subgrade. The minimum thickness of the concrete working slab should be 100 mm and the concrete should have a 28-day compressive strength of not less than 20 MPa. A sample Non-Standard Special Provision to address this requirement is included in Appendix D.

6.8.7 Frost Tapers

Frost tapers, if required, should be constructed in accordance with OPSD 803.031 (*Frost Treatment – Pipe Culverts*) for new SPCSP culverts, or in general accordance with OPSD 803.010 (*Backfill and Cover for Concrete Culverts*) for the new precast box culvert. Considering the relatively significant change in the Highway 532 grade north of Dam Creek (i.e., between about Elevations 196.2 m and 200 m along an approximately 100 m long stretch), an extensive excavation and backfilling operation would be necessary to construct the frost tapers. However, given that the embankment fill in the immediate proximity of the culvert is generally comprised of material with a low degree of frost susceptibility (i.e., gravelly sand to sand and gravel, some fines), and given that Highway 532 is a secondary highway, it is understood that frost tapers may not be required.

6.8.8 Erosion Protection

Provisions should be made for scour and erosion protection at the culvert(s) location. In order to prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring, although the risk may not be very high given the predominantly cohesive founding soils), or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles, and potentially settlement of the overlying roadway surface), a clay seal or concrete cut-off wall should be provided at the upstream end of the culvert(s). If a clay seal is adopted, the clay material should meet the requirements of OPSS.PROV 1205 (*Clay Seal*), and the seal should be a minimum 1 m thick if constructed of natural clay or soil-bentonite mix and extend from a depth of 1 m below the scour level, to a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and to a minimum vertical height equivalent to the high water level, including along the embankment slope. Alternatively, a 0.6 m thick clay blanket (if constructed of natural clay or a soil-bentonite mix) may be constructed, extending upstream three times the culvert height and along the adjacent slopes to a height corresponding to the high water level. A cut-off wall instead of clay seal can also be considered. If the replacement option will involve the installation of new twin SPCSP culverts, the wall should be constructed in accordance with



OPSD 812.010 (*Cut Off Wall for Structural Plate Pipe Arch and Circular CSP*). Ultimately, the requirements for scour mitigation measures at the culvert inlet should be assessed by the hydraulics design engineer.

The requirements for and design of erosion protection measures for the inlet and outlet of the culverts should also be assessed by the hydraulics design engineer. As a minimum, rip-rap treatment for the outlet of the culvert(s) should be consistent with the standard presented in OPSD 810.010 (*Rip-Rap Treatment for Sewer and Culvert Outlets*). Erosion protection for the inlet of the culverts should generally follow the standard presented in OPSD 810.010, with the rip-rap placed up to the toe of slope level, in combination with the cut-off measures noted above. Similarly, rip-rap should be provided over the full extent of the clay blanket, including the creek side slopes and fill slope over the culvert(s).

6.8.9 Platform Widening Construction

Placement of granular fill satisfying OPSS.PROV 1010 Granular 'B' Type I or Type II requirements for construction of new platform widening should be carried out in accordance with the requirements as outlined in OPSS.PROV 206 (*Grading*). The granular fill should be compacted in accordance with OPSS.PROV 501 (*Compacting*). Inspection and field testing should be carried out by qualified personnel during construction to confirm that appropriate materials are being utilized and that adequate levels of compaction are being achieved. Side slopes of the granular fill should be no steeper than 2H:1V.

The placement of the new granular fill should also be carried out in accordance with OPSD 208.010 (*Benching of Earth Slopes*) to integrate the new fill into the existing embankment side slopes.

In order to reduce erosion of the embankment side slopes due to surface water runoff, placement of topsoil and seeding or pegged sod is recommended as soon as practicable after construction of the embankments. The erosion protection must be in accordance with OPSS.PROV 804 (*Seed and Cover*).

6.8.10 Analytical Testing of Construction Materials

The results of analytical tests carried out on two samples of the varved silt to clayey silt and silty clay deposit recovered from Boreholes DCC-01 (advanced near the southern culvert) and DCC-04 (advanced near the northern culvert) are presented in Section 4.4 and on the Certificates of Analysis in Appendix C.

The analytical test results of the soil samples were compared to Table 7.1 (Relative Effect of Resistivity on Corrosion Potential/Aggressiveness (from NCHRP 1978)), as presented in the Federal Highway Administration/National Highway Institute Publication No. FHWA-NHI-14-007 (Federal Highway Administration, 2015), to assess the relative level of corrosion potential on buried steel in contact with soil. The resistivity values measured on the soil samples are 2,200 ohm·cm and 5,100 ohm·cm. These results indicate "mildly corrosive" (i.e., resistivity between 5,000 ohm·cm and 10,000 ohm·cm) to "moderately corrosive" soils (i.e., resistivity between 2,000 ohm·cm and 5,000 ohm·cm).

Given that the existing culvert will likely be replaced with a new precast concrete box culvert, the analytical test results were also compared to CSA A23.1 Table 3 (*Additional requirements for concrete subjected to sulphate attack*) to assess the potential severity of sulphate attack on concrete during its service life. The sulphate concentrations measured on the soil samples were about 0.004% and less than 0.002%, which is below the moderate degree of exposure (i.e., below the class S-3 exposure limits). Therefore, based on the two soil samples tested, and considering that the unpaved stretch of Highway 556 is not exposed to de-icing salts/chemicals, when the designer is selecting the exposure class for the concrete structure, the effects of sulphates from the cohesive



deposit in contact with the concrete structure may not need to be considered. However, if the proposed structure is expected to be exposed to de-icing salt or other solutions, consideration should be given by the designer to designing the concrete structure for a “C” type exposure class as defined by CSA A23.1 Table 1.

It is also noted that the measured pH levels were about 8.0 and 8.2, suggesting that the soils are basic (i.e., pH greater than 7).

Ultimately, it is the designer’s decision to determine the appropriate exposure class and to ensure that all aspects of CSA A23.1 Section 4.1.1 (*Durability Requirements*) are satisfied.

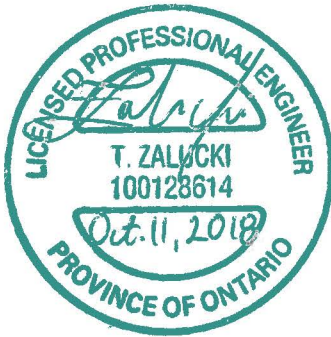
7.0 CLOSURE

The Foundation Design Report was prepared by Mr. Tomasz Zalucki, P.Eng., a geotechnical engineer with Golder. Mr. Paul Dittrich, P.Eng., a Principal and MTO Foundations Designated Contact for Golder, conducted an independent quality control review of the report.



Report Signature Page

GOLDER ASSOCIATES LTD.



Tomasz Zalucki, P.Eng.
Geotechnical Engineer



J. Paul Dittrich, Ph.D., P.Eng.
MTO Foundations Designated Contact, Principal

TZ/JPD/tz/rb

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[https://golderassociates.sharepoint.com/sites/14262g/deliverables/04-final fidr/dam creek culvert/1670846-07-rpt-rev0-dam creek culverts final fidr-20181011.docx](https://golderassociates.sharepoint.com/sites/14262g/deliverables/04-final%20fidr/dam%20creek%20culvert/1670846-07-rpt-rev0-dam%20creek%20culverts%20final%20fidr-20181011.docx)



REFERENCES

- Azzouz, A.S., Krizek, R.J., and Corotis, R.B. 1976. Regression Analysis of Soil Compressibility. Soils and Foundations, Tokyo, Vol. 16, No. 2, pp. 19-29.
- Bowles, J.E. 1984. Physical and Geotechnical Properties of Soils, Second Edition. McGraw Hill Book Company, New York.
- Bjerrum, L. 1973. Problems of Soil Mechanics and Construction of Soft Clays and Structurally Unstable Soils. State of the Art Report, Session 4. Proceedings, 8th International Conference on Soil Mechanics and Foundation Engineering, Moscow, Vol. 3, pp. 111-159.
- Canadian Geotechnical Society. 2006. Canadian Foundation Engineering Manual, 4th Edition. The Canadian Geotechnical Society, BiTech Publisher Ltd., British Columbia.
- Canadian Standards Association (CSA). 2014. Canadian Highway Bridge Design Code and Commentary on CAN/CSA S6-14. CSA Special Publication, S6.1-14.
- Federal Highway Administration. February 2015. Geotechnical Engineering Circular No. 7, Soil Nail Walls - Reference Manual, Publication No. FHWA-NHI-14-007, FHWA GEC 2007. Distributed by the U.S. Department of Transportation, Federal Highway Administration/National Highway Institute. Prepared by Ryan R. Berg and Associates Inc.
- McQuay, D.F. 1980. Sault Ste. Marie Area (NTS 41K/NE), District of Algoma; Ontario Geological Survey, Northern Ontario Engineering Geology Terrain Study 91, 21p. Accompanied by Maps 5012 and 5013, Scale 1:100000.
- Koppula, S.D. 1986. Discussion: Statistical Estimation of Compression Index, Geotechnical Testing Journal, ASTM, Vol. 4, No. 2, pp. 68-73.
- Kulhawy, F.H. and Mayne, P.W. 1990. Manual on Estimating Soil Properties for Foundation Design. EL 6800, Research Project 1493 6. Prepared for Electric Power Research Institute, Palo Alto, California.
- Ladd, C.C, Foott, R., Ishihara, K., Schlosser, F., and Poulos, H.G. 1977. Stress-deformation and strength characteristics. Proceedings of the 9th International Conference on Soil Mechanics and Foundation Engineering, Tokyo, Vol. 2, pp. 421-494.
- Lo, K.Y. and Milligan, V. 1967. Shear strength properties of two stratified clays. Journal of the Soil Mechanics and Foundations Division, Proceedings of the American Society of Civil Engineers, Vol. 93, No. SM1 Paper No. 5056, pp. 1-15.
- Mesri, G. 1975. Discussion on new design procedure for stability of soft clays. ASCE Journal of the Geotechnical Engineering Division, Vol. 101, GT4, pp. 409-412.
- Mitchell, J.K. 1993. Fundamentals of Soil Behaviour. 2nd Edition, John Wiley and Sons Inc., New York.
- Nishida, Y. 1956. A Brief Note on Compression Index of Soils. Journal of Soil Mechanics and Foundations Division, ASCE, Vol. 82, No. SM3, pp. 1027-1-1027-14.
- Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41KNE, Study Number 91.
- Ontario Ministry of Northern Development of Mines. Bedrock Geology of Ontario – East Central Sheet, Ontario Geological Survey – Map 2544.
- Peck, R.B., Hanson, W.E., and Thornburn, T.H. 1974. Foundation Engineering, 2nd Edition, John Wiley and Sons, New York.



Quigley, R.M. and Ogunbadejo, T.A. 1972. Clay Layer Fabric and Oedometer Consolidation of a Soft Varved Clay. Canadian Geotechnical Journal, Vol. 9, pp. 165-175.

Terzaghi, K. and Peck, R.B. 1967. Soil Mechanics in Engineering Practice, 2nd Edition, John Wiley and Sons, New York.

Unified Facilities Criteria U.S. Navy. 1986. NAVFAC Design Manual 7.02. Soil Mechanics, Foundation and Earth Structures. Alexandria, Virginia.

ASTM International:

- | | |
|------------|--|
| ASTM D1586 | Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils |
| ASTM D1587 | Standard Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes. |
| ASTM D2573 | Standard Test Method for Field Vane Shear Strength Test in Cohesive Soil |

Canadian Standards Association (CSA):

- | | |
|------------------|---|
| CAN/CSA A23.1-14 | Concrete Materials and Methods of Concrete Construction |
|------------------|---|

Commercial Software:

Slide (Version 6.0) by Rocscience Inc.

Settle^{3D} (Version 4.0) by Rocscience Inc.

Ontario Occupational Health and Safety Act:

Ontario Regulation 213 Construction Projects (as amended)

Ontario Provincial Standard Specifications (OPSS), Construction:

- | | |
|---------------|---|
| OPSS.PROV 401 | Construction Specification for Trenching, Backfilling, and Compacting |
| OPSS PROV 421 | Construction Specification for Pipe Culvert Installation in Open Cut |
| OPSS 422 | Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cut |
| OPSS.PROV 501 | Construction Specification for Compacting |
| OPSS.PROV 539 | Construction Specification for Temporary Protection Systems |
| OPSS.PROV 804 | Construction Specification for Seed and Cover |
| OPSS 902 | Construction Specification for Excavating and Backfilling – Structures |

Ontario Provincial Standard Specifications (OPSS), Materials:

- | | |
|----------------|---|
| OPSS.PROV 1002 | Material Specification for Aggregates - Concrete |
| OPSS.PROV 1010 | Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material |
| OPSS.PROV 1205 | Material Specification for Clay Seal |
| OPSS 1860 | Material Specification for Geotextiles |



Ontario Provincial Standard Drawings (OPSD):

OPSD 208.010	Benching of Earth Slopes
OPSD 802.014	Flexible Pipe Embedment in Embankment; Original Ground: Earth or Rock
OPSD 802.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m
OPSD 803.031	Frost Treatment – Pipe Culverts, Frost Penetration Line Between Top of Pipe and Bedding Grade
OPSD 810.010	General Rip-Rap Treatment for Sewer and Culvert Outlets
OPSD 812.010	Cut Off Wall for Structural Plate Pipe Arch and Circular CSP

Ontario Regulations:

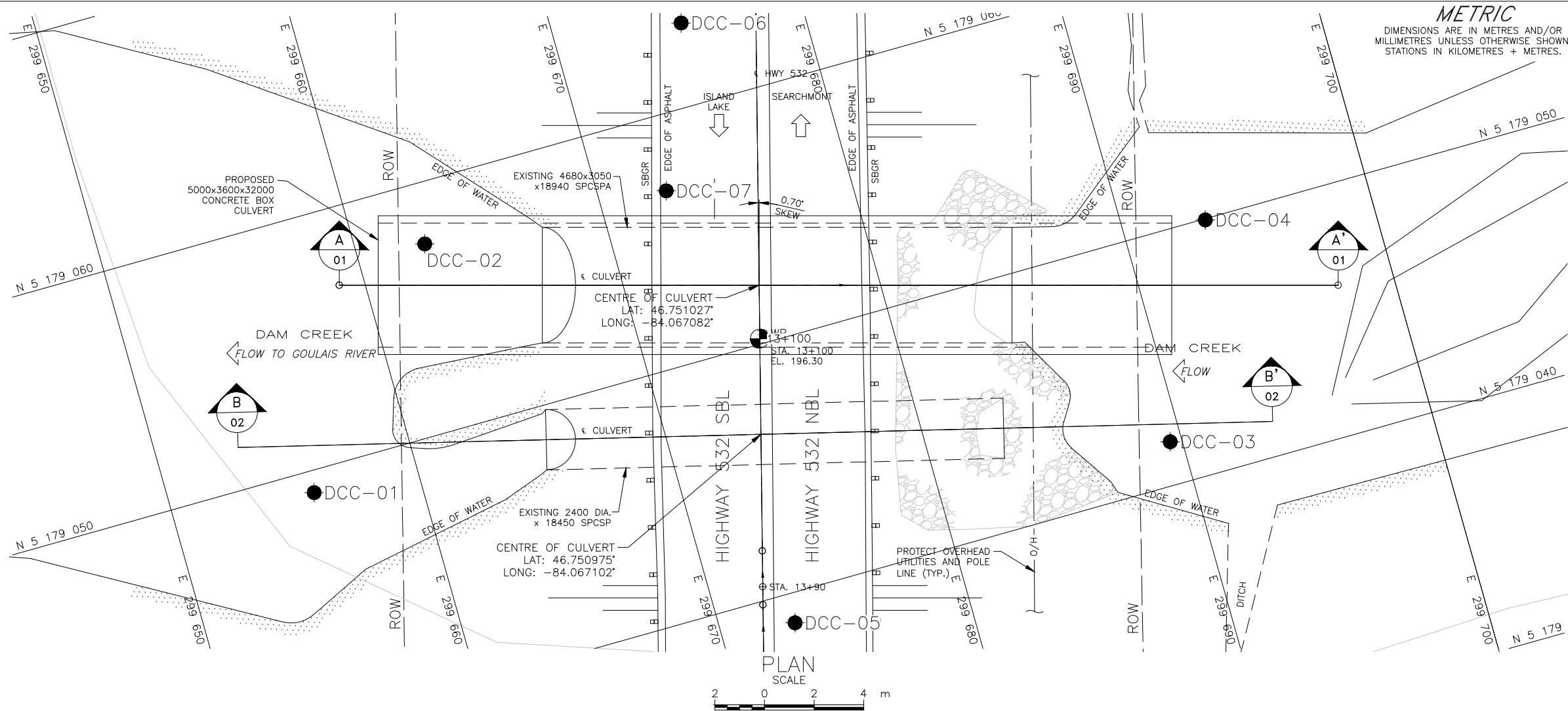
R.R.O 1990, Regulation 903 Wells, under Ontario Water Resources Act, R.S.O. 1990, c. O.40

Ontario Special Provisions (SP):

SP 517F01 Temporary Flow Passage System



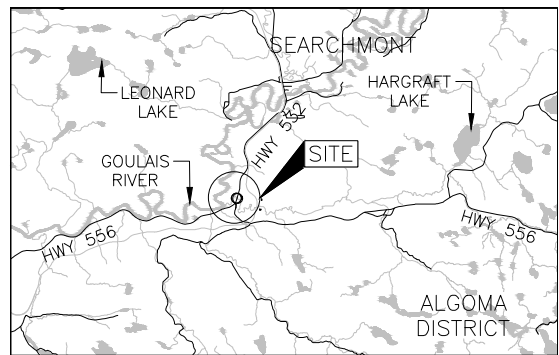
DRAWINGS



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

CONT No.
WP No.5261-13-01

HIGHWAY 532
DAM CREEK CULVERTS
BOREHOLE LOCATIONS AND
SOIL STRATA



LEGEND

- Borehole - Current Investigation
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)

BOREHOLE CO-ORDINATES (MTM NAD83 ZONE 13)

No.	ELEVATION	NORTHING	EASTING
DCC-01	191.5	5179049.1	299655.7
DCC-02	191.3	5179057.6	299662.8
DCC-03	191.9	5179041.7	299689.5
DCC-04	191.8	5179050.0	299693.3
DCC-05	196.3	5179038.8	299673.0
DCC-06	196.0	5179063.3	299675.1
DCC-07	196.1	5179057.0	299672.7



NOTES

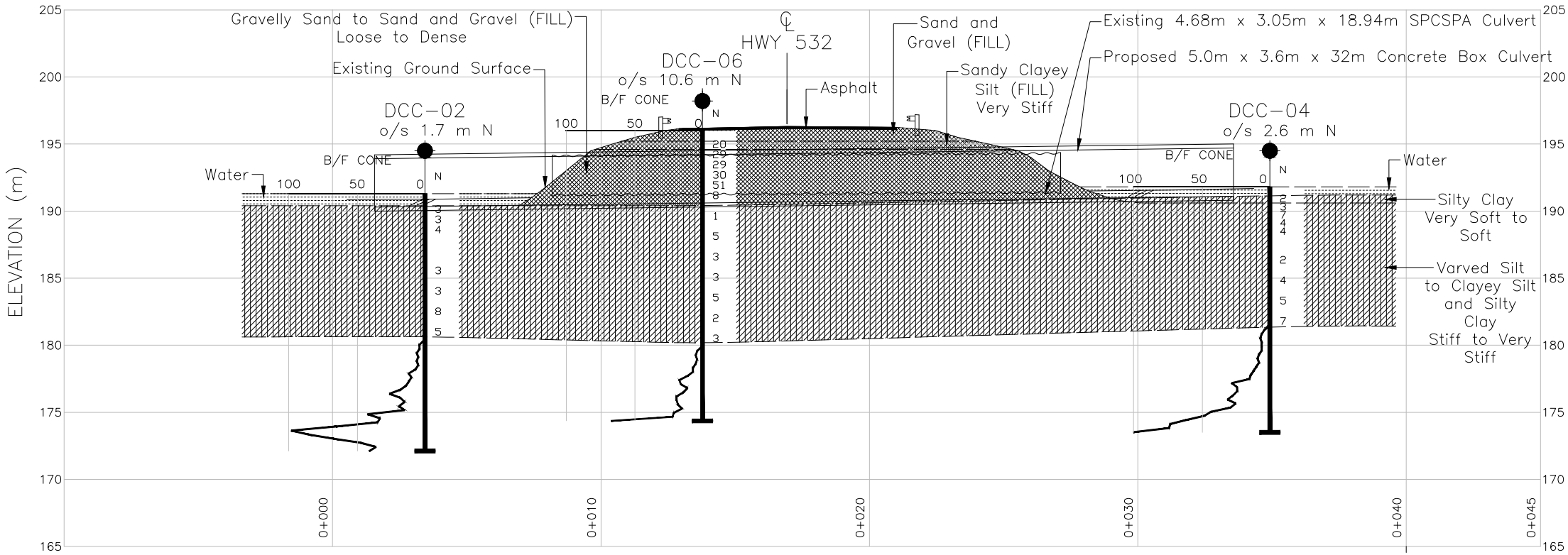
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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 client, drawing file nos. 60546679-P90 GEOTECH.dwg, dated March, 2018, received March 19, 2018.

