FOUNDATION INVESTIGATION AND DESIGN REPORT

Highway 66, Station 16+083, Township of Gauthier Culvert Replacement
Ministry of Transportation, Ontario
GWP 5210-14-00

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PART A

FOUNDATION INVESTIGATION REPORT

HIGHWAY 66, STA 16+083, TOWNSHIP OF GAUTHIER

CULVERT REPLACEMENT

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 5210-14-00

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services related to the replacement of the culvert on Highway 66 at Station 16+083, in the Township of Gauthier, approximately 1.0 km west of Yost Road, Ontario. The Key Plan of the general location of this section of Highway 66 and the location of the investigated area are shown on Drawing 1.

The purpose of this investigation is to establish the subsurface conditions at the culvert replacement site by borehole drilling with laboratory testing carried out on selected soil samples.

The Terms of Reference (TOR) and the scope of work for the foundation investigation are outlined in MTO's Request for Proposal, dated February 2018, and the subsequent clarifications/addenda, which forms part of the Consultant's Assignment Number 5017-E-0039 for this project. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for this project dated November 2018.

2.0 SITE DESCRIPTION

It should be noted that the orientation (i.e., north, south, east, west) stated in the text of the report is typically referenced to project north and therefore may differ from magnetic north shown on Drawing 1. For the purpose of this report, Highway 66 is oriented in a west-east direction with the culvert positioned perpendicular to the highway generally in a north-south orientation. At the culvert location, the creek flows in a north to south direction.

The existing structure consists of a 1.2 m high by 1.3 m wide span 24.6 m long Creosote Timber Culvert (CTC). The culvert inlet (north end) and outlet (south end) inverts are at approximately Elevations 282.7 m and 282.5 m, respectively. The highway grade at the culvert location is at approximately Elevation 285.4 m and the highway embankment is about 2.7 m to 2.9 m high relative to the culvert inlet and outlet invert, respectively. In general, the topography within the vicinity of the culvert consists of relatively flat, forested terrain.

At the time of the subsurface exploration field work, the embankment side slopes appeared to be grass covered and stable, with no signs of slope instability or roadway settlement although a longitudinal and a transverse crack of the pavement surface is evident in the culvert area. The ground surface conditions at select locations of the culvert area are shown on Photographs 1 to 4.

3.0 INVESTIGATION PROCEDURES

Field work for this subsurface exploration was carried out on May 13 and 14, 2019, during which time five boreholes (Boreholes C256-1 to C256-5) were advanced at the approximate locations shown on Drawing 1. Boreholes C256-1 to C256-3 were advanced from the roadway surfaces/shoulders through the roadway embankment and Boreholes C256-4 and C256-5 were advanced near the south and north toes of the highway embankment adjacent to the culvert outlet and inlet, respectively. The boreholes were advanced using a track mounted CME-55LC drilling rig supplied and operated by George Downing Estate Drilling (Downing) of Grenville-Sur-La-Rouge, Quebec. Traffic control, where required, was performed in accordance with MTO's Ontario Traffic Control Manual Book 7 – Temporary Conditions.

The boreholes were advanced using 108 mm I.D. Hollow Stem Augers. Soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers driven by an automatic or cathead hammer in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586). In situ vane shear tests were carried out in cohesive soils for determination of the undrained shear strength, in accordance with Standard Test Method for Field Vane Shear Test in Saturated Fine Grained Soils (ASTM 2573) using an MTO standard “N”-size vane. The groundwater level inside the augers was observed open completion of the drilling operations. The boreholes were backfilled upon completion in accordance with Ontario Regulation 903 (wells) as amended. The boreholes drilled through the paved section of Highway 66 were capped at ground surface using cold patch asphalt.

Field work was supervised on a full-time basis by a member of Golder’s technical staff who: located the boreholes in the field; arranged for the clearance of underground services; supervised the drilling and sampling operations; logged the boreholes; and examined the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder’s geotechnical laboratory in Sudbury for further examination and laboratory testing. Index and classification testing consisting of water content determinations, grain size distributions, and Atterberg limits was carried out on selected soil samples. The geotechnical laboratory testing was completed according to ASTM and MTO LS standards, as applicable. One soil sample was submitted to Bureau Veritas Laboratories (formerly Maxxam) of Mississauga, an accredited analytical laboratory, for testing a suite of corrosivity indicator parameters.

The as-drilled borehole locations were measured relative to highway chainages/station marked on the pavement by a member of our technical staff and converted into northing/easting coordinates on the plan drawing. The ground surface elevations at the borehole locations were surveyed by Golder relative to the highway and culvert centreline, with the elevation of the centrelines provided by AECOM. The MTM NAD 83-CSRS CBN v6-2010.0 (Zone 12) northing and easting coordinates, geographical coordinates, ground surface elevations referenced to Geodetic datum, and borehole depths at each borehole location are presented on the borehole records in Appendix A and summarized below.

Borehole Number	MTM NAD 83 Northing (m) (Latitude)	MTM NAD 83 Easting (m) (Longitude)	Ground Surface Elevation (m)	Borehole Depth (m)
C256-1	5331091.7 (48.112667)	392465.2 (-79.822574)	285.6	21.0
C256-2	5331081.1 (48.112571)	392477.3 (-79.822414)	285.6	16.5
C256-3	5331102.7 (48.112765)	392465.3 (-79.822571)	285.3	16.5
C256-4	5331080.4 (48.112565)	392465.5 (-79.822572)	284.5	10.4
C256-5	5331104.7 (48.112781)	392482.9 (-79.822334)	284.1	10.4

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain Study (NOEGTS)[1] mapping, the culvert site is located within a glaciolacustrine plain, with the subsoils consisting primarily of clay.

Based on geological mapping (MNDM)[2], the site is underlain by mafic to intermediate metavolcanics rocks.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the summary results of in situ and laboratory testing are given on the Record of Borehole sheets contained in Appendix A. The plotted results of geotechnical laboratory testing are contained in Appendix B. The results of the in-situ field tests (i.e., SPT 'N'-values and in situ vane shear strengths) as presented on the Record of Borehole sheets and discussed in Section 4.2 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profiles shown on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The results of the analytical laboratory testing (by Bureau Veritas Laboratories) are summarized in Section 4.4 and the detailed laboratory testing report is included in Appendix B.

The subsurface conditions will vary between and beyond the borehole locations, however, the factual data presented on the Record of Borehole Sheets governs any interpretation of the site conditions. A summary description of the soil deposits and groundwater conditions encountered in the boreholes is provided below. It should be noted that the interpreted stratigraphy shown on Drawing 1 is a simplification of the subsurface conditions.

4.2.1 Asphalt/Fill

An approximately 120 mm thick layer of asphalt pavement was encountered in Boreholes C256-2 and C256-3 at Elevations 285.6 m and 285.3 m, respectively. A 0.4 m to 3.0 m thick layer of embankment fill, consisting of an upper 0.2 m to 0.4 m thick layer of sand and gravel in Boreholes C256-1 to C256-3, and C256-5, underlain by a 1.9 m to 2.9 m thick layer of sand in Boreholes C256-2 and C256-3, was encountered below the asphalt in Boreholes C256-2 and C256-3 and at ground surface in Boreholes C256-1 and C256-5.

The SPT "N"-values measured within the non-cohesive sand fill layer range from 3 blows to 78 blows per 0.3 m of penetration, indicating a very loose to very dense compactness condition. However, the upper portion of the fill was frozen at the time of the investigation and therefore the SPT "N"-values measured within the upper portion of the sand fill layer may not be representative of the in-situ compactness condition of the fill.

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[1] Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41PNE.

[2] Ontario Ministry of Northern Development and Mines. Bedrock Geology of Ontario, East-Central Sheet. Map 2543.

4.2.2 Organic Silt/Peat

A 0.8 m thick deposit of organic silt was encountered at ground surface in Borehole C256-4 at Elevation 284.5 m. A 1.4 m and 1.1 m thick deposit of amorphous peat was encountered beneath the organic silt and fill in Boreholes C256-4 and C256-5, respectively, at Elevation 283.7 m.

The SPT “N”-values measured within the amorphous peat deposit are 2 blows per 0.3 m of penetration, indicating a very soft consistency.

4.2.3 Sand

A 1.5 m to 3.4 m thick deposit of non-cohesive sand was encountered underlying the fill in Boreholes C256-1 to C256-3, and underlying the peat deposit in Boreholes C256-4 and C256-5, between Elevations 283.4 m and 282.3 m.

The SPT “N”-values measured within the sand deposit range from 1 blow to 8 blows per 0.3 m of penetration, indicating a very loose to loose compactness condition.

Grain size distribution analysis was carried out on four samples of the sand deposit and the results are presented on Figure B-1 in Appendix B. The natural moisture content measured on samples of the sand deposit ranges from about 23 per cent to 27 per cent.

4.2.4 Silt

A 0.8 m thick deposit of non-cohesive silt was encountered underlying the sand deposit in Boreholes C256-4 and C256-5, at Elevations 280.8 m and 280.4 m, respectively.

The SPT “N”-values measured within the silt deposit are 2 blows and 5 blows per 0.3 m of penetration, indicating a very loose to loose compactness condition.

Grain size distribution analysis was carried out on one sample of the silt deposit and the result is presented on Figure B-2 in Appendix B. The natural moisture content measured on one sample of the silt deposit is about 27 per cent.

4.2.5 Sandy Silt to Silt and Sand

A 4.2 m to 5.7 m thick deposit of non-cohesive sandy silt to silt and sand was encountered underlying the sand deposit in Boreholes C256-1 to C256-3 and underlying the silt deposit in Boreholes C256-4 and C256-5, between Elevations 280.8 m and 279.5 m.

The SPT “N”-values measured within the sandy silt to silt and sand deposit range from 0 blows (weight of hammer – WH) to 11 blows per 0.3 m of penetration indicating that the deposit has a very loose to compact compactness condition.

Grain size distribution analysis was carried out on four samples of the silt and sand portion of the deposit and the results are presented on Figure B-3 in Appendix B. The natural moisture content measured on samples of the sandy silt to silt and sand deposit ranges from about 25 per cent to 29 per cent.

4.2.6 Silt to Clayey Silt

A 1.7 m to 4.9 m thick deposit of silt to clayey silt was encountered underlying the sandy silt to silt and sand deposit in Boreholes C256-1 to C256-5, between Elevations 275.8 m and 275.1 m. Boreholes C256-4 and C256-5 were terminated within the silt to clayey silt deposit at a depth of 10.4 m below ground surface.

The SPT “N”-values measured within the silt to clayey silt deposit range from 0 blows (weight of hammer – WH) to 6 blows per 0.3 m of penetration. In-situ field vane tests carried out within the deposit measured undrained shear strengths ranging from about 77 kPa to about 85 kPa, with one value greater than 100 kPa, and a sensitivity of about 2. The SPT “N”-values, together with the field vane test results, suggest that the deposit has a stiff to very stiff consistency / very loose to loose compactness condition.

Grain size distribution analysis was carried out on three samples of the silt to clayey silt deposit and the results are presented on Figure B-4 in Appendix B. Atterberg limit testing was carried out on five samples from this deposit: one sample tested non-plastic; and four samples measured liquid limits ranging from about 20 per cent to 24 per cent, plastic limits ranging from about 15 per cent to 17 per cent, and plasticity indices ranging from about 3 per cent to 7 per cent. The Atterberg limit test results are shown on Figure B-5 in Appendix B and indicate that the deposit ranges from a non-plastic silt, to silt of slight plasticity to clayey silt of low plasticity. The natural moisture content measured on samples of the silt to clayey silt deposit ranges from about 23 per cent to 30 per cent.

4.2.7 Varved Clay and Clayey Silt

A 1.4 m to 6.4 m thick cohesive deposit of varved clay and clayey silt, trace sand, was encountered below the silt to clayey silt deposit in Boreholes C256-1 to C256-3, between Elevations 271.7 m and 270.5 m. Boreholes C256-1 to C256-3 were terminated within this deposit between Elevations 269.1 m and 264.6 m.

The SPT “N”-values measured within the varved clay and clayey silt deposit range from 0 blows (weight of hammer – WH) to 4 blows per 0.3 m of penetration. In-situ field vane tests carried out within the deposit measured undrained shear strengths ranging from about 43 kPa to 91 kPa and a sensitivity of about 2.0. The SPT “N”-values, together with the field vane test results, suggest that the varved deposit has a firm to stiff consistency.

Grain size distribution testing was carried out on two samples of the combined varved clay and clayey silt and the results are presented on Figure B-6. Atterberg limit testing was carried out on three samples from the varved deposit and measured liquid limits ranging from about 24 per cent to 56 per cent, plastic limits ranging from about 15 per cent to 23 per cent, and plasticity indices ranging from about 9 per cent to 34 per cent. The Atterberg limit test results are shown on Figure B-7 in Appendix B and indicate that the deposit (combined clay and clayey silt varves) ranges from clayey silt of low plasticity to clay of high plasticity (with clayey silt and clay varves). The natural moisture content measured on samples of the combined varved clay and clayey silt deposit ranges from about 28 per cent to 55 per cent.

4.3 Groundwater Conditions

The unstabilized groundwater levels measured inside the augers upon completion of drilling are summarized below. Groundwater and creek water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

Borehole No.	Depth to Unstabilized Groundwater Level (m)	Approximate Groundwater Elevation (m)
C256-1	1.5	284.1
C256-2	1.3	284.3
C256-3	1.4	283.9
C256-4	0.7	283.8
C256-5	0.5	283.6

4.4 Analytical Laboratory Testing Results

Analytical testing was carried out on a sample of the sand deposit recovered from Borehole C256-1 (Sample 4). The soil sample was submitted to Bureau Veritas Laboratories of Mississauga, Ontario for corrosivity testing. The analytical laboratory test results are summarized below, and the detailed analytical laboratory test report is included in Appendix B.

Borehole No.	Borehole Sample No.	Depth (m)	Parameters					
			Resistivity (ohm-cm)	Electrical Conductivity (µmho/cm)	Soluble Sulphate (SO4) Content (µg/g)	Chloride (Cl) Content (µg/g)	Sulphide (µg/g)	pH
C256-1	4	3.0 – 3.6	22,000	46	<20[1]	<20[1]	<0.30[1]	6.30

Notes:
1. The sulphate, chloride, and sulphide concentrations are below the reportable detection limits of 20 µg/g, 20 µg/g and 0.30 µg/g, respectively.

Redox potential testing was carried out on the sample noted above and yielded a value of -95.6 mV. The redox potential laboratory test report, provided by Eurofins Environmental Testing, is presented in Appendix B.

5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Mathew Riopelle, under the overall direction of Mr. André Bom, P.Eng., an Associate of Golder. This Foundation Investigation Report was prepared by Ms. Anastasia Poliacik, P.Eng., a geotechnical engineer with Golder. Mr. André Bom, P.Eng., reviewed the report. Mr. Jorge Costa, P.Eng., an MTO Foundations Designated Contact and Senior Consultant with Golder, conducted an independent quality control review of this report.

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PART B

FOUNDATION DESIGN REPORT
HIGHWAY 66, STA 16+083, TOWNSHIP OF GAUTHIER
CULVERT REPLACEMENT
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5210-14-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations related to the replacement of the culvert on Highway 66 at Station 16+083, in the Township of Gauthier, approximately 1.0 km west of Yost Road, Ontario. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current subsurface exploration. The discussion and recommendations presented are intended to provide the designer with sufficient information to assess feasible foundation alternatives and culvert types and to design the proposed replacement culvert. This foundation investigation report, discussion and recommendations are intended for the use of the Ministry of Transportation, Ontario (MTO) and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part A (Foundation Investigation) of the 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 the 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 Proposed Culvert Alignment and Installation Options

The existing structure consists of a 1.2 m high by 1.3 m wide span 24.6 m long Creosote Timber Culvert (CTC). The culvert inlet (north end) and outlet (south end) inverts are approximately Elevations 282.7 m and 282.5 m, respectively. The highway grade at the culvert location is approximately Elevation 285.4 m and the highway embankment is about 2.7 m to 2.9 m high relative to the culvert inlet and outlet invert, respectively, and the thickness of soil cover is therefore about 1.5 m to 1.7 m.

Based on the drawings provided by AECOM via email on July 2, 2019, and our site observations during the foundation exploration work, the existing culvert crosses the Highway 66 embankment on a perpendicular alignment, and we understand from AECOM that the proposed replacement culvert will cross the highway on or near the same alignment and the proposed culvert will consist of a 1.2 m high by 1.8 m wide box, with similar invert elevations to the existing structure (i.e., Elevation 282.7 m and 282.5 m). Assuming a 0.2 m thick base slab, the proposed replacement culvert will be founded at about Elevation 282.5 m and 282.3 m at the culvert inlet (north end) and outlet (south end), respectively. The excavation for the proposed culvert replacement will extend to about Elevation 282.2 m and 282.0 m to accommodate a 300 mm thick bedding layer.

