FOUNDATION INVESTIGATION AND DESIGN REPORT

Highway 65, Station 15+380, Township of James
Culvert Replacement
Ministry of Transportation, Ontario
GWP 5204-14-00

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PART A

FOUNDATION INVESTIGATION REPORT
HIGHWAY 65, STA 15+380, TOWNSHIP OF JAMES
CULVERT REPLACEMENT
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5204-14-00

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 located on Highway 65 at Station 15+380, approximately 700 m southeast of the intersection with Highway 560, in the Township of James, Ontario. The Key Plan of the general location of this section of Highway 65 and the location of the investigated area are shown on Drawing 1.

The purpose of this investigation is to establish the subsurface conditions for the culvert replacement 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 the Drawing 1. For the purpose of this report, Highway 65 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, creek water flows in a north-south direction.

The existing culvert consists of a 750 mm diameter, 26 m long Corrugated Steel Pipe (CSP). The inlet (north end) and outlet (south end) inverts are approximately at Elevations 283.3 m and 281.7 m, respectively. In general, the topography within the vicinity of the culvert consists of relatively flat terrain to the north with the Montreal River flowing easterly about 30 m to the south of Highway 65. At the culvert location, the highway grade is at approximately Elevation 286.3 m and the embankment is approximately 3.0 m and 4.6 m high relative to the culvert invert at the inlet and outlet, respectively. The ground surface conditions at select locations in the culvert area are shown on Photographs 1 to 4.

3.0 INVESTIGATION PROCEDURES

Field work for this subsurface investigation was carried out on October 17 and 18 and on November 15, 2018 during which time five boreholes (Boreholes C2-1 to C2-5) were advanced at approximate locations shown on Drawing 1. Three boreholes were advanced through the roadway embankment and one borehole was advanced near the north toe of the highway embankment slope adjacent to the culvert inlet using a track mounted CME-55LC drill rig supplied and operated by George Downing Estate Drilling (Downing) of Grenville-Sur-La-Rouge, Quebec. One borehole was advanced near the south toe of the highway embankment slope adjacent to the culvert outlet using a portable tripod supplied and operated by Downing. Traffic control, where required, was performed in accordance with MTO's Ontario Traffic Control Manual Book 7 – Temporary Conditions.

Boreholes C2-1 to C2-4 were advanced by the drill rig used 108 mm I.D. Hollow Stem Augers and NW casing with wash boring techniques. Borehole C2-5 was advanced by the portable tripod used NW casing with wash boring techniques. 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). The split-spoon sampler utilized by the portable drilling equipment to obtain soil samples in Borehole C2-5 was driven by a ½ weight hammer and the STP “N”-values were adjusted to the inferred values that would be obtained using a standard weight (63.6 kg) hammer. The groundwater level inside the augers/casing was observed during the drilling operations. The boreholes were backfilled using the native sand soil cuttings upon completion consistent with Ontario Regulation 903 (Wells) considering the consistent subsurface soil conditions at the boreholes. The roadway surface at the boreholes drilled through Highway 65 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 and organic content determinations, grain size distributions, and Atterberg limits were carried out on selected soil samples. The geotechnical laboratory testing was completed according to ASTM and MTO LS standards, as applicable.

The as-drilled borehole locations were measured relative to highway chainages/station marked on the pavement by a member of our technical staff to an accuracy of 0.1 m and converted into northing/easting coordinates on the plan drawing provided by AECOM. The ground surface elevations at the borehole locations were surveyed by Golder relative to the highway and culvert centreline to an accuracy of 0.1 m, with the elevation of the centreline 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)
C2-1	5287952.5 (47.728673)	355694.4 (-80.321486	286.6	15.9
C2-2	5287958.8 (47.728731	355674.3 (-80.321753)	286.1	15.9
C2-3	5287949.0 (47.728642)	355686.5 (-80.321592)	286.3	20.4
C2-4	5287964.1 (47.728777)	355698.2 (-80.321434)	285.0	11.3
C2-5	5287940.4 (47.728565)	355675.9 (-80.321734)	282.1	11.3

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain Study (NOEGTS)[1] mapping, the subsoils in the vicinity of the culvert site are located within a glaciolacustrine plain, consisting of clay and sand.

Based on geological mapping (MNDM)[2], the site is underlain by siltstone, argillite, sandstone and conglomerate.

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 detailed results of geotechnical laboratory testing are contained in Appendix B. The results of the in-situ field tests (i.e., SPT "N" values) as presented on the Record of Borehole sheets and discussed in Section 4 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 subsurface conditions will vary between and beyond the borehole locations, however, the factual data presented on the record of borehole 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 approximate 50 mm to 75 mm thick layer of asphalt pavement was penetrated in the roadway Boreholes C2-1 to C2-3, from pavement surface between Elevations 286.6 m and 286.1 m. A 0.8 m to 0.9 m thick layer of embankment fill consisting of sand and gravel was encountered below the asphalt pavement in Boreholes C2-1 to C2-3, between Elevations 286.5 m and 286.0 m. A 1.6 m to 2.7 m thick layer of fill comprised of clayey silt to silt, underlain by a 2.1 m thick layer of sandy silt fill in one borehole, was encountered in Boreholes C2-1 to C2-3, between Elevations 285.6 m and 285.2 m. Pockets of organic silt were encountered within the fill at a depth of about 3.7 m to 4.9 m in Borehole C2-2 and at a depth of about 3.6 m in Borehole C2-3.

From ground surface at the culvert ends in Boreholes C2-4 and C2-5, a 0.8 m and 0.6 m thick layer of silty sandy topsoil fill was encountered at Elevations 285.0 and 282.1, respectively. A 2.9 m and 1.2 m thick layer of fill comprised of sand and silty sand was encountered at Elevations 284.2 m and 280.7 m in Boreholes C2-4 and C2-5, respectively.

The SPT "N"-values measured within the sand and gravel fill range between 47 blows and 58 blows per 0.3 m of penetration indicating a dense to very dense compactness condition. The SPT "N"-values measured within the silty sandy topsoil fill and sand/silty sand/clayey silt/sandy silt fill range between 2 blows and 34 blows per 0.3 m

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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

of penetration indicating a very loose to compact compactness condition. Within the fill in Borehole C2-2, one SPT "N"-value of 50 blows per 0.07 m of penetration was likely a result of the sand and gravel and possible cobbles, indicating a dense to very dense compactness condition.

Grain size distribution analysis was carried out on four samples of the clayey silt fill layers and the results are presented on Figure B-1 in Appendix B. Atterberg limits tests were carried out on two samples within the cohesive fill and measured liquid limits of 27 per cent and 28 per cent, plastic limits of 18 per cent and 20 per cent and the plasticity indexes of 8 per cent. The results of the Atterberg limit tests are presented on Figure B-2 in Appendix B and indicate the samples are comprised of clayey silt of low plasticity. Grain size distribution analysis was carried out on two samples of the sand fill and the results are presented on Figure B-3 in Appendix B. The natural moisture content measured on samples of clayey silt fill ranges from 21 per cent to 27 per cent and on samples of the sand fill is about 10 per cent and 20 per cent.

4.2.2 Clayey Silt-Silt

A 4.3 m and 1.8 m thick deposit of clayey silt-silt was encountered underlying the fill deposit in Boreholes C2-1, and C2-5, at Elevations 284.0 m and 279.5 m, respectively. The deposit contains trace to some sand.

The SPT "N"-values measured within the cohesive deposit range from 2 blows to 15 blows per 0.3 m of penetration suggesting that the deposit has a very soft to stiff consistency.

Grain size distribution analysis was carried out on three samples of the deposit and the results are presented on Figure B-4 in Appendix B. Atterberg limit tests were carried out on three samples of the deposit and measured liquid limits ranging from 23 per cent to 39 per cent, plastic limits ranging from 17 per cent to 28 per cent and plasticity indices ranging from 5 percent to 11 per cent. The results of the Atterberg limit test are presented in Figure B-5 and indicate the samples are comprised of silt of intermediate plasticity to clayey silt-silt of low plasticity. An organic content test conducted on one of the silt samples of the deposit yielding 2.6 per cent organic content. The natural moisture content measured on samples of the deposit range from 24 per cent to 40 per cent.

4.2.3 Silt

A 1.0 m thick deposit of silt, containing trace sand, was encountered underlying the fill deposit in Borehole C2-3 at Elevation 282.6 m.

An STP "N"-value of 8 blows per 0.3 m of penetration was measured within the silt deposit, indicating a loose compaction condition.

4.2.4 Sand

A deposit of sand was encountered underlying the clayey silt-silt deposit in Boreholes C2-1 and C2-5, underlying the fill in Boreholes C2-2 and C2-4 and underlying the silt deposit in Borehole C2-3, between Elevations 281.6 m and 277.7 m. The boreholes were terminated within the sand after penetrating into the deposit for a thickness between 6.9 m and 15.7 m.

The SPT “N”-values measured within the sand deposit range from 3 blows to 29 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 eight samples of the deposit and the results are presented on Figure B-6 in Appendix B. The natural moisture content measured on samples on the deposit ranged from 19 per cent to 26 per cent.

4.3 Groundwater Conditions

The unstabilized groundwater levels relative to ground surface measured inside the casing or augers upon completion of drilling are summarized below. The creek water level near the culvert inlet, as surveyed by Golder on October 18, 2018, is about Elevation 283.4 m. 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)
C2-1	4.9	281.7
C2-2	3.2	282.9
C2-3	4.4	281.9
C2-4	3.4	281.6
C2-5	0.8	281.3

4.4 Analytical Laboratory Testing Results

Analytical testing was carried out on a sand and gravel fill soil sample recovered from Borehole C2-3. The soil sample was submitted to Maxxam Analytics of Sudbury, Ontario for testing of a suite of corrosivity parameters. The detailed analytical laboratory test results are presented on the laboratory testing report in Appendix B and the test results are summarized below.

Borehole No.	Sample No.	Depth (m)	Parameters				
			Resistivity (ohm/cm)	Electrical Conductivity (µmho/cm)	Soluble Sulphate (SO4) Content (µg/g)	Chloride (Cl) Content (µg/g)	pH
C2-3	Sa 4	2.2 – 2.5	2300	429	<20[1]	150	7.74

Note:
1. The sulphate concentration is below the reportable detection limit of 20 µg/g

5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Tibor Berecz, under the overall direction of Mr. André Bom, P.Eng. This Foundation Investigation Report was prepared by Mr. Gavin Mundry, and Mr. André Bom, P.Eng. carried out a technical review of the report. Mr. Jorge Costa, P.Eng., an MTO Foundations Designated Contact and Senior Consultant for Golder, conducted an independent quality control review of this report.