NO.	DATE	BY	REVISION
Geocres No. 41K-107			
HWY. 532	PROJECT NO. 1670846		DIST. ALGOMA
SUBM'D. TZ	CHKD. TZ	DATE: 9/28/2018	SITE: 38S-040C
DRAWN: SMD	CHKD. JPD	APPD. JPD	DWG. 01



HORIZONTAL SCALE
2 0 2 4 m

A-A CULVERT PROFILE
01

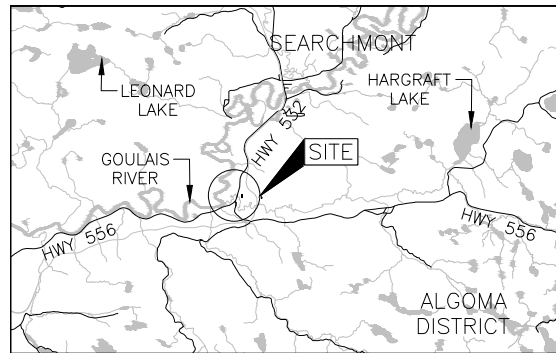
VERTICAL SCALE
4 0 4 8 m

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

CONT No.
WP No.5261-13-01

HIGHWAY 532
DAM CREEK CULVERTS
SOIL STRATA

SHEET



KEY PLAN
SCALE
2 0 2 4 km

LEGEND

- Borehole - Current Investigation
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)

BOREHOLE CO-ORDINATES (MTM NAD83 ZONE 13)

No.	ELEVATION	NORTHING	EASTING
DCC-01	191.5	5179049.1	299655.7
DCC-03	191.9	5179041.7	299689.5
DCC-05	196.3	5179038.8	299673.0



NOTES

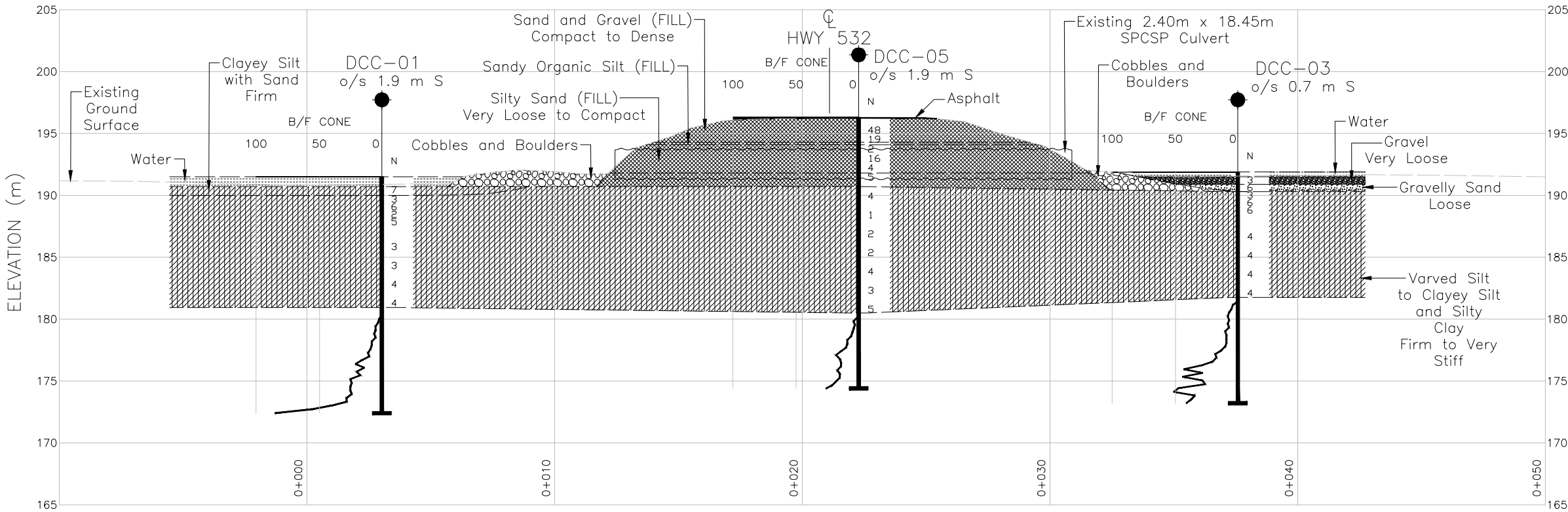
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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 client, drawing file nos. Dam Creek_Existing Culvert Section.dwg, dated March, 2018, received March 19, 2018.

NO.	DATE	BY	REVISION
Geocres No. 41K-107			
HWY. 532		PROJECT NO. 1670846	
SUBM'D. TZ		DATE: 9/28/2018	DIST. ALGOMA
DRAWN: SMD		CHKD. JPD	SITE: 38S-040C
		APPD. JPD	DWG. 02



HORIZONTAL SCALE
2 0 2 4 m

B-B CULVERT PROFILE
01

VERTICAL SCALE
4 0 4 8 m



TABLES



TABLE 1 – SUMMARY OF FOUNDATION ENGINEERING PARAMETERS

Foundation Investigation Area (Relevant Boreholes)	Stratigraphic Unit	Top Elevation (m)	Thickness (m)	γ (kN/m ³)	ϕ' (°)	c' (kPa)	s_u (kPa)	σ_p' (kPa)	e_o	C_c	C_r	m_v (kPa ⁻¹)	E' (MPa)	c_v (cm ² /s)
Dam Creek Culverts (DCC-01 to DCC-06)	New Granular Fill	~ 196.0	Up to about 3.5 at toe of existing embankment	21	37	0	--	--	--	--	--	--	--	--
	Gravelly Sand to Sand and Gravel (Fill)	196.3 – 191.8	0.8 – 4.2	22	28 – 32	0	--	--	--	--	--	--	--	--
	Sandy Clayey Silt (Fill)	~ 195.2	~ 0.6	19	32	0	125	--	--	--	--	--	--	--
	Sandy Organic Silt (Fill)	~ 194.3	~ 0.2	19	30	0	--	--	--	--	--	--	--	--
	Silty Sand (Fill)	~ 194.1	~ 2.3	19	28	0	--	--	--	--	--	--	--	--
	Gravelly Sand to Gravel	~ 191.5	~ 1.2	22	28	0	--	--	--	--	--	--	10	--
	Clayey Silt with Sand to Silty Clay to Varved Silt to Clayey Silt and Silty Clay	191.2 – 190.3	13.0 – 13.9 ¹	19	26	0	30 - 55 ²	180 - 335 ²	1.30 ²	0.60 ²	0.040 ²	--	--	1.25 x 10 ⁻²

Note:

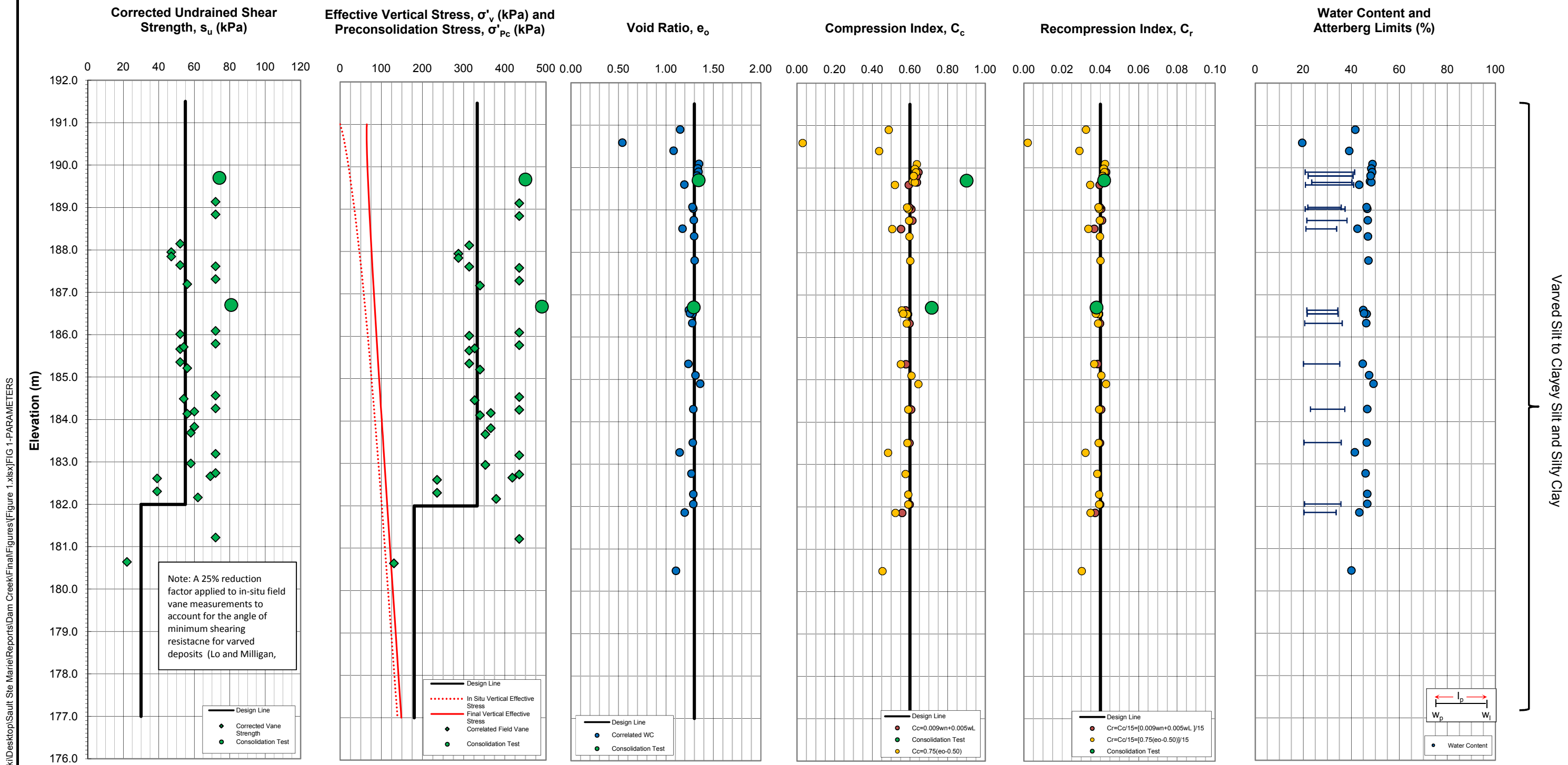
1. The overall thickness of the varved deposit was inferred from DCPTs as outlined in Section 6.5.2.2 of the report.
2. Complete plots of the parameters (i.e., undrained shear strength (s_u), preconsolidation stress (σ_p'), void ratio (e_o), compression index (C_c) and recompression index (C_r)) versus elevation for the varved deposit are presented on Figure 1



FIGURES

SUMMARY PLOT OF ENGINEERING PARAMETERS FOR VARVED
COHESIVE DEPOSIT
Highway 532 - Dam Creek Culverts

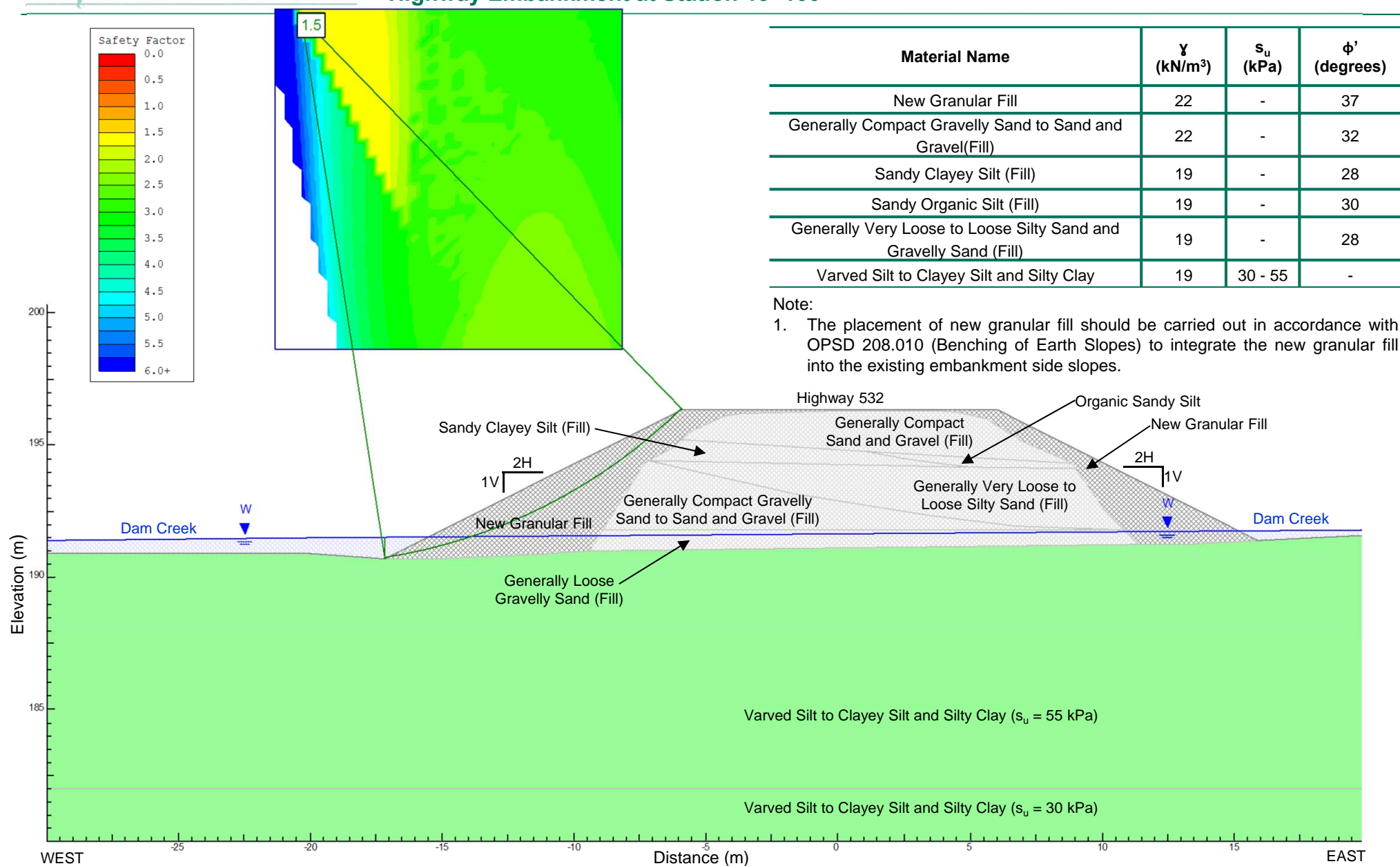
FIGURE 1





Highway 532 – Dam Creek Culverts Replacement Global Slope Stability (Temporary/Short-Term Condition) Highway Embankment at Station 13+100

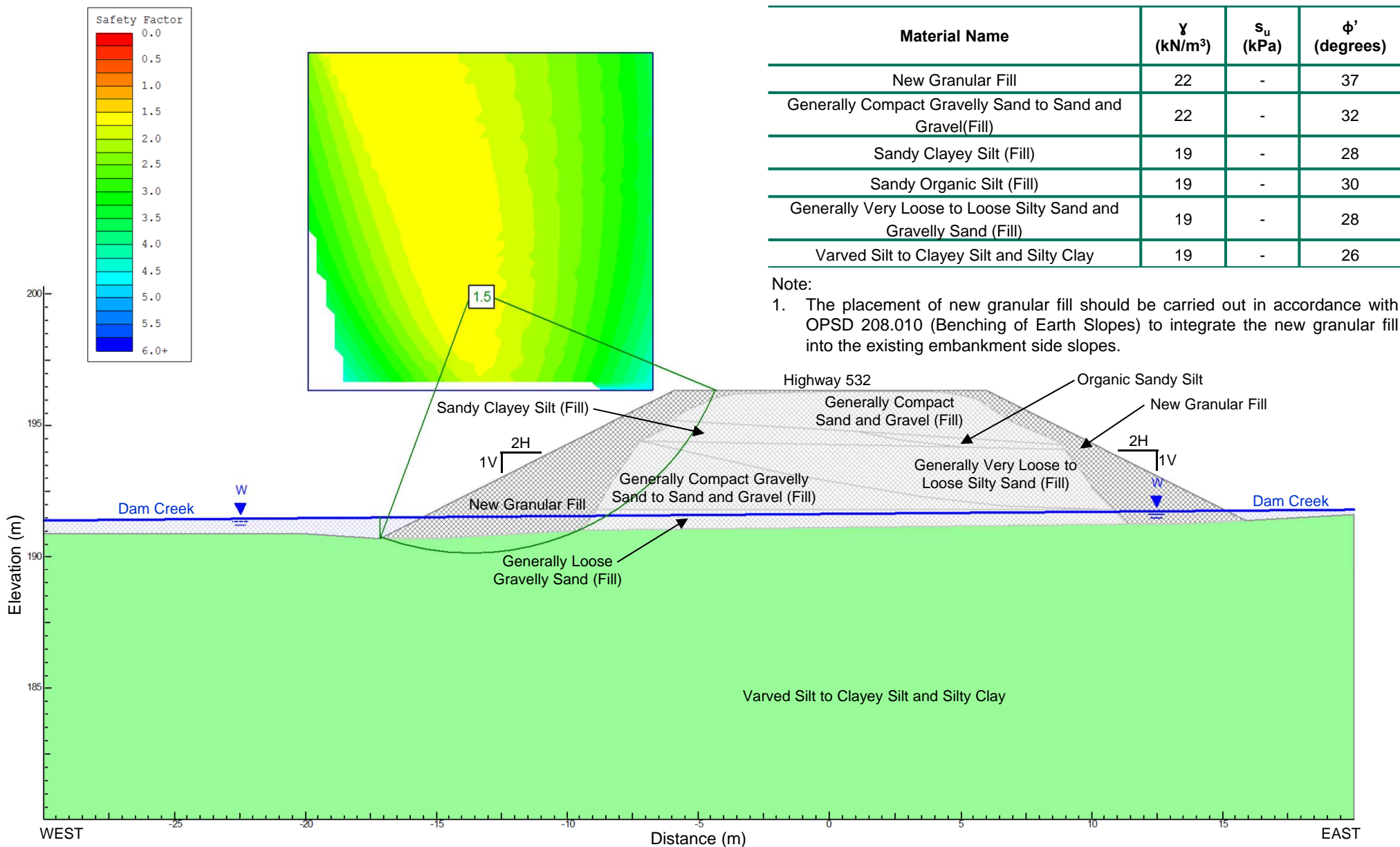
Figure 2





Highway 532 – Dam Creek Culverts Replacement Global Slope Stability (Permanent/Long-Term Condition) Highway Embankment at Station 13+100

Figure 3





APPENDIX A

Records of Borehole Sheets



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

Condition	N 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



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

PROJECT		1670846		RECORD OF BOREHOLE No DCC-01				SHEET 2 OF 2		METRIC			
G.W.P.		5261-13-01		LOCATION		N 5179049.1; E 299655.7 MTM NAD 83 ZONE 13 (LAT. 46.750998; LONG. -84.067337)				ORIGINATED BY		AJ	
DIST		ALGOMA HWY 556		BOREHOLE TYPE		Portable Equipment - Wash Boring; BW Casing				COMPILED BY		AK	
DATUM		Geodetic		DATE		August 23, 2017				CHECKED BY		TZ	
SOIL PROFILE		SAMPLES				GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80		
	--- CONTINUED FROM PREVIOUS PAGE ---												
	END OF BOREHOLE Dynamic Core Penetration Test (DCPT)						176						
							175						
							174						
							173						
172.4	END OF DCPT												
19.1	NOTE: 1. Borehole DCC-01 advanced in Dam Creek near the outlet (west side of Highway 532) of the existing southern culvert.												