We understand from AECOM that a temporary roadway protection system is being considered for staging of the culvert replacement in open cut, and that a permanent grade raise or widening of the roadway embankment is not required.

6.2 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the *Canadian Highway Bridge Design Code* (CHBDC, 2014) and its *Commentary*, Highway 66, the culvert and its foundation system at Station 16+083 are expected to carry medium traffic volumes and their performance will have potential impacts on other transportation corridors; hence, the culvert foundation system is classified as 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 Part A of the report), 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 ultimate limit state (ULS) and serviceability limit state (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, as applicable.

6.3 Assessment of Alternative Culvert Installation Methods

Alternative methods of culvert installation, such as by a trenchless method and open cut construction have been considered for this site, as presented in Table 1, attached. Given the subsurface conditions at this site (such as a groundwater level present at about the trenchless/tunnel obvert level, very loose to compact sand subgrade or very loose to very dense sand fill/native sand mixed-face conditions), required culvert size to accommodate the estimated flows (the existing 1.2 m high by 1.3 m wide culvert is reportedly undersized), resulting limited/reduced thickness of soil cover on a larger piper culvert (a 1.2 m high by 1.8 m wide box being about equivalent to a 1.7 m diameter culvert and potentially requiring a 1.9 m diameter liner), it is considered that a trenchless installation method is not feasible for this site. Open cut construction is considered suitable to accommodate either a box culvert (1.2 m high by 1.8 m wide) or an equivalent size (for flow) pipe culvert (1.7 m diameter), although a pipe culvert would result in much less soil cover being available.

Based on the above considerations and comparison of alternative culvert types and construction methods, a concrete box culvert is considered most suitable as the replacement structure at this site. Recommendations for the foundation/geotechnical design of a box culvert are provided below; as well as for a pipe culvert in the event that such a structure is preferred or is more appropriate, given other considerations beyond foundation/geotechnical aspects.

6.4 Box Culvert Foundations

6.4.1 Founding Level

It is understood that the invert level of the proposed box culvert (i.e., the top of the base slab) will be about the existing invert level (the culvert inlet and outlet inverts are approximately Elevations 282.7 m and 282.5 m, respectively). Assuming a 0.2 m thick base slab, the proposed replacement culvert will be founded at about Elevation 282.5 m and 282.3 m and the culvert inlet (north end) and outlet (south end), respectively. It is recommended that the box culvert and levelling pad be constructed on a minimum 300 mm thick bedding layer over the native very loose to loose sand deposit.

It is not necessary to found a pre-cast box culvert at or below the standard depth of frost penetration for frost protection purposes, as pre-cast box structures are tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur.

Where any sub-excavation is required, the sub-excavated areas should be backfilled with granular material meeting OPSS.PROV 1010 (*Aggregates*) Granular 'A' or Granular 'B' Type II, placed and compacted, in accordance with OPSS.PROV 501 (*Compacting*), as amended by SP 105S22. In wet conditions, it is recommended that Granular B Type II be used as sub-excavation backfill and bedding.

6.4.2 Geotechnical Resistances

A 1.8 m wide box culvert box culvert, 24.6 m long, placed on a 300 mm thick bedding layer over properly prepared subgrade, at the proposed founding elevations noted above, should be designed based on a factored ultimate geotechnical resistance of 100 kPa and a factored serviceability geotechnical resistance (for 25 mm of settlement) of 50 kPa. The factored serviceability geotechnical resistance considers both the influence factor and the SLS factor from CHBDC (2014).

The factored geotechnical resistances and corresponding settlement are dependent on the culvert base width, depth of embedment, configuration, and applied loads; the geotechnical resistances should, therefore, be reviewed if the selected culvert width or founding elevation differ from those given above. In addition, these geotechnical resistances are provided for loads applied perpendicular to the base surface of the culvert; where applicable, inclination of the load should be taken into account in accordance with Section 6.10.4 and Section C6.10.4 of CHBDC (2014) and its Commentary.

6.4.3 Resistance to Lateral Load/Sliding Resistance

Resistance to lateral forces/sliding between the pre-cast concrete box culvert and the subgrade should be calculated in accordance with Section 6.10.5 of the CHBDC (2014) applying the appropriate consequence and degree of site understanding factors as noted in Section 6.3.1. For a precast concrete box culvert founded on a compacted granular bedding layer, the sliding resistance may be calculated based on the unfactored coefficient of friction, tan Φ', which can be taken as follows, as interpreted from NAVFAC (1982):

- Precast concrete box culvert to compacted granular bedding (Granular 'A' or Granular 'B' Type II): $\tan \delta = 0.5$

6.5 Lateral Earth Pressures for Design

The lateral earth pressures acting on the walls of the culvert will depend on the type and method of placement of the backfill materials, the nature of the soils 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:

- Select, free draining granular fill meeting the specifications of OPSS.PROV 1010 (*Materials Specification for Aggregates*) Granular 'A' or Granular 'B' Type II, should be used as backfill behind the culvert walls and on top of the culvert as per OPSD 803.010 (*Backfill and Cover for Concrete Culverts).* Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (*Compacting*), as amended by SP 105 S22.

- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the walls, in accordance with the CHBDC (2014) Section 6.12.3 and Figure 6.6. Hand-operated compaction equipment should be used to compact the backfill soils, immediately behind the walls as per OPSS.PROV 501, as amended by SP 105 S22. Other surcharge loadings should be accounted for in the design, as required.

- For wingwalls or headwalls if required at this site, (retaining walls that are restrained), granular fill should be placed in a zone with the width equal to at least 2.4 m (equivalent to the depth of frost penetration as interpreted from OPSD 3090.100 (*Foundation Frost Penetration Depth for Northern Ontario*), behind the back of the wall on Figure C6.20(a) of the Commentary to the CHBDC (2014). For unrestrained walls, fill should be placed within the wedge-shaped zone defined by a line drawn flatter than 1 horizontal to 1 vertical (1H:<1V) extending up and back from the rear face of the footing or pile cap on Figure C6.20(b) of the Commentary to the CHBDC (2014).

- For restrained walls in box culvert design, granular fill should be placed in a zone with the width equal to at least 2.4 m behind the back of the wall (in accordance with Figure C6.20(a) of the *Commentary* to the *CHBDC 2014*). The pressures acting on the culvert walls/wingwalls-headwalls are based on the adjacent embankment fill material 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
Sand	20 kN/m^3	0.50	0.33

If the culvert structure does not allow lateral yielding, at-rest earth pressures should be assumed for the foundation design. If the culvert structure allows for lateral yielding, active earth pressures should be used in the foundation design. 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).

6.6 Box Culvert Construction by Open Cut Excavation

6.6.1 Settlement and Stability

Provided the existing / proposed reconstructed embankment is not widened or raised during or following culvert replacement, settlement of the foundation soils beneath the culvert is not anticipated to be a concern. If an embankment grade raise or widening is ultimately required, a settlement analysis of the culvert/embankment foundation soils should be carried out.

Global stability analyses of the reconstructed embankment in the culvert area, with side slopes reconstructed at an inclination of 2 Horizontal to 1 Vertical (2H:1V), were carried out using the commercially available program SLIDE 2018, produced by Rocscience, Inc., employing the Morgenstern-Price method of analysis. As the replacement culvert is not a structural culvert, a target minimum Factor of Safety of 1.3 is considered appropriate for adoption for the design of the embankment slopes under static conditions. As the subsurface soils underling the culvert area are also comprised of a deposit of varved clayey silt and clay underlying the silt and sand deposit and silt to clayey silt deposit, a reduction factor of 25 per cent was applied to the undrained shear strength measured by the field vanes in this cohesive stratum, as interpreted from published technical literature on stratified clay deposits by Lo and Milligan (1967), although the cohesive deposit is located at a depth much greater than the lowest required Factor of Safety (FoS = 1.3) slope failure surface.

The parameters used in the global slope stability analyses and the results of the analyses carried out for the short-term (temporary) condition and for the long-term (permanent) condition are shown on Figures 1 and 2, respectively. The slope stability analyses indicate that a Factor of Safety greater than 1.3 was calculated against global instability. The proposed reconstructed embankment (not widened or raised) will be stable from a slope stability perspective if it is reconstructed of granular material and with side slopes at an inclination no steeper than 2H:1V.

6.6.2 Bedding / Embedment and Cover

Box culvert bedding and cover should be placed in accordance with OPSD 803.010 (*Backfill and Cover for Concrete Culverts*) and OPSS 422 (*Precast Reinforced Concrete Box Culverts*).

It is recommended that a minimum 300 mm thick layer of OPSS.PROV 1010 (*Aggregates*) Granular ‘A’ or Granular ‘B’ Type II material be used for bedding and cover purposes. In addition, the 75 mm thick uncompacted levelling pad should consist of OPSS.PROV 1010 Granular ‘A’ or concrete fine aggregate meeting the gradation requirements specified in OPSS.PROV 1002 (*Aggregates – Concrete*).

All unsuitable, deleterious, organic materials, and fill materials are to be removed from the base/below the culvert (and bedding) footprint along its entire alignment. Based on the foundation exploration and existing/proposed culvert invert levels and 300 mm thick bedding layer, the subgrade under the replacement culvert will consist of native very loose to loose sand and is considered suitable for support of the bedding materials and culvert.

All bedding, embedment and cover materials should be placed and compacted in accordance with OPSS.PROV 501 (*Compacting*), as amended by Special Provision (SP) 105 S22.

6.6.3 Trench Backfill

The excavated embankment fill materials from the culvert site will vary in quality and composition and are comprised of sand and gravel fill to sand fill, potentially organic silt / peat, and native sand. The existing organic silt and peat should not be reused as backfill for reconstruction of the highway embankment in the immediate vicinity or over the new culvert.

Granular material which meets the requirements of OPSS.PROV 1010 (Aggregates) Select Subgrade Material (SSM) or Granular ‘B’ Type I may be used as trench backfill. These materials should also be placed and compacted in accordance with OPSS.PROV 501 (Compacting), as amended by SP 105 S22.

6.7 Circular Pipe Culvert Installation by Open Cut Excavation

6.7.1 Settlement and Stability

As presented in Section 6.6.1, provided the existing / proposed reconstructed embankment is not widened or raised during or following culvert replacement, settlement of the foundation soils beneath the culvert is not anticipated to be a concern. If an embankment grade raise is required to provide for additional cover thickness to the culvert, a settlement analysis of the culvert / embankment foundation soils should be carried out.

Provided the existing embankment height is maintained, the north and south side slopes are reconstructed no steeper than at 2H:1V, and excavation side slopes graded to match the existing 8H:1V and 3.5H:1V, respectively, following culvert replacement, the embankment side slopes will be stable from a global stability perspective.

6.7.2 Bedding / Embedment and Cover

Pipe culverts (less than 3 m diameter) should be designed in general accordance with the MTO Gravity Pipe Design Guidelines (2014). It is not necessary to found a pipe culvert below the depth of frost penetration, as pipe culverts are generally tolerant of small magnitudes of movement related to freeze-thaw cycles.

A circular concrete pipe culvert installed by open cut method should be completed in accordance with Ontario Provincial Standard Drawing (OPSD) 802.031 (*Rigid Pipe Bedding, Cover and Backfill)*. If the replacement culvert is to consist of a corrugated steel pipe (CSP) or plastic (HDPE or PVC) pipe installed by open cut method, it should be constructed in accordance with OPSD 802.010 (*Flexible Pipe Embedment and Backfill*) for Type 3 soil.

The bedding layer should be at least 300 mm thick under rigid pipe, and 500 mm under flexible pipe. The bedding shall be compatible with the type / class of pipe material, the surrounding subsoil and anticipated loading conditions, and should consist of OPSS.PROV 1010 (Aggregates) Granular ‘A’ or Granular ‘B’ Type II material.

All unsuitable, deleterious, organic materials and fill materials are to be removed from the base/below the pipe culvert (and bedding) footprint along its entire alignment. Based on the foundation exploration and existing/proposed culvert invert levels, 300 mm to 500 mm thick bedding layer, the subgrade under the replacement culvert will consist of firm to stiff varved clay and clayey silt and is considered suitable for support of the culvert and bedding materials.

From the top of the bedding to 300 mm above the top of the culvert, Granular ‘A’ should be used as cover around the culvert. All bedding, embedment, and cover materials should be placed, and culvert construction carried out in accordance with OPSS.PROV 421 (*Pipe Culvert Installation in Open Cut*) and OPSS 401.PROV (*Trenching, Backfilling and Compacting*), and the bedding/embedment/cover soil should be compacted in accordance with OPSS.PROV 501 (*Compacting*), as amended by SP 105 S22. If the bottom of the excavation is wet and dewatering is not satisfactorily maintaining the water level sufficiently below the base of the excavation to allow compaction, it is recommended that OPSS.PROV 1010 (*Aggregates*) Granular ‘B’ Type II material be used as additional sub-excavation backfill below the bedding, as may be required. In wet subgrade conditions, Granular ‘B’ Type II should be used for bedding.

6.7.3 Trench Backfill

The excavated embankment fill materials from the culvert site will vary in quality and composition and are comprised of sand and gravel fill to sand fill, potentially organic silt / peat, and native sand. The existing organic silt and peat should not be reused as backfill for reconstruction of the highway embankment in the immediate vicinity or over the new culvert.

Granular material which meets the requirements of OPSS.PROV 1010 (Aggregates) SSM or Granular ‘B’ Type I may be used as trench backfill. These materials should also be placed and compacted in accordance with OPSS.PROV 501 (Compacting), as amended by SP 105 S22.

6.8 Analytical Testing of Existing Soil

The results of analytical tests on one sample of the native sand deposit recovered from Borehole C256-1 is summarized in Section 4.4. The potential for sulphate attack and corrosion are discussed in the following paragraphs; however, it is ultimately up to the designer to determine the appropriate construction materials, including the exposure class, and ensuring that all aspects of CSA A23.1-14 (2014) Section 4.1.1 “Durability Requirements” are followed when designing concrete elements. The culvert should be designed with consideration given to Table 7.1 of the MTO Gravity Pipe Design Guidelines (2014).

6.8.1 Potential for Sulphate Attack

The analytical test results were compared to CSA A23.1-14 Table 3 ("Additional requirements for concrete subjected to sulphate attack") for the potential sulphate attack on concrete. The water soluble-sulphate concentration measured in the soil sample is less than the reportable detection limit of 0.002 per cent, which is below the exposure class of S-3 (Moderate) and is considered Negligible according to Table 7.2 in the MTO Gravity Pipe Design Guidelines (2014). Therefore, based on the test result for the sample, when the designer is selecting the exposure class for the culvert/structure, the effects of sulphates from within the near surface/culvert invert native soil(s) may not need to be considered. However, as the culvert will extend under the roadway shoulders and be exposed to de-icing salt, concrete should be designed for a “C” type exposure class as defined by CSA A23.1-14 Table 1.

6.8.2 Potential for Corrosion

The soil has a pH of 6.3 and according to the MTO Gravity Pipe Design Guidelines (2014), the pH is not considered detrimental to culvert durability. The resistivity is 22,000 ohm-cm, which indicates that the soil corrosiveness is very low (10,000>R>6,000 ohm-cm), as per Table 3.2 of the MTO Gravity Pipe Design Guidelines (2014). It is also noted that sulphide concentration is below the reportable detection limit of 0.30 µg/g in the analyzed test sample, and sulphide is considered very corrosive to cast iron/steel materials (Cashman and Preene, 2001).

6.9 Construction Considerations

6.9.1 Open Cut Excavation

The proposed open cut excavation through the embankment and into the subgrade to the base of the culvert bedding level associated with the removal of the existing culvert and construction of the new culvert by open cut and re-construction of the embankment, will advance through the granular embankment fill and into a native soils, below the groundwater level. Where space permits for an open cut excavation into these materials, the excavation must be carried out in accordance with the guidelines outlined in the *Occupation Health and Safety Act* (OHSA) for Construction Activities. Above the water table, the existing fill materials are classified as Type 3 soil, according to OHSA and temporary excavations (i.e., those which are open for a relatively short time period) should be made with side slopes no steeper than 1 horizontal to 1 vertical (1H:1V). Below the water table, the existing fill materials and underlying native soils are classified as Type 4 soil, according to OHSA and temporary excavations (i.e., those which are open for a relatively short time period) into this soil type should be made with side slopes no steeper than 3 horizontal to 1 vertical (3H:1V).