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PART B

FOUNDATION DESIGN REPORT
HIGHWAY 65, STA 15+380, TOWNSHIP OF JAMES
CULVERT REPLACEMENT
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5204-14-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design and recommendations for the proposed replacement of the culvert crossing Highway 65 at about Station 15+380, approximately 700 m southeast of the intersection with Highway 560, in the Township of James, Ontario. These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current subsurface investigation assessment of alternative installation methods, discussion, and recommendations are based on interpretation of the factual data obtained from the boreholes advanced during this subsurface investigation. The discussion and recommendations presented are intended to provide the designer with sufficient information to assess feasible foundation alternatives and to design the proposed replacement culvert. The 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. 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 General

The existing culvert consists of a 750 mm diameter, 26 m long Corrugated Steel Pipe. Based on the drawings provided by AECOM via email on March 14, 2019 and our site observations during the Foundations Investigation field program, the existing culvert crosses perpendicular to the existing Highway 65 embankment; and we understand from AECOM that the proposed replacement culvert will cross the highway on or near the existing culvert alignment and will be of similar circular size as the existing culvert. The invert at the inlet (north end) and outlet (south end) of the proposed culvert is about Elevations 283.3 m and 281.7 m, respectively, and the embankment is 3.0 m to 4.6 m high relative to the culvert invert at the respective ends. Based on documentation supplied by AECOM, the existing culvert is sagging in the middle; and site observations indicate that there is a steep fore slope to the south near the embankment toe at and adjacent to the outlet end of the culvert. There did not appear to be signs of embankment instability nor are there indications of pavement distress in the culvert area. We understand from AECOM that temporary grade lowering of the highway is being considered to allow for culvert replacement, but a permanent grade raise or widening is not required. We further understand that a temporary detour will not be required/utilized for traffic staging during culvert replacement operations.

Due to the relatively shallow thickness of the roadway embankment side slope along the northern end of the culvert near the inlet and the relatively steep incline of the culvert (about 6 %), replacing the culvert using a trenchless method is not preferred replacement option at this site.

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*, the section of Highway 65 crossing over the proposed culvert and its foundation system is expected to carry medium traffic volumes and its performance will have potential impacts on other transportation corridors; hence, the structure 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.

6.3 Circular Culvert Installation by Open Cut Excavation

6.3.1 Settlement and Stability

Provided the proposed reconstructed embankment is not widened or raised following culvert replacement, immediate or long-term settlement of the foundation soils beneath the culvert is not anticipated. For the purposes of this report, we have assumed that a temporary widening is not required. If a temporary or permanent widening or grade raise is required, then a settlement analysis should be carried out, although it is expected that settlement of the subgrade would be less than 25 mm and most of this settlement would occur during construction given the presence of primarily non-cohesive soils below ground surface.

The proposed reconstructed embankment (after culvert replacement) will be stable from a slope stability perspective if it is reconstructed of granular material and with side slopes at an inclination of 2 horizontal to 1 vertical (2H:1V).

6.3.2 Bedding and Cover

It is not necessary to found pipe culverts below the depth for frost penetration, as pipe culverts are tolerant of small magnitudes of movement related to freeze-thaw cycles. A circular pipe concrete 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)*, and should be designed in accordance with the MTO Gravity Pipe Design Guidelines (2014). If the replacement culvert is to consist of a CSP or plastic pipe installed by open cut method, it should be constructed in accordance with OPSD 802.014 (Flexible Pipe Embedment in Embankment). All unsuitable deleterious organic and fill materials are to be removed from the base/below the culvert along the entire alignment. The bedding should be compatible with the class of pipe, the surrounding subsoil and anticipated loading conditions and should consist of OPSS.PROV 1010 (Aggregates) Granular ‘A’ material. Depending on the success of the contractor’s groundwater control methods, and the quality of the bearing stratum exposed at the base of the excavation, a thicker bedding layer may be required at some locations where wet and softened soil conditions, unsuitable fill, or organic material are present at base of the excavation. Therefore, the Contract Documents should include a provision for additional thickness of compacted Granular ‘A’ bedding, if required.

From the top of the bedding to 300 mm above the obvert of the culvert, Granular ‘A’ should be used around the culvert. All bedding 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 (*Trenching, Backfilling and Compacting*), and the bedding/cover soil should be compacted in accordance with OPSS.PROV 501 (*Compacting*). 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 for bedding and as any additional sub-excavation backfill below the bedding, as required.

6.3.2.1 *Trench Backfill*

The excavated embankment fill materials from the culvert site will vary in quality and composition of sand and gravel, clayey silt to sandy silt, silty sand to sand and silty sandy topsoil/organic soil. The majority of the excavated materials, where encountered above the water table, should be generally near their estimated optimum water contents for compaction provided they are protected from precipitation once they are exposed. Soils encountered below the water table would likely require significant drying in order to reach optimum water content for compaction. The excavated granular fill where encountered above the groundwater level and maintained at suitable water content, may be reused as trench backfill over the culvert cover material, provided these materials are free of organics, or other deleterious material (wood, construction rubble) and are placed and compacted accordance with OPSS.PROV 501 (*Compacting*). The silt to sandy silt, silty sandy topsoil organics and silt to sand fill, or the native sand and silt if excavated, should not be reused as backfill.

Alternatively, 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*).

6.4 Analytical Testing for Construction Materials

The results of analytical tests on Sample #4 of sand and gravel fill recovered in Borehole C2-3 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.

6.4.1 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 of fill, when the designer is selecting the exposure class for the structure, the effects of sulphates from within the fill may not need to be considered.

6.4.2 Potential for Corrosion

The soil has a pH of 7.74 and according to the MTO Gravity Pipe Design Guidelines (2014), the pH is not considered detrimental to culvert durability. The resistivity is 2300 ohm-cm, which indicates that the soil corrosiveness is moderate (4,500>R>2,000 ohm-cm), as per Table 3.2 of the MTO Gravity Pipe Design Guidelines (2014). However, as the culvert will also be located under the roadway shoulders and be exposed to de-icing salt, therefore, concrete should be designed for a "C" type exposure class as defined by CSA A23.1-14 Table 1. The culvert should be designed with consideration given to Table 7.1 of the MTO Gravity Pipe Design Guidelines (2014).

6.5 Construction Considerations

6.5.1 Open Cut Excavation

The proposed open cut excavation through the roadway embankment and into the subgrade to the base of the culvert bedding level will generally advance through sand and gravel, clayey silt to sandy silt, silty sandy organics and clayey silt to sand fill materials and into silt to sand native materials. The excavation is anticipated to extend to or below the groundwater level. Where space permits, an open cut excavation into these materials should 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 material and underlying native granular soils are classified as Type 3 soil (assuming that the native granular soils are dewatered), 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 material and underlying native fine grained granular 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 the 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.

6.5.2 Groundwater Control

The groundwater level is expected to be at or slightly above the proposed culvert invert. The excavations for open cut installation should be expected to extend below the groundwater level. Groundwater control will be required to allow for stable slopes/walls of the open cut excavation. The groundwater should be lowered to at least 1 m below the base of excavation to maintain basal stability. Groundwater may be controlled by providing an active dewatering system installed and operated, in advance of the excavation, or in combination with a sheet piling wall.

The contractor is responsible for the assessment of dewatering requirements, which depends on their chosen method of open cut excavation as well as construction / operation / maintenance and decommissioning. The contractor is also responsible for confirming that the radius of the drawdown does not impact the existing embankment. Groundwater and/or surface water control will be required for excavation and construction of the culvert. Dewatering should be carried out in accordance with OPSS.PROV 517 (*Dewatering*) and in accordance with OPSS.PROV 421 (*Pipe Culvert Installation in Open Cut*).

Surface water into excavations should be directed away from open excavation areas to prevent ponding of water that could result in disturbance and weakening of the subgrade.

6.5.3 Temporary Protection Systems

If required, temporary excavation protection and support systems should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*). 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. 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 the approximate construction costs during detail design.

Stratigraphic Unit	Bulk Unit Weight, γ (kN/m^3)	Internal Angle of Friction, φ (Degrees)	Undrained Shear Strength, s_u (kPa)	Lateral Earth Pressure Coefficients$^{1/2}$		
				Passive, K_p^{3}	Active, K_a	At-rest, K_o
Embankment Fill - Dense to very dense sand and gravel	20	32	-	3.25	0.31	0.47
Fill (Roadway) – Loose to compact clayey silt to sandy silt	19	29	-	2.85	0.35	0.52
Very loose to compact silt	19	29	-	2.85	0.35	0.52
Compact sand	20	32	-	3.25	0.31	0.47

Notes:

1. The design groundwater level may be assumed to be about Elevation 282 m, based on the water levels in the open boreholes upon completion of drilling operations.
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.

It is recommended that the ground surface extending back / upwards from the top of the protection system to the existing Highway 65 be graded to an inclination no steeper than 2 horizontal to 1 vertical (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). Full removal of the protection system should be considered to mitigate potential impediments to future rehabilitation/reconstruction work. If partial removal is required rather than full removal, SP amending OPSS.PROV 539 is included in Appendix C should be included in the Contract. Vibration and noise controls during extraction of any temporary systems should meet the same tolerable limits used for installation.

6.5.4 Obstructions

There is potential for the presence of cobbles within the highway embankment fill as encountered in Borehole C2-2. Evidence of boulders was not directly encountered during the drilling investigation progress in either the fill or native soils at the site. Based on experience on similar projects, cobbles and boulders can be present within highway embankment fill which could affect the installation of temporary protection systems. There is also the potential for the presence of organic material (as encountered in all five Boreholes), roots and tree stumps, at the interface of fill and native soils under the existing embankment, due to possible poor stripping practices during the embankment construction. A Notice to Contractor to identify to the contractor the possible presence of cobbles, boulders and deleterious material such as asphalt fragments within the fill soils and organics at the fill and native soil interface, should be included in the Contract Documents, a copy of which is included in Appendix C.

6.5.5 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.

6.5.6 Embankment Reconstruction/Erosion Protection/Topsoil-Seeding

Fill for reconstruction of the embankment after open cut culvert replacement should consist of OPSS.PROV 1010 (Aggregates) Granular ‘A’, Granular ‘B’ Type I or Type II, or Select Subgrade Material. The embankment fill should be placed and compacted in accordance with OPSS.PROV 501 (Compacting) and OPSS.PROV 206 (Grading). Embankment side slopes should be constructed no steeper than 2 Horizontal to 1 Vertical (2H:1V) in granular fill.

Erosion protection should be addressed by the designers at the culvert ends if the potential for hydraulic scour is possible depending on the water flow conditions.

To reduce surface water erosion on the granular embankment side slopes below the pavement structure, topsoil and seeding as per OPSS 802 (Topsoil) and OPSS.PROV 804 (Seed and Cover) should be carried out as soon as possible after construction of the embankments. If this slope protection is not in place before winter, then alternate protection measures, such as covering the slope with straw, or gravel sheeting as per OPSS.PROV 511 (Rip Rap, Rock Protection and Granular Sheeting), and OPSS.PROV 1004 (Aggregates – Miscellaneous) will be required to reduce the potential for erosion and to reduce the potential for the requirement of remedial works on the side slopes in the spring prior to topsoil dressing and seeding.