GTA-MTO 001 S:\CLIENTS\MTOS\SAULT_STE_MARIE\02_DATA\GINT\SAULT_STE_MARIE.GPJ GAL-GTA.GDT 28/9/18

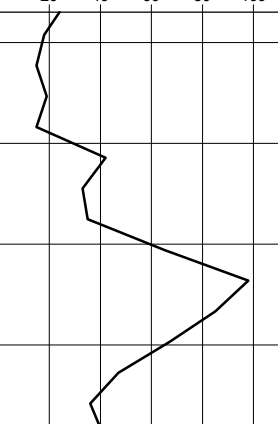
PROJECT 1670846		RECORD OF BOREHOLE No DCC-02		SHEET 1 OF 2		METRIC	
G.W.P. 5261-13-01		LOCATION N 5179057.6; E 299662.8 MTM NAD 83 ZONE 13 (LAT. 46.751074; LONG. -84.067245)		ORIGINATED BY AK			
DIST ALGOMA HWY 556		BOREHOLE TYPE Portable Equipment - Wash Boring; BW Casing		COMPILED BY AK			
DATUM Geodetic		DATE August 15 and 16, 2017		CHECKED BY TZ			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED						
191.3 0.0	WATER SURFACE WATER						20 40 60 80 100	20 40 60						
190.4 0.9	Varved SILT to CLAYEY SILT and SILTY CLAY, trace sand Stiff Grey Wet		1	SS	3									
			2	SS	3									
			3	SS	4									
				4	SS	3								
			5	SS	3									
			6	SS	8									
180.6 10.7	END OF BOREHOLE Dynamic Core Penetration Test (DCPT)		7	SS	5									

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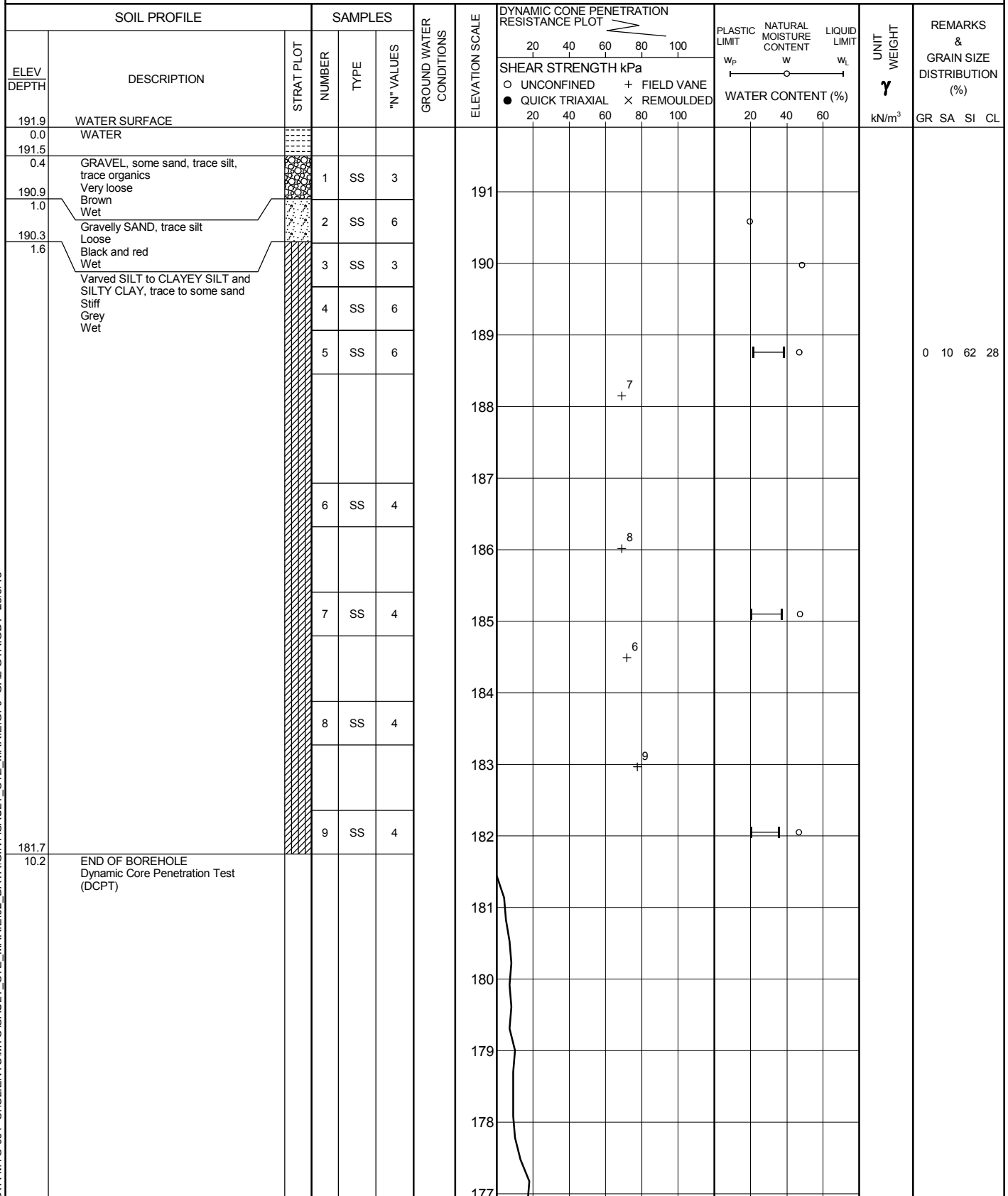
+ 3, X 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

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PROJECT		1670846		RECORD OF BOREHOLE				No DCC-02		SHEET 2 OF 2		METRIC	
G.W.P.		5261-13-01		LOCATION		N 5179057.6; E 299662.8 MTM NAD 83 ZONE 13 (LAT. 46.751074; LONG. -84.067245)				ORIGINATED BY		AK	
DIST		ALGOMA HWY 556		BOREHOLE TYPE		Portable Equipment - Wash Boring; BW Casing				COMPILED BY		AK	
DATUM		Geodetic		DATE		August 15 and 16, 2017				CHECKED BY		TZ	
SOIL PROFILE		SAMPLES				GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80		
	--- CONTINUED FROM PREVIOUS PAGE ---							SHEAR STRENGTH kPa		WATER CONTENT (%)			
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					
								20 40 60 80 100		20 40 60			
172.1	END OF BOREHOLE Dynamic Core Penetration Test (DCPT)						176						
19.2	END OF DCPT NOTES: 1. Borehole DCC-02 advanced in Dam Creek near the outlet (west side of Highway 532) of the existing northern culvert. 2. Samples 1 to 3 were collected with a split-spoon sampler driven by a 50 lbs manual hammer. SPT N- values shown here have been adjusted to reflect values that would be obtained with a standard weight hammer.												

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PROJECT 1670846		RECORD OF BOREHOLE No DCC-03		SHEET 1 OF 2		METRIC	
G.W.P. 5261-13-01		LOCATION N 5179041.7; E 299689.5 MTM NAD 83 ZONE 13 (LAT. 46.750931; LONG. -84.066895)		ORIGINATED BY AJ			
DIST ALGOMA HWY 556		BOREHOLE TYPE Portable Equipment - Wash Boring; BW Casing		COMPILED BY AK			
DATUM Geodetic		DATE August 25, 2017		CHECKED BY TZ			



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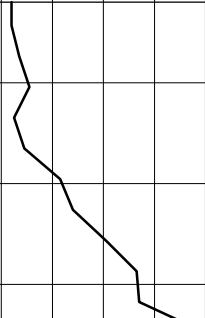
PROJECT		RECORD OF BOREHOLE				No DCC-03		SHEET 2 OF 2		METRIC						
1670846		G.W.P. 5261-13-01		LOCATION N 5179041.7; E 299689.5 MTM NAD 83 ZONE 13 (LAT. 46.750931; LONG. -84.066895)		ORIGINATED BY		AJ								
DIST ALGOMA HWY 556		BOREHOLE TYPE		Portable Equipment - Wash Boring; BW Casing		COMPILED BY		AK								
DATUM Geodetic		DATE		August 25, 2017		CHECKED BY		TZ								
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	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
	--- CONTINUED FROM PREVIOUS PAGE ---						20	40	60	80	100					
	END OF BOREHOLE Dynamic Core Penetration Test (DCPT)						20	40	60	80	100					
173.2							176									
							175									
							174									
18.7	END OF DCPT NOTE: 1. Borehole DCC-03 advanced in Dam Creek near inlet (east side of Highway 532) of the existing southern culvert.															

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PROJECT <u>1670846</u>		RECORD OF BOREHOLE No DCC-04				SHEET 2 OF 2		METRIC	
G.W.P. <u>5261-13-01</u>		LOCATION <u>N 5179050.0; E 299693.3 MTM NAD 83 ZONE 13 (LAT. 46.751006; LONG. -84.066846)</u>				ORIGINATED BY <u>AJ</u>			
DIST <u>ALGOMA</u> HWY <u>556</u>		BOREHOLE TYPE <u>Portable Equipment - Wash Boring; BW Casing</u>				COMPILED BY <u>AK</u>			
DATUM <u>Geodetic</u>		DATE <u>August 26, 2017</u>				CHECKED BY <u>TZ</u>			

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			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		W _p	W		
	--- CONTINUED FROM PREVIOUS PAGE ---						<div style="display: flex; justify-content: space-between; border-bottom: 1px solid black; margin-bottom: 5px;"> 20 40 60 80 100 </div> <div style="display: flex; justify-content: space-between; border-bottom: 1px solid black; margin-bottom: 5px;"> 20 40 60 80 100 </div> <div style="display: flex; justify-content: space-between; font-size: 0.8em;"> ○ UNCONFINED + FIELD VANE </div> <div style="display: flex; justify-content: space-between; font-size: 0.8em;"> ● QUICK TRIAXIAL × REMOULDED </div>						
173.5	END OF BOREHOLE Dynamic Core Penetration Test (DCPT)					176							
175						175							
174						174							
18.3	END OF DCPT NOTE: 1. Borehole DCC-04 advanced on Dam Creek near the inlet (east side of Highway 532) of the existing northern culvert.												

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PROJECT 1670846		RECORD OF BOREHOLE No DCC-05		SHEET 1 OF 2		METRIC	
G.W.P. 5261-13-01		LOCATION N 5179038.8; E 299673.0 MTM NAD 83 ZONE 13 (LAT. 46.750905; LONG. -84.067112)		ORIGINATED BY AJ			
DIST ALGOMA HWY 556		BOREHOLE TYPE 152mm O.D. Solid Stem Augers; Wash Boring; NW Casing		COMPILED BY AK			
DATUM Geodetic		DATE September 6, 2017		CHECKED BY TZ			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								20	40	60	80	100	W _p	W	W _L					
196.3	GROUND SURFACE																			
0.0	ASPHALT (about 40 mm thick) Sand and gravel, some silt, trace clay (FILL) Compact to dense Brown Moist		1	SS	48															
194.3			2A	SS	19															
2.2	Sandy organic silt, trace to some wood pieces (FILL) Brown Moist		2B																	
	Silty sand, some gravel, trace clay (FILL) Very loose to compact Brown Moist - Clayey silt seams encountered below a depth of about 3.0 m		3	SS	2															
			4	SS	16															
			5	SS	4															
191.8			6	SS	5															
4.5	Gravelly sand, trace to some silt, trace clay (FILL) Loose Grey Moist																			
190.7	Varved SILT to CLAYEY SILT and SILTY CLAY, trace sand Stiff to very stiff Grey Wet		7	SS	4															
5.6																				
			8	SS	1															
			9	SS	2															
			10	SS	2															
			11	SS	4															
			12	SS	3															

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

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PROJECT		1670846		RECORD OF BOREHOLE No DCC-05				SHEET 2 OF 2		METRIC								
G.W.P.		5261-13-01		LOCATION		N 5179038.8; E 299673.0 MTM NAD 83 ZONE 13 (LAT. 46.750905; LONG. -84.067112)				ORIGINATED BY		AJ						
DIST		ALGOMA HWY 556		BOREHOLE TYPE		152mm O.D. Solid Stem Augers; Wash Boring; NW Casing				COMPILED BY		AK						
DATUM		Geodetic		DATE		September 6, 2017				CHECKED BY		TZ						
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	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100						
180.5	END OF BOREHOLE Dynamic Core Penetration Test (DCPT)		13	SS	5		181											
15.8								180										
								179										
								178										
								177										
							176											
							175											
174.4	END OF DCPT																	
21.9	NOTES: 1. Borehole DCC-05 was advanced on the northbound lane of Highway 532 to the south of the existing culverts. 2. Drilling water introduced into borehole at a depth of about 4.6 m below ground surface as part of wash boring method to advance the borehole. Consequently, the water level was not recorded in the open borehole upon completion of drilling.																	

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PROJECT		1670846		RECORD OF BOREHOLE		No DCC-06		SHEET 1 OF 2		METRIC			
G.W.P.		5261-13-01		LOCATION		N 5179063.3; E 299675.1 MTM NAD 83 ZONE 13 (LAT. 46.751126; LONG. -84.067084)		ORIGINATED BY		AJ			
DIST		ALGOMA HWY 556		BOREHOLE TYPE		152mm O.D. Solid Stem Augers; Wash Boring; NW Casing		COMPILED BY		AK			
DATUM		Geodetic		DATE		September 6 and 7, 2017		CHECKED BY		TZ			
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			20 40 60 80 100	20 40 60 80 100	W _p W W _L	WATER CONTENT (%)		
196.0	GROUND SURFACE												
0.8	ASPHALT (40 mm thick) Sand and gravel, trace silt (FILL) Brown Moist												
195.2													
0.8	Sandy clayey silt, trace gravel (FILL) Very stiff Brown Moist		1	SS	20								4 29 55 12
194.6													
1.4	Gravelly sand, some silt, trace clay to sand and gravel, some silt, trace clay (FILL) Loose to dense Brown Moist - Auger grinding noted between depths of about 2.7 m and 4.6 m due to inferred cobbles		2	SS	29								
			3	SS	29								
			4	SS	30								28 58 13 1
			5	SS	51								
			6	SS	8								
190.4	- Wood fragments and organics encountered at a depth of about 4.9 m - Difficulty with auger advancement at a depth of about 5.2 m due to gravel and inferred cobbles; switch to wash boring with casing Varved SILT to CLAYEY SILT and SILTY CLAY, trace sand Stiff to very stiff Grey Wet												
5.6			7	SS	1								0 3 59 38
			8	SS	5								
			9	SS	3								
			10	SS	3								
			11	SS	5								
			12	SS	2								

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

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PROJECT		1670846		RECORD OF BOREHOLE No DCC-06				SHEET 2 OF 2		METRIC			
G.W.P.		5261-13-01		LOCATION		N 5179063.3; E 299675.1 MTM NAD 83 ZONE 13 (LAT. 46.751126; LONG. -84.067084)		ORIGINATED BY		AJ			
DIST		ALGOMA HWY 556		BOREHOLE TYPE		152mm O.D. Solid Stem Augers; Wash Boring; NW Casing		COMPILED BY		AK			
DATUM		Geodetic		DATE		September 6 and 7, 2017		CHECKED BY		TZ			
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _p W W _L	WATER CONTENT (%)		
180.2	END OF BOREHOLE		13	SS	3								
15.9	Dynamic Core Penetration Test (DCPT)												
174.4	END OF DCPT												
21.6	NOTES:												
	1. Borehole DCC-06 was advanced on the southbound lane of Highway 532 to north of the existing culverts.												
	2. Drilling water introduced into borehole at a depth of about 5.2 m below ground surface as part of wash boring method to advance the borehole. Consequently, the water level was not recorded in the open borehole upon completion of drilling.												



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



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

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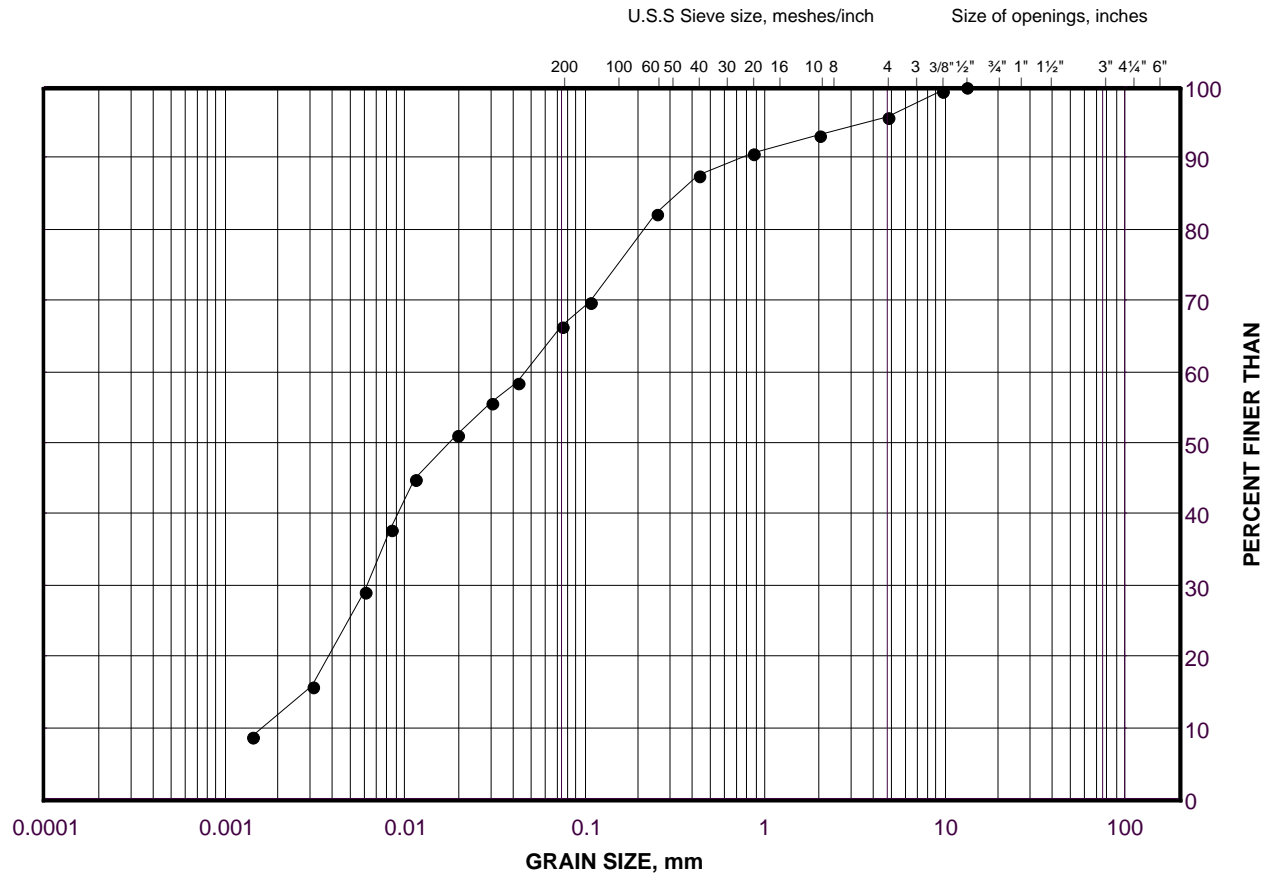
APPENDIX B

Geotechnical Laboratory Test Results

GRAIN SIZE DISTRIBUTION

Sandy Clayey Silt (Fill)

FIGURE B1



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

LEGEND

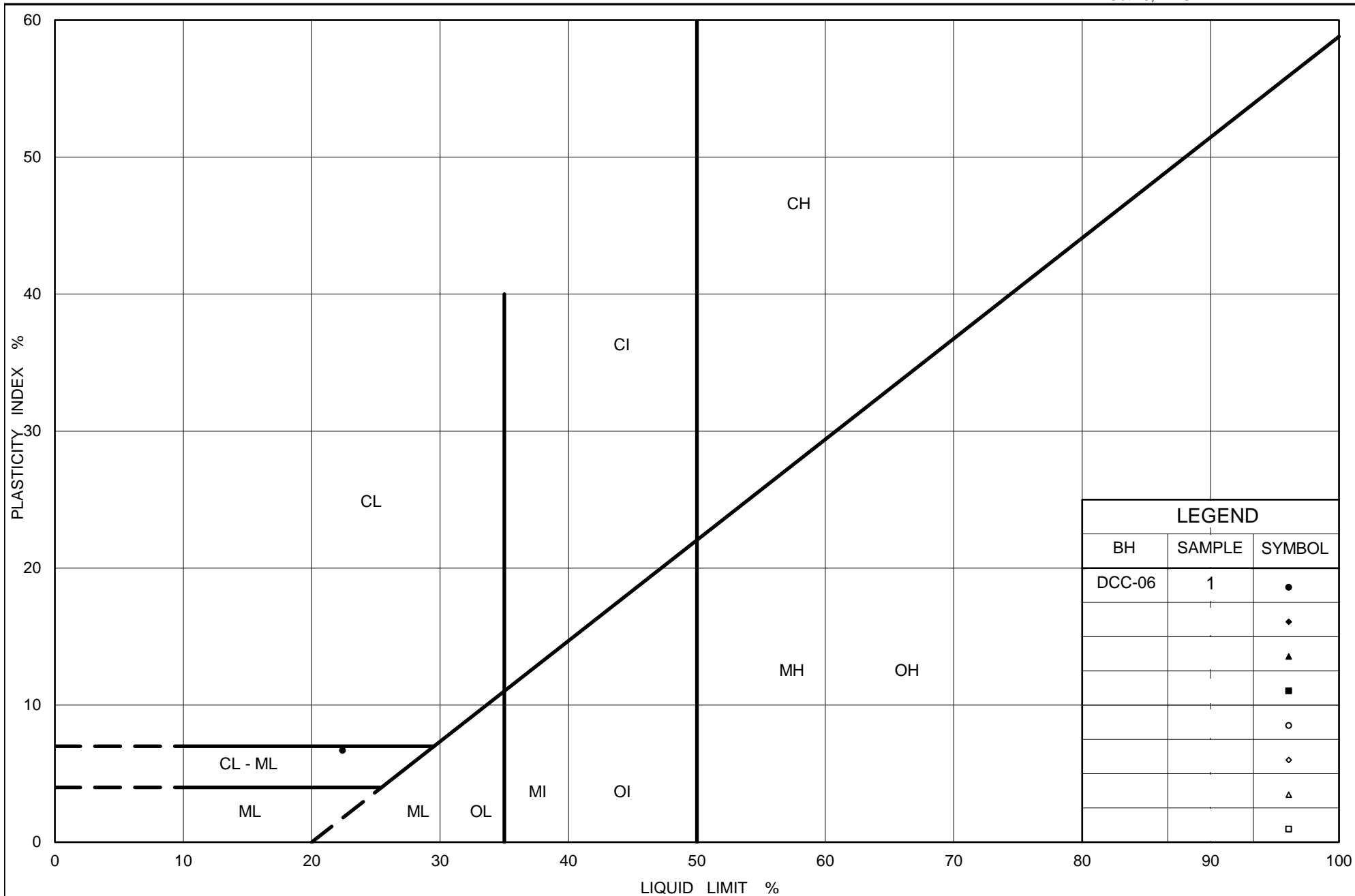
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	DCC-06	1	194.9

Project Number: 1670846

Checked By: TZ

Golder Associates

Date: 27-Mar-18



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Ontario

PLASTICITY CHART

Sandy Clayey Silt (Fill)