Depending upon the construction procedures adopted by the contractor, groundwater seepage conditions, and weather conditions at the time of construction, some local flattening of the slopes of open cut excavations may be required, especially in looser/softer zones or where localized seepage is encountered. Further, layering of soils and the effectiveness of the contractor’s dewatering systems could affect the OHSA classification and, therefore, the classification of soils for OHSA purposes must be made at the time the excavation is open and can be directly observed during construction.

6.9.2 Groundwater / Surface Water Control

The groundwater level is expected to be above the proposed culvert founding level along most of its alignment and therefore the excavation for the culvert replacement should be expected to extend below the groundwater level. The groundwater should be lowered to at least 1 m below the base of the excavation to maintain basal stability and allow for construction in dry conditions. Groundwater may be controlled by providing an active dewatering system consisting of an adequate number of sumps and pumps installed and operated in advance/during the excavation, or in combination with temporary support systems such as a sheet piling wall and/or cofferdams (as required).

The contractor is responsible for the assessment of dewatering requirements, which depends on their chosen method of open cut excavation for replacement, as well as on the method and procedure for construction/operation/maintenance and decommissioning. The contractor is also responsible for confirming that the radius of groundwater drawdown does not impact the existing embankment and any surrounding features.

Surface water should be directed away from open excavation areas to prevent ponding of water that could result in disturbance and weakening of the subgrade and/or affect construction or lining operations, as applicable. Depending on the water flow through the watercourse at the time of construction and staging/diversion requirements/limitations, temporary cofferdams may also be required.

Groundwater and surface water control will be required for excavation and construction of the culvert replacement. Dewatering operations must be in accordance with OPSS.PROV 517 (*Dewatering*) and MTO’s Special Provision 517F01 (*Temporary Flow Passage System*) recommending that the design be carried out by an engineer.

6.9.3 Temporary Protection Systems

In order to replace the existing culvert and allow at least one lane of live traffic to pass during construction, temporary protection systems will likely be required. The temporary excavation protection and support systems should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*) as amended by SP 105 S09. The lateral movement of the protection systems should meet Performance Level 2 as specified in OPSS.PROV 539, provided that any utilities, if present, can tolerate this magnitude of deformation.

It is anticipated that a driven interlocking steel sheet pile system is suitable at this site. The contractor may alternatively use a soldier pile and lagging system; however, the site would need to be adequately dewatered prior to installation of the lagging boards as the cohesionless fills and saturated sand deposit will not have adequate stand-up time to permit installation of the lagging boards.

The sheet piles or soldier piles will need to extend to a sufficient depth to provide the necessary passive resistance for the retained soil height, plus any surcharge loads behind the protection system. Lateral support to the sheet pile wall or soldier pile wall could be provided in the form of struts, rakers, or temporary anchors, if and as required to carry out the design of the system.

Vibratory equipment for the installation of temporary protection systems may be used at this site provided that it does not impact the embankment or nearby buried infrastructure or structures, if present. The installation of temporary protection systems by vibratory equipment should be monitored to ensure the vibration levels produced by such construction activity are within tolerable limits and in consultation with the infrastructure/utility and property owners within the zone of influence of the site.

While the selection and design of the temporary protection system will be the responsibility of the contractor, the following information is provided to MTO and its designers to aid in the assessment of feasible alternatives.

Stratigraphic Unit	Bulk Unit Weight, γ (kN/m^3)	Angle of Internal Friction, φ (degrees)	Undrained Shear Strength, s_u (kPa)	Lateral Earth Pressure Coefficients[1/2]		
				Active, K_a	At-rest, K_o	Passive, K_p[3]
Existing Embankment Fill – Very loose to very dense sand and gravel and sand	20	31	-	0.32	0.48	3.12
Very loose to loose organic silt / peat	16	28	-	0.36	0.53	2.77
Very loose to loose sand / very loose silt / very loose to compact sand and silt to silt and sand	19	29	-	0.35	0.52	2.88
Very loose to loose / stiff to very stiff silt to clayey silt	18	29	40	0.35	0.52	2.88
Firm to stiff varved clay and clayey silt	18	28	30[4]	0.36	0.53	2.77

Notes:

1. The design groundwater level may be assumed to be Elevation 284 m near the inlet and outlet, based on the ground surface and water levels in the boreholes.
2. 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.
3. The total passive resistance below the base of the excavation (i.e., adjacent to the temporary protection system) 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 CHBDC (2014) to account for the fact that a large strain would be required for mobilization of the full passive resistance.
4. Derived from the in-situ vane shear test results reduced by 25 per cent for the varved stratum.

It is recommended that the ground surface extending back/upwards from the top of the protection system to the existing Highway 66 surface be graded to an inclination no steeper than 2H:1V. This should be shown on the Contract staging drawings.

The loading from construction equipment as well as any material stockpiles within a distance defined by a 1 horizontal to 1 vertical line drawn from the bottom of the excavation to the existing ground surface should be included as a surcharge in the design of the temporary protection system.

Consideration could be given to either partial or full removal of the temporary protection system upon completion of construction or each stage of construction (as required). Vibration and noise controls during extraction of any temporary systems should meet the same tolerable limits used for installation.

6.9.4 Subgrade Protection

For open cut culvert installation, the subgrade soils will be susceptible to disturbance from construction traffic and/or ponded water. To limit this degradation, it is recommended that the granular bedding layer be placed immediately after preparation and approval of the subgrade.

6.9.5 Embankment Reconstruction

Engineered fill for reconstruction of the embankment after open cut culvert replacement should consist of OPSS.PROV 1010 (*Aggregates*) Granular 'A' or Granular 'B' Type I or SSM material. The embankment fill should be placed and compacted in accordance with OPSS.PROV 501 (*Compacting*), as amended by SP 105 S22, and OPSS.PROV 206 (*Grading*). Embankment side slopes should be constructed no steeper than 2H:1V in granular fill.

6.9.6 Surficial Embankment Stability and Erosion Protection

Depending on the selected embankment reconstruction fill material type, slope geometry, surface treatment and weather conditions (i.e., precipitation, cycles of wetting-drying, and/or freezing-thawing), surficial instability of the embankment side slopes may occur, which could include localized sloughing and erosion. As such, in order to maintain the integrity of the new embankments, erosion protection measures may be required depending on the fill type selected for construction.

Based on the specified material types and hence the gradation envelope for embankment reconstruction materials, granular fill such as OPSS.PROV 1010 (*Aggregates*) Granular 'A', or Granular 'B' Type I, have a low potential for erosion. For embankments constructed of granular fill, erosion control may be limited to seeding following the construction specifications of OPSS 802 (*Topsoil*) and OPSS.PROV 804 (*Seed and Cover*). On-going maintenance for embankments constructed of this material is not expected to be required once the vegetation has been established.

The specification for OPSS.PROV 1010 (*Aggregates*) SSM allows for much more variation in the gradation of the material compared to Granular 'A', or Granular 'B' Type I, and therefore has the potential to be low - erodible to moderate - erodible. Erosion protection for slopes constructed of SSM should consist of erosion control blankets and seeding. Slopes constructed of SSM and properly protected from erosion should require limited on-going maintenance.

7.0 CLOSURE

This Foundation Design report was prepared by Ms. Anastasia Poliacik, P.Eng., a geotechnical engineer of Golder. Mr. André Bom, P.Eng., reviewed the report. Mr. Jorge Costa, P.Eng., an MTO Foundations Designated Contact and Senior Consultant with Golder, conducted an independent and quality control review of the report.

Signature Page

Golder Associates Ltd.

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J. M. A. COSTA
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AB/JMAC/ca

https://golderassociates.sharepoint.com/sites/1809001/deliverables/foundations/2. reporting/r16 - gau 256/3. final/1896349 r-rev0 aecom culvert gau256 hwy 66 fidr 27feb_2020.docx

REFERENCES

Canadian Standards Associations (CSA) Group 2014. Canadian Highway Bridge Design Code and Commentary S6-14.

Canadian Standards Association (CSA), 2014. CSA A23.1-09 Concrete Materials and Methods of Construction (R2014).

Cashman, P.M. and Preene M. (2001) Groundwater Lowering in Construction, A Practical Guide. Spoon Press Publisher.

Lo, K.Y. and Milligan, V. 1967. Journal of the Soil Mechanics and Foundations Division, Vol. 93, Issue 1, Pg. 1-15.

Ministry of Transportation, Ontario, MTO Gravity Pipe Design Guidelines, April 2014.

Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41PNE.

Ontario Ministry of Northern Development and Mines. Bedrock Geology of Ontario, East-Central Sheet. Map 2543.

Ontario Regulation 903 (Wells).

Occupational Health and Safety Act and Regulation for Construction Projects (as amended).

ASTM International:

ASTM D1586 Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils.

ASTM D2573 Standard Test Method for Field Vane Shear Test in Saturated Fine Grained Soils.

Ontario Provincial Standard Drawings (OPSD)

OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less than or Equal to 3.0 m
OPSD 812.010	Flexible Pipe Embedment and Backfill, Earth Excavation
OPSD 802.031	Rigid Pipe Bedding, Cover, And Backfill, Type 3 Soil - Earth Excavation
OPSD 3090.100	Foundation Frost Penetration Depths for Northern Ontario

Ontario Provincial Standard Specifications (OPSS) – Provincial Oriented

OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 401	Construction Specification for Trenching, Backfilling, and Compacting
OPSS.PROV 421	Construction Specification for Pipe Culvert Installation in Open Cut
OPSS.PROV 422	Construction Specification for Precast Reinforced Concrete Box Culverts
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS 802	Construction Specification for Topsoil
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material

Special Provisions

SP 105S22	Amendment to OPSS 501
SP109 S12	Amendment to OPSS 902
SP 105S09	Amendment to OPSS 539

Proprietary Software:

Rocscience Inc.SLIDE 2018

Table 1: Culvert Replacement Alternatives – Station 16+083 Township of Gauthier

Replacement Alternatives	Advantages	Disadvantages	Risks / Consequences
Trenchless Installation (1.7 m dia. equivalent to 1.2 m high by 1.8 m wide flow capacity)	■ Pipe ramming installed without significant removal of soils prior to full casing penetration through embankment. ■ Relatively low cost for pipe ramming. ■ Relatively small site operations footprint. ■ Within size range typical in Ontario. ■ Less traffic disruptions than open cut methods. ■ Various potential installation methods available.	■ Site conditions and pipe/casing size (1.7 m dia. And potentially 1.9 m dia., respectively) potentially preclude installation by HDD, TBM, PTMT, and TBM methods as well as Jack and Bore; likely restricted to Pipe Ramming. ■ Adjacent water body may preclude the use of trenchless. ■ Combination of ground density, final pipe diameter and length of installation may be near the upper limit of feasibility for a single pipe installation. ■ Density of ground in some areas may encourage/require premature removal of soils from within the casing. ■ Obstructions, if encountered, although not present at the boreholes, may require shaft excavation from the surface. ■ Vibrations from pipe driving can lead to densification and settlement of loose granular materials surrounding and overlying the casing/pipe and result in settlement of roadway surface. ■ Alignment control can be difficult when penetrating soils of differing densities. ■ For a 1.7 m dia. Culvert or a 1.9 m dia. Casing, the soil cover thickness is between about 0.8 m and 1.2 m which is insufficient to address MTO's CMO Guidelines for Tunnelling (i.e., min 1.5 m cover) and the cover to pipe diameter ratio is less than 1, precluding a trenchless method.	■ Need for removal of soil from within casings because of driving resistance (binding of casings, weight of spoil, obstructions) could lead to excess ground losses and surface settlement. ■ Nominal cover thickness results in high-risk trenchless crossing. ■ Inadequate soil cover (thickness or ratio to culvert diameter) potentially leading to loss of soil, road heave and/or settlement.
Cut and Cover (Pipe or Box Type Culvert)	■ Risks of ground losses affecting traffic are better controlled than for trenchless methods. ■ Depth of excavation is within typical limits for conventional excavation support, slopes and dewatering systems. ■ With appropriate planning, excavation methods can be adapted to address obstructions (i.e., timber) and soft/loose soils. ■ Can accommodate a culvert of various sizes and alternative type (i.e., pipe of box) to provide the required flow capacity. ■ Box type culvert can be made adequately large to accommodate required flow capacity.	■ Traffic disruption (staging of crossing construction). ■ Roadway protection required for staged excavation. ■ Proactive dewatering required (e.g., vacuum well points). ■ Pipe type culvert (CSP/concrete/HDPE) of adequate size to accommodate the required flow would result in highly reduced cover thickness.	■ Traffic staging problems (e.g., temporary concrete barriers, seasonal construction). ■ Dewatering planning as part of bid may not be adequate and result in real or strategic claims.

MINISTRY OF TRANSPORTATION, ONTARIO

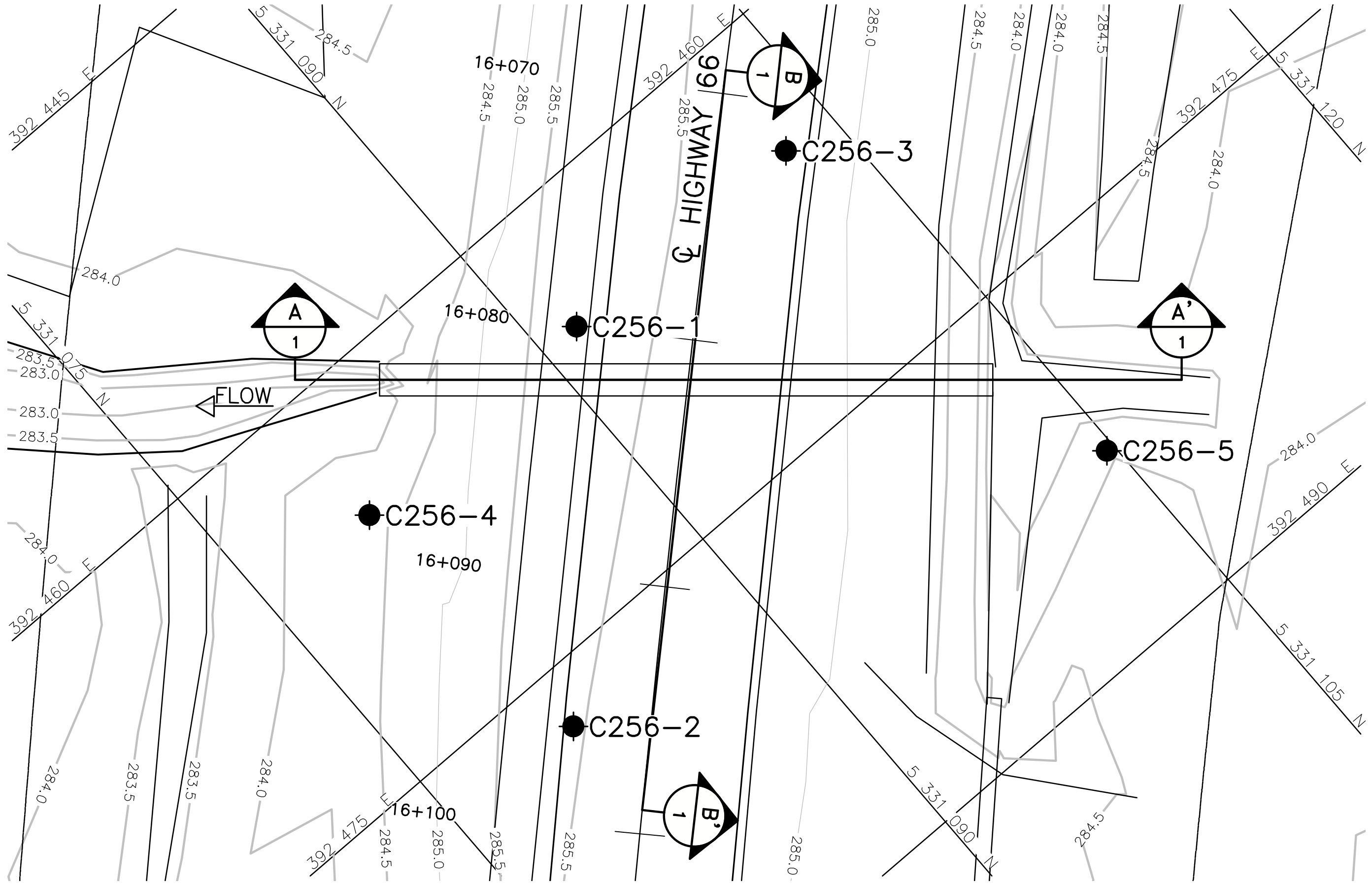
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 5210-14-00