7.0 CLOSURE

This foundation design report was prepared by Mr. Gavin Mundry, a member of the geotechnical group with Golder, and the technical aspects were reviewed by Mr. André Bom, P.Eng., a senior geotechnical engineer and Associate of Golder. 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

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Geotechnical Engineer-in-Training

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MTO Foundations Designated Contact, Senior Consultant

TB/GM/AB/JMAC/sb

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https://golderassociates.sharepoint.com/sites/1809001/deliverables/foundations/2. reporting/r03 - jam102/3. final/1896349-r-rev0-aecom culvert 2 (jam 102) hwy 65 fidr 17jun_19.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)

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

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

Ontario Regulation 903 (Wells) as amended

ASTM International:

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

Ontario Provincial Standard Drawings (OPSD)

OPSD 802.014	Flexible Pipe Embedment in Embankment Original Ground: Earth or Rock
OPSD 802.031	Rigid Pipe Bedding, Cover, And Backfill, Type 3 Soil - Earth Excavation

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 501	Construction Specification for Compacting
OPSS.PROV 511	Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting
OPSS.PROV 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS. PROV 802	Construction Specification for Topsoil
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS.PROV 1004	Material Specification for Aggregates – Miscellaneous
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

MINISTRY OF TRANSPORTATION, ONTARIO

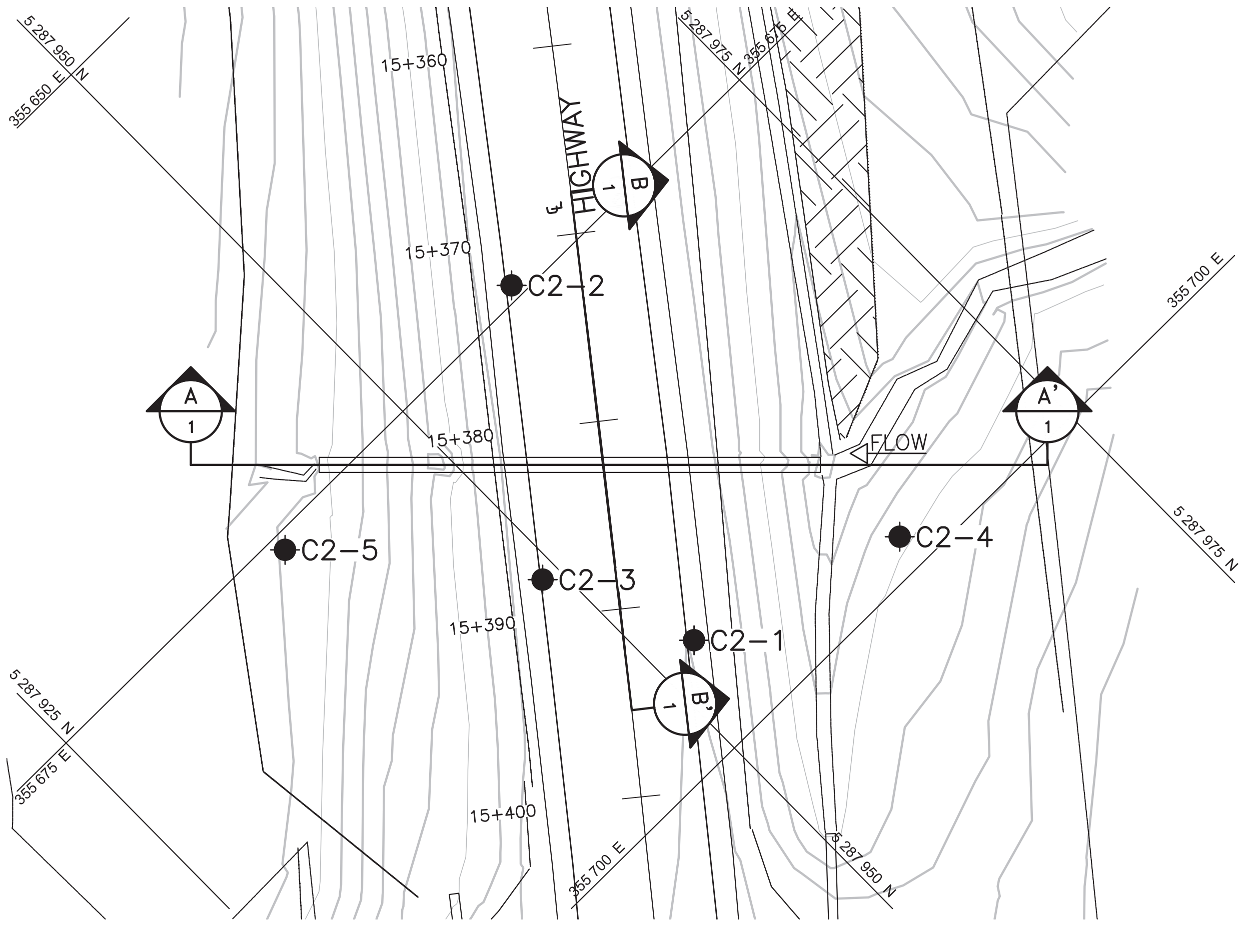
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 5204-14-00

SHEET

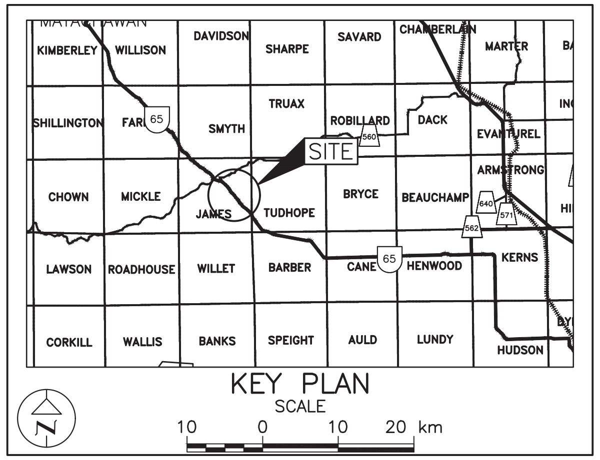
HIGHWAY 65
STATION 15+380
TOWNSHIP OF JAMES CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

GOLDER



PLAN

SCALE
4 0 4 8 m

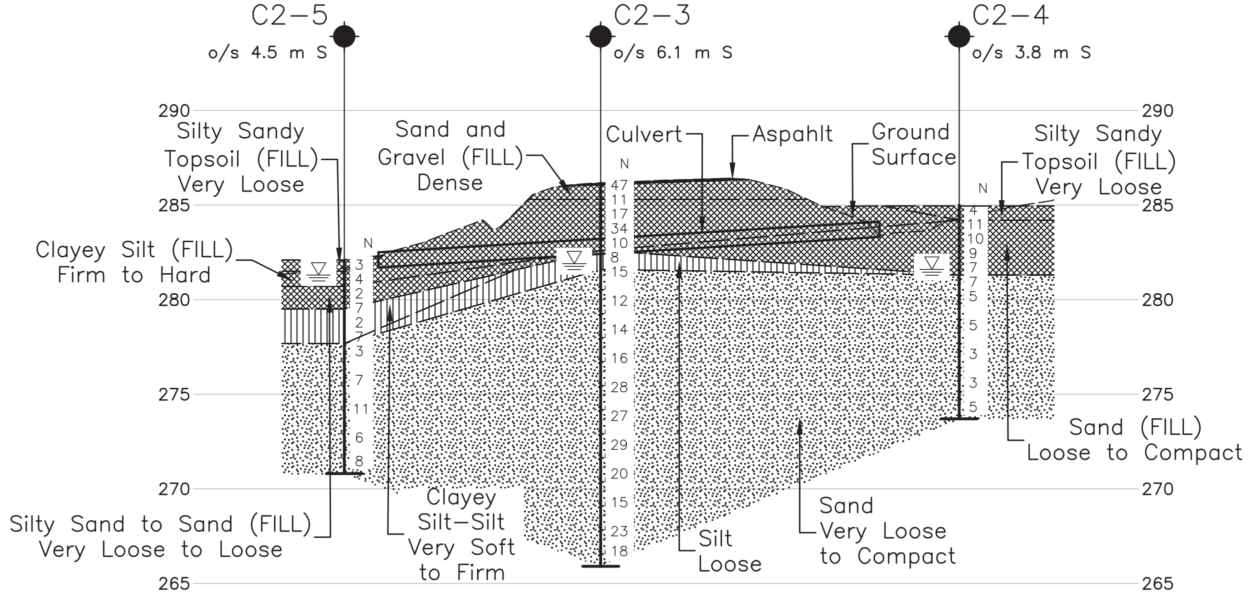


KEY PLAN

SCALE
10 0 10 20 km

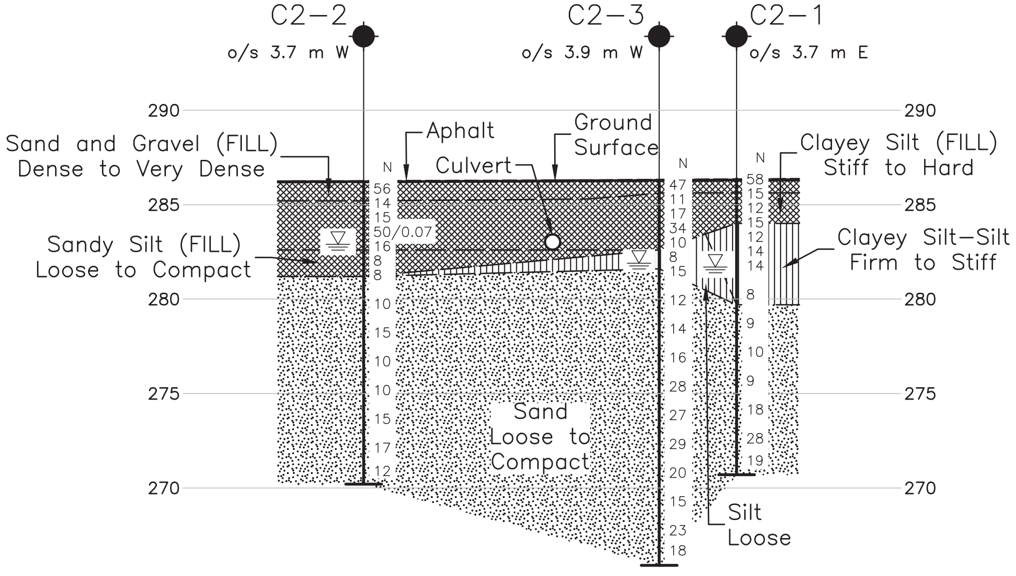
LEGEND

●	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



A–A' 1 CULVERT CENTERLINE PROFILE

HORIZONTAL SCALE
4 0 4 8 m
4 0 4 8 m
VERTICAL SCALE



B–B' 1 HIGHWAY CENTERLINE PROFILE

HORIZONTAL SCALE
4 0 4 8 m
4 0 4 8 m
VERTICAL SCALE

J.M.A. COSTA
MAY 21, 2019

A.J.K. BOM
100075715
MAY 28, 2019

BOREHOLE CO-ORDINATES (NAD 83 MTM ZONE 12)

No.	ELEVATION	NORTHING	EASTING
C2-1	286.6	5287952.5	355694.4
C2-2	286.1	5287958.8	355674.3
C2-3	286.3	5287949.0	355686.5
C2-4	285.0	5287964.1	355698.2
C2-5	282.1	5287940.4	355675.9

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 AECOM, drawing file nos. B065JAM.dwg, received MAR 15, 2019.

NO.	DATE	BY	REVISION
.	.	.	.