Figure No. B2

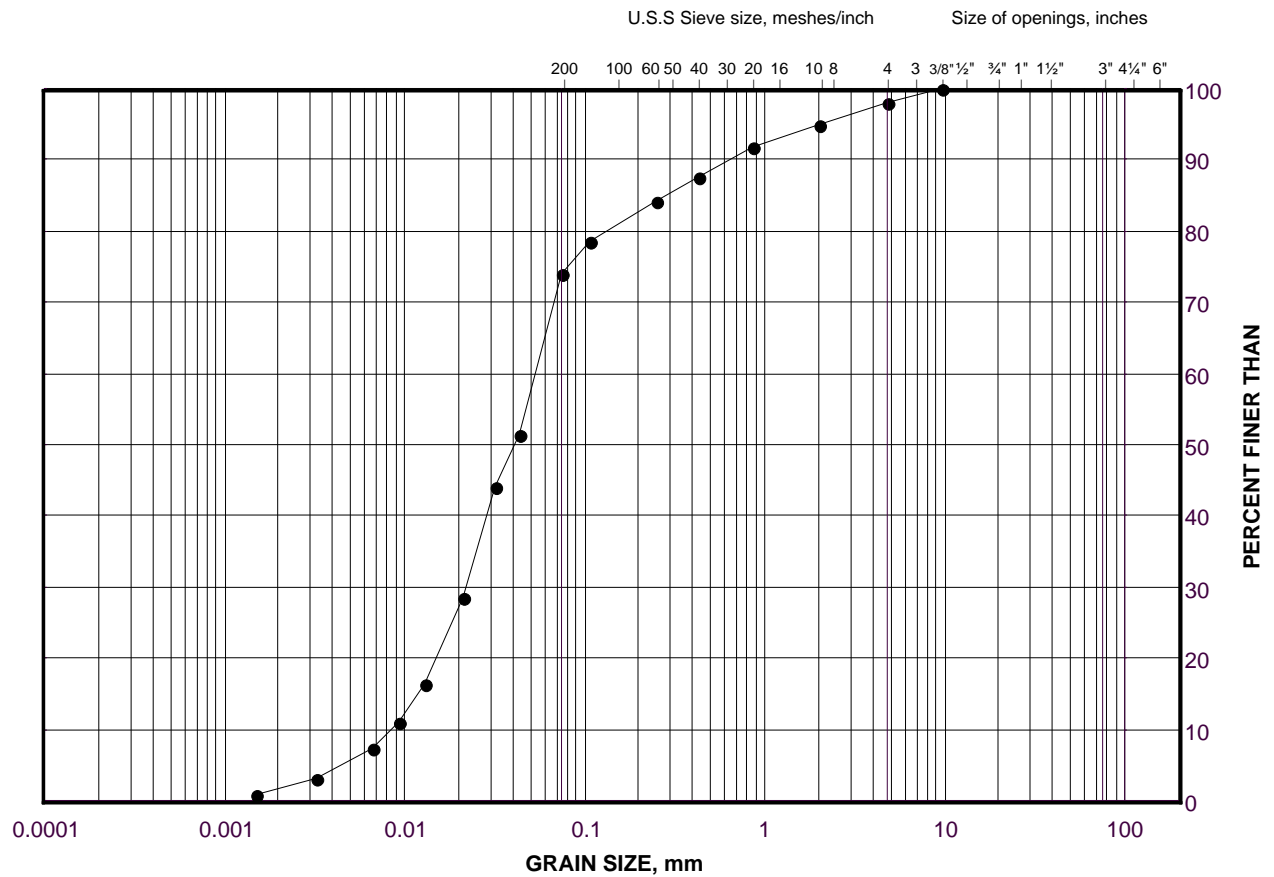
Project No. 1670846

Checked By: TZ

GRAIN SIZE DISTRIBUTION

Sandy Organic Silt (Fill)

FIGURE B3



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

LEGEND

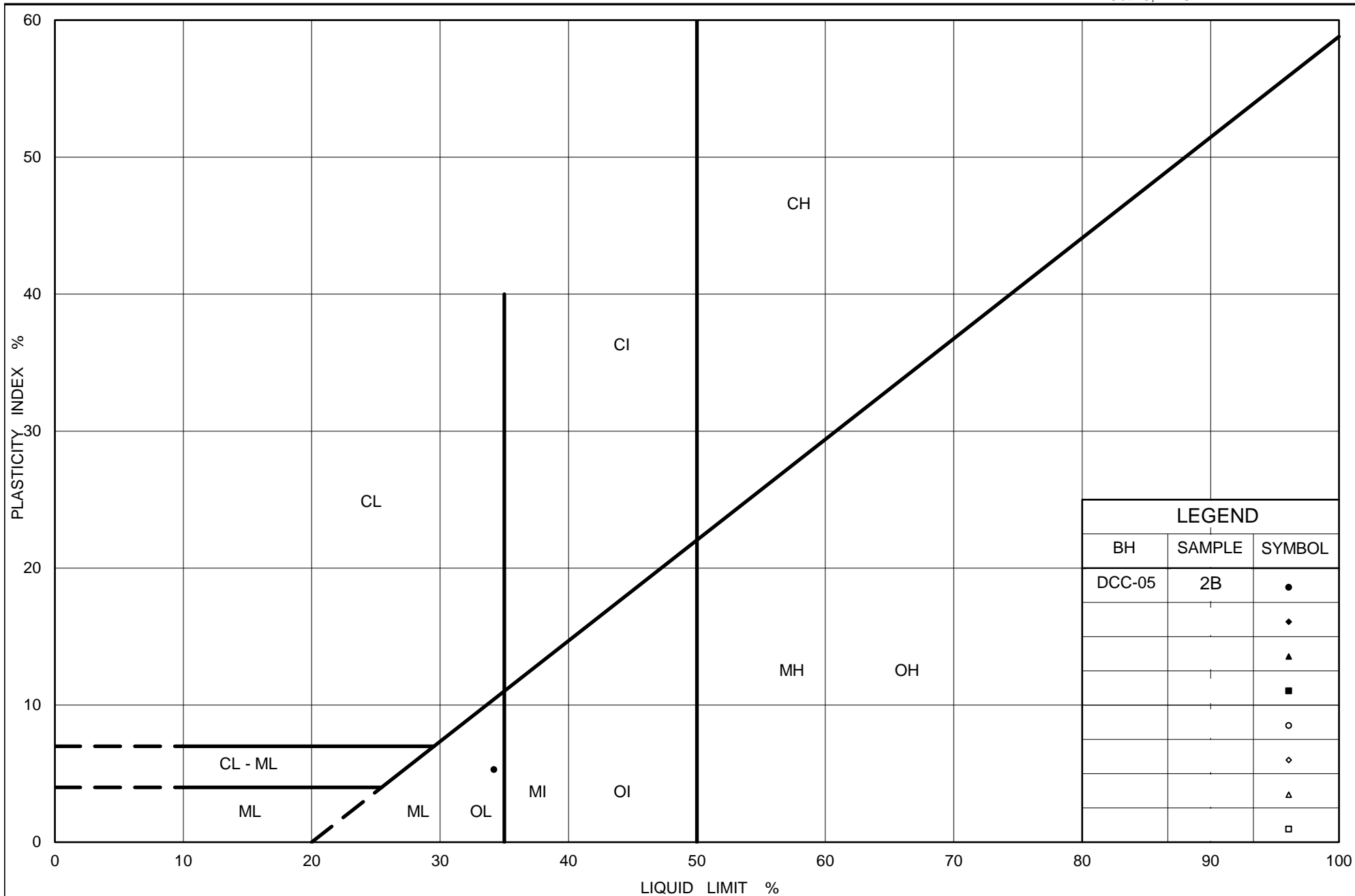
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	DCC-05	2B	194.2

Project Number: 1670846

Checked By: TZ

Golder Associates

Date: 27-Mar-18



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PLASTICITY CHART Organic Silt (Fines Portion) (Fill)

Figure No. B4

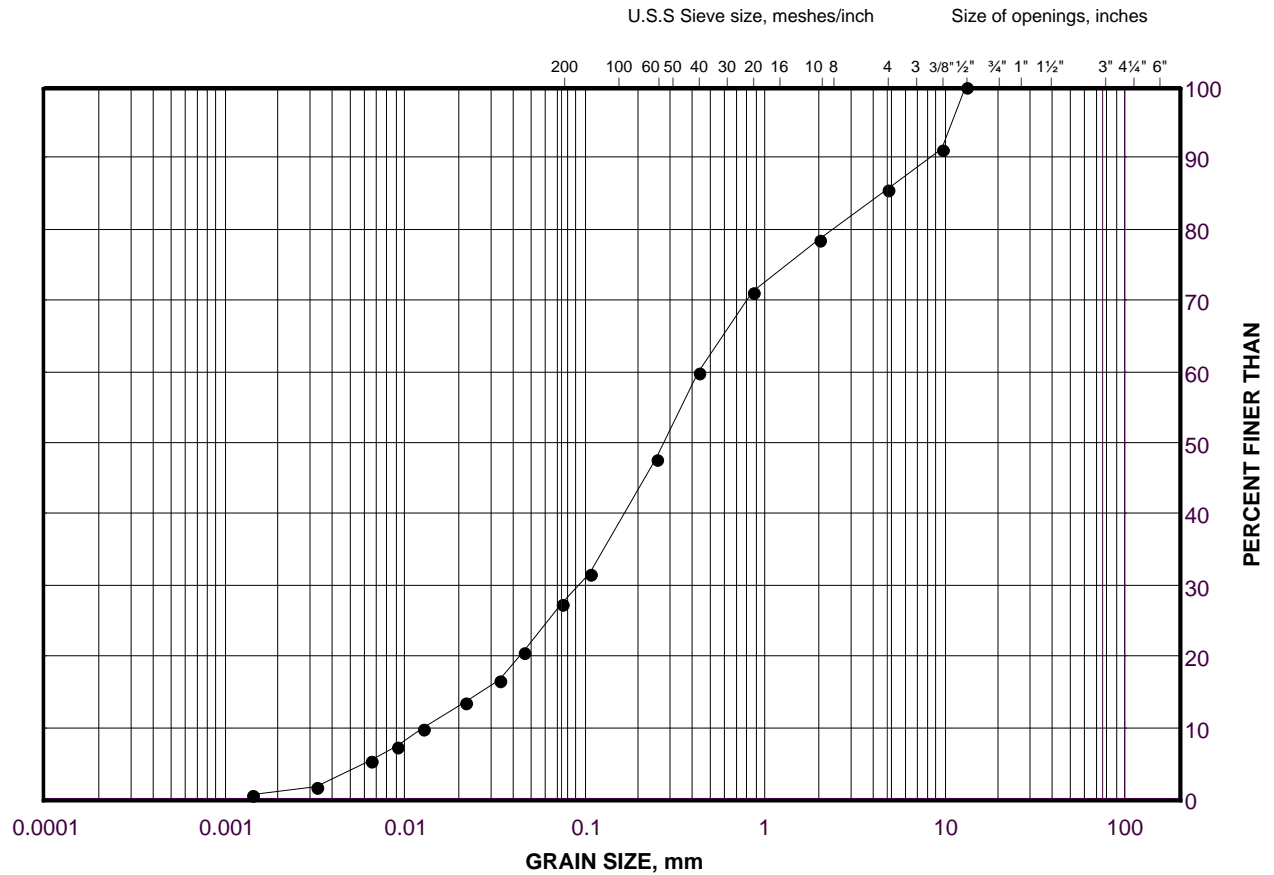
Project No. 1670846

Checked By: TZ

GRAIN SIZE DISTRIBUTION

Silty Sand (Fill)

FIGURE B5



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	DCC-05	4	192.9

Project Number: 1670846

Checked By: TZ

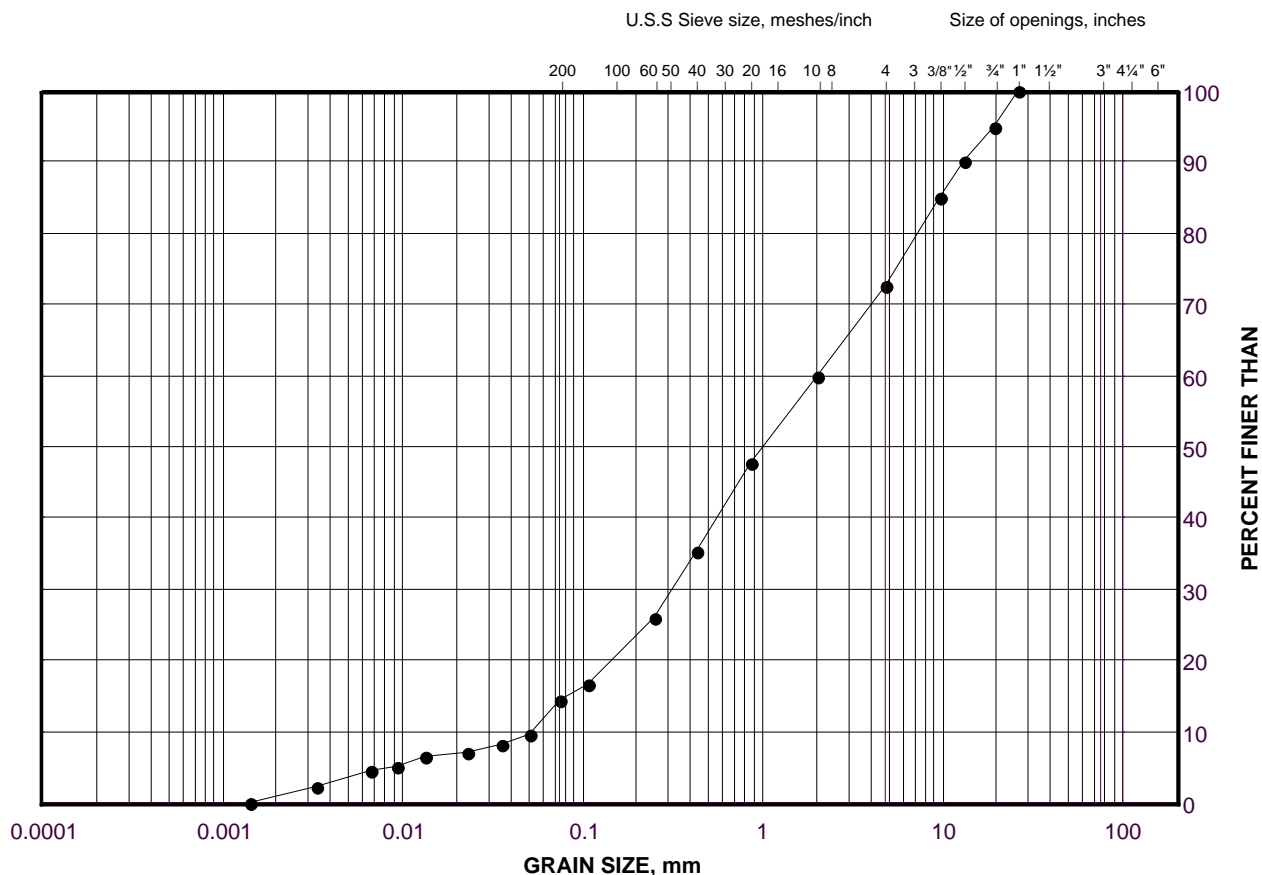
Golder Associates

Date: 27-Mar-18

GRAIN SIZE DISTRIBUTION

Gravelly Sand (Fill)