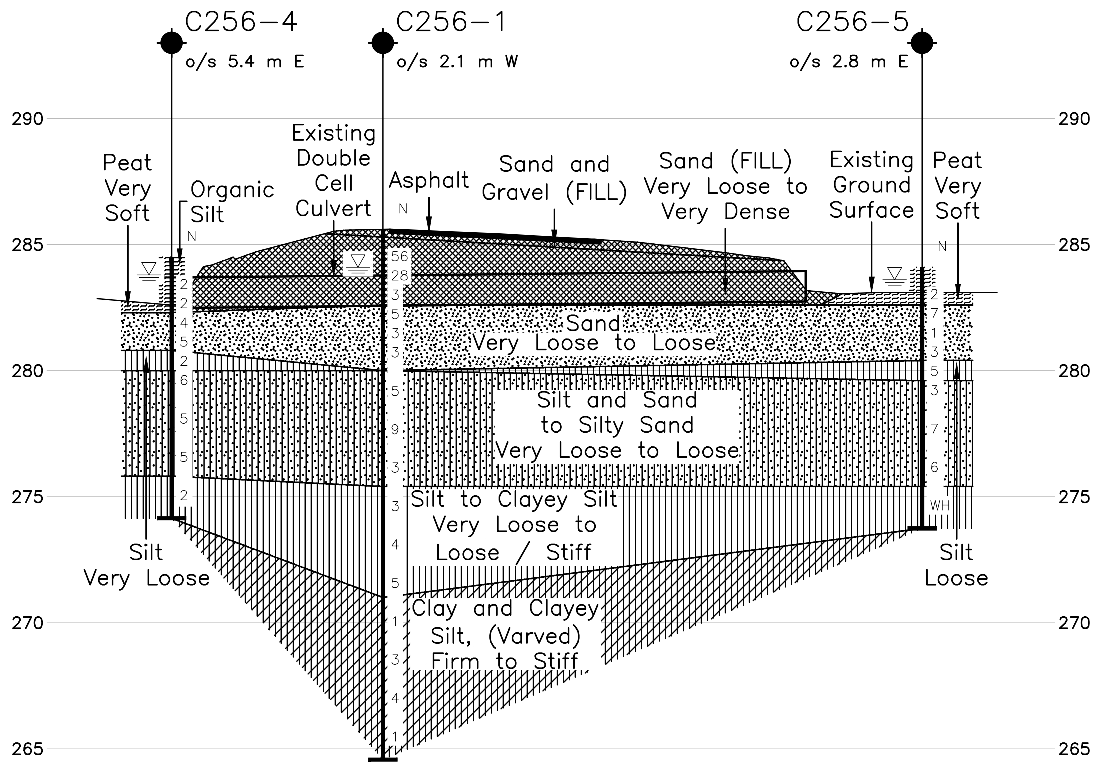
HIGHWAY 66
STATION 16+083
TOWNSHIP OF GAUTHIER CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

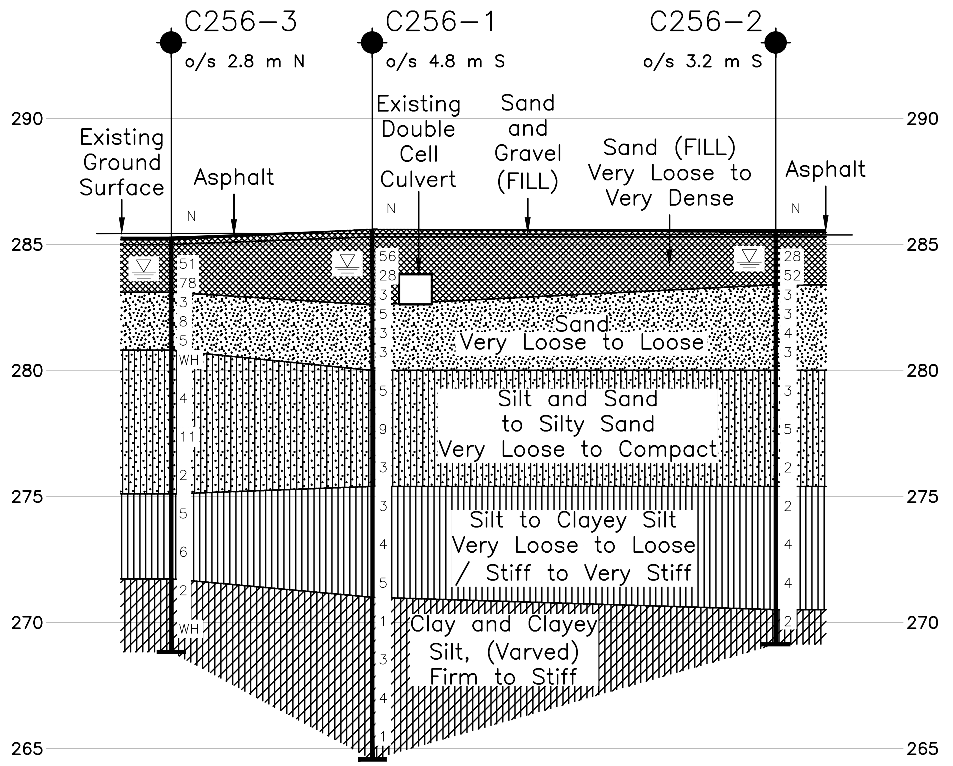
GOLDER



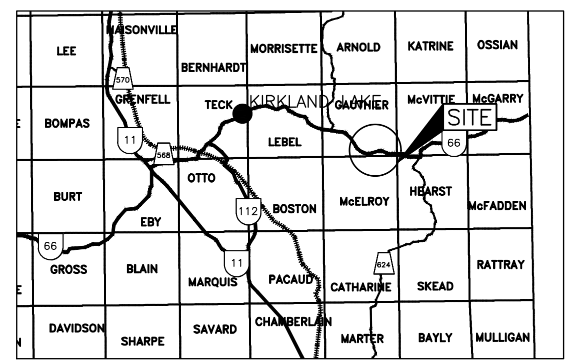
PLAN
SCALE
3 0 3 6 m



CULVERT CENTERLINE PROFILE
A-A' 1
HORIZONTAL SCALE
3 0 3 6 m
3 0 3 6 m
VERTICAL SCALE



HIGHWAY CENTERLINE PROFILE
B-B' 1
HORIZONTAL SCALE
3 0 3 6 m
3 0 3 6 m
VERTICAL SCALE



KEY PLAN
SCALE
10 0 10 20 km

LEGEND

●	Borehole – Current Investigation
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
▽	WL upon completion of drilling

BOREHOLE CO-ORDINATES (NAD 83 MTM ZONE 12)

No.	ELEVATION	NORTHING	EASTING
C256-1	285.6	5331091.7	392465.2
C256-2	285.6	5331081.1	392477.3
C256-3	285.3	5331102.7	392465.3
C256-4	284.5	5331080.4	392465.5
C256-5	284.1	5331104.7	392482.9

J.M.A.COSTA
FEB 20, 2020

A.J.K. BOM
100075715
FEB 25, 2020

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 CALLON DIETZ LTD. drawing file no. gwp52101400b.dwg, received AUGUST 14, 2019.

NO.	DATE	BY	REVISION
.	.	.	.

Geocres No. 32D-27

HWY. 66		PROJECT NO. 1896349	DIST. .
SUBM'D. TB	CHKD. AP	DATE: 2/20/2020	SITE: .
DRAWN: TR	CHKD. AB	APPD. JMAC	DWG. 1

PLOT DATE: February 25, 2020
FILENAME: S:\Clients\MTO\Hwy65&66\99_PROJ\1896349_AECOM_Hwy65-66-566\40_PROD\0016_R16_GAU256\1896349-0016-BG-0001.dwg

Photograph 1: Drilling rig set up at Borehole C256-1, looking south east (May 2019)

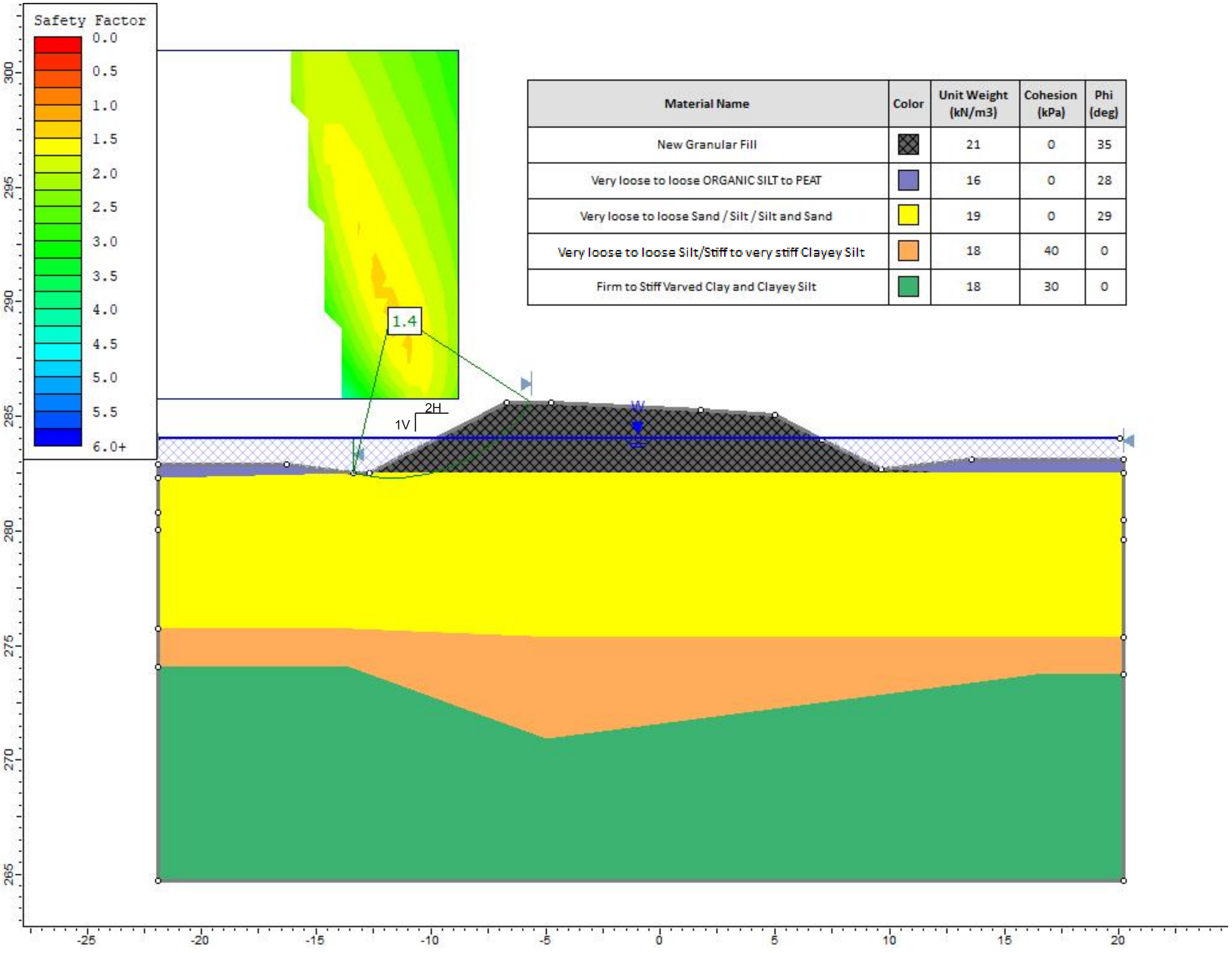
Photograph 2: North End (Inlet) of Culvert (May 2019)

Photograph 3: Drilling rig setup at Borehole C256-5, near Culvert Inlet (May 2019)

Photograph 4: South end (Outlet) of Culvert (May 2018)

Figure 1

Global Stability Analysis – Short-term Condition
Highway 66, Sta. 16+083, Township of Gauthier Culvert



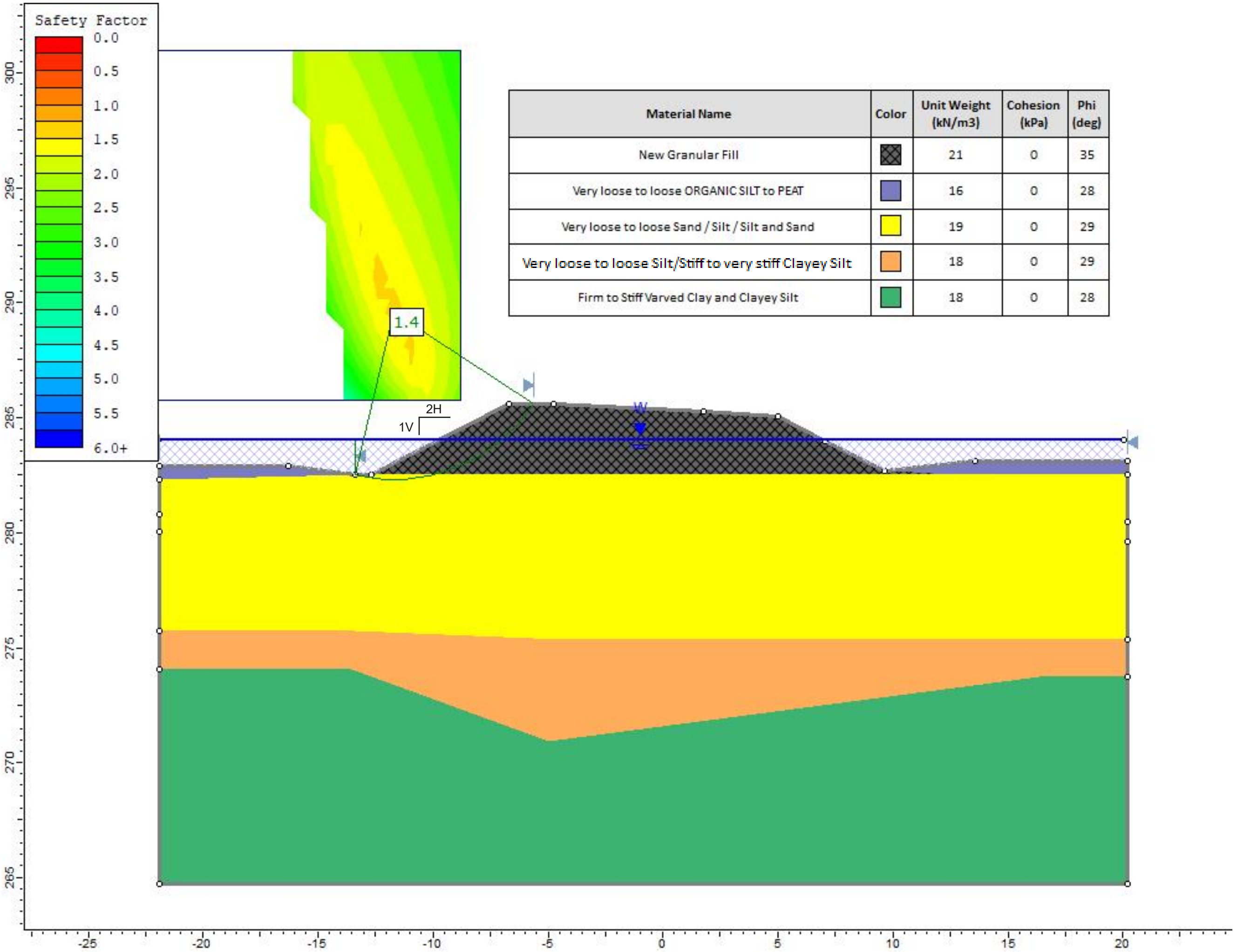
Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)
New Granular Fill	▩	21	0	35
Very loose to loose ORGANIC SILT to PEAT	🟪	16	0	28
Very loose to loose Sand / Silt / Silt and Sand	🟨	19	0	29
Very loose to loose Silt/Stiff to very stiff Clayey Silt	🟧	18	40	0
Firm to Stiff Varved Clay and Clayey Silt	🟩	18	30	0

Date: November 2019
Project No: 1896349-R16

Analysis By: AMP **Reviewed By:** JMAC

Figure 2

Global Stability Analysis – Long-term Condition
Highway 66, Sta. 16+083, Township of Gauthier Culvert



Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)
New Granular Fill	▩	21	0	35
Very loose to loose ORGANIC SILT to PEAT	🟪	16	0	28
Very loose to loose Sand / Silt / Silt and Sand	🟨	19	0	29
Very loose to loose Silt/Stiff to very stiff Clayey Silt	🟧	18	0	29
Firm to Stiff Varved Clay and Clayey Silt	🟩	18	0	28

Date: November 2019
Project No: 1896349-R16

Analysis By: AMP **Reviewed By: JMAC**

APPENDIX A

Record of Boreholes

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS
MINISTRY OF TRANSPORTATION, ONTARIO

PARTICLE SIZES OF CONSTITUENTS

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

MODIFIERS FOR SECONDARY COMPONENTS[1,2]

Percentage by Mass	Modifier
> 35	Use 'and' to combine primary and secondary component (*i.e.,* SAND and gravel)
> 20 to 35	Primary soil name prefixed with "gravelly, sandy" as applicable
> 10 to 20	some (*i.e.,* some sand)
≤ 10	trace (*i.e.,* trace fines)

1. Only applicable to components not described by Primary Group Name.
2. Classification of Primary Group Name based on Unified Soil Classification System (ASTM D2487) for coarse-grained soils; fine-grained soils described per current MTO Soil Classification System.