Geocres No. 41P-78

HWY. 65		PROJECT NO. 1896349	DIST. .
SUBM'D. GM	CHKD. TB	DATE: 5/21/2019	SITE: .
DRAWN: TR	CHKD. AB	APPD. JMAC	DWG. 1

PLOT DATE: May 28, 2019
FILENAME: S:\Clients\MTO\Hwy65&66\99_PROJ\1896349_AECOM_Hwy65-66-566\40_PROD\0003_R03_Jam102\1896349-0003-BG-0001.dwg

Photograph 1: Culvert Inlet (North End), Facing Southwest (October 2018)

Photograph 2: Culvert Outlet (South End), Facing Northwest (October, 2018)

Photograph 3: Road surface in Culvert Area, Facing West (October, 2018)

Photograph 4: Borehole C2-5 Location South of Hwy 65, Facing Southwest (November 2018)

APPENDIX A

Record of Boreholes

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
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_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 $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

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

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

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

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, 60º 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 cm^2 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

Compactness 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	c_u, s_u 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	Sand and Gravel
	With (cohesive)	Silty Clay with sand / Clayey Silt with sand

RECORD OF BOREHOLE No C2-1

1 OF 2 **METRIC**

PROJECT 1896349

G.W.P. 5204-14-00

LOCATION N 5287952.5; E 355694.4 NAD83 MTM ZONE 12 (LAT. 47.728673; LONG. -80.321486)

ORIGINATED BY TB/GM

DIST

HWY 65

BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers, NW Casing and Wash Boring

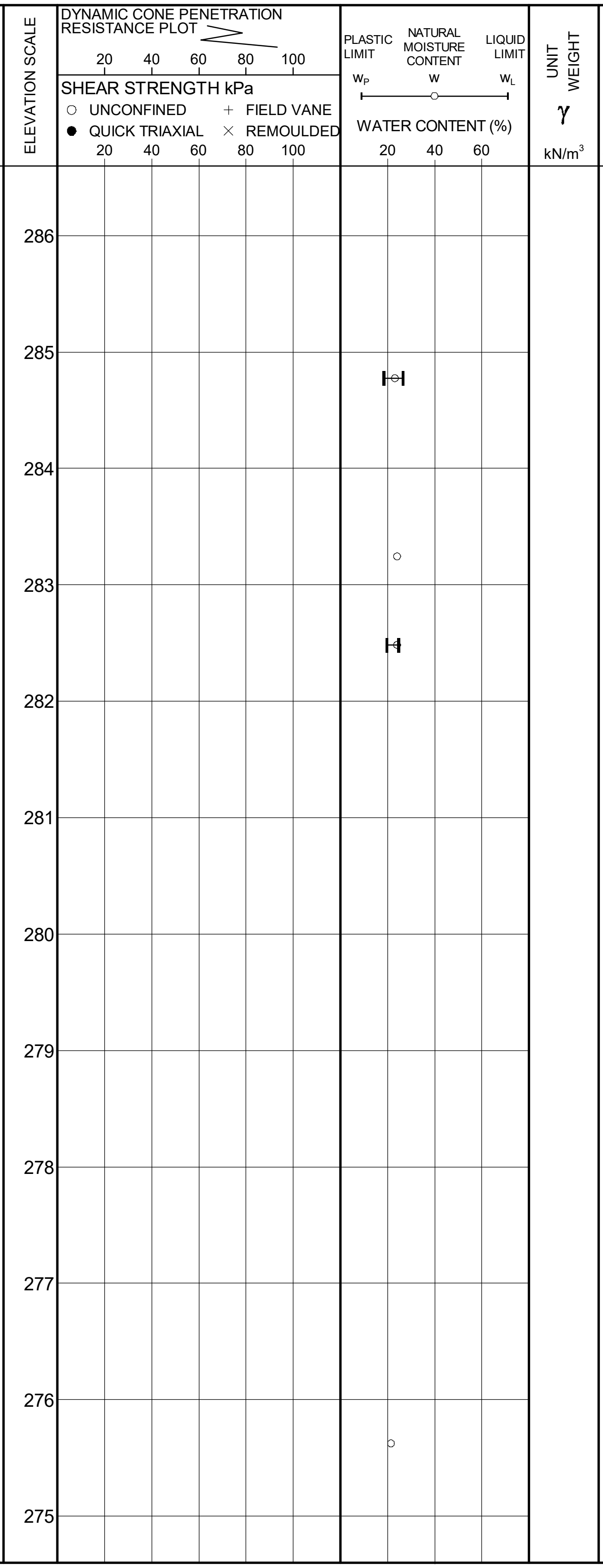
COMPILED BY GM

DATUM GEODETIC

DATE October 17, 2018

CHECKED BY AB

SOIL PROFILE		SAMPLES				REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
286.6	GROUND SURFACE								
0.0	ASPHALT (50 mm)								
0.1	Sand and gravel (FILL) Very dense Brown Moist	1	SS	58					
285.6 1.0	Clayey silt, trace sand (FILL) Stiff Brown Moist to wet	2 A B	SS	15					
		3	SS	12		0	3	74	23
284.0 2.6	CLAYEY SILT-SILT Firm to stiff Brown Moist to wet	4 A B	SS	15					
	Organic pocket in sample 4B	5	SS	12					
	Sand layer from 3.4 m to 3.7 m depth								
		6	SS	14		0	0	84	16
		7	SS	14	▽				
	Sand layer from 6.7 m to 6.8 m	8	SS	8					
279.7 6.9	SAND, trace to some silt Loose to compact Brown to grey Wet								
		9	SS	9					
	Silt to sandy silt layer from 9.0 m to 9.6 m	10	SS	10					
		11	SS	9		0	90	(10)	



Continued Next Page

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

PROJECT 1896349

RECORD OF BOREHOLE No C2-1

2 OF 2 **METRIC**

G.W.P. 5204-14-00

LOCATION N 5287952.5; E 355694.4 NAD83 MTM ZONE 12 (LAT. 47.728673; LONG. -80.321486)

ORIGINATED BY TB/GM

DIST

HWY 65

BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers, NW Casing and Wash Boring

COMPILED BY GM

DATUM GEODETIC

DATE October 17, 2018

CHECKED BY AB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION *--- CONTINUED FROM PREVIOUS PAGE ---*	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	SAND, trace to some silt Loose to compact Brown to grey Wet		12	SS	18		274				
							273				
			13	SS	28						
							272				
			14	SS	19		271				
270.7 15.9	END OF BOREHOLE Note: 1. Water level at a depth of 4.9 m below ground surface (Elev. 281.7 m) upon completion of drilling.										

SUD-MTO 001 S:\CLIENTS\MTO\HWY65&66\02_DATA\GINT\1896349.GPJ GAL-MISS.GDT 5-27-19 TR

$+^3, \times^3$: Numbers refer to Sensitivity

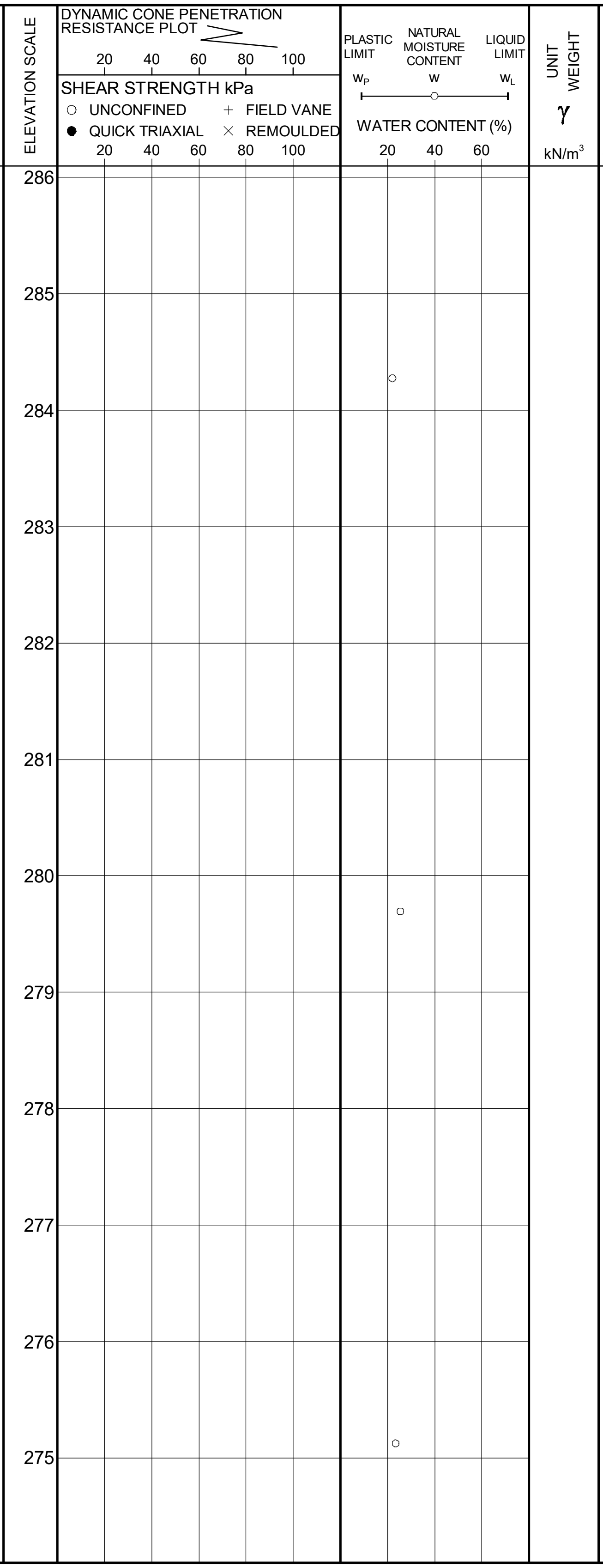
$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No C2-2

1 OF 2 **METRIC**

PROJECT 1896349		ORIGINATED BY	TB/GM
G.W.P. 5204-14-00	LOCATION N 5287958.8; E 355674.3 NAD83 MTM ZONE 12 (LAT. 47.728731; LONG. -80.321753)		
DIST	HWY 65	BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers, NW Casing and Wash Boring	COMPILED BY GM
DATUM GEODETIC	DATE October 18, 2018	CHECKED BY	AB

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
286.1	GROUND SURFACE					
0.0	ASPHALT (75 mm)					
0.1	Sand and gravel (FILL) Very dense Brown Moist	1	SS	56		
285.2 0.9	Clayey silt, trace sand (FILL) Stiff Brown to grey Moist	2	SS	14		
		3	SS	15		0 1 90 9
	Sand and gravel and possible cobbles from 2.3 m to 2.5 m	4	SS	50/0.07		
283.3 2.8	Sandy silt, trace gravel (FILL) Loose to compact Grey Moist	5	SS	16	▽	
	Organic silt pockets from 3.7 m to 4.9 m	6	SS	8		
		7 A 7 B	SS	8		
281.2 4.9	SAND, trace silt, trace clay Loose to compact Brown to grey Wet	8	SS	10		0 98 (2)
		9	SS	15		
		10	SS	10		
	Silt from 11.0 m to 11.1 m	11	SS	10		0 92 6 2



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

PROJECT 1896349

RECORD OF BOREHOLE No C2-2

2 OF 2 **METRIC**

G.W.P. 5204-14-00

LOCATION N 5287958.8; E 355674.3 NAD83 MTM ZONE 12 (LAT. 47.728731; LONG. -80.321753)

ORIGINATED BY TB/GM

DIST

HWY 65

BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers, NW Casing and Wash Boring

COMPILED BY GM

DATUM GEODETIC

DATE October 18, 2018

CHECKED BY AB

SOIL PROFILE			SAMPLES								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	SAND, trace silt, trace clay Loose to compact Brown to grey Wet						274				
			12	SS	15						
							273				
			13	SS	17		272				
							271				
			14	SS	12						
270.2 15.9	END OF BOREHOLE Note: 1. Water level at a depth of 3.2 m below ground surface (Elev. 282.9 m) upon completion of drilling.										