FIGURE B6



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	DCC-06	4	192.7

Project Number: 1670846

Checked By: TZ

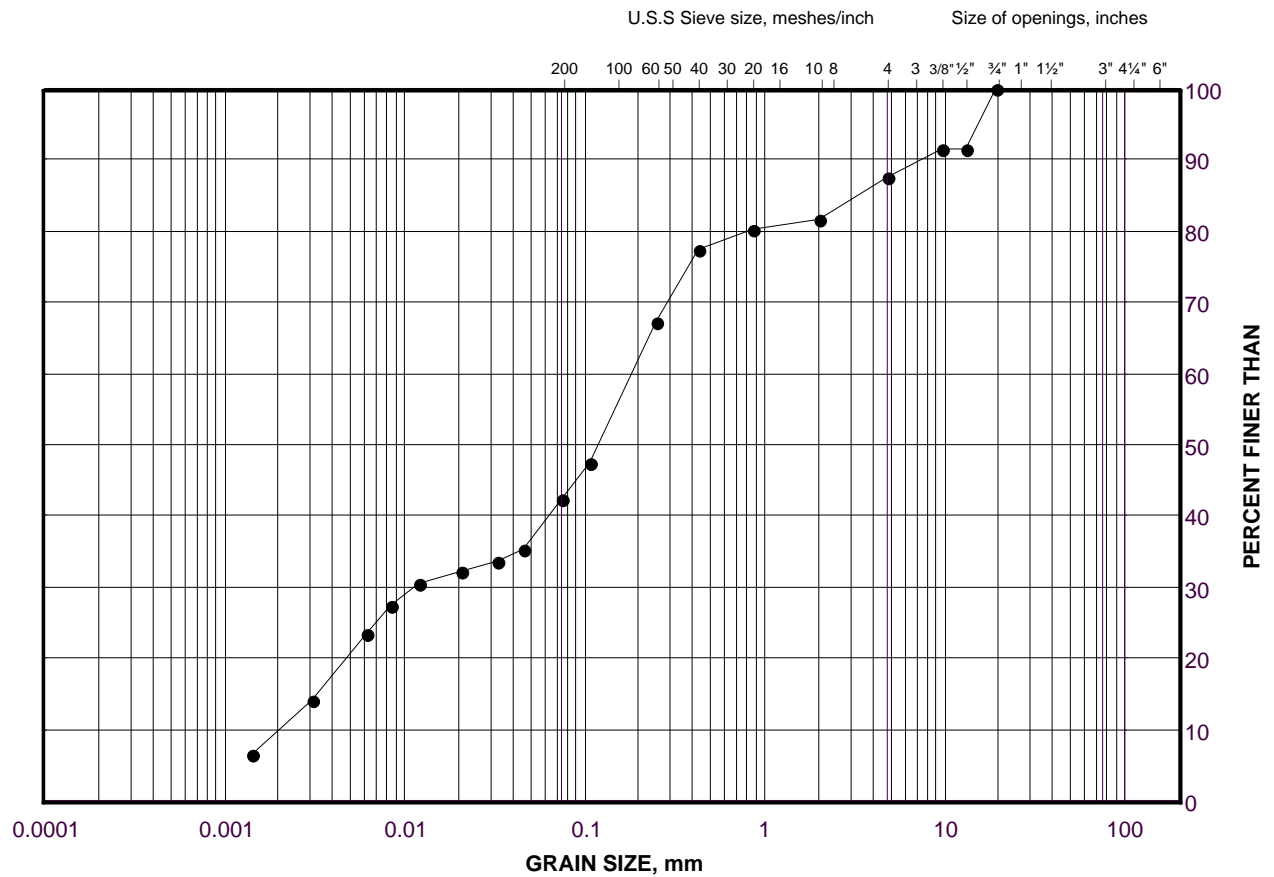
Golder Associates

Date: 27-Mar-18

GRAIN SIZE DISTRIBUTION

Clayey Silt with Sand

FIGURE B7



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	DCC-01	1	190.4

Project Number: 1670846

Checked By: TZ

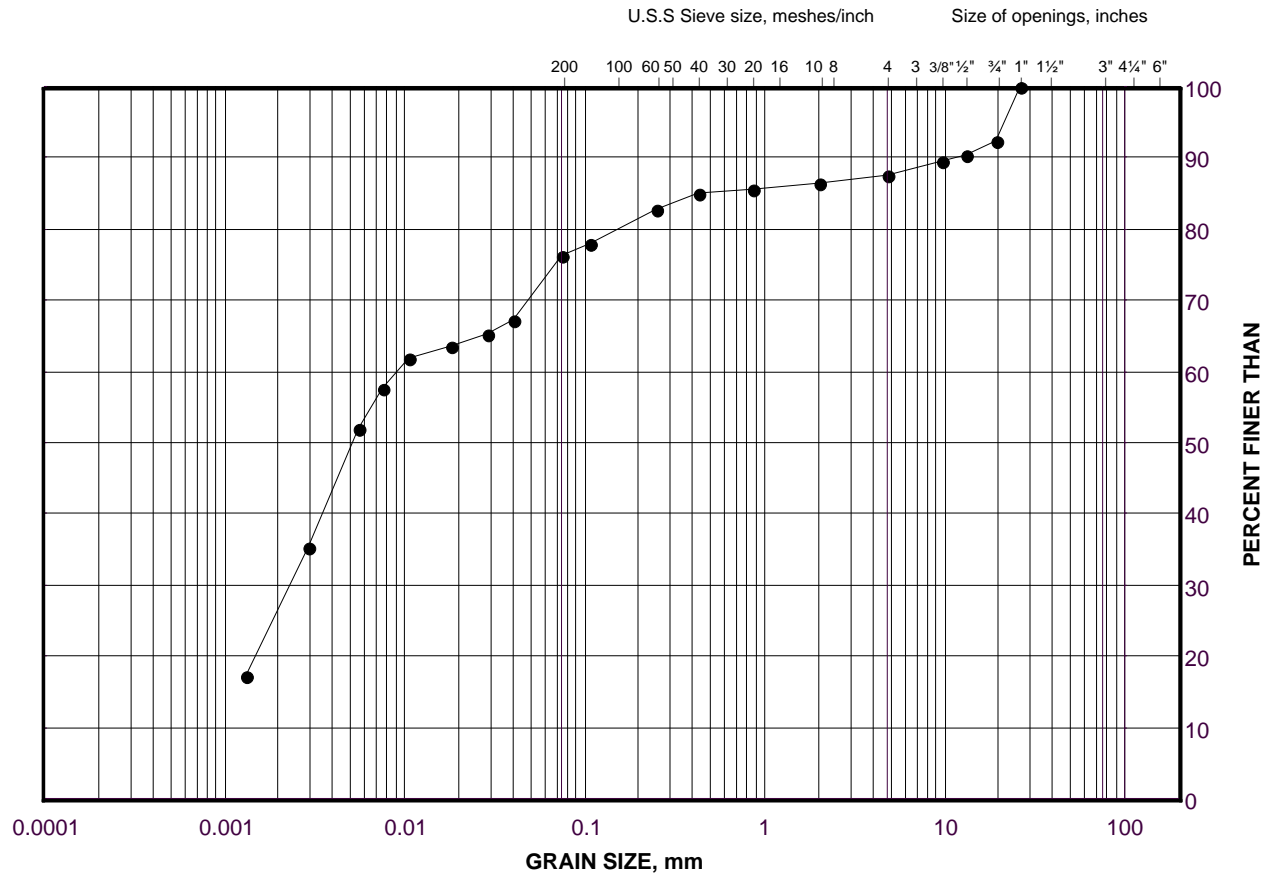
Golder Associates

Date: 27-Mar-18

GRAIN SIZE DISTRIBUTION

Silty Clay

FIGURE B8



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

LEGEND

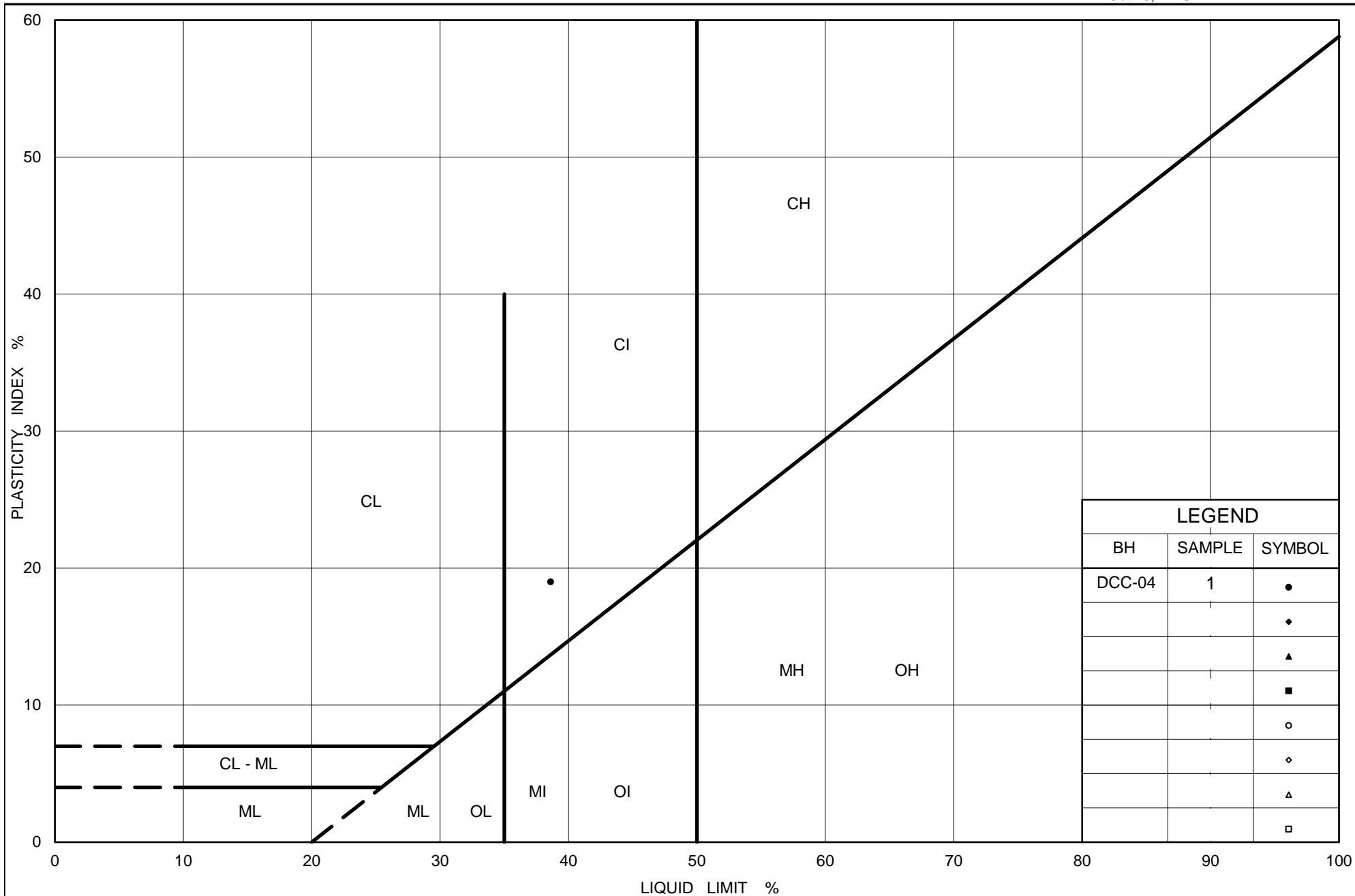
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	DCC-04	1	190.9

Project Number: 1670846

Checked By: _____

Golder Associates

Date: 13-Apr-18



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PLASTICITY CHART Silty Clay

Figure No. B9

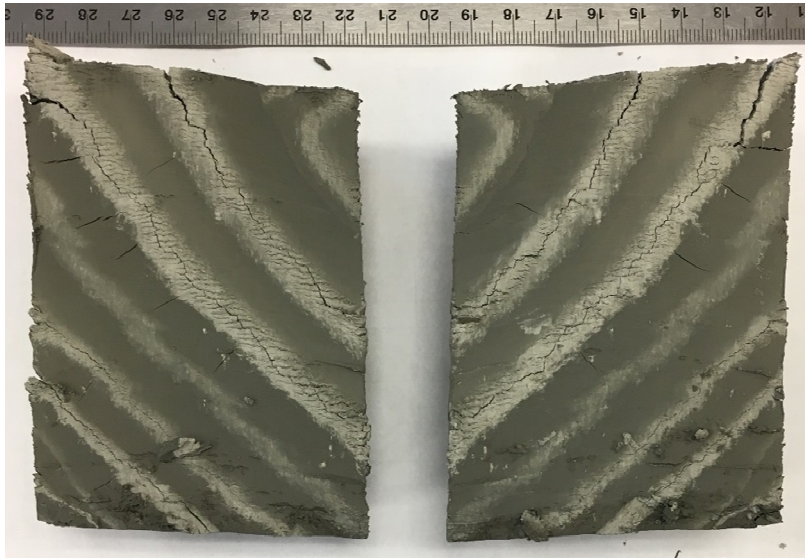
Project No. 1670846

Checked By: TZ

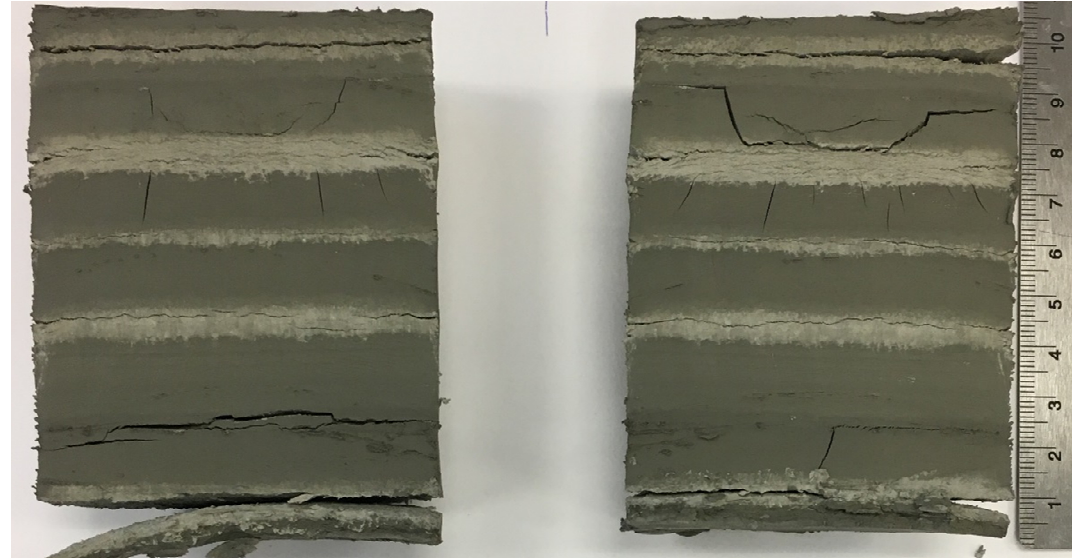


Varved Clayey Silt and Silty Clay

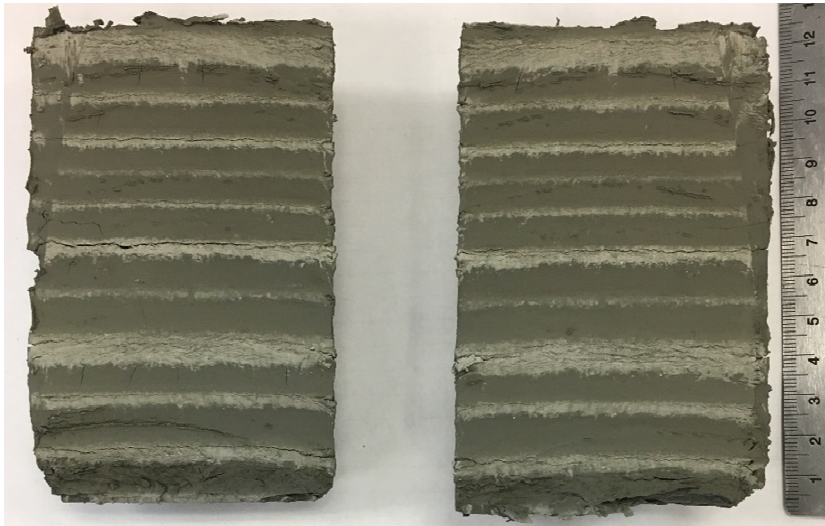
Figure B10



Photograph 1: Soil sample from Borehole DCC-07 Sample 1



Photograph 3: Soil sample from Borehole DCC-07 Sample 3



Photograph 2: Soil sample from Borehole DCC-07 Sample 2

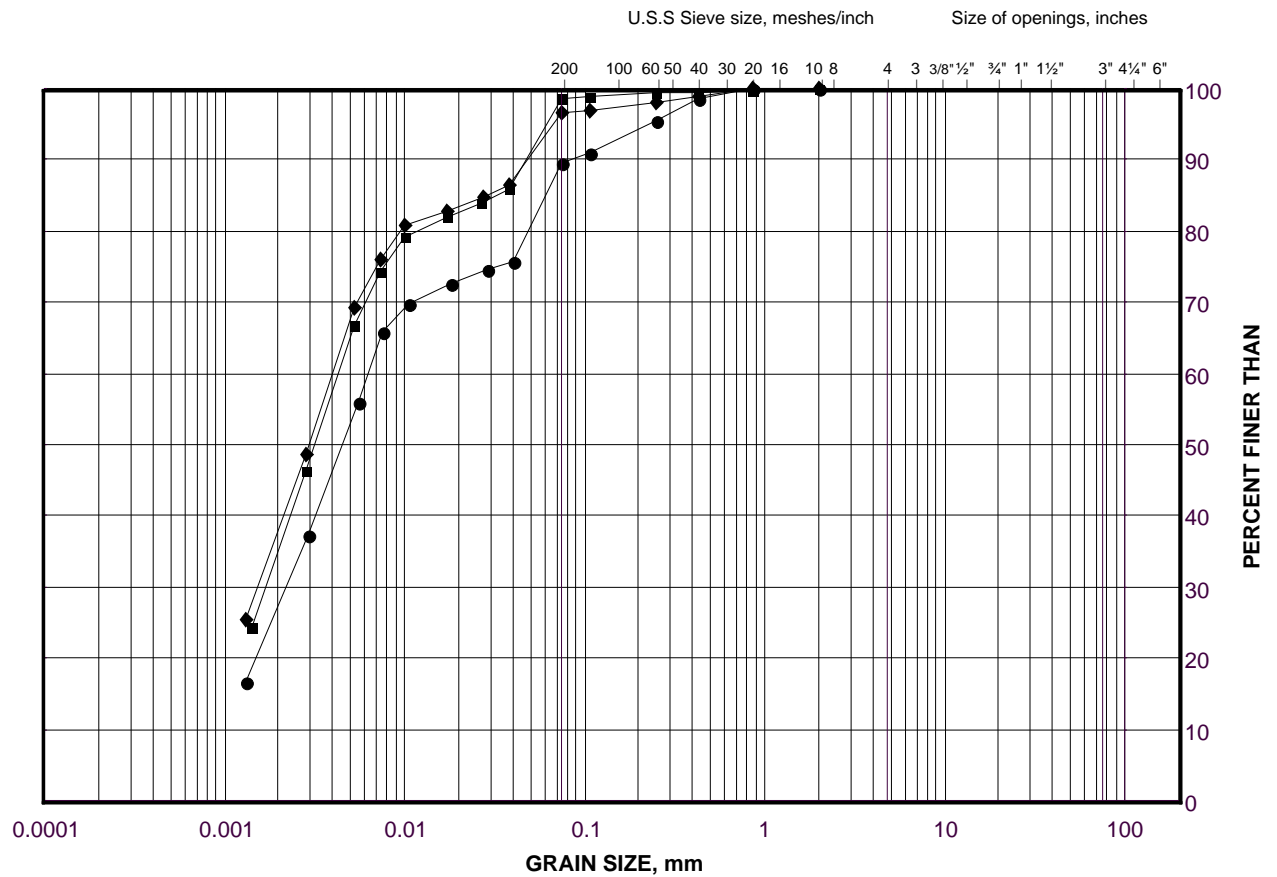
Notes:

1. The dark laminae represent silty clay of intermediate plasticity, while the lighter laminae represent clayey silt of low plasticity and/or silt.
2. The soil samples were extracted from Shelby tubes and partially dried to illustrate the distinctions between the various laminae.
3. The laminae seen in Sample 1 are oriented approximately 50 degrees from the horizontal axis.

GRAIN SIZE DISTRIBUTION

Silty Clay Laminæ

FIGURE B11



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

LEGEND

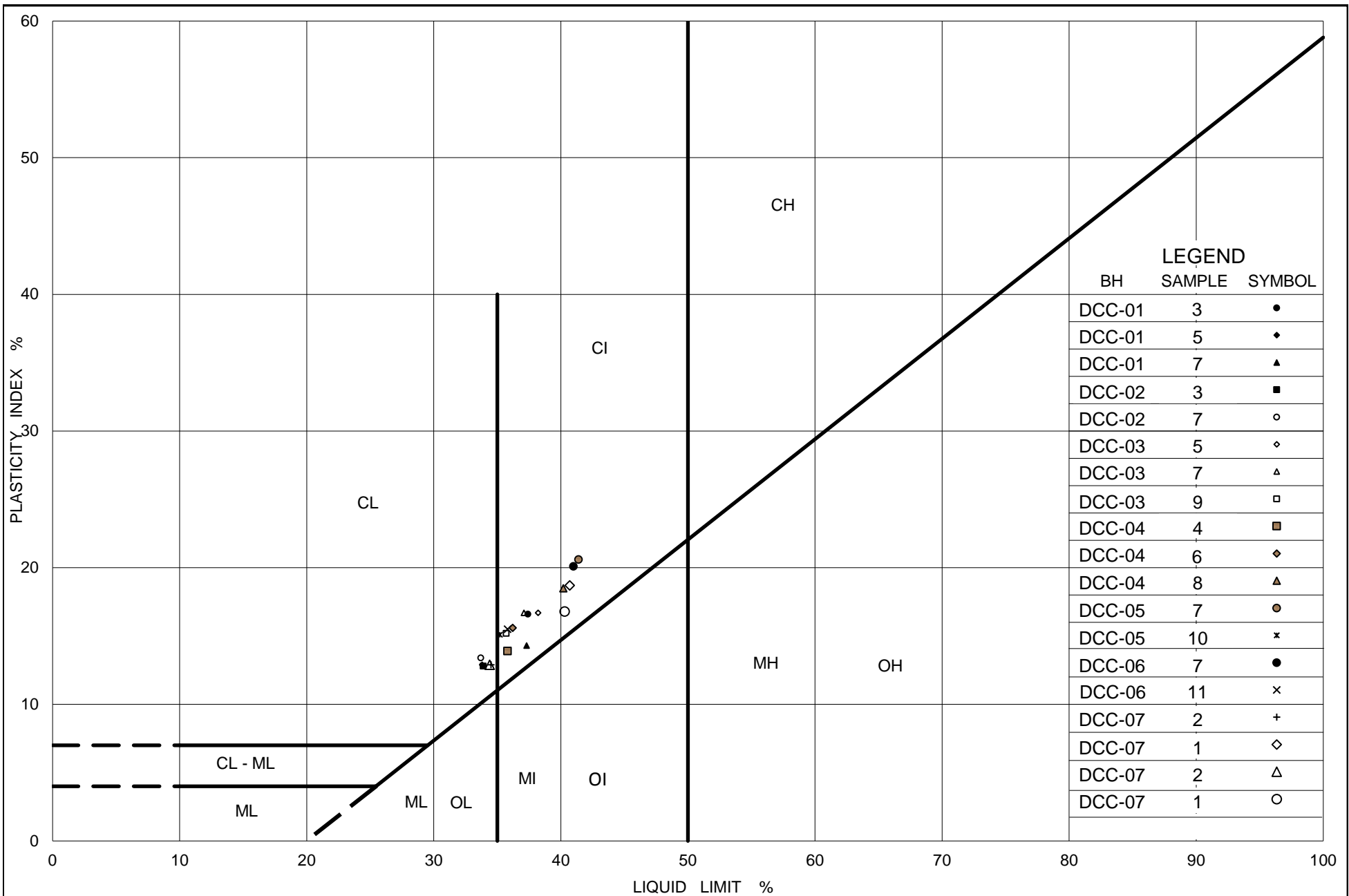
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	DCC-03	5	188.8
■	DCC-05	7	189.9
◆	DCC-06	7	189.6

Project Number: 1670846

Checked By: _____

Golder Associates

Date: 13-Apr-18



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Ontario

PLASTICITY CHART

Clayey Silt Laminae and Silty Clay Laminae

Figure No. B12

Project No. 1670846

Checked By: TZ

CONSOLIDATION TEST SUMMARY
ASTM D2435/D2435M

FIGURE B13
(1 of 4)

SAMPLE IDENTIFICATION

Project Number	1670846	Sample Number	1
Borehole Number	DCC-07	Sample Depth, m	6.4

TEST CONDITIONS

Test Type	Laboratory Standard	Load Duration, hr	24
Oedometer Number	2		
Date Started	08/21/2018		
Date Completed	09/04/2018		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	2.54	Unit Weight, kN/m ³	17.07
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m ³	11.51
Area, cm ²	31.65	Specific Gravity, assumed	2.75
Volume, cm ³	80.29	Solids Height, cm	1.083
Water Content, %	48.38	Volume of Solids, cm ³	34.26
Wet Mass, g	139.80	Volume of Voids, cm ³	46.03
Dry Mass, g	94.22	Degree of Saturation, %	99.0

TEST COMPUTATIONS

Stress kPa	Corr. Height cm	Void Ratio	Average Height cm	t ₉₀ sec	c _v cm ² /s	m _v m ² /kN	k cm/s
0.00	2.537	1.344	2.537				
6.01	2.538	1.344	2.537				
10.64	2.536	1.342	2.537	60	2.27E-02	1.62E-04	3.60E-07
20.68	2.534	1.340	2.535	38	3.58E-02	8.24E-05	2.90E-07
40.08	2.526	1.333	2.530	90	1.51E-02	1.67E-04	2.46E-07
78.73	2.515	1.323	2.520	101	1.33E-02	1.09E-04	1.43E-07
155.86	2.493	1.303	2.504	98	1.36E-02	1.13E-04	1.50E-07
310.57	2.459	1.272	2.476	118	1.10E-02	8.48E-05	9.16E-08
620.30	2.338	1.159	2.399	109	1.12E-02	1.55E-04	1.70E-07
1239.82	2.058	0.901	2.198	392	2.61E-03	1.78E-04	4.55E-08
2477.58	1.907	0.761	1.983	265	3.14E-03	4.83E-05	1.49E-08
618.88	1.930	0.782	1.918				
155.86	1.962	0.812	1.946				
39.89	1.999	0.846	1.980				
10.72	2.032	0.877	2.015				

Notes:
k calculated using cv based on t₉₀ values.
Specimen swelled under 6.01 kPa.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.93	Unit Weight, kN/m ³	19.96
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m ³	15.13
Area, cm ²	31.65	Specific Gravity, assumed	2.75
Volume, cm ³	61.07	Solids Height, cm	1.083
Water Content, %	31.91	Volume of Solids, cm ³	34.26
Wet Mass, g	124.29	Volume of Voids, cm ³	26.81
Dry Mass, g	94.22		

Prepared By: LH

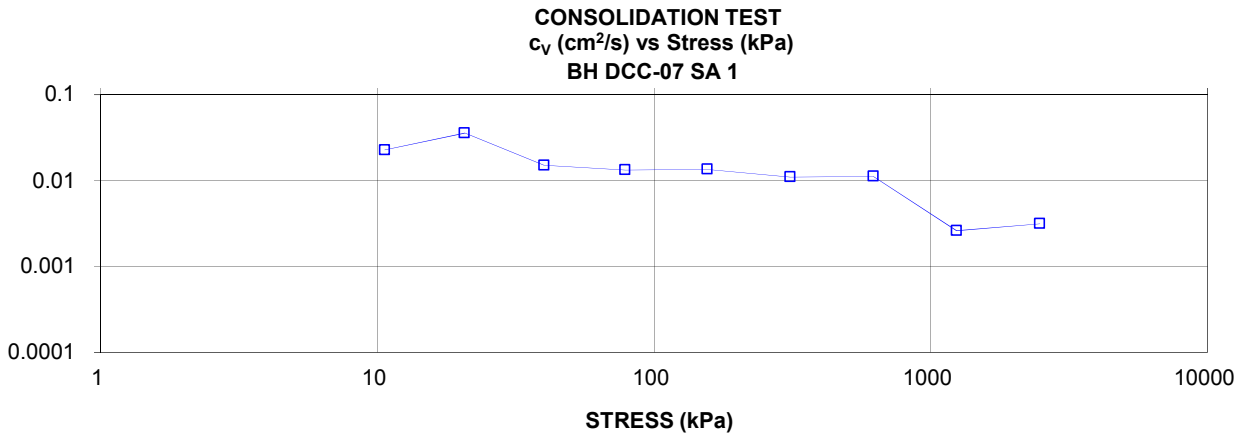
Golder Associates Ltd.