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Cone Penetration Test (CPT)

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

Dynamic Cone Penetration Resistance (DCPT); N_d:

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

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

SAMPLES

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

SOIL TESTS

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

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

COARSE-GRAINED SOILS

Compactness[1]

Term	SPT 'N' (blows/0.3m)[2]
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	➢ 50

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

FINE-GRAINED SOILS

Consistency

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

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

Field Moisture Condition

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

LIST OF SYMBOLS
MINISTRY OF TRANSPORTATION, ONTARIO

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
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
U	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

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

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

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

RECORD OF BOREHOLE No C256-1

1 OF 2 **METRIC**

PROJECT 1896349

G.W.P. 5210-14-00

DIST

HWY 66

DATUM GEODETIC

LOCATION N 5331091.7; E 392465.2 NAD83 MTM ZONE 12 (LAT. 48.112667; LONG. -79.822574)

BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers

DATE May 14, 2019

ORIGINATED BY MR

COMPILED BY TR

CHECKED BY AB

SOIL PROFILE

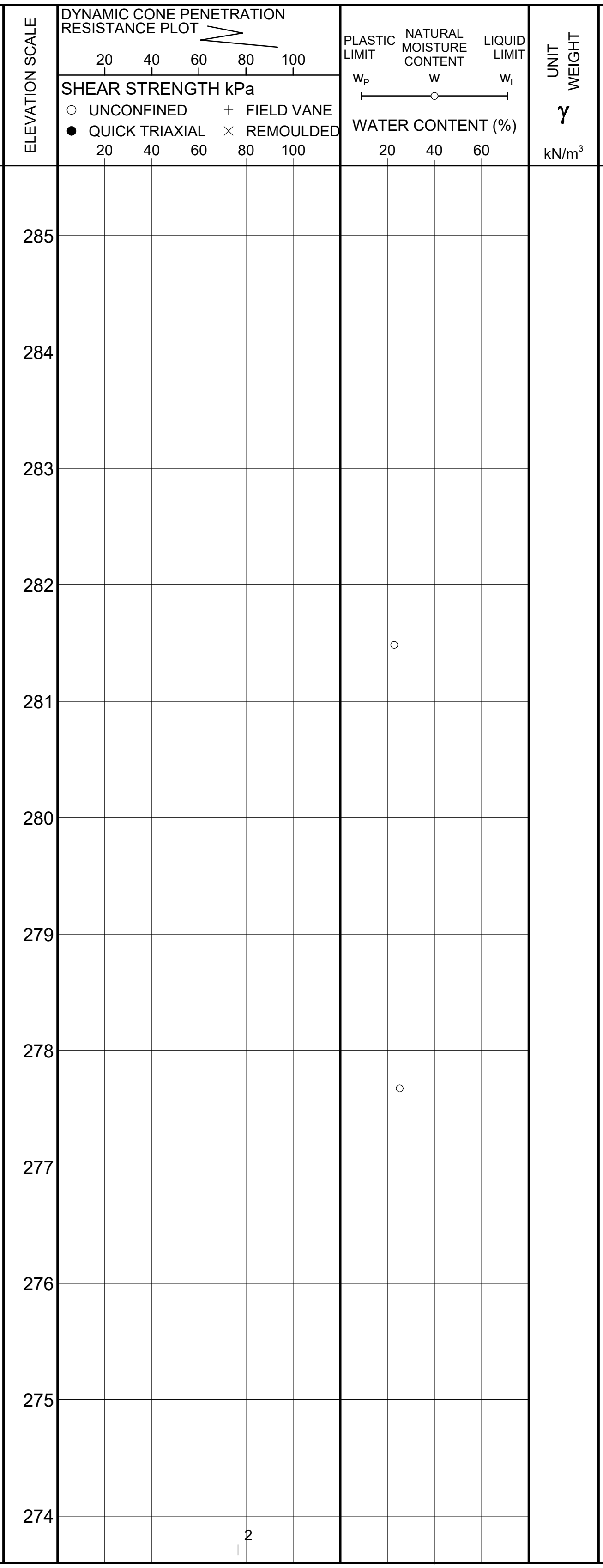
ELEV DEPTH	DESCRIPTION
285.6	GROUND SURFACE
0.0	Sand and gravel (FILL) Brown Frozen
285.3 0.3	Sand, trace gravel (FILL) Very loose to very dense Brown Frozen to wet
282.6 3.0	SAND, trace silt Very loose to loose Grey Wet
280.0 5.6	SILT and SAND, trace to some clay Very loose to loose Grey Wet
275.4 10.2	SILT to CLAYEY SILT, trace to some sand Very loose to loose / stiff Grey Wet

Continued Next Page

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	56				
2	SS	28				
3	SS	3				
4	SS	5				
5	SS	3	0	98	(2)	
6	SS	3				
7	SS	5				
8	SS	9	0	48	45	7
9	SS	3				
10	SS	3				

GROUND WATER CONDITIONS: ▽ (at approx. elev. 284.2)



+ 3, × 3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No C256-1

2 OF 2 **METRIC**

PROJECT 1896349

G.W.P. 5210-14-00

LOCATION N 5331091.7; E 392465.2 NAD83 MTM ZONE 12 (LAT. 48.112667; LONG. -79.822574)

ORIGINATED BY MR

DIST

HWY 66

BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers

COMPILED BY TR

DATUM GEODETIC

DATE May 14, 2019

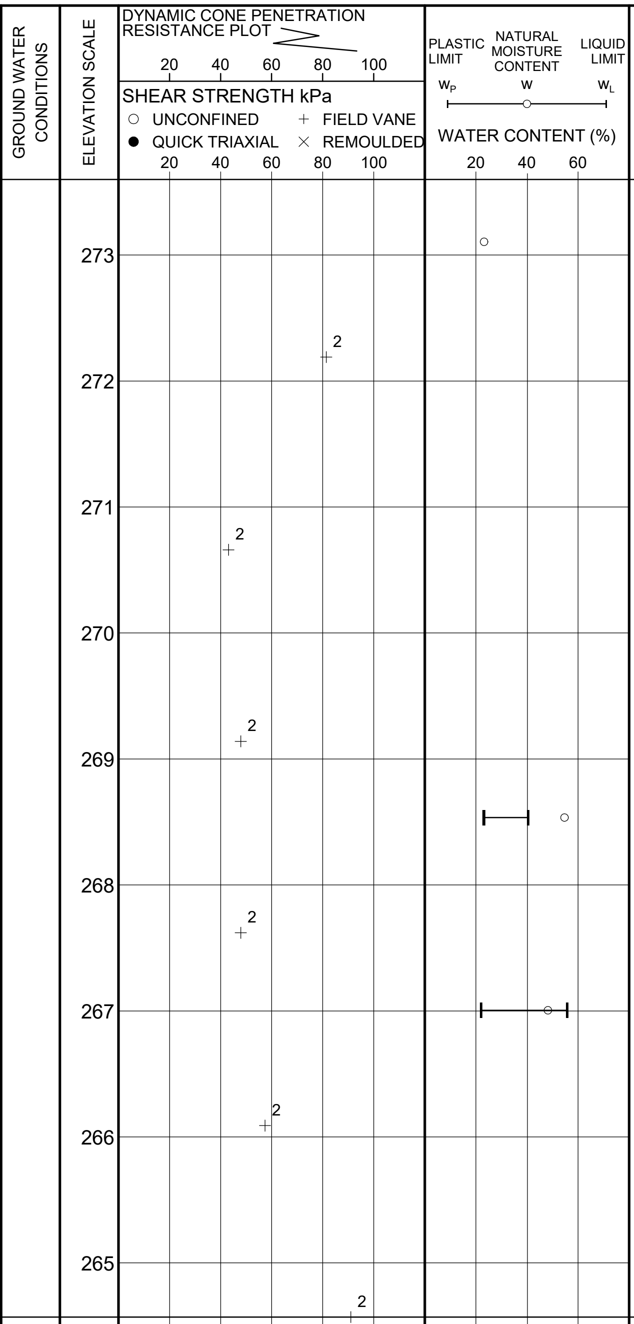
CHECKED BY AB

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	--- CONTINUED FROM PREVIOUS PAGE ---								
	SILT to CLAYEY SILT, trace to some sand Very loose to loose / stiff Grey Wet	11	SS	4	NP	0	10	83	7
		12	SS	5					
271.0 14.6	CLAY and CLAYEY SILT, varved, trace sand Firm to stiff Grey Wet	13	SS	1					
		14	SS	3					
		15	SS	4		0	1	43	56
		16	SS	1					
264.6 21.0	END OF BOREHOLE								

NOTES:

1. Water level measured at a depth of 1.5 m below ground surface (Elev. 284.1 m) inside augers upon completion of drilling.

2. Borehole caved to a depth of 18.3 m below ground surface (Elev. 267.3 m) upon completion of drilling.



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

RECORD OF BOREHOLE No C256-2

1 OF 2 **METRIC**

PROJECT 1896349

G.W.P. 5210-14-00

LOCATION N 5331081.1; E 392477.3 NAD83 MTM ZONE 12 (LAT. 48.112571; LONG. -79.822414)

ORIGINATED BY MR

DIST HWY 66

BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers

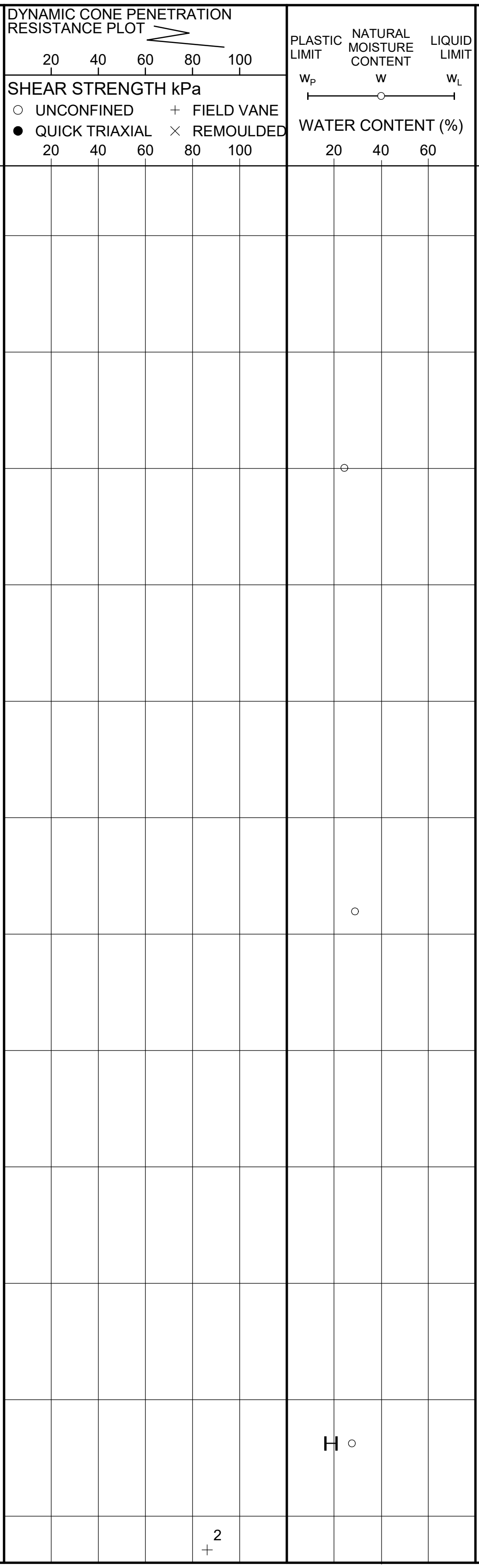
COMPILED BY TR

DATUM GEODETIC

DATE May 13, 2019

CHECKED BY AB

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	GR	SA	SI	CL
285.6	GROUND SURFACE									
0.0	ASPHALT (120 mm)									
	Sand and gravel (FILL)									
0.3	Sand (FILL) Compact to very dense Wet to frozen Brown					285				
		1	SS	28	▽					
		2	SS	52		284				
283.4 2.2	SAND, trace silt Very loose Grey Wet									
		3	SS	3		283	0	93	(7)	
		4	SS	3		282				
		5	SS	4						
		6	SS	3		281				
280.0 5.6	SAND and SILT to Silty SAND, trace clay Very loose Grey Wet					280				
		7	SS	3		279	0	57	40	3
		8	SS	5		278				
						277				
		9	SS	2		276				
275.4 10.2	SILT to CLAYEY SILT, trace sand Very loose to loose / stiff to very stiff Grey Wet					275				
		10	SS	2			0	2	75	23
						274				



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

○3% STRAIN AT FAILURE

RECORD OF BOREHOLE No C256-2

2 OF 2 **METRIC**

PROJECT 1896349

G.W.P. 5210-14-00

LOCATION N 5331081.1; E 392477.3 NAD83 MTM ZONE 12 (LAT. 48.112571; LONG. -79.822414)

ORIGINATED BY MR

DIST HWY 66

BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers

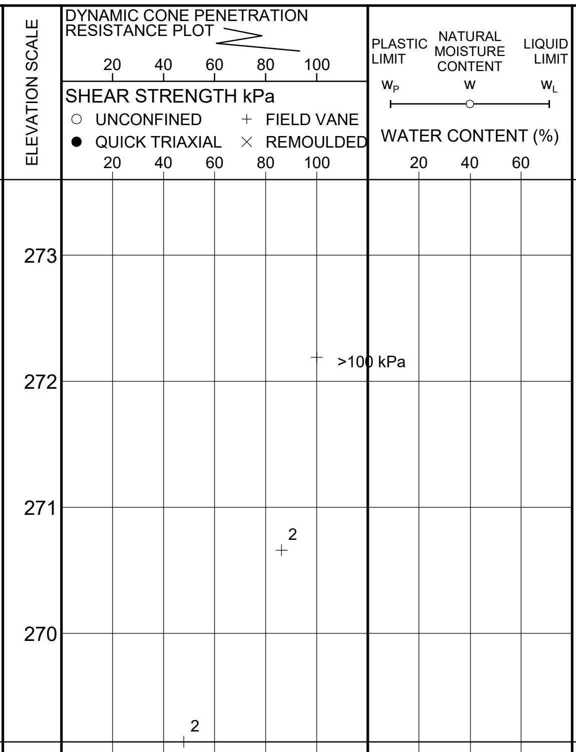
COMPILED BY TR

DATUM GEODETIC

DATE May 13, 2019

CHECKED BY AB

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---							
	SILT to CLAYEY SILT, trace sand Very loose to loose / stiff to very stiff Grey Wet		11	SS	4			
			12	SS	4			
270.5 15.1	CLAY and CLAYEY SILT, varved, trace sand Firm Grey Wet		13	SS	2			
269.1 16.5	END OF BOREHOLE							



NOTES:

1. Water level measured at a depth of 1.3 m below ground surface (Elev. 284.3 m) inside augers upon completion of drilling.