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

RECORD OF BOREHOLE No C2-3

1 OF 2 **METRIC**

PROJECT 1896349
G.W.P. 5204-14-00
DIST
HWY 65
DATUM GEODETIC
LOCATION N 5287949.0; E 355686.5 NAD83 MTM ZONE 12 (LAT. 47.728642; LONG. -80.321592)
BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers, NW Casing and Wash Boring
DATE October 18, 2018
ORIGINATED BY TB/GM
COMPILED BY GM
CHECKED BY AB

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES			GR	SA	SI	CL
286.3	GROUND SURFACE									
0.0 0.1	ASPHALT (50 mm)									
	Sand and gravel (FILL) Dense Brown Moist	1	SS	47		286				
285.3 1.0	Clayey silt, trace gravel, trace sand (FILL) Stiff to hard Brown to grey Moist	2	SS	11		285				
		3	SS	17			4	5	83	8
	Sand and gravel layer from 2.2 m to 2.5 m	4	SS	34		284				
		5	SS	10		283				
282.6	Organic silt pockets at 3.6 m									
3.7	SILT, trace sand Loose Grey to dark brown Moist	6	SS	8	∇	282				
281.6 4.7	SAND, trace to some silt Compact Brown to grey Wet	7	SS	15		281				
		8	SS	12		280	0	92	(8)	
		9	SS	14		279 278				
		10	SS	16		277 276				
		11	SS	28		275	0	98	(2)	

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED: 20 40 60 80 100
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L
WATER CONTENT (%): 20 40 60
UNIT WEIGHT γ kN/m³

Continued Next Page

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

RECORD OF BOREHOLE No C2-3

2 OF 2 **METRIC**

PROJECT 1896349

G.W.P. 5204-14-00

LOCATION N 5287949.0; E 355686.5 NAD83 MTM ZONE 12 (LAT. 47.728642; LONG. -80.321592)

ORIGINATED BY TB/GM

DIST

HWY 65

BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers, NW Casing and Wash Boring

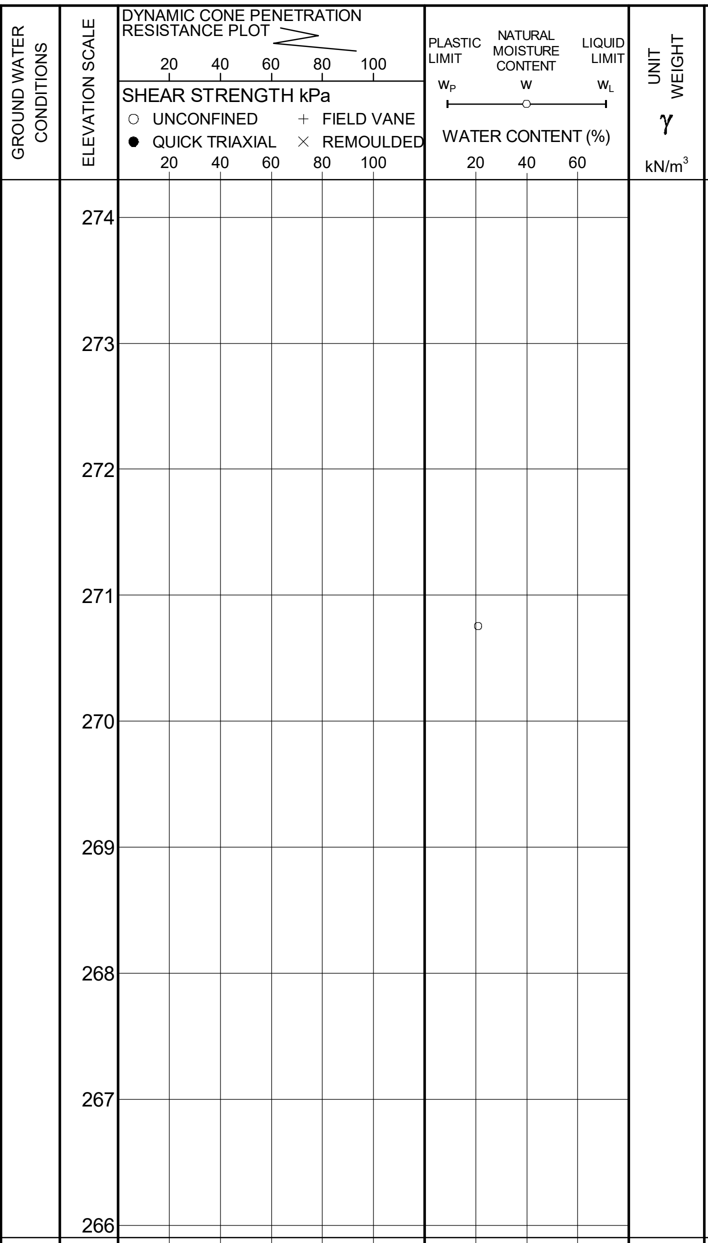
COMPILED BY GM

DATUM GEODETIC

DATE October 18, 2018

CHECKED BY AB

SOIL PROFILE		SAMPLES			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
	--- CONTINUED FROM PREVIOUS PAGE ---							
	SAND, trace to some silt Compact Brown to grey Wet							
		12	SS	27				
		13	SS	29				
		14	SS	20	0	98	(2)	
		15	SS	15				
		16	SS	23				
		17	SS	18				
265.9 20.4	END OF BOREHOLE							



Note:

1. Water level at a depth of 4.4 m below ground surface (Elev. 281.9 m) upon completion of drilling.

$+^3, \times^3$: Numbers refer to Sensitivity

$\bigcirc^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No C2-4

1 OF 2 **METRIC**

PROJECT 1896349

G.W.P. 5204-14-00

DIST

HWY 65

DATUM GEODETIC

LOCATION N 5287964.1; E 355698.2 NAD83 MTM ZONE 12 (LAT. 47.728777; LONG. -80.321434)

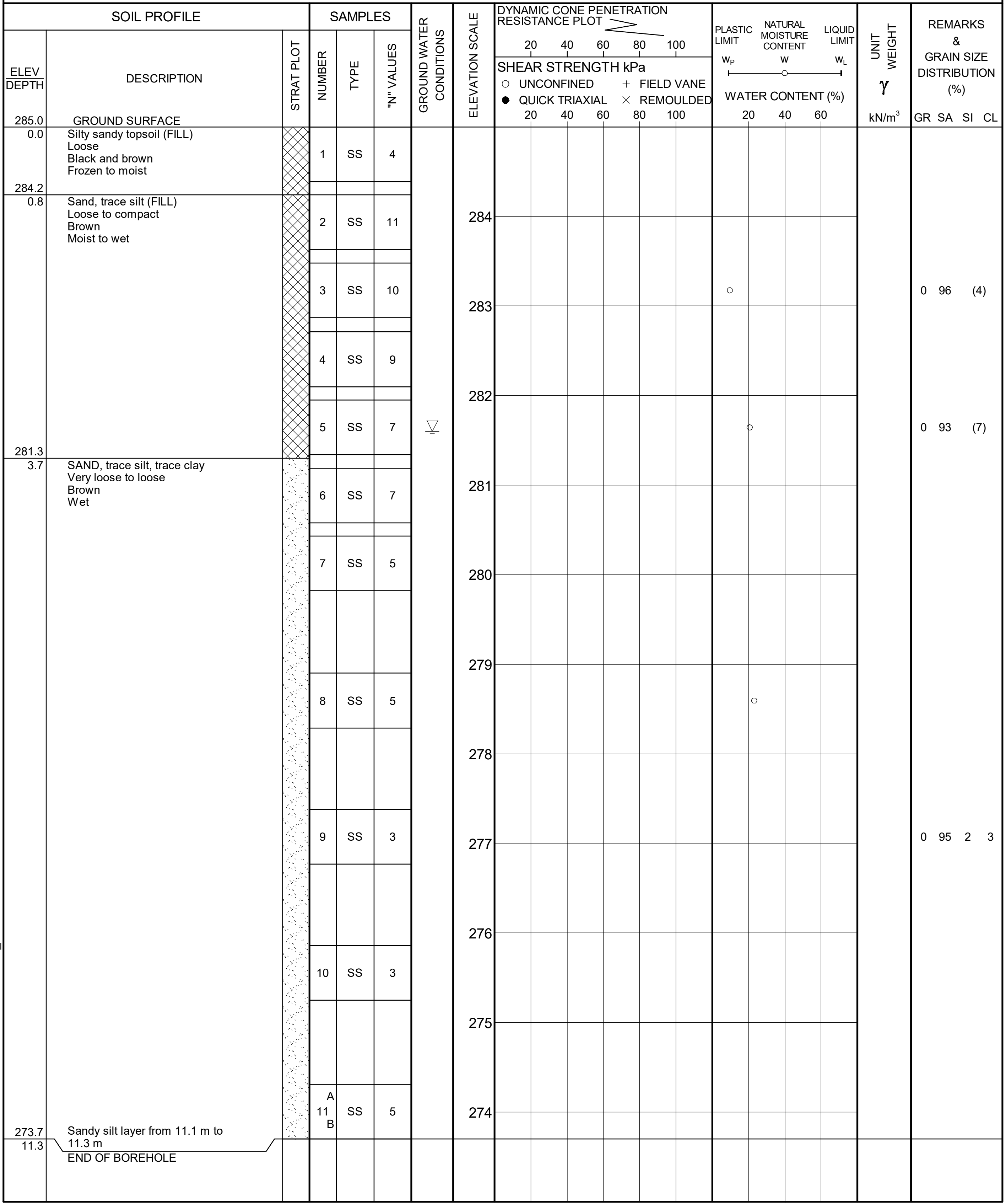
BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers

DATE November 15, 2018

ORIGINATED BY MR

COMPILED BY GM

CHECKED BY AB



ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
285.0	GROUND SURFACE								
0.0	Silty sandy topsoil (FILL) Loose Black and brown Frozen to moist	1	SS	4					
284.2 0.8	Sand, trace silt (FILL) Loose to compact Brown Moist to wet	2	SS	11					
		3	SS	10		0	96	(4)	
		4	SS	9					
		5	SS	7	∇	0	93	(7)	
281.3 3.7	SAND, trace silt, trace clay Very loose to loose Brown Wet	6	SS	7					
		7	SS	5					
		8	SS	5					
		9	SS	3		0	95	2	3
		10	SS	3					
		11 A B	SS	5					
273.7 11.3	Sandy silt layer from 11.1 m to 11.3 m END OF BOREHOLE								