Checked By: TZ

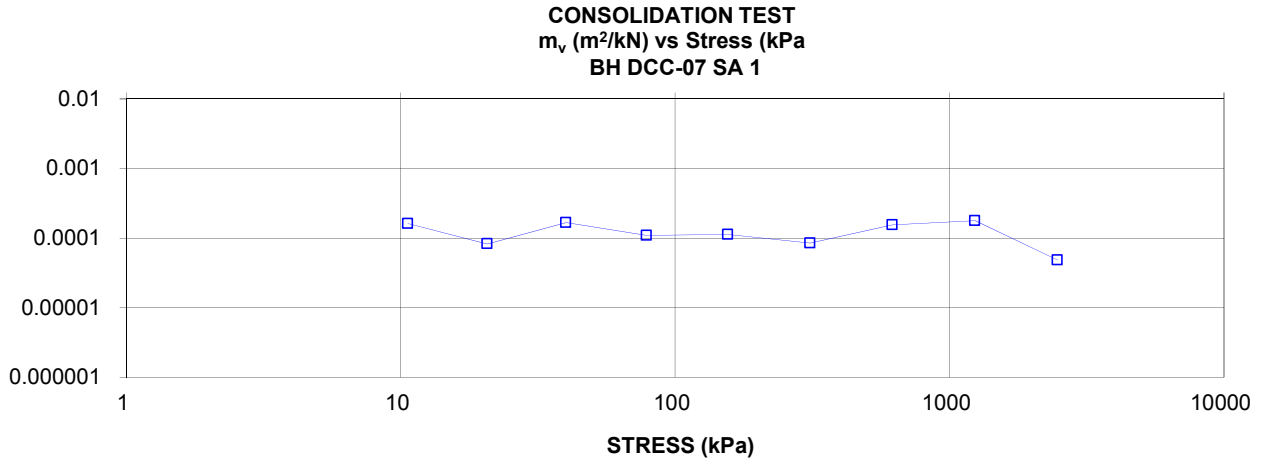
CONSOLIDATION TEST SUMMARY

FIGURE B13
(2 of 4)

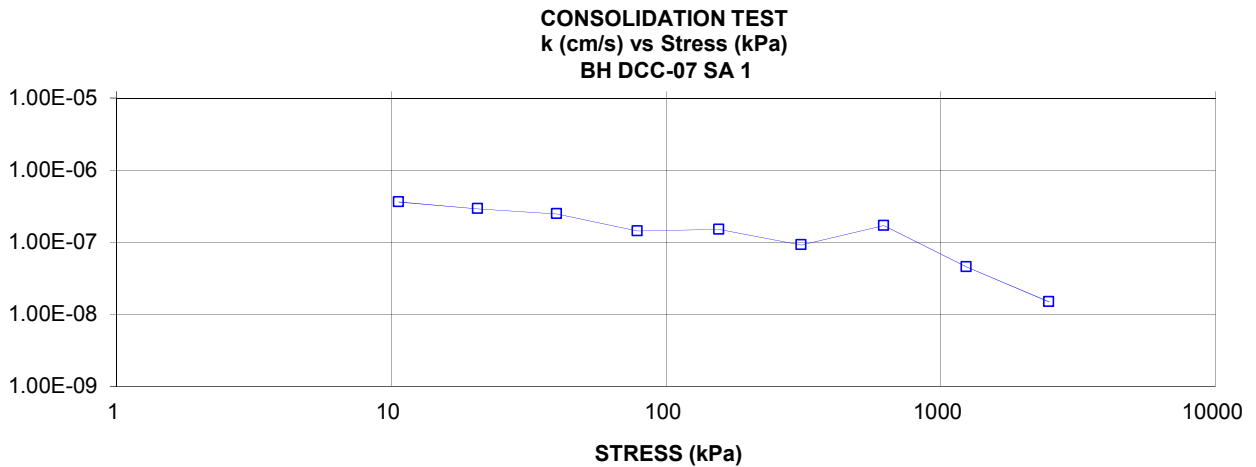
COEFFICIENT OF CONSOLIDATION,
 c_v , cm²/s



VOLUME COMPRESSIBILITY,
 m_v , m²/kN



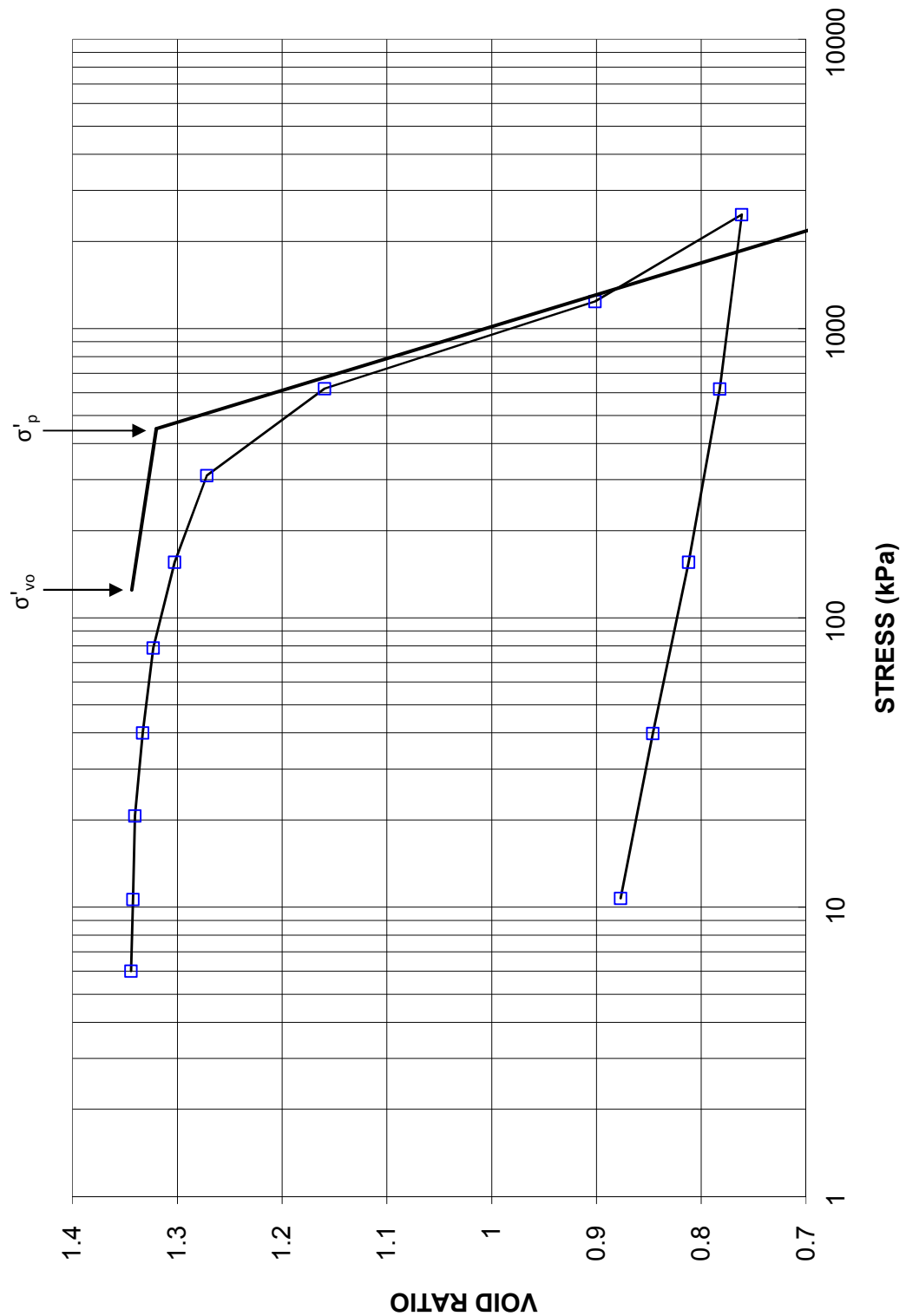
HYDRAULIC CONDUCTIVITY,
 k , cm/s



**CONSOLIDATION TEST
VOID RATIO VS LOG STRESS**

**FIGURE B13
(3 of 4)**

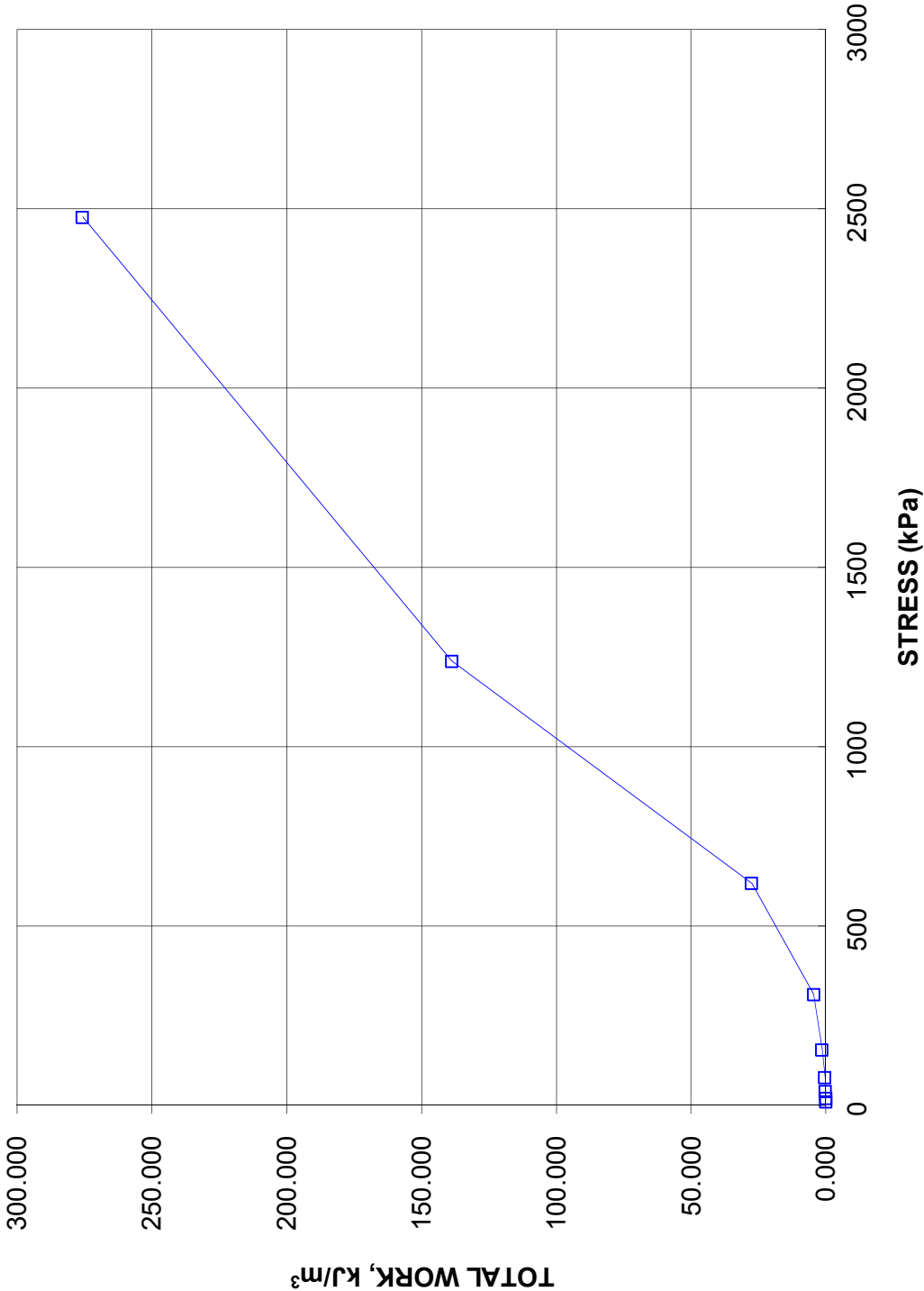
**CONSOLIDATION TEST
VOID RATIO vs STRESS
BH DCC-07 SA 1**



CONSOLIDATION TEST
TOTAL WORK VS STRESS

FIGURE B13
(4 of 4)

CONSOLIDATION TEST
TOTAL WORK, kJ/m³ vs STRESS
BH DCC-07 SA 1



CONSOLIDATION TEST SUMMARY
ASTM D2435/D2435M

FIGURE B14
(1 of 4)

SAMPLE IDENTIFICATION

Project Number	1670846(1023)	Sample Number	2
Borehole Number	DCC-07	Sample Depth, ft	9.4

TEST CONDITIONS

Test Type	Laboratory Standard	Load Duration, hr	24
Oedometer Number	1		
Date Started	08/21/2018		
Date Completed	09/04/2018		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	2.56	Unit Weight, kN/m ³	17.06
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m ³	11.76
Area, cm ²	31.67	Specific Gravity, assumed	2.75
Volume, cm ³	80.91	Solids Height, cm	1.114
Water Content, %	45.05	Volume of Solids, cm ³	35.29
Wet Mass, g	140.77	Volume of Voids, cm ³	45.62
Dry Mass, g	97.05	Degree of Saturation, %	95.8

TEST COMPUTATIONS

Stress kPa	Corr. Height cm	Void Ratio	Average Height cm	t ₉₀ sec	c _v cm ² /s	m _v m ² /kN	k cm/s
0.00	2.555	1.293	2.555				
5.90	2.549	1.287	2.552				
10.72	2.544	1.283	2.547	60	2.29E-02	3.90E-04	8.75E-07
20.43	2.539	1.278	2.541	135	1.01E-02	2.22E-04	2.20E-07
39.86	2.525	1.266	2.532	74	1.84E-02	2.72E-04	4.89E-07
78.56	2.509	1.252	2.517	86	1.56E-02	1.62E-04	2.48E-07
155.86	2.486	1.231	2.498	98	1.35E-02	1.17E-04	1.55E-07
310.89	2.447	1.196	2.466	101	1.28E-02	9.92E-05	1.24E-07
620.01	2.358	1.116	2.403	217	5.64E-03	1.12E-04	6.17E-08
1239.14	2.146	0.926	2.252	623	1.73E-03	1.34E-04	2.27E-08
2478.41	2.014	0.807	2.080	290	3.16E-03	4.19E-05	1.30E-08
620.30	2.035	0.826	2.024				
160.20	2.064	0.852	2.050				
40.05	2.096	0.880	2.080				
10.63	2.121	0.904	2.108				

Notes:
k calculated using cv based on t₉₀ values.
Specimen swelled under 5.90 kPa.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	2.04	Unit Weight, kN/m ³	19.43
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m ³	14.77
Area, cm ²	31.67	Specific Gravity, assumed	2.75
Volume, cm ³	64.45	Solids Height, cm	1.114
Water Content, %	31.58	Volume of Solids, cm ³	35.29
Wet Mass, g	127.70	Volume of Voids, cm ³	29.16
Dry Mass, g	97.05		

Prepared By: LH

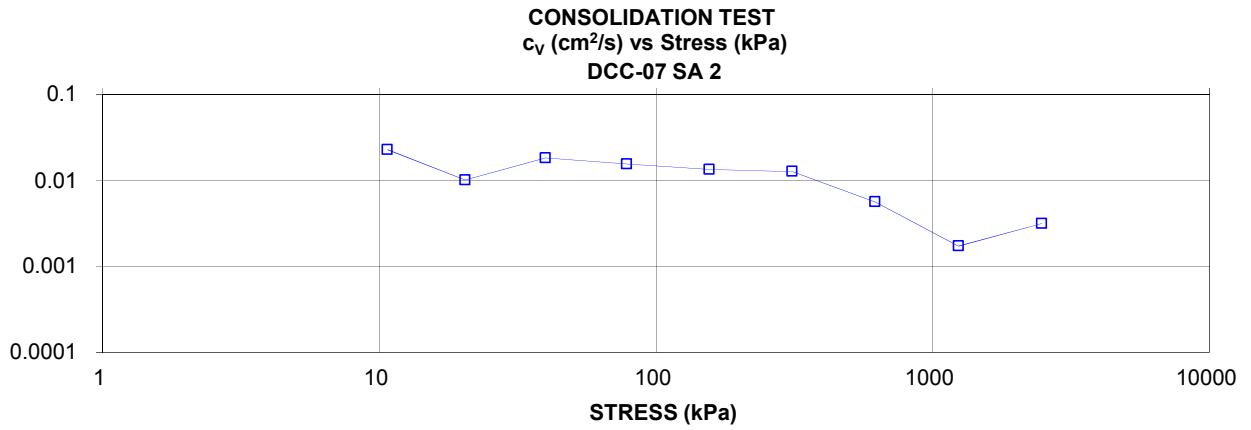
Golder Associates Ltd.

Checked By: TZ

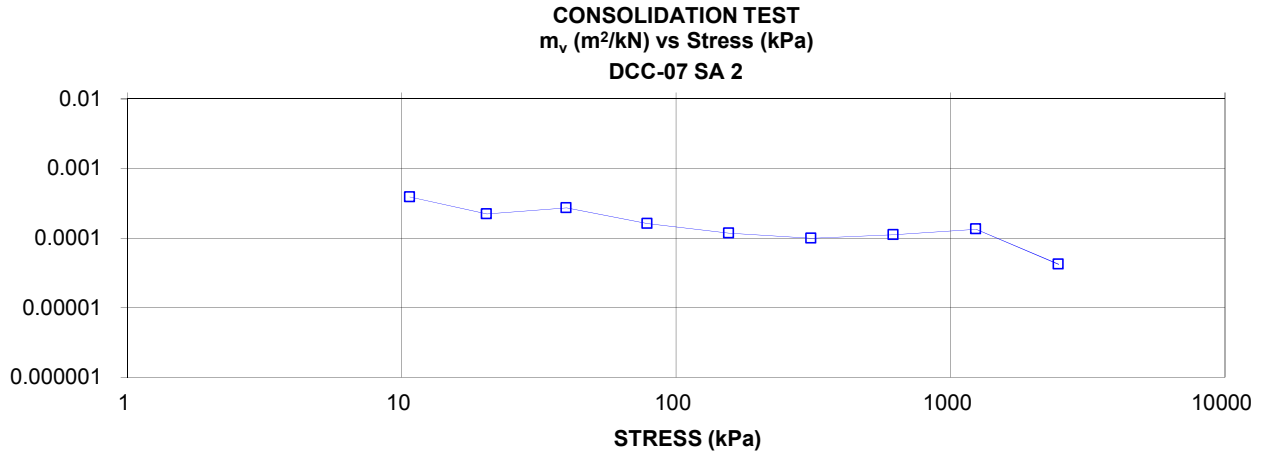
CONSOLIDATION TEST SUMMARY

FIGURE B14
(2 of 4)

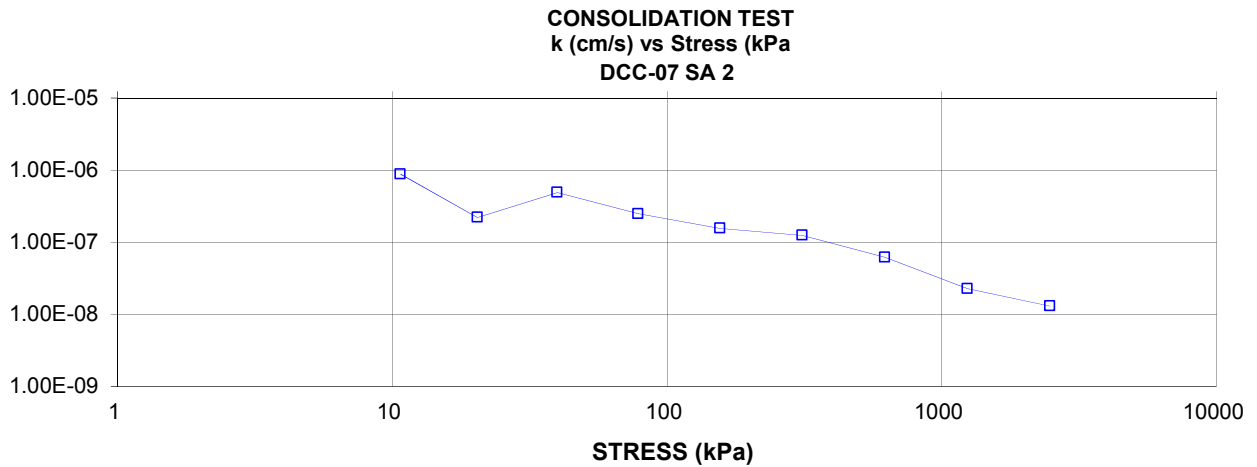
COEFFICIENT OF CONSOLIDATION,
 c_v cm²/s