2. Borehole caved to a depth of 3.3 m below ground surface (Elev. 282.3 m) upon completion of drilling.

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

RECORD OF BOREHOLE No C256-3

1 OF 2 **METRIC**

PROJECT 1896349

G.W.P. 5210-14-00

LOCATION N 5331102.7; E 392465.3 NAD83 MTM ZONE 12 (LAT. 48.112765; LONG. -79.822571)

ORIGINATED BY MR

DIST

HWY 66

BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers

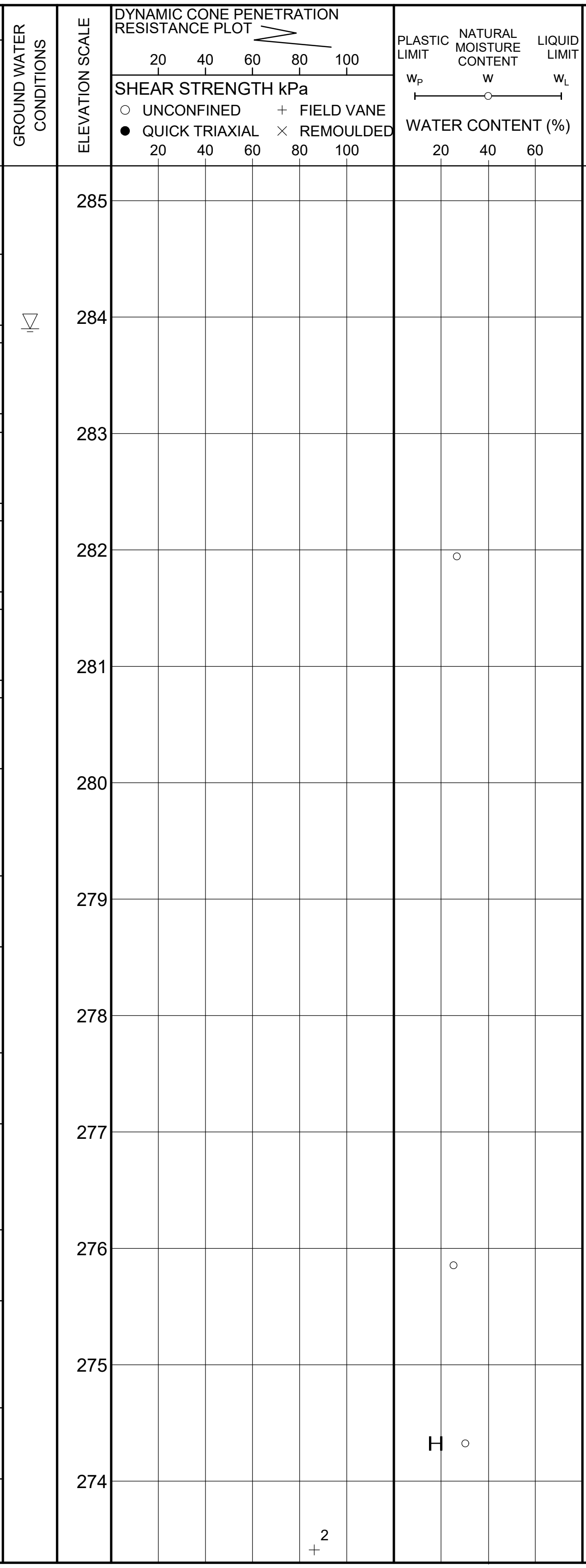
COMPILED BY TR

DATUM GEODETIC

DATE May 14, 2019

CHECKED BY AB

SOIL PROFILE		SAMPLES			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
285.3	GROUND SURFACE							
0.0	ASPHALT (120 mm)							
	Sand and gravel (FILL)							
0.3	Sand, trace gravel, trace silt (FILL) Very dense Brown Frozen	1	SS	51				
		2	SS	78				
283.1 2.2	SAND, trace silt Very loose to loose Brown to grey Wet	3	SS	3				
		4	SS	8	0	98	(2)	
		5	SS	5				
280.8 4.5	SILT and SAND, trace clay Very loose to compact Grey Wet	6	SS	WH				
		7	SS	4				
		8	SS	11				
		9	SS	2	0	37	57	6
275.1 10.2	SILT to CLAYEY SILT, trace sand Loose / Stiff Grey Wet	10	SS	5				



UNIT WEIGHT γ kN/m³

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

○3% STRAIN AT FAILURE

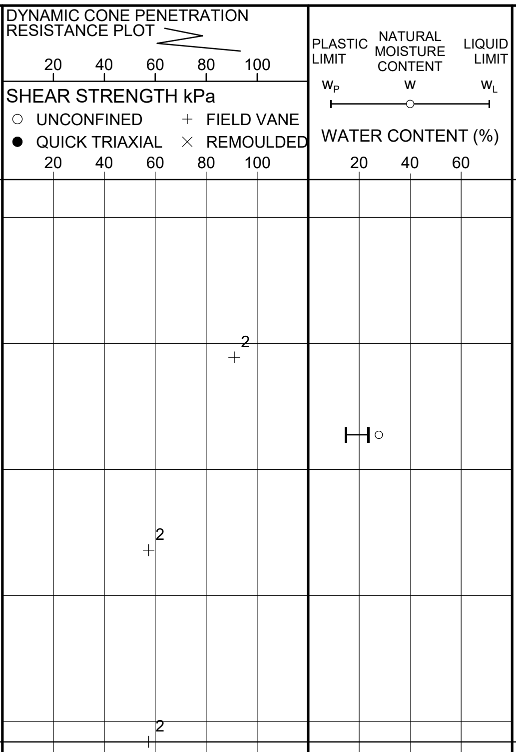
PROJECT 1896349

RECORD OF BOREHOLE No C256-3

2 OF 2 **METRIC**

G.W.P. 5210-14-00
LOCATION N 5331102.7; E 392465.3 NAD83 MTM ZONE 12 (LAT. 48.112765; LONG. -79.822571)
ORIGINATED BY MR
DIST
HWY 66
BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers
COMPILED BY TR
DATUM GEODETIC
DATE May 14, 2019
CHECKED BY AB

SOIL PROFILE			SAMPLES						REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	--- CONTINUED FROM PREVIOUS PAGE ---											
	SILT to CLAYEY SILT, trace sand Loose / Stiff Grey Wet		11	SS	6		273 272					
271.7 13.6	CLAY and CLAYEY SILT, varved, trace sand Stiff Grey Wet		12	SS	2		271		0	2	75	23
			13	SS	WH		270 269					
268.8 16.5	END OF BOREHOLE NOTES: 1. Water level measured at a depth of 1.4 m below ground surface (Elev. 283.9 m) inside augers upon completion of drilling. 2. Borehole caved to a depth of 5.5 m below ground surface (Elev. 279.8 m) upon completion of drilling.											



+3, ×3: Numbers refer to Sensitivity

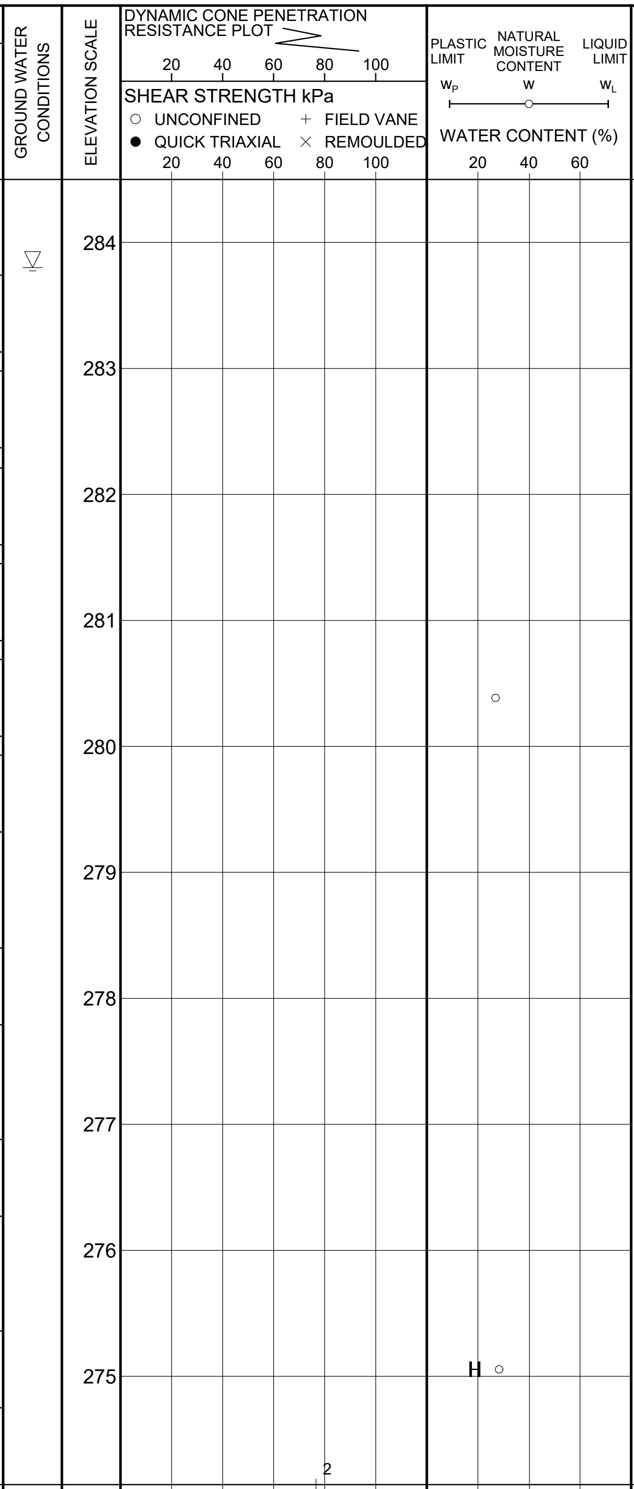
○3% STRAIN AT FAILURE

RECORD OF BOREHOLE No C256-4

1 OF 1 **METRIC**

PROJECT 1896349			
G.W.P. 5210-14-00	LOCATION N 5331080.4; E 392465.5 NAD83 MTM ZONE 12 (LAT. 48.112565; LONG. -79.822572)	ORIGINATED BY MR
DIST	HWY 66	BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers	COMPILED BY TR
DATUM GEODETIC		DATE May 13, 2019	CHECKED BY AB

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
284.5	GROUND SURFACE							
0.0	ORGANIC SILT Black Wet							
283.7 0.8	Amorphous PEAT Very soft Dark brown Wet	1	SS	2				
		2	SS	2				
282.3 2.2	SAND, trace silt Very loose to loose Grey Wet	3	SS	4				
		4	SS	5				
280.8 3.7	SILT, some clay, trace sand Very loose Grey Wet	5	SS	2	0	4	83	13
280.0 4.5	Sandy SILT to SILT and SAND, trace clay Loose Grey Wet	6	SS	6				
		7	SS	5				
		8	SS	5				
275.8 8.7	SILT Very loose Grey Wet	9	SS	2	0	1	84	15
274.1 10.4	END OF BOREHOLE							



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

NOTES:

1. Water level measured at a depth of 0.7 m below ground surface (Elev. 283.8 m) inside augers upon completion of drilling.
2. Borehole caved to a depth of 2.5 m below ground surface (Elev. 282.0 m) upon completion of drilling.

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

RECORD OF BOREHOLE No C256-5

1 OF 1 **METRIC**

PROJECT 1896349

G.W.P. 5210-14-00

LOCATION N 5331104.7; E 392482.9 NAD83 MTM ZONE 12 (LAT. 48.112781; LONG. -79.822334)

ORIGINATED BY MR

DIST HWY 66

BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers

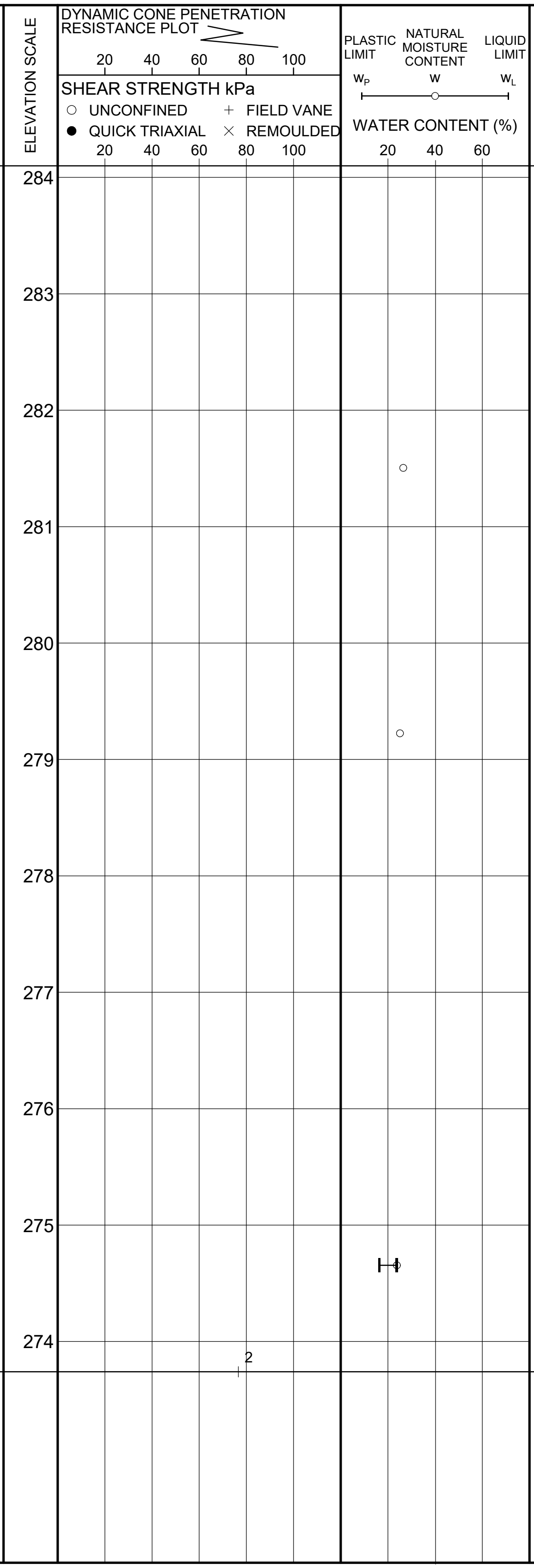
COMPILED BY TR

DATUM GEODETIC

DATE May 14, 2019

CHECKED BY AB

SOIL PROFILE ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
284.1	GROUND SURFACE								
0.0	Sand and gravel (FILL) Brown Moist								
283.7 0.4	Amorphous PEAT Very soft Dark brown Wet	1	SS	2	▽				
282.6 1.5	SAND, trace silt Very loose to loose Brown to grey Wet	2	SS	7					
		3	SS	1		0	97	(3)	
		4	SS	3					
280.4 3.7	SILT Loose Grey Wet	5	SS	5					
279.6 4.5	Sandy SILT to SILT and SAND, trace to some clay Very loose to loose Grey Wet	6	SS	3		0	36	54	10
		7	SS	7					
		8	SS	6					
275.4 8.7	SILT to CLAYEY SILT Stiff Grey Wet	9	SS	WH					
273.7 10.4	END OF BOREHOLE NOTE: 1. Water level measured at a depth of 0.5 m below ground surface (Elev. 283.6 m) inside augers upon completion of drilling. 2. Borehole caved to a depth of 2.4 m below ground surface (Elev. 281.7 m) upon completion of drilling.								