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

SUD-MTO 001 S:\CLIENTS\MTO\HWY65&66\02_DATA\GINT\1896349.GPJ GAL-MISS.GDT 5-27-19 TR

PROJECT 1896349

RECORD OF BOREHOLE No C2-4

2 OF 2 **METRIC**

G.W.P. 5204-14-00

LOCATION N 5287964.1; E 355698.2 NAD83 MTM ZONE 12 (LAT. 47.728777; LONG. -80.321434)

ORIGINATED BY MR

DIST HWY 65

BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers

COMPILED BY GM

DATUM GEODETIC

DATE November 15, 2018

CHECKED BY AB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION *--- CONTINUED FROM PREVIOUS PAGE ---*	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Note: 1. Water level at a depth of 3.4 m below ground surface (Elev. 281.6 m) upon completion of drilling.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

SUD-MTO 001 S:\CLIENTS\MTO\HWY65&66\02_DATA\GINT\1896349.GPJ GAL-MISS.GDT 5-27-19 TR

RECORD OF BOREHOLE No C2-5

1 OF 2 **METRIC**

PROJECT 1896349

G.W.P. 5204-14-00

DIST

HWY 65

DATUM GEODETIC

LOCATION N 5287940.4; E 355675.9 NAD83 MTM ZONE 12 (LAT. 47.728565; LONG. -80.321734)

BOREHOLE TYPE NW Casing and Wash Boring

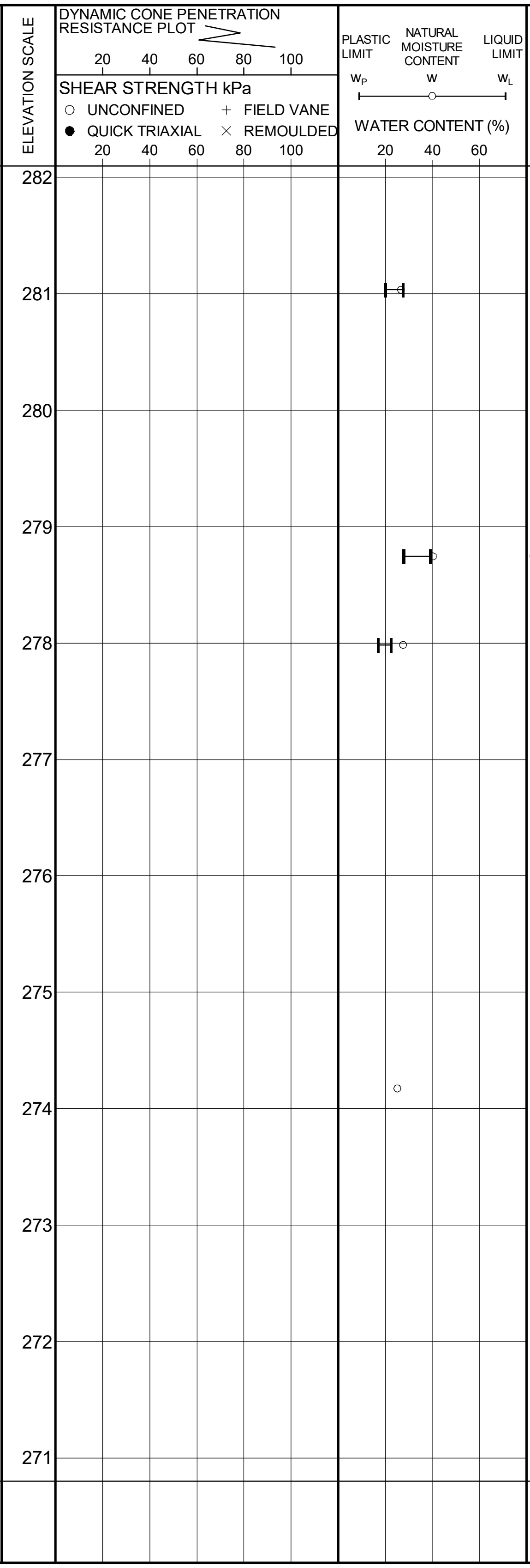
DATE November 15, 2018

ORIGINATED BY MR

COMPILED BY GM

CHECKED BY AB

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
282.1	GROUND SURFACE									
0.0	Silty sandy topsoil, trace gravel, trace wood (FILL) Very loose Brown and black Moist	1	SS	3						
281.5 0.6	Clayey silt, some sand, trace organics (FILL) Firm Brown Moist	2	SS	4	∇		0	15	69	16
280.7 1.4	Silty sand to sand, trace organics (FILL) Very loose to loose Grey to brown Wet	3	SS	2						
279.5 2.6	CLAYEY SILT-SILT, some sand, trace organics Very soft to firm Dark brown Wet	4 A 4 B	SS	7						
		5	SS	2		OC=2.6%	0	7	87	6
		6	SS	7			0	12	74	14
277.7 4.4	SAND, trace silt Loose to compact Brown Wet	7	SS	3						
		8	SS	7						
		9	SS	11			0	96	(4)	
		10	SS	6						
		11	SS	8						
270.8 11.3	END OF BOREHOLE									



Continued Next Page

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

PROJECT 1896349

RECORD OF BOREHOLE No C2-5

2 OF 2 **METRIC**

G.W.P. 5204-14-00

LOCATION N 5287940.4; E 355675.9 NAD83 MTM ZONE 12 (LAT. 47.728565; LONG. -80.321734)

ORIGINATED BY MR

DIST

HWY 65

BOREHOLE TYPE NW Casing and Wash Boring

COMPILED BY GM

DATUM GEODETIC

DATE November 15, 2018

CHECKED BY AB

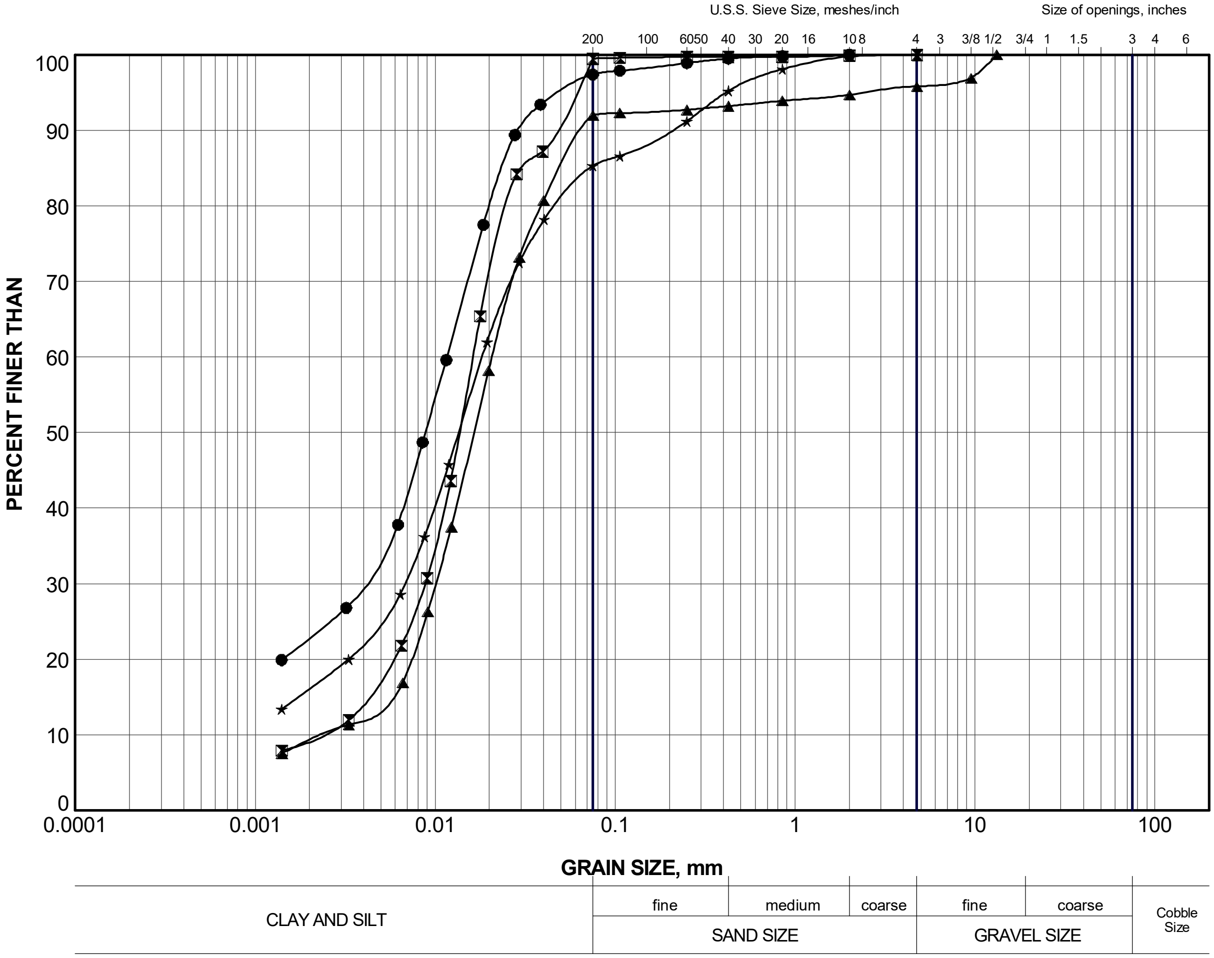
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION --- *CONTINUED FROM PREVIOUS PAGE* ---	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Note: 1. Water level at a depth of 0.8 m below ground surface (Elev. 281.3 m) upon completion of drilling. 2. Split Spoon samples obtained by driving with a 1/2 weight hammer. SPT 'N' values have been adjusted to the inferred values that would be obtained using a standard weight hammer.										