VOLUME COMPRESSIBILITY,
 m_v m²/kN



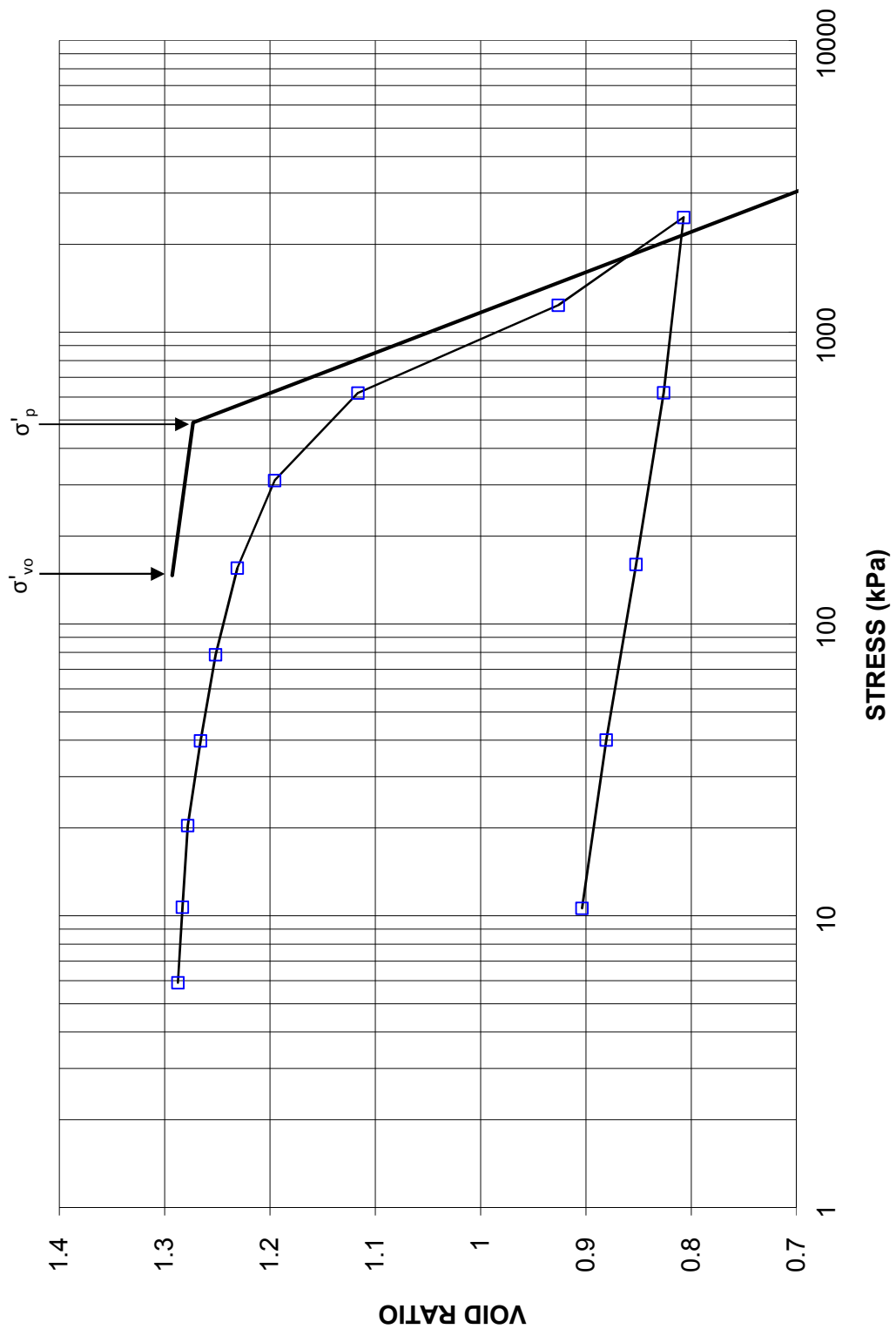
HYDRAULIC CONDUCTIVITY,
 k cm/s



**CONSOLIDATION TEST
VOID RATIO VS LOG STRESS**

**FIGURE B14
(3 of 4)**

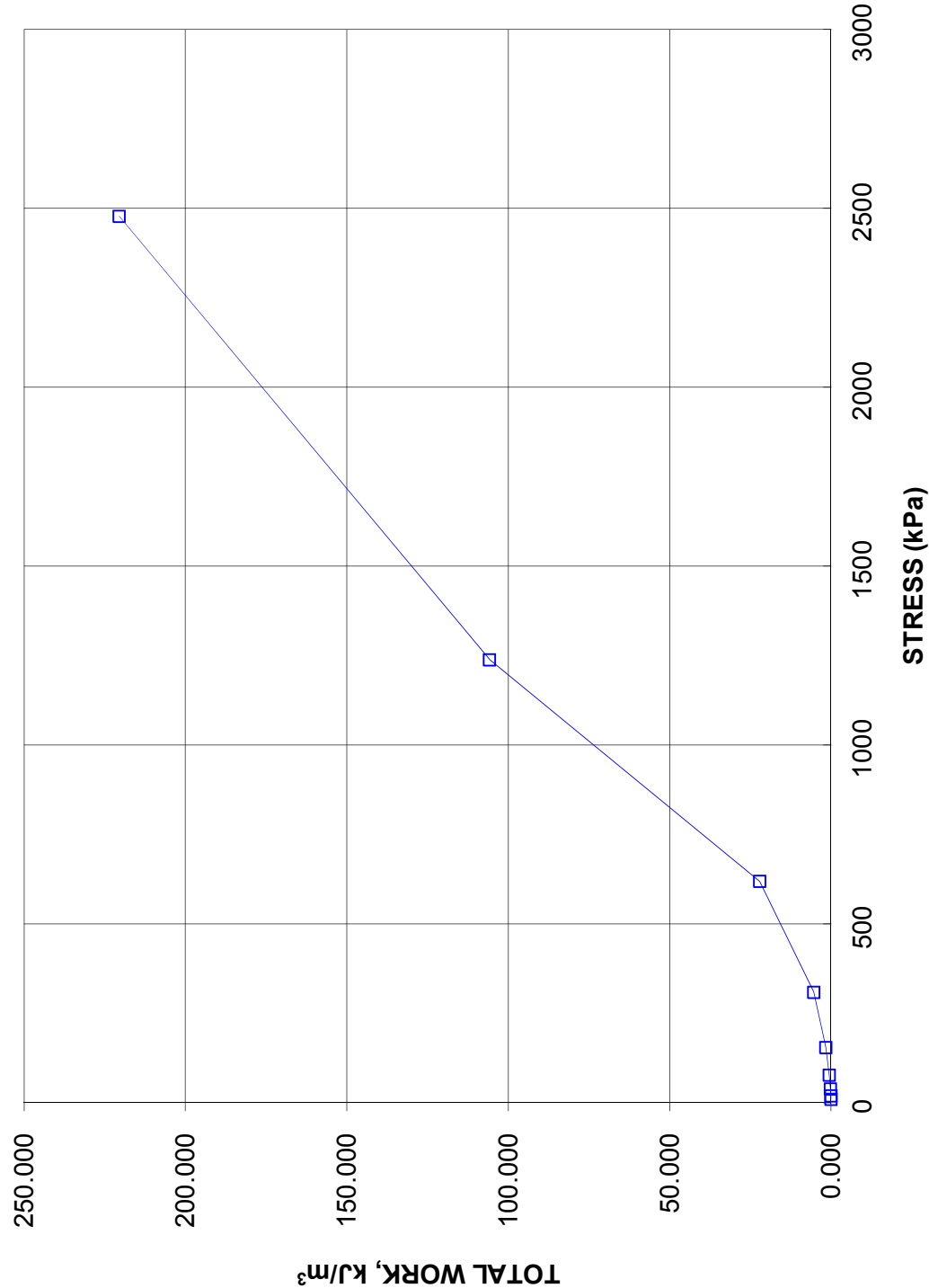
**CONSOLIDATION TEST
VOID RATIO vs STRESS
DCC-07 SA 2**



CONSOLIDATION TEST
TOTAL WORK VS STRESS

FIGURE B14
(4 of 4)

CONSOLIDATION TEST
TOTAL WORK, kJ/m³ vs STRESS
DCC-07 SA 2





APPENDIX C

Analytical Laboratory Test Results

Your Project #: 1670846
Your C.O.C. #: 628368-01-01

Attention: Darcy Hansen

Golder Associates Ltd
Mississauga - Standing Offer
6925 Century Ave
Suite 100
Mississauga, ON
CANADA L5N 7K2

Report Date: 2017/09/20
Report #: R4722990
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B7J9789

Received: 2017/09/13, 11:39

Sample Matrix: Soil
Samples Received: 8

Analyses	Date		Date Analyzed	Laboratory Method	Reference
	Quantity	Extracted			
Chloride (20:1 extract)	8	N/A	2017/09/18	CAM SOP-00463	EPA 325.2 m
Conductivity	8	N/A	2017/09/18	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl ₂ EXTRACT	8	2017/09/15	2017/09/15	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	8	2017/09/14	2017/09/18	CAM SOP-00414	SM 22 2510 m
Sulphate (20:1 Extract)	8	N/A	2017/09/18	CAM SOP-00464	EPA 375.4 m
Sulphide (from Campobello) (1)	8	N/A	N/A		

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported: unless indicated otherwise, associated sample data are not blank corrected.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.

Results relate to samples tested.

This Certificate shall not be reproduced except in full, without the written approval of the laboratory.

Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

(1) This test was performed by Campo to Burnaby Subcontract

Your Project #: 1670846
Your C.O.C. #: 628368-01-01

Attention:Darcy Hansen

Golder Associates Ltd
Mississauga - Standing Offer
6925 Century Ave
Suite 100
Mississauga, ON
CANADA L5N 7K2

Report Date: 2017/09/20
Report #: R4722990
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B7J9789
Received: 2017/09/13, 11:39

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Ema Gitej, Senior Project Manager

Email: EGitej@maxxam.ca

Phone# (905)817-5829

=====

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

RESULTS OF ANALYSES OF SOIL

Maxxam ID		FCS510	FCS510	FCS511	FCS512	FCS513	FCS514		
Sampling Date		2017/08/23	2017/08/23	2017/09/07	2017/09/06	2017/07/16	2017/07/11		
COC Number		628368-01-01	628368-01-01	628368-01-01	628368-01-01	628368-01-01	628368-01-01		
	UNITS	ACB-03 SA4	ACB-03 SA4 Lab-Dup	ACC1-03 SA2	ACCS-03 SA2	MRB-04 SA3	MRB-03 SA5	RDL	QC Batch

Calculated Parameters									
Resistivity	ohm-cm	7300		15000	4100	5900	2400		5165355
Inorganics									
Soluble (20:1) Chloride (Cl)	ug/g	55	58	24	130	58	260	20	5167700
Conductivity	umho/cm	137	133	69	246	169	424	2	5167946
Available (CaCl2) pH	pH	6.48		6.20	5.13	5.62	5.77		5165977
Soluble (20:1) Sulphate (SO4)	ug/g	<20	<20	64	22	29	<20	20	5167702
RDL = Reportable Detection Limit									
QC Batch = Quality Control Batch									
Lab-Dup = Laboratory Initiated Duplicate									

Maxxam ID		FCS515	FCS516	FCS517		
Sampling Date		2017/08/23	2017/07/29	2017/08/02		
COC Number		628368-01-01	628368-01-01	628368-01-01		
	UNITS	DCC-01 SA2	MCC-03 SA1	WRC-01 SA3	RDL	QC Batch
Calculated Parameters						
Resistivity	ohm-cm	2200	24000	43000		5165355
Inorganics						
Soluble (20:1) Chloride (Cl)	ug/g	190	<20	<20	20	5167700
Conductivity	umho/cm	450	41	23	2	5167946
Available (CaCl2) pH	pH	8.18	6.90	6.62		5165977
Soluble (20:1) Sulphate (SO4)	ug/g	<20	<20	24	20	5167702
RDL = Reportable Detection Limit						
QC Batch = Quality Control Batch						

TEST SUMMARY

Maxxam ID: FCS510
Sample ID: ACB-03 SA4
Matrix: Soil

Collected: 2017/08/23
Shipped:
Received: 2017/09/13

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5167700	N/A	2017/09/18	Deonarine Ramnarine
Conductivity	AT	5167946	N/A	2017/09/18	Neil Dassanayake
pH CaCl2 EXTRACT	AT	5165977	2017/09/15	2017/09/15	Tahir Ahmed
Resistivity of Soil		5165355	2017/09/18	2017/09/18	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5167702	N/A	2017/09/18	Deonarine Ramnarine
Sulphide (from Campobello)	SPEC	5170216	N/A	2017/09/19	Lims Auto Schedule Runner

Maxxam ID: FCS510 Dup
Sample ID: ACB-03 SA4
Matrix: Soil

Collected: 2017/08/23
Shipped:
Received: 2017/09/13

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5167700	N/A	2017/09/18	Deonarine Ramnarine
Conductivity	AT	5167946	N/A	2017/09/18	Neil Dassanayake
Sulphate (20:1 Extract)	KONE/EC	5167702	N/A	2017/09/18	Deonarine Ramnarine

Maxxam ID: FCS511
Sample ID: ACC1-03 SA2
Matrix: Soil

Collected: 2017/09/07
Shipped:
Received: 2017/09/13

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5167700	N/A	2017/09/18	Deonarine Ramnarine
Conductivity	AT	5167946	N/A	2017/09/18	Neil Dassanayake
pH CaCl2 EXTRACT	AT	5165977	2017/09/15	2017/09/15	Tahir Ahmed
Resistivity of Soil		5165355	2017/09/18	2017/09/18	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5167702	N/A	2017/09/18	Deonarine Ramnarine
Sulphide (from Campobello)	SPEC	5170216	N/A	2017/09/19	Lims Auto Schedule Runner

Maxxam ID: FCS512
Sample ID: ACCS-03 SA2
Matrix: Soil

Collected: 2017/09/06
Shipped:
Received: 2017/09/13

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5167700	N/A	2017/09/18	Deonarine Ramnarine
Conductivity	AT	5167946	N/A	2017/09/18	Neil Dassanayake
pH CaCl2 EXTRACT	AT	5165977	2017/09/15	2017/09/15	Tahir Ahmed
Resistivity of Soil		5165355	2017/09/18	2017/09/18	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5167702	N/A	2017/09/18	Deonarine Ramnarine
Sulphide (from Campobello)	SPEC	5170216	N/A	2017/09/19	Lims Auto Schedule Runner

Maxxam ID: FCS513
Sample ID: MRB-04 SA3
Matrix: Soil

Collected: 2017/07/16
Shipped:
Received: 2017/09/13

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5167700	N/A	2017/09/18	Deonarine Ramnarine

TEST SUMMARY

Maxxam ID: FCS513
Sample ID: MRB-04 SA3
Matrix: Soil

Collected: 2017/07/16
Shipped:
Received: 2017/09/13

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Conductivity	AT	5167946	N/A	2017/09/18	Neil Dassanayake
pH CaCl2 EXTRACT	AT	5165977	2017/09/15	2017/09/15	Tahir Ahmed
Resistivity of Soil		5165355	2017/09/18	2017/09/18	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5167702	N/A	2017/09/18	Deonarine Ramnarine
Sulphide (from Campobello)	SPEC	5170216	N/A	2017/09/19	Lims Auto Schedule Runner

Maxxam ID: FCS514
Sample ID: MRB-03 SA5
Matrix: Soil

Collected: 2017/07/11
Shipped:
Received: 2017/09/13

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5167700	N/A	2017/09/18	Deonarine Ramnarine
Conductivity	AT	5167946	N/A	2017/09/18	Neil Dassanayake
pH CaCl2 EXTRACT	AT	5165977	2017/09/15	2017/09/15	Tahir Ahmed
Resistivity of Soil		5165355	2017/09/18	2017/09/18	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5167702	N/A	2017/09/18	Deonarine Ramnarine
Sulphide (from Campobello)	SPEC	5170216	N/A	2017/09/19	Lims Auto Schedule Runner

Maxxam ID: FCS515
Sample ID: DCC-01 SA2
Matrix: Soil

Collected: 2017/08/23
Shipped:
Received: 2017/09/13

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5167700	N/A	2017/09/18	Deonarine Ramnarine
Conductivity	AT	5167946	N/A	2017/09/18	Neil Dassanayake
pH CaCl2 EXTRACT	AT	5165977	2017/09/15	2017/09/15	Tahir Ahmed
Resistivity of Soil		5165355	2017/09/18	2017/09/18	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5167702	N/A	2017/09/18	Deonarine Ramnarine
Sulphide (from Campobello)	SPEC	5170216	N/A	2017/09/19	Lims Auto Schedule Runner

Maxxam ID: FCS516
Sample ID: MCC-03 SA1
Matrix: Soil

Collected: 2017/07/29
Shipped:
Received: 2017/09/13

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5167700	N/A	2017/09/18	Deonarine Ramnarine
Conductivity	AT	5167946	N/A	2017/09/18	Neil Dassanayake
pH CaCl2 EXTRACT	AT	5165977	2017/09/15	2017/09/15	Tahir Ahmed
Resistivity of Soil		5165355	2017/09/18	2017/09/18	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5167702	N/A	2017/09/18	Deonarine Ramnarine
Sulphide (from Campobello)	SPEC	5170216	N/A	2017/09/19	Lims Auto Schedule Runner

TEST SUMMARY

Maxxam ID: FCS517
Sample ID: WRC-01 SA3
Matrix: Soil

Collected: 2017/08/02
Shipped:
Received: 2017/09/13

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5167700	N/A	2017/09/18	Deonarine Ramnarine
Conductivity	AT	5167946	N/A	2017/09/18	Neil Dassanayake
pH CaCl2 EXTRACT	AT	5165977	2017/09/15	2017/09/15	Tahir Ahmed
Resistivity of Soil		5165355	2017/09/18	2017/09/18	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5167702	N/A	2017/09/18	Deonarine Ramnarine
Sulphide (from Campobello)	SPEC	5170216	N/A	2017/09/19	Lims Auto Schedule Runner

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	5.7°C
-----------	-------

Custody seal was present and intact.

Sample FCS513 [MRB-04 SA3] : Sample submitted and analyzed past the recommended hold time for pH, Chloride, Sulphate and Conductivity/Resistivity analysis.

Sample FCS514 [MRB-03 SA5] : Sample submitted and analyzed past the recommended hold time for pH, Chloride, Sulphate and Conductivity/Resistivity analysis.

Sample FCS517 [WRC-01 SA3] : Sample submitted and analyzed past the recommended hold time for pH, Chloride, Sulphate and Conductivity/Resistivity analysis.

Results relate only to the items tested.

QUALITY ASSURANCE REPORT

Golder Associates Ltd
Client Project #: 1670846
Sampler Initials: DH

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
5165977	Available (CaCl ₂) pH	2017/09/15			99	97 - 103			0.11	N/A
5167700	Soluble (20:1) Chloride (Cl)	2017/09/18	NC	70 - 130	104	70 - 130	<20	ug/g	5.5	35
5167702	Soluble (20:1) Sulphate (SO ₄)	2017/09/18	124	70 - 130	107	70 - 130	<20	ug/g	NC	35
5167946	Conductivity	2017/09/18			101	90 - 110	<2	umho/cm	3.2	10

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spike amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than the native sample concentration)

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (absolute difference <= 2x RDL).

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Cristina Carriere

Cristina Carriere, Scientific Service Specialist

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Your Project #: 1670846
Your C.O.C. #: 628368-02-01

Attention: Darcy Hansen

Golder Associates Ltd
Mississauga - Standing Offer
6925 Century Ave
Suite 100
Mississauga, ON
CANADA L5N 7K2

Report Date: 2017/10/23
Report #: R4798069
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B7L2287

Received: 2017/09/27, 12:13

Sample Matrix: Soil
Samples Received: 2

Analyses	Date		Date	Laboratory Method	Reference
	Quantity	Extracted	Analyzed		
Chloride (20:1 extract)	2	N/A	2017/10/03	CAM SOP-00463	EPA 325.2 m
Conductivity	2	N/A	2017/10/02	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl ₂ EXTRACT	2	2017/09/29	2017/09/29	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	2	2017/09/27	2017/10/02	CAM SOP-00414	SM 22 2510 m
Sulphate (20:1 Extract)	2	N/A	2017/10/03	CAM SOP-00464	EPA 375.4 m
Sulphide (from Campobello) (1)	2	N/A	N/A		

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported: unless indicated otherwise, associated sample data are not blank corrected.

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Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.

Results relate to samples tested.

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Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

(1) This test was performed by Campo to Burnaby Subcontract

Your Project #: 1670846
Your C.O.C. #: 628368-02-01

Attention:Darcy Hansen

Golder Associates Ltd
Mississauga - Standing Offer
6925 Century Ave
Suite 100
Mississauga, ON
CANADA L5N 7K2

Report Date: 2017/10/23
Report #: R4798069
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B7L2287
Received: 2017/09/27, 12:13

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Ema Gitej, Senior Project Manager

Email: EGitej@maxxam.ca

Phone# (905)817-5829

=====

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RESULTS OF ANALYSES OF SOIL

Maxxam ID		FFD202	FFD203	FFD203		
Sampling Date		2017/08/26	2017/09/09	2017/09/09		
COC Number		628368-02-01	628368-02-01	628368-02-01		
	UNITS	DCC-04 SA-2	ACB-06 SA-3	ACB-06 SA-3 Lab-Dup	RDL	QC Batch
Calculated Parameters						
Resistivity	ohm-cm	5100	7200			5185712
Inorganics						
Soluble (20:1) Chloride (Cl)	ug/g	<20	70	69	20	5191890
Conductivity	umho/cm	198	139	131	2	5191368
Available (CaCl2) pH	pH	8.03	4.97			5188854
Soluble (20:1) Sulphate (SO4)	ug/g	39	<20	<20	20	5191917
RDL = Reportable Detection Limit						
QC Batch = Quality Control Batch						
Lab-Dup = Laboratory Initiated Duplicate						

TEST SUMMARY

Maxxam ID: FFD202
Sample ID: DCC-04 SA-2
Matrix: Soil

Collected: 2017/08/26
Shipped:
Received: 2017/09/27

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5191890	N/A	2017/10/03	Alina Dobreanu
Conductivity	AT	5191368	N/A	2017/10/02	Neil Dassanayake
pH CaCl2 EXTRACT	AT	5188854	2017/09/29	2017/09/29	Tahir Anwar
Resistivity of Soil		5185712	2017/10/02	2017/10/02	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5191917	N/A	2017/10/03	Alina Dobreanu
Sulphide (from Campobello)	SPEC	5223606	N/A		Ema Gitej

Maxxam ID: FFD203
Sample ID: ACB-06 SA-3
Matrix: Soil

Collected: 2017/09/09
Shipped:
Received: 2017/09/27

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5191890	N/A	2017/10/03	Alina Dobreanu
Conductivity	AT	5191368	N/A	2017/10/02	Neil Dassanayake
pH CaCl2 EXTRACT	AT	5188854	2017/09/29	2017/09/29	Tahir Anwar
Resistivity of Soil		5185712	2017/10/02	2017/10/02	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5191917	N/A	2017/10/03	Alina Dobreanu
Sulphide (from Campobello)	SPEC	5223606	N/A		Ema Gitej

Maxxam ID: FFD203 Dup
Sample ID: ACB-06 SA-3
Matrix: Soil

Collected: 2017/09/09
Shipped:
Received: 2017/09/27

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5191890	N/A	2017/10/03	Alina Dobreanu
Conductivity	AT	5191368	N/A	2017/10/02	Neil Dassanayake
Sulphate (20:1 Extract)	KONE/EC	5191917	N/A	2017/10/03	Alina Dobreanu

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	1.7°C
-----------	-------

Results relate only to the items tested.