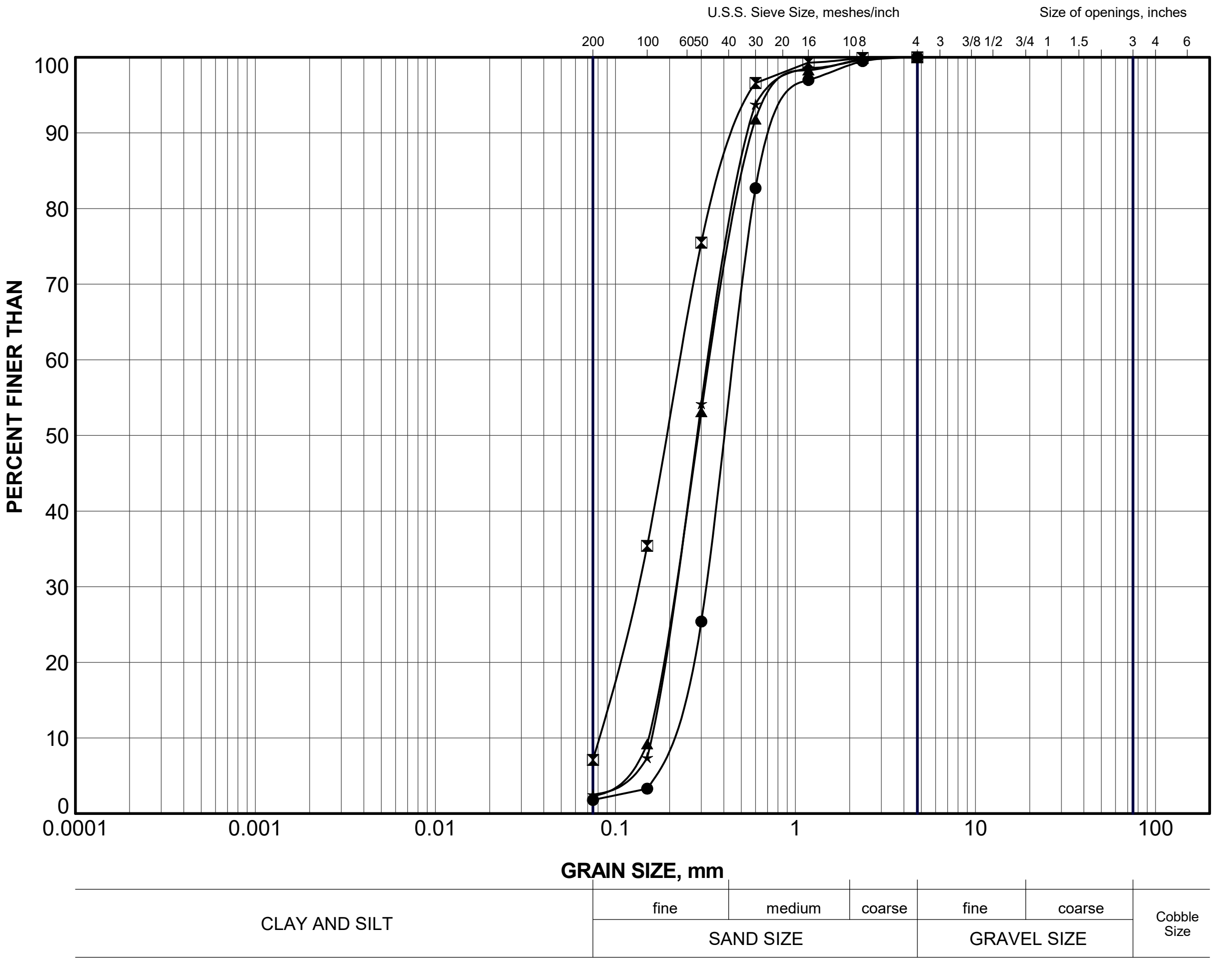
UNIT WEIGHT γ kN/m³

+3, ×3: Numbers refer to Sensitivity

○3% STRAIN AT FAILURE

APPENDIX B

Laboratory Test Results



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C256-1	5	281.5
⧗	C256-2	3	283.0
▲	C256-3	4	282.0
★	C256-5	3	281.5

PROJECT

HIGHWAY 66
STATION 16+083
TOWNSHIP OF GAUTHIER CULVERT

TITLE

GRAIN SIZE DISTRIBUTION

SAND

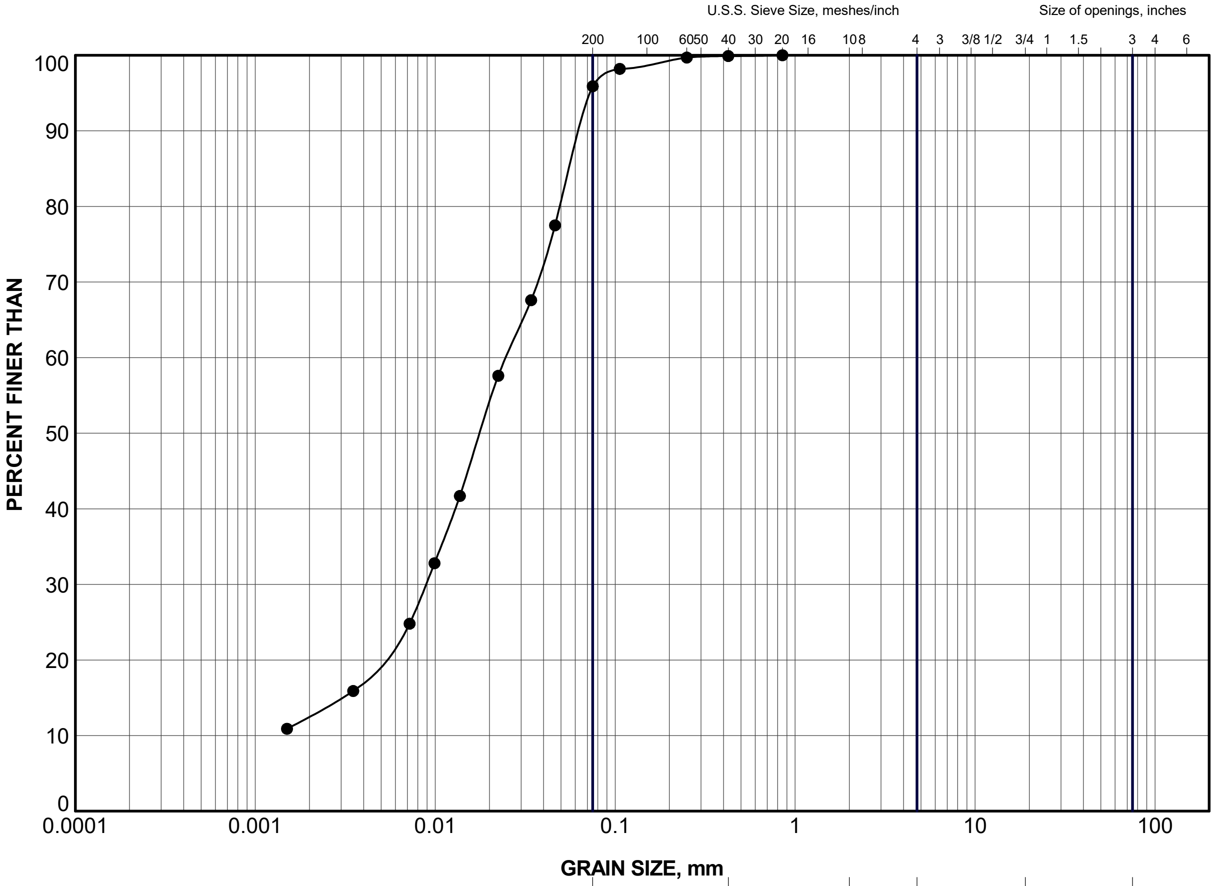
GOLDER

SUDBURY, ONTARIO

PROJECT No.		1896349	FILE No.	1896349.GPJ
DRAWN	TR	Nov 2019	SCALE N/A	REV.
CHECK	AMP	Nov 2019		
APPR	JMAC	Nov 2019		

FIGURE B-1

SUD-MTO GSD GLDR_LDN.GDT



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C256-4	5	280.4

PROJECT

HIGHWAY 66
STATION 16+083
TOWNSHIP OF GAUTHIER CULVERT

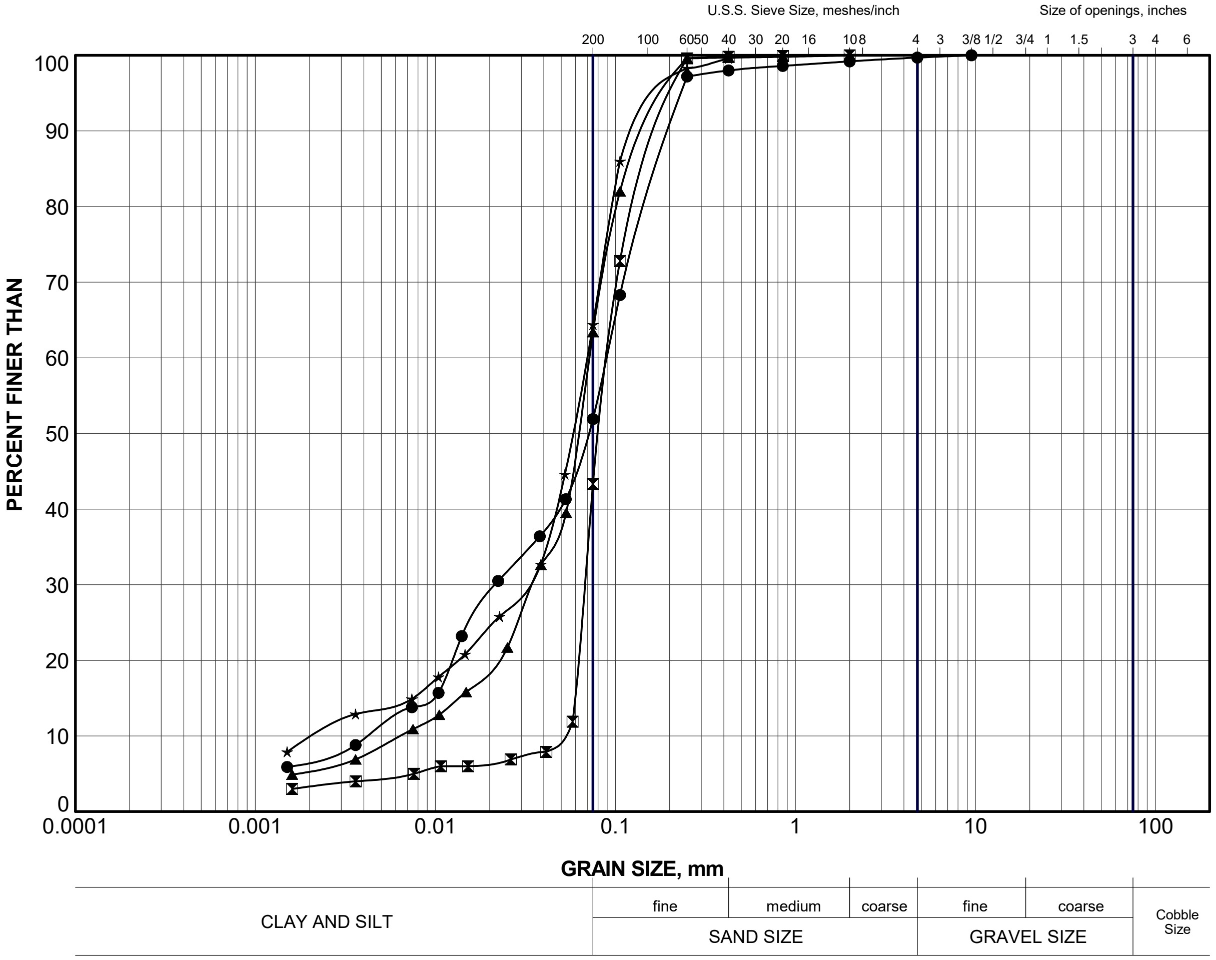
TITLE

GRAIN SIZE DISTRIBUTION
SILT

GOLDER
SUDBURY, ONTARIO

PROJECT No.		1896349	FILE No.	1896349.GPJ
DRAWN	TR	Nov 2019	SCALE N/A	REV.
CHECK	AMP	Nov 2019		
APPR	JMAC	Nov 2019	**FIGURE B-2**	

SUD-MTO GSD GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C256-1	8	277.7
⧗	C256-2	7	279.2
▲	C256-3	9	275.9
★	C256-5	6	279.2

PROJECT

HIGHWAY 66
STATION 16+083
TOWNSHIP OF GAUTHIER CULVERT

TITLE

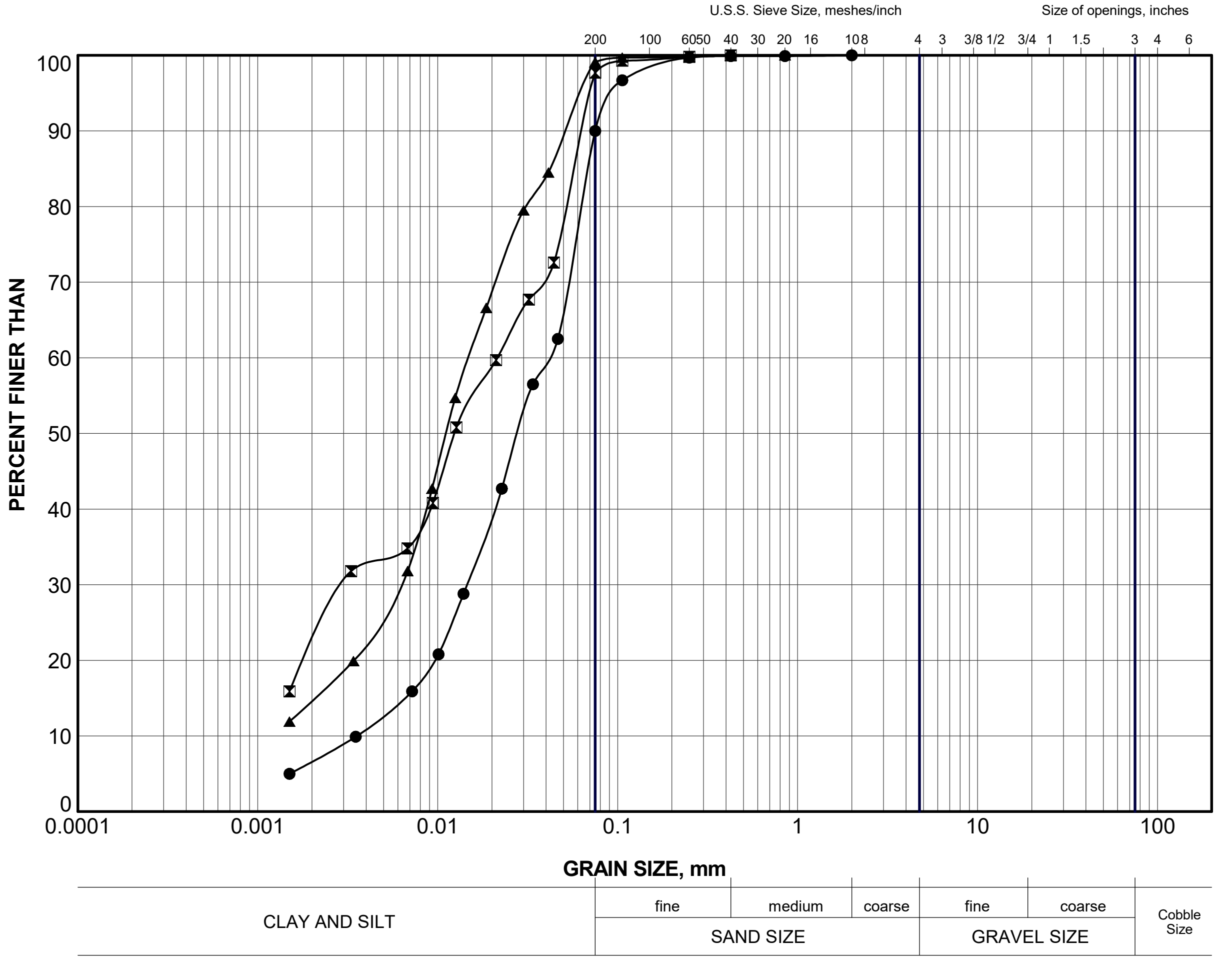
GRAIN SIZE DISTRIBUTION

SILT and SAND

GOLDER
SUDBURY, ONTARIO

PROJECT No.		1896349	FILE No.	1896349.GPJ
DRAWN	TR	Nov 2019	SCALE N/A	REV.
CHECK	AMP	Nov 2019		
APPR	JMAC	Nov 2019	**FIGURE B-3**	

SUD-MTO GSD GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C256-1	11	273.1
⧗	C256-2	10	274.6
▲	C256-4	9	275.1

PROJECT

HIGHWAY 66
STATION 16+083
TOWNSHIP OF GAUTHIER CULVERT

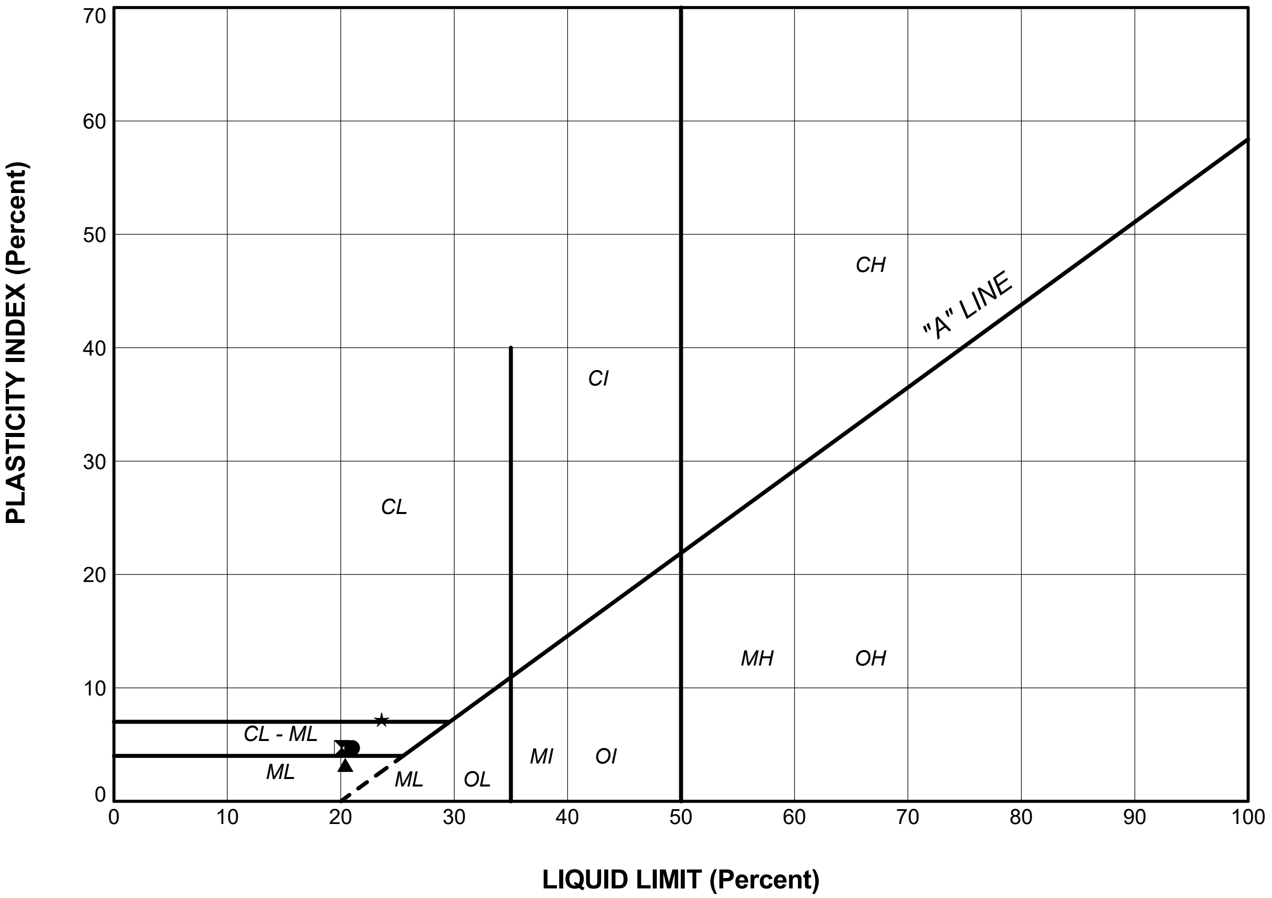
TITLE

GRAIN SIZE DISTRIBUTION
SILT to CLAYEY SILT

GOLDER
SUDBURY, ONTARIO

PROJECT No.		1896349	FILE No. 1896349.GPJ
DRAWN	TR	Nov 2019	SCALE N/A REV.
CHECK	AMP	Nov 2019	
APPR	JMAC	Nov 2019	**FIGURE B-4**