+^{3}, ×^{3}: Numbers refer to Sensitivity

○ $^{3\%}$ STRAIN AT FAILURE

APPENDIX B

Laboratory Test Results



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C2-1	3	284.8
⧗	C2-2	3	284.3
▲	C2-3	3	284.5
★	C2-5	2	281.0

PROJECT

HIGHWAY 65
STATION 15+380
TOWNSHIP OF JAMES CULVERT

TITLE

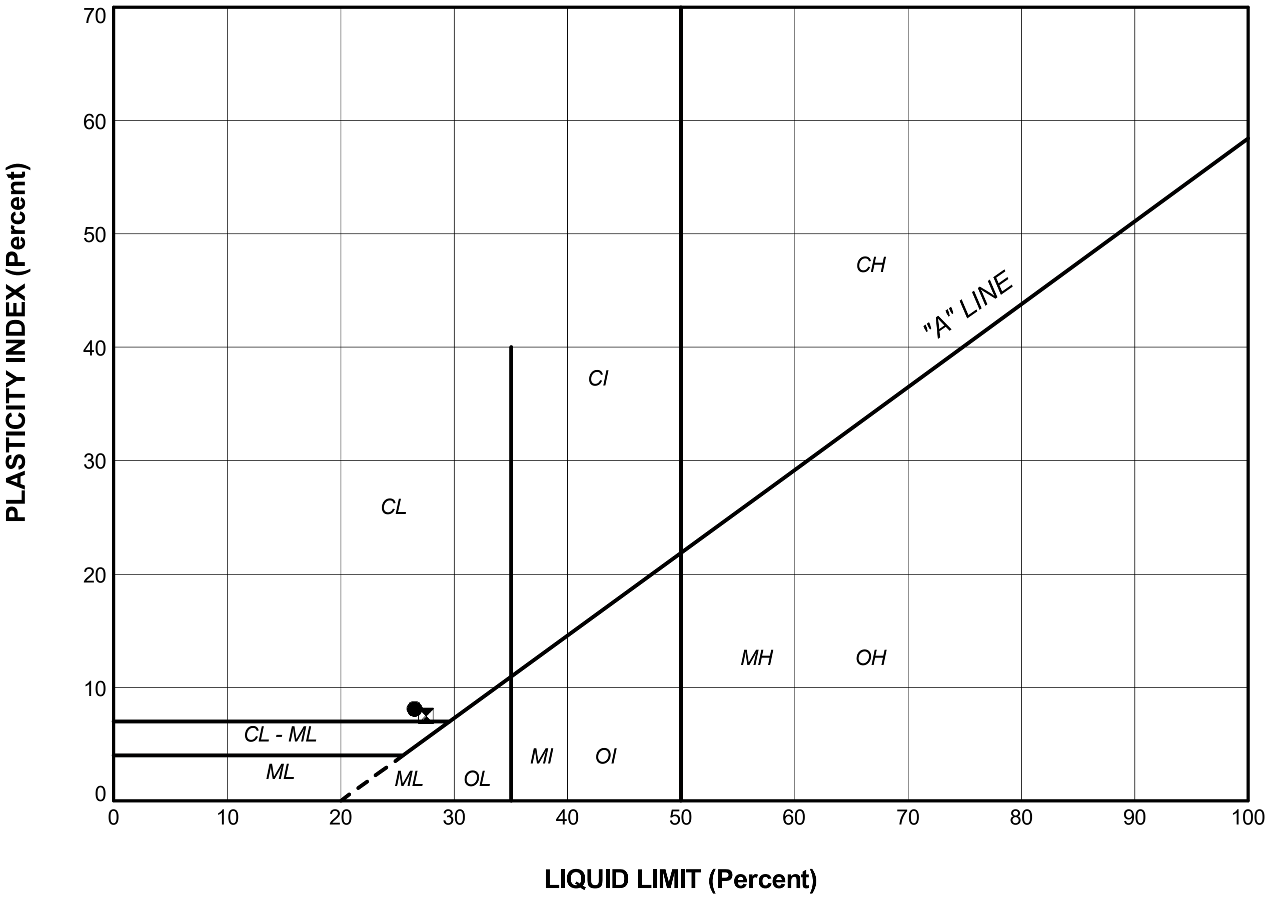
GRAIN SIZE DISTRIBUTION

Clayey Silt (FILL)

GOLDER
SUDBURY, ONTARIO

PROJECT No.		1896349	FILE No.	1896349.GPJ
DRAWN	TR	Apr 2019	SCALE N/A	REV.
CHECK	AB	Apr 2019		
APPR	JMAC	Apr 2019	FIGURE B-1	

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
●	C2-1	3	26.5	18.4	8.1
⧗	C2-5	2	27.5	20.0	7.5

PROJECT

HIGHWAY 65
STATION 15+380
TOWNSHIP OF JAMES CULVERT

TITLE

PLASTICITY CHART

Clayey Silt (FILL)

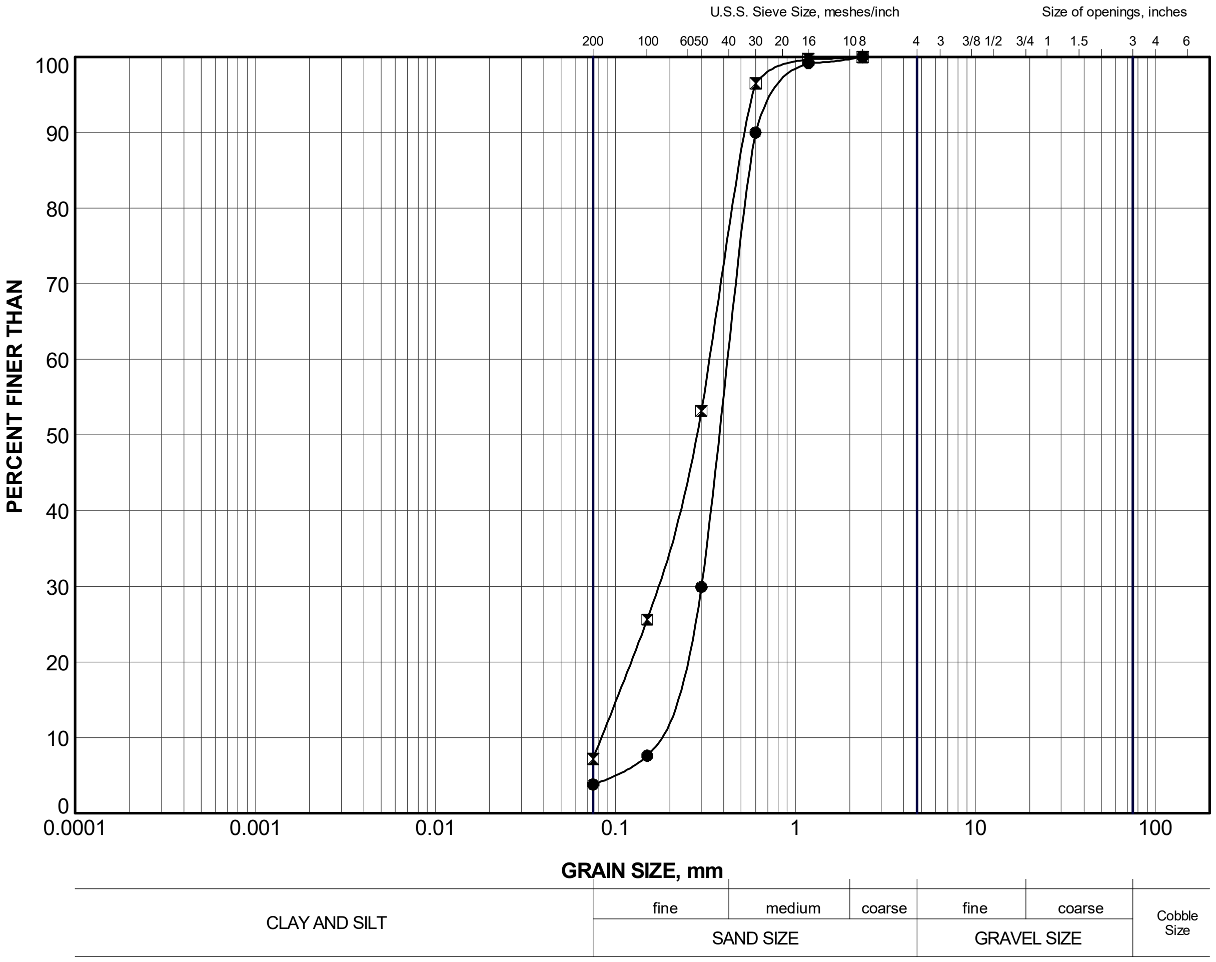
GOLDER
SUDBURY, ONTARIO

PROJECT No.		1896349
DRAWN	TR	Apr 2019
CHECK	AB	Apr 2019
APPR	JMAC	Apr 2019

FILE No. 1896349.GPJ
SCALE N/A
REV.

FIGURE B-2

SUD-MTO PL GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C2-4	3	283.2
⧗	C2-4	5	281.7

PROJECT

HIGHWAY 65
STATION 15+380
TOWNSHIP OF JAMES CULVERT

TITLE

GRAIN SIZE DISTRIBUTION

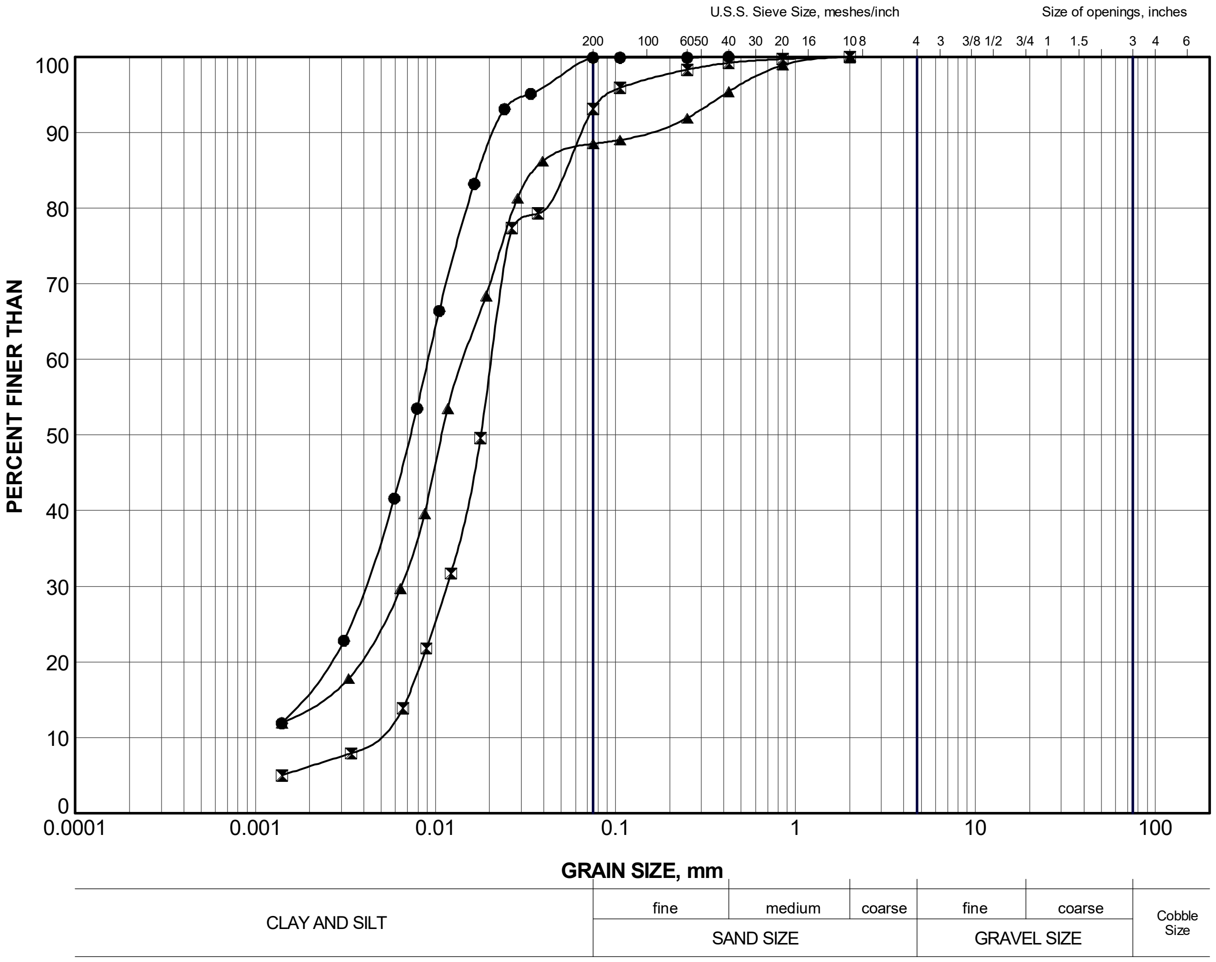
Sand (FILL)