QUALITY ASSURANCE REPORT

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
5188854	Available (CaCl ₂) pH	2017/09/29			100	97 - 103			0.80	N/A
5191368	Conductivity	2017/10/02			98	90 - 110	<2	umho/cm	5.7	10
5191890	Soluble (20:1) Chloride (Cl)	2017/10/03	NC	70 - 130	108	70 - 130	<20	ug/g	0.87	35
5191917	Soluble (20:1) Sulphate (SO ₄)	2017/10/03	102	70 - 130	104	70 - 130	<20	ug/g	NC	35

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

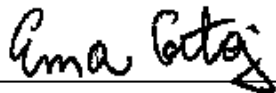
Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spike amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than the native sample concentration)

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (absolute difference <= 2x RDL).

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).



Ema Gitej, Senior Project Manager



Eva Pranjic, M.Sc., C.Chem, Scientific Specialist

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Your Project #: MB7J9789
Site Location: 1670846
Your C.O.C. #: B7J9789-M058-01-01

Attention:EMA GITEJ

MAXXAM ANALYTICS
CAMPOBELLO
6740 CAMPOBELLO ROAD
MISSISSAUGA, ON
CANADA L5N 2L8

Report Date: 2017/09/18
Report #: R2445858
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B780085

Received: 2017/09/16, 12:10

Sample Matrix: Soil
Samples Received: 8

Analyses	Quantity	Date	Date	Laboratory Method	Analytical Method
		Extracted	Analyzed		
Moisture	8	2017/09/18	2017/09/18	BBY8SOP-00017	BCMOE BCLM Dec2000 m
Sulphide in Soil	8	2017/09/18	2017/09/18	BBY6SOP-00006	SM 22 4500 S2- D m

Remarks:

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Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.

Results relate to samples tested.

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* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Your Project #: MB7J9789
Site Location: 1670846
Your C.O.C. #: B7J9789-M058-01-01

Attention:EMA GITEJ

MAXXAM ANALYTICS
CAMPOBELLO
6740 CAMPOBELLO ROAD
MISSISSAUGA, ON
CANADA L5N 2L8

Report Date: 2017/09/18
Report #: R2445858
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B780085
Received: 2017/09/16, 12:10

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Letitia Prefontaine, B.Sc., Senior Project Manager

Email: LPrefontaine@maxxam.ca

Phone# (604)639-2616

=====

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Maxxam Job #: B780085
Report Date: 2017/09/18

MAXXAM ANALYTICS
Client Project #: MB7J9789
Site Location: 1670846
Sampler Initials: DH

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		RZ2662	RZ2662	RZ2663		RZ2664		
Sampling Date		2017/08/23	2017/08/23	2017/09/07		2017/09/06		
COC Number		B7J9789-M058-01-01	B7J9789-M058-01-01	B7J9789-M058-01-01		B7J9789-M058-01-01		
	UNITS	ACB-03 SA4	ACB-03 SA4 Lab-Dup	ACC1-03 SA2	RDL	ACCS-03 SA2	RDL	QC Batch

MISCELLANEOUS

Sulphide	ug/g	0.69 (1)	<0.50	0.52	0.50	1.06 (2)	0.55	8761700
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RDL = Reportable Detection Limit

Lab-Dup = Laboratory Initiated Duplicate

(1) Matrix spike exceeds acceptance limits due to matrix interference. Re-analysis yields similar results.

(2) RDL raised due to high sample moisture content.

Maxxam ID		RZ2665	RZ2666		RZ2667		
Sampling Date		2017/07/16	2017/07/11		2017/08/23		
COC Number		B7J9789-M058-01-01	B7J9789-M058-01-01		B7J9789-M058-01-01		
	UNITS	MRB-04 SA3	MRB-03 SA5	RDL	DCC-01 SA2	RDL	QC Batch

MISCELLANEOUS

Sulphide	ug/g	<0.50	0.52	0.50	0.68 (1)	0.55	8761700
----------	------	-------	------	------	----------	------	---------

RDL = Reportable Detection Limit

(1) RDL raised due to high sample moisture content.

Maxxam ID		RZ2668	RZ2669		
Sampling Date		2017/07/29	2017/08/02		
COC Number		B7J9789-M058-01-01	B7J9789-M058-01-01		
	UNITS	MCC-03 SA1	WRC-01 SA3	RDL	QC Batch

MISCELLANEOUS

Sulphide	ug/g	0.78	0.57	0.50	8761700
----------	------	------	------	------	---------

RDL = Reportable Detection Limit

Maxxam Job #: B780085
Report Date: 2017/09/18

MAXXAM ANALYTICS
Client Project #: MB7J9789
Site Location: 1670846
Sampler Initials: DH

PHYSICAL TESTING (SOIL)

Maxxam ID		RZ2662	RZ2663	RZ2664	RZ2665		
Sampling Date		2017/08/23	2017/09/07	2017/09/06	2017/07/16		
COC Number		B7J9789-M058-01-01	B7J9789-M058-01-01	B7J9789-M058-01-01	B7J9789-M058-01-01		
	UNITS	ACB-03 SA4	ACC1-03 SA2	ACCS-03 SA2	MRB-04 SA3	RDL	QC Batch

Physical Properties							
Moisture	%	24	22	28	8.2	0.30	8761682
RDL = Reportable Detection Limit							

Maxxam ID		RZ2666	RZ2667	RZ2668	RZ2669		
Sampling Date		2017/07/11	2017/08/23	2017/07/29	2017/08/02		
COC Number		B7J9789-M058-01-01	B7J9789-M058-01-01	B7J9789-M058-01-01	B7J9789-M058-01-01		
	UNITS	MRB-03 SA5	DCC-01 SA2	MCC-03 SA1	WRC-01 SA3	RDL	QC Batch

Physical Properties							
Moisture	%	13	32	14	17	0.30	8761682
RDL = Reportable Detection Limit							

Maxxam Job #: B780085
Report Date: 2017/09/18

MAXXAM ANALYTICS
Client Project #: MB7J9789
Site Location: 1670846
Sampler Initials: DH

TEST SUMMARY

Maxxam ID: RZ2662
Sample ID: ACB-03 SA4
Matrix: Soil

Collected: 2017/08/23
Shipped:
Received: 2017/09/16

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Moisture	BAL/BAL	8761682	2017/09/18	2017/09/18	Lolita Obusan
Sulphide in Soil	SPEC/COL	8761700	2017/09/18	2017/09/18	Prabhleen Sodhi

Maxxam ID: RZ2662 Dup
Sample ID: ACB-03 SA4
Matrix: Soil

Collected: 2017/08/23
Shipped:
Received: 2017/09/16

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Sulphide in Soil	SPEC/COL	8761700	2017/09/18	2017/09/18	Prabhleen Sodhi

Maxxam ID: RZ2663
Sample ID: ACC1-03 SA2
Matrix: Soil

Collected: 2017/09/07
Shipped:
Received: 2017/09/16

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Moisture	BAL/BAL	8761682	2017/09/18	2017/09/18	Lolita Obusan
Sulphide in Soil	SPEC/COL	8761700	2017/09/18	2017/09/18	Prabhleen Sodhi

Maxxam ID: RZ2664
Sample ID: ACCS-03 SA2
Matrix: Soil

Collected: 2017/09/06
Shipped:
Received: 2017/09/16

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Moisture	BAL/BAL	8761682	2017/09/18	2017/09/18	Lolita Obusan
Sulphide in Soil	SPEC/COL	8761700	2017/09/18	2017/09/18	Prabhleen Sodhi

Maxxam ID: RZ2665
Sample ID: MRB-04 SA3
Matrix: Soil

Collected: 2017/07/16
Shipped:
Received: 2017/09/16

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Moisture	BAL/BAL	8761682	2017/09/18	2017/09/18	Lolita Obusan
Sulphide in Soil	SPEC/COL	8761700	2017/09/18	2017/09/18	Prabhleen Sodhi

Maxxam ID: RZ2666
Sample ID: MRB-03 SA5
Matrix: Soil

Collected: 2017/07/11
Shipped:
Received: 2017/09/16

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Moisture	BAL/BAL	8761682	2017/09/18	2017/09/18	Lolita Obusan
Sulphide in Soil	SPEC/COL	8761700	2017/09/18	2017/09/18	Prabhleen Sodhi

Maxxam Job #: B780085
Report Date: 2017/09/18

MAXXAM ANALYTICS
Client Project #: MB7J9789
Site Location: 1670846
Sampler Initials: DH

TEST SUMMARY

Maxxam ID: RZ2667
Sample ID: DCC-01 SA2
Matrix: Soil

Collected: 2017/08/23
Shipped:
Received: 2017/09/16

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Moisture	BAL/BAL	8761682	2017/09/18	2017/09/18	Lolita Obusan
Sulphide in Soil	SPEC/COL	8761700	2017/09/18	2017/09/18	Prabhleen Sodhi

Maxxam ID: RZ2668
Sample ID: MCC-03 SA1
Matrix: Soil

Collected: 2017/07/29
Shipped:
Received: 2017/09/16

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Moisture	BAL/BAL	8761682	2017/09/18	2017/09/18	Lolita Obusan
Sulphide in Soil	SPEC/COL	8761700	2017/09/18	2017/09/18	Prabhleen Sodhi

Maxxam ID: RZ2669
Sample ID: WRC-01 SA3
Matrix: Soil

Collected: 2017/08/02
Shipped:
Received: 2017/09/16

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Moisture	BAL/BAL	8761682	2017/09/18	2017/09/18	Lolita Obusan
Sulphide in Soil	SPEC/COL	8761700	2017/09/18	2017/09/18	Prabhleen Sodhi

Maxxam Job #: B780085
Report Date: 2017/09/18

MAXXAM ANALYTICS
Client Project #: MB7J9789
Site Location: 1670846
Sampler Initials: DH

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	9.0°C
Package 2	6.0°C

Sample RZ2662 [ACB-03 SA4] : Sample was extracted past method specified hold time for Moisture. {Exceedance of hold time increases the uncertainty of test results but does not necessarily imply that results are compromised.} Sample received past method specified hold time for Moisture. Sample analyzed past method specified hold time for Sulphide in Soil. Sample received past method specified hold time for Sulphide in Soil.

Sample RZ2663 [ACC1-03 SA2] : Sample analyzed past method specified hold time for Sulphide in Soil. {Exceedance of hold time increases the uncertainty of test results but does not necessarily imply that results are compromised.} Sample received past method specified hold time for Sulphide in Soil.

Sample RZ2664 [ACCS-03 SA2] : Sample analyzed past method specified hold time for Sulphide in Soil. {Exceedance of hold time increases the uncertainty of test results but does not necessarily imply that results are compromised.} Sample received past method specified hold time for Sulphide in Soil.

Sample RZ2665 [MRB-04 SA3] : Sample was extracted past method specified hold time for Moisture. {Exceedance of hold time increases the uncertainty of test results but does not necessarily imply that results are compromised.} Sample received past method specified hold time for Moisture. Sample analyzed past method specified hold time for Sulphide in Soil. Sample received past method specified hold time for Sulphide in Soil.

Sample RZ2666 [MRB-03 SA5] : Sample was extracted past method specified hold time for Moisture. {Exceedance of hold time increases the uncertainty of test results but does not necessarily imply that results are compromised.} Sample received past method specified hold time for Moisture. Sample analyzed past method specified hold time for Sulphide in Soil. Sample received past method specified hold time for Sulphide in Soil.

Sample RZ2667 [DCC-01 SA2] : Sample was extracted past method specified hold time for Moisture. {Exceedance of hold time increases the uncertainty of test results but does not necessarily imply that results are compromised.} Sample received past method specified hold time for Moisture. Sample analyzed past method specified hold time for Sulphide in Soil. Sample received past method specified hold time for Sulphide in Soil.

Sample RZ2668 [MCC-03 SA1] : Sample was extracted past method specified hold time for Moisture. {Exceedance of hold time increases the uncertainty of test results but does not necessarily imply that results are compromised.} Sample received past method specified hold time for Moisture. Sample analyzed past method specified hold time for Sulphide in Soil. Sample received past method specified hold time for Sulphide in Soil.

Results relate only to the items tested.

Maxxam Job #: B780085
Report Date: 2017/09/18

QUALITY ASSURANCE REPORT

MAXXAM ANALYTICS
Client Project #: MB7J9789
Site Location: 1670846
Sampler Initials: DH

QC Batch	Parameter	Date	Matrix Spike		Spiked Blank		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
8761682	Moisture	2017/09/18					<0.30	%	0 (1)	20
8761700	Sulphide	2017/09/18	39 (2,3)	75 - 125	84	75 - 125	<0.50	ug/g	NC (4)	30

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (absolute difference $\leq 2 \times \text{RDL}$).

(1) Duplicate Parent ID

(2) Recovery or RPD for this parameter is outside control limits. The overall quality control for this analysis meets acceptability criteria.

(3) Matrix Spike Parent ID [RZ2662-01]

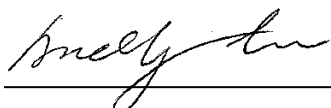
(4) Duplicate Parent ID [RZ2662-01]

Maxxam Job #: B780085
Report Date: 2017/09/18

MAXXAM ANALYTICS
Client Project #: MB7J9789
Site Location: 1670846
Sampler Initials: DH

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).



Andy Lu, Ph.D., P.Chem., Scientific Specialist

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Your Project #: MB7L2287
Site Location: 1670846
Your C.O.C. #: B7L2287-M058-01-01

Attention: SUBCONTRACTOR

MAXXAM ANALYTICS
OTTAWA
32 COLONNADE RD N
UNIT 1000
NEPEAN, ON
CANADA K2E7J6

Report Date: 2017/10/04
Report #: R2454826
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B785668
Received: 2017/10/02, 08:55

Sample Matrix: Soil
Samples Received: 2

Analyses	Quantity	Date	Date	Laboratory Method	Analytical Method
		Extracted	Analyzed		
Moisture	2	2017/10/03	2017/10/03	BBY8SOP-00017	BCMOE BCLM Dec2000 m
Sulphide in Soil	2	2017/10/02	2017/10/04	BBY6SOP-00006	SM 22 4500 S2- D m

Remarks:

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Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Your Project #: MB7L2287
Site Location: 1670846
Your C.O.C. #: B7L2287-M058-01-01

Attention:SUBCONTRACTOR

MAXXAM ANALYTICS
OTTAWA
32 COLONNADE RD N
UNIT 1000
NEPEAN, ON
CANADA K2E7J6

Report Date: 2017/10/04
Report #: R2454826
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B785668
Received: 2017/10/02, 08:55

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Letitia Prefontaine, B.Sc., Senior Project Manager
Email: LPrefontaine@maxxam.ca
Phone# (604)639-2616

=====

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Job #: B785668
Report Date: 2017/10/04

MAXXAM ANALYTICS
Client Project #: MB7L2287
Site Location: 1670846

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		SC4339		SC4340	SC4340		
Sampling Date		2017/08/26		2017/09/09	2017/09/09		
COC Number		B7L2287-M058-01-01		B7L2287-M058-01-01	B7L2287-M058-01-01		
	UNITS	DCC-04 SA-2	RDL	ACB-06 SA-3	ACB-06 SA-3 Lab-Dup	RDL	QC Batch
MISCELLANEOUS							
Sulphide	ug/g	0.92	0.55	0.60	0.50	0.50	8779137
RDL = Reportable Detection Limit							
Lab-Dup = Laboratory Initiated Duplicate							

Maxxam Job #: B785668
Report Date: 2017/10/04

MAXXAM ANALYTICS
Client Project #: MB7L2287
Site Location: 1670846

PHYSICAL TESTING (SOIL)

Maxxam ID		SC4339	SC4340	SC4340		
Sampling Date		2017/08/26	2017/09/09	2017/09/09		
COC Number		B7L2287-M058-01-01	B7L2287-M058-01-01	B7L2287-M058-01-01		
	UNITS	DCC-04 SA-2	ACB-06 SA-3	ACB-06 SA-3 Lab-Dup	RDL	QC Batch
Physical Properties						
Moisture	%	29	18	17	0.30	8779668
RDL = Reportable Detection Limit						
Lab-Dup = Laboratory Initiated Duplicate						

Maxxam Job #: B785668
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MAXXAM ANALYTICS
Client Project #: MB7L2287
Site Location: 1670846

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	7.3°C
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Samples received past hold time for sulphide in soil analysis.

Sample SC4339 [DCC-04 SA-2] : Sample was extracted past method specified hold time for Moisture. {Exceedance of hold time increases the uncertainty of test results but does not necessarily imply that results are compromised.} Sample received past method specified hold time for Moisture. Sample analyzed past method specified hold time for Sulphide in Soil. Sample received past method specified hold time for Sulphide in Soil. Sample analyzed past method specified hold time for Moisture.

Sample SC4340 [ACB-06 SA-3] : Sample was extracted past method specified hold time for Moisture. {Exceedance of hold time increases the uncertainty of test results but does not necessarily imply that results are compromised.} Sample received past method specified hold time for Moisture. Sample analyzed past method specified hold time for Sulphide in Soil. Sample received past method specified hold time for Sulphide in Soil. Sample analyzed past method specified hold time for Moisture.

Results relate only to the items tested.

Maxxam Job #: B785668
Report Date: 2017/10/04

MAXXAM ANALYTICS
Client Project #: MB7L2287
Site Location: 1670846

QUALITY ASSURANCE REPORT

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	UNITS	QC Limits
8779137	KAB	Matrix Spike [SC4340-01]	Sulphide	2017/10/04		33 (1)	%	75 - 125
8779137	KAB	Spiked Blank	Sulphide	2017/10/04		114	%	75 - 125
8779137	KAB	Method Blank	Sulphide	2017/10/04	<0.50		ug/g	
8779137	KAB	RPD [SC4340-01]	Sulphide	2017/10/04	17		%	30
8779668	LO1	Method Blank	Moisture	2017/10/03	<0.30		%	
8779668	LO1	RPD [SC4340-01]	Moisture	2017/10/03	5.0		%	20

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

(1) Recovery or RPD for this parameter is outside control limits. The overall quality control for this analysis meets acceptability criteria.

Maxxam Job #: B785668
Report Date: 2017/10/04

MAXXAM ANALYTICS
Client Project #: MB7L2287
Site Location: 1670846

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).



Rob Reinert, B.Sc., Scientific Specialist

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APPENDIX D

Special Provisions/Non-Standard Special Provisions

OPERATION CONSTRAINT – Preload Period Between Stations 13+090 and 13+100

Special Provision

The Contractor shall schedule his operation to include preloading of the embankment widening on Highway 556 between approximately Station 13+090 and 13+100. The embankment widening shall be constructed to the design top of the grade elevation of the Granular 'B' sub-base material and fills shall remain in place for a minimum period of 10 days before final grading and paving.

Prior to placement of the Granular 'A' base material and paving, the Contractor shall conduct a survey to determine the elevations of the top of the Granular 'B' sub-base material and shall place additional Granular 'B' Type II material as and where required to achieve the pavement design sub-base elevation.

The Contractor shall not proceed with final granular placement and paving until approval has been given by the Contract Administrator.

**OBSTRUCTIONS DURING INSTALLATION OF TEMPORARY COFFERDAMS AND
ROADWAY PROTECTION SYSTEMS – Item No.**

Non-Standard Special Provision

The Contactor is advised of the presence of cobbles and boulders encountered at the creek bed, especially at the inlet and outlet of the existing southern culvert at approximately Station 13+096; as well as cobbles inferred to be encountered within the existing embankment fill.

Consideration of the presence of these cobbles and boulders must be made in the selection of appropriate equipment/tools during installation of temporary cofferdams and roadway protection systems.

WORKING SLAB – Item No.

Non-Standard Special Provision

Amendment to OPSS.PROV 902, November 2010

Construction Specification for Excavating and Backfilling - Structures

902.07.05.02 Excavation for Foundations

Section 902.07.05.02 of OPSS.PROV 902 shall be amended by the addition of the following after the second paragraph:

The subgrade soils within the footprint of the proposed culvert(s) may be susceptible to disturbance and loosening/softening from construction traffic and ponded water.

If the footings are not placed on the prepared subgrade within four hours of its inspection and approval, a concrete working slab of 20 MPa compressive strength at 28-days with minimum thickness of 100 mm, shall be placed on the foundation subgrade. A minimum 75 mm thick uncompacted levelling pad consisting of Granular 'A' material (OPSS.PROV 1010) or concrete fine aggregate (meeting the grading requirements specified in OPSS.PROV 1002) shall be provided on top of the concrete working slab if a concrete culvert(s) is constructed at the site.

OBSTRUCTIONS – Item No.

Non-Standard Special Provision

Amendment to OPSS 902, November 2010

Construction Specification for Excavating and Backfilling - Structures

902.07.05 Excavation

902.07.05.02 Excavation for Foundations

Section 902.07.05.02 of OPSS 902 shall be amended by the addition of the following:

The Contactor is advised of the presence of cobbles and boulders encountered at the creek bed, especially at the inlet and outlet of the existing southern culvert at approximately Station 13+096; as well as cobbles inferred to be encountered within the existing embankment fill.

Consideration of the presence of these cobbles and boulders must be made in the selection of appropriate equipment and procedures for excavations.

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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