SUD-MTO GSD GLDR_LDN.GDT



SOIL TYPE	**PLASTICITY**
C = Clay	L = Low
M = Silt	I = Intermediate
O = Organic	H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	C256-2	10	21.0	16.3	4.7
⧗	C256-3	10	20.1	15.4	4.7
▲	C256-4	9	20.4	17.2	3.2
★	C256-5	9	23.6	16.4	7.2

PROJECT

HIGHWAY 66
STATION 16+083
TOWNSHIP OF GAUTHIER CULVERT

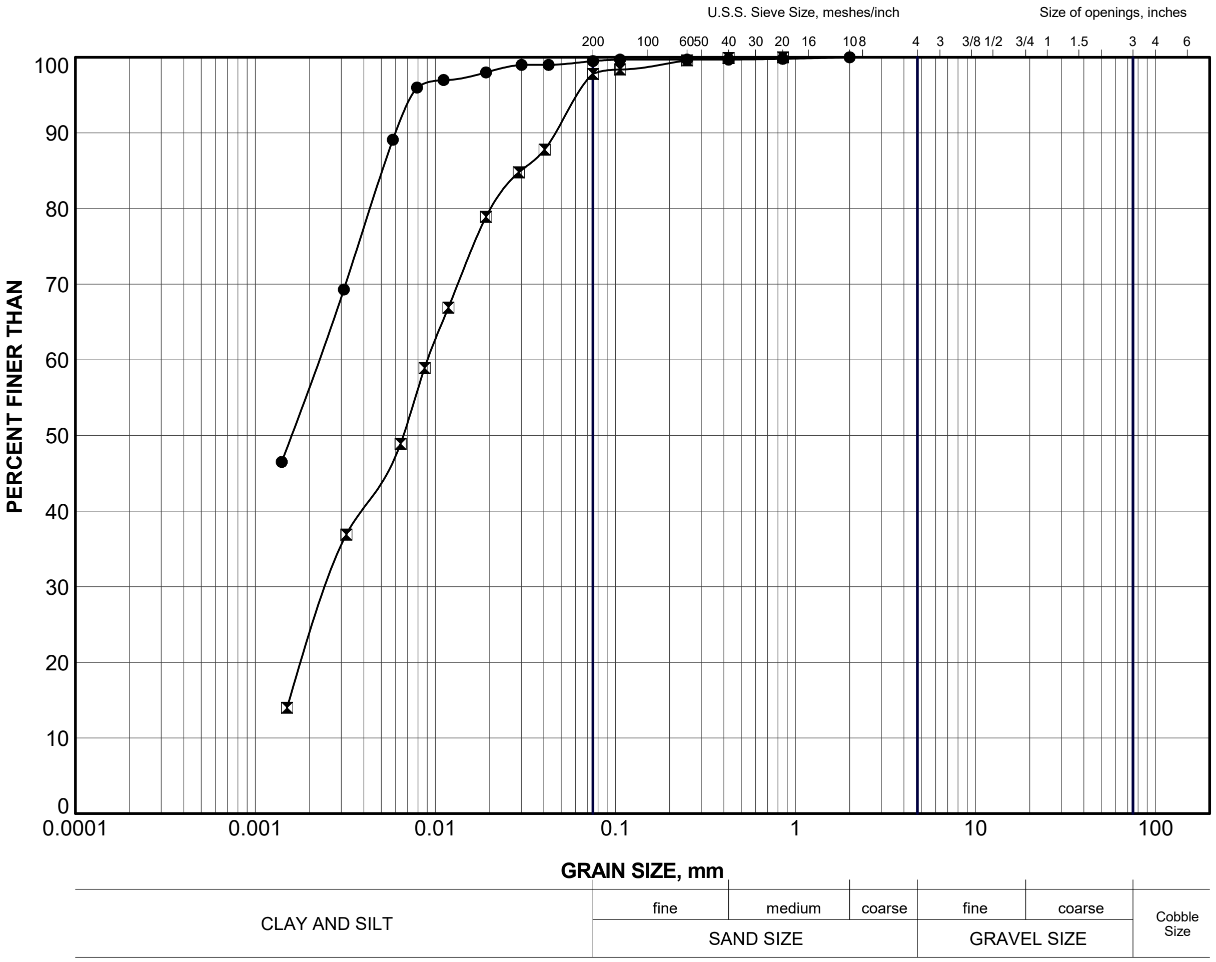
TITLE

PLASTICITY CHART
SILT to CLAYEY SILT

GOLDER
SUDBURY, ONTARIO

PROJECT No.		1896349	FILE No.	1896349.GPJ
DRAWN	TR	Nov 2019	SCALE N/A	REV.
CHECK	AMP	Nov 2019		
APPR	JMAC	Nov 2019	**FIGURE B-5**	

SUD-MTO PL GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C256-1	15	267.0
⧗	C256-3	12	271.3

PROJECT

HIGHWAY 66
STATION 16+083
TOWNSHIP OF GAUTHIER CULVERT

TITLE

GRAIN SIZE DISTRIBUTION

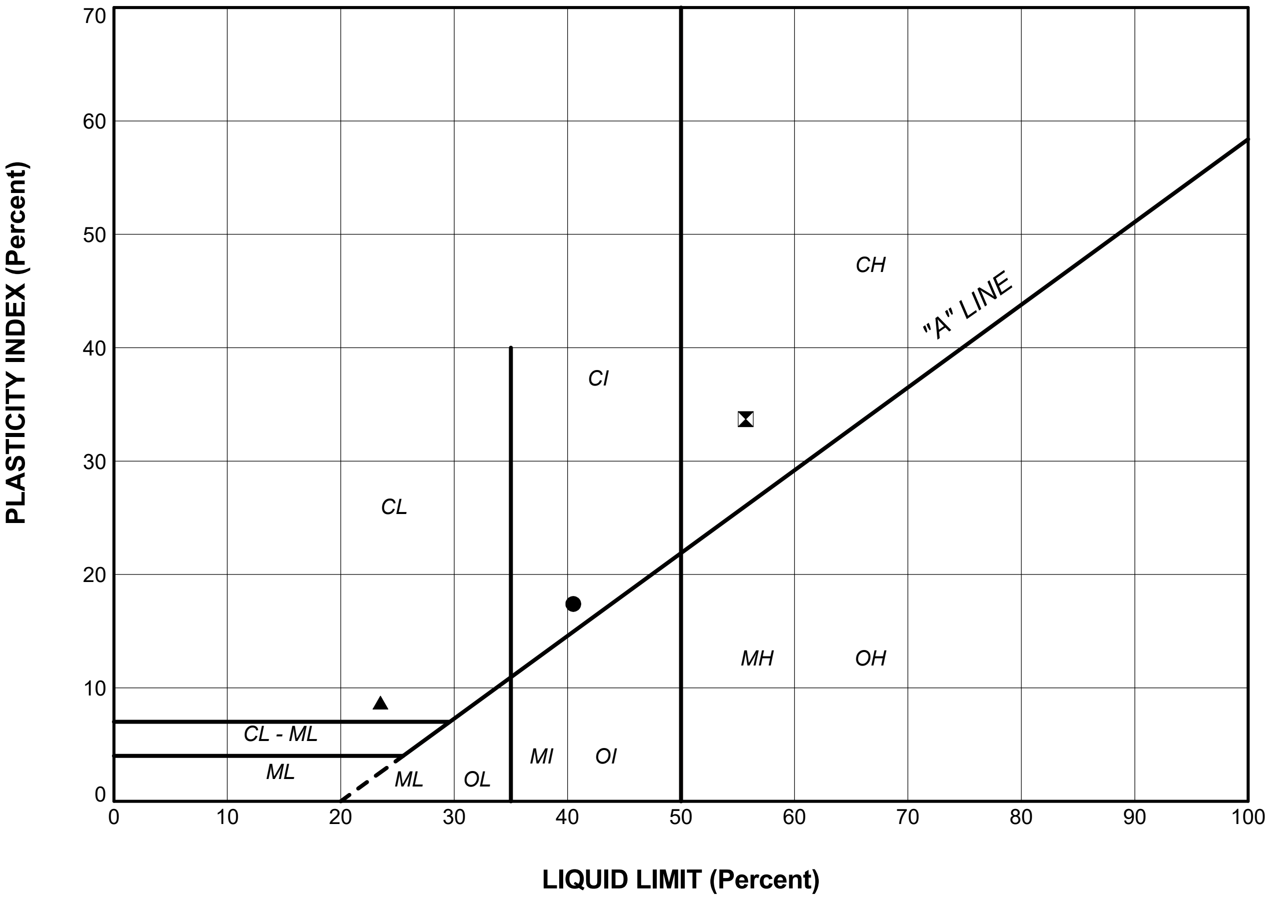
CLAY and CLAYEY SILT, varved (combined components)

GOLDER

SUDBURY, ONTARIO

PROJECT No.		1896349	FILE No.	1896349.GPJ
DRAWN	TR	Nov 2019	SCALE N/A	REV.
CHECK	AMP	Nov 2019		
APPR	JMAC	Nov 2019	**FIGURE B-6**	

SUD-MTO GSD GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	C256-1	14	40.5	23.1	17.4
⧗	C256-1	15	55.7	22.0	33.7
▲	C256-3	12	23.5	14.8	8.7

PROJECT
HIGHWAY 66
STATION 16+083
TOWNSHIP OF GAUTHIER CULVERT

TITLE
PLASTICITY CHART
CLAY and CLAYEY SILT, varved (combined components)

GOLDER
SUDBURY, ONTARIO

PROJECT No.		1896349	FILE No.	1896349.GPJ
DRAWN	TR	Nov 2019	SCALE N/A	REV.
CHECK	AMP	Nov 2019	**FIGURE B-7**	
APPR	JMAC	Nov 2019		

SUD-MTO PL GLDR_LDN.GDT

RESULTS OF ANALYSES OF SOIL

BV Labs ID		JTI432			JTI433	JTI434	JTI435	JTI436		
Sampling Date		2019/05/03 10:45			2019/05/04 14:47	2019/05/08 12:39	2019/05/11 16:36	2019/05/14 08:49		
COC Number		127611			127611	127611	127611	127611		
	UNITS	**C236-1 Lab-Dup**	**RDL**	**QC Batch**	**C267-1**	**C228-1**	**C227-1**	**C256-1**	**RDL**	**QC Batch**
CONVENTIONALS										
Sulphide	ug/g				<0.30	<0.30	<0.30	<0.30	0.30	6150574
Calculated Parameters										
Resistivity	ohm-cm				23000	12000	2500	22000		6129977
Inorganics										
Soluble (20:1) Chloride (Cl-)	ug/g				<20	29	250	<20	20	6133046
Conductivity	umho/cm				43	84	405	46	2	6135430
Available (CaCl2) pH	pH				7.74	6.56	7.00	6.30		6133358
Soluble (20:1) Sulphate (SO4)	ug/g				<20	<20	<20	<20	20	6133048
Physical Testing										
Moisture-Subcontracted	%	15	0.30	6150575	21	20	20	20	0.30	6150575

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
Lab-Dup = Laboratory Initiated Duplicate

APPENDIX C

Non-Standard Special Provisions and Notice to Contractor

DEWATERING SYSTEM - Item No.
TEMPORARY FLOW PASSAGE SYSTEM - Item No.

Special Provision No. 517F01 July 2017

Amendment to OPSS 517, November 2016

Design Storm Return Period and Preconstruction Survey Distance

517.01 SCOPE

Section 517.01 of OPSS 517 is deleted in its entirety and replaced with the following:

This specification covers the requirements for the design, operation, and removal of a dewatering or temporary flow passage system or both to control water during construction, and the control of the water prior to discharge to the natural environment and sewer systems.

517.04 DESIGN AND SUBMISSION REQUIREMENTS

517.04.01 Design Requirements

Subsection 517.04.01 of OPSS 517 is amended by deleting the first paragraph in its entirety and replacing it with the following:

A dewatering or temporary flow passage system or both shall be designed to control water at the locations specified in the Contract Documents and at any other location where a system is necessary to complete the work. The design of the system shall be sufficient to permit the work at each location to be carried out as specified in the Contract Documents.

Subsection 517.04.01 of OPSS 517 is further amended by deleting the second last paragraph in its entirety and replacing it with the following:

Temporary flow passage systems shall be designed, as a minimum, for a 2 year design storm return period and groundwater discharge, except for the work specified in Table A. For the work specified in Table A, the temporary flow passage system shall be designed, as a minimum, for the design storm return period specified in Table A and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

Intensity-Duration Factor (IDF) curve location, site specific minimum return period, return period flow estimates, and other information is provided in Table A. The IDF information can be accessed through the MTO IDF Curve Look up Tool on the Drainage and Hydrology page of MTO's website. The return period flow estimates do not include flow volumes from groundwater discharge. The Owner specifically excludes these flow estimates from the warranty in the Reliance on Contract Documents subsection of OPSS 100, MTO General Conditions of Contract.

Table A

IDF Curve Location	Latitude: 48.112684					Longitude: -79.822512
Temporary Flow Passage Systems						
Site Name / Station Reference	Minimum Return Period (Years)	Return Period Flow Estimates (m^3/s)				Design Engineer Requirements (Note 1)
		2 Year	5 Year	10 Year	25 Year	
Highway 66, Station 16+083, Township of Gauthier Culvert Replacement	***	****	****	****	****	Yes
Dewatering Systems						
Site Name / Station Reference	Preconstruction Survey Distance (Note 2) (m)					Design Engineer Requirements (Note 1)
Highway 66, Station 16+083, Township of Gauthier Culvert Replacement	N/A					Yes

Note:

1. "Yes" means the design Engineer and design-checking Engineer shall have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work. "No" means a minimum experience level is not required for the design Engineer and design-checking Engineer.
2. "N/A" indicates a preconstruction survey is not required.

NOTES TO DESIGNER:

Designer Fill-in for Table A:

* Enter the latitude and longitude co-ordinates of the IDF Curve as obtained using the MTO IDF Curve Look up Tool. Create additional tables, as necessary, if more than one (1) IDF curve was used on the contract (i.e. on a very long contract there may be two IDF curves used to better represent rainfall events for two (2) different sections of the contract).

** Fill-in site name, work, and station reference as appropriate for the dewatering system and/or temporary flow passage system item locations.

*** For temporary flow passage system item locations, fill-in the minimum design storm return period for the site based on MTO Drainage Design Standard TW-1.

**** For temporary flow passage system item locations, fill-in the design flow rate estimates for the various return periods.

***** Insert "Yes" when recommended by the Foundation Engineer. Insert "No" otherwise.

****** Fill-in the required distance for preconstruction survey if recommended by the Foundation Engineer. Fill-in "N/A" if not recommended.

WARRANT: Always with these tender items.

GOLDER

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