GOLDER

SUDBURY, ONTARIO

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

SUD-MTO GSD GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C2-1	6	282.5
⧗	C2-5	5	278.8
▲	C2-5	6	278.0

PROJECT

HIGHWAY 65
STATION 15+380
TOWNSHIP OF JAMES CULVERT

TITLE

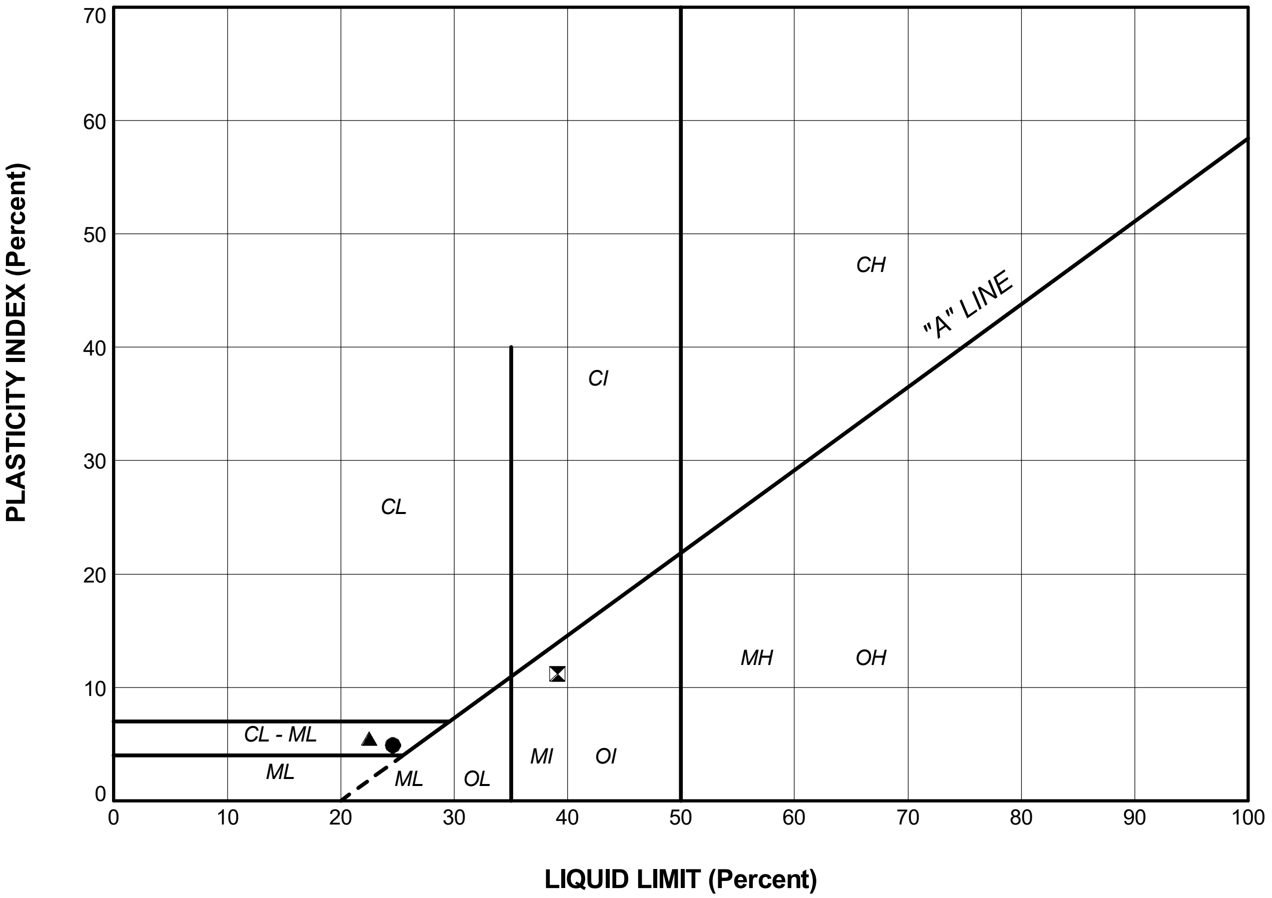
GRAIN SIZE DISTRIBUTION

CLAYEY SILT - SILT

GOLDER
SUDBURY, ONTARIO

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

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
●	C2-1	6	24.6	19.7	4.9
⧗	C2-5	5	39.1	27.9	11.2
▲	C2-5	6	22.5	17.0	5.5

PROJECT

HIGHWAY 65
STATION 15+380
TOWNSHIP OF JAMES CULVERT

TITLE

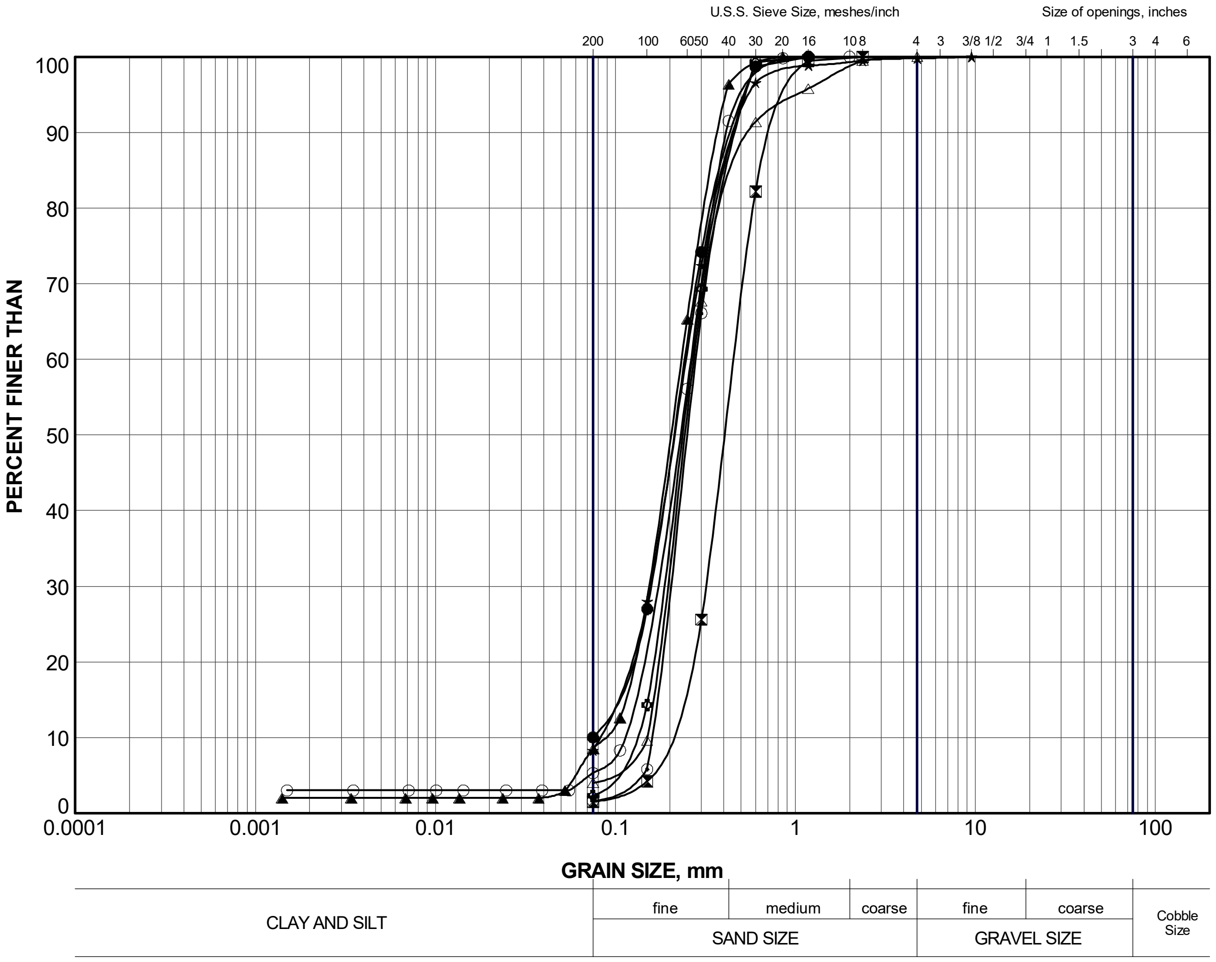
PLASTICITY CHART

CLAYEY SILT - SILT

GOLDER
SUDBURY, ONTARIO

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

SUD-MTO PL GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C2-1	11	275.6
⧗	C2-2	8	279.7
▲	C2-2	11	275.1
★	C2-3	8	279.9
⊙	C2-3	11	275.3
✿	C2-3	14	270.8
○	C2-4	9	277.1
△	C2-5	9	274.2

PROJECT

HIGHWAY 65
STATION 15+380
TOWNSHIP OF JAMES CULVERT

TITLE

GRAIN SIZE DISTRIBUTION
SAND

GOLDER
SUDBURY, ONTARIO

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

SUD-MTO GSD GLDR_LDN.GDT

RESULTS OF ANALYSES OF SOIL

Maxxam ID		IBQ378	IBQ379			IBQ379			IBQ380		
Sampling Date		2018/10/18 08:42	2018/10/11 09:58			2018/10/11 09:58			2018/10/12 09:34		
COC Number		35870	35870			35870			35870		
	UNITS	**C2-3 SA# 4A**	**C8-3 SA# 3**	**RDL**	**QC Batch**	**C8-3 SA# 3 Lab-Dup**	**RDL**	**QC Batch**	**C9-3 SA# 3**	**RDL**	**QC Batch**
Calculated Parameters											
Resistivity	ohm-cm	2300	3300		5794629				2500		5794629
Inorganics											
Soluble (20:1) Chloride (Cl-)	ug/g	150	71	20	5799805	77	20	5799805	170	20	5799805
Conductivity	umho/cm	429	302	2	5797627				396	2	5797627
Available (CaCl2) pH	pH	7.74	7.81		5796193				7.76		5796193
Soluble (20:1) Sulphate (SO4)	ug/g	<20	<20	20	5799807	<20	20	5799807	<20	20	5799807

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

Maxxam ID		IBQ380			IBQ381		
Sampling Date		2018/10/12 09:34			2018/10/13 09:21		
COC Number		35870			35870		
	UNITS	**C9-3 SA# 3 Lab-Dup**	**RDL**	**QC Batch**	**C19-3 SA# 3**	**RDL**	**QC Batch**
Calculated Parameters							
Resistivity	ohm-cm				10000		5794629
Inorganics							
Soluble (20:1) Chloride (Cl-)	ug/g				21	20	5799805
Conductivity	umho/cm	397	2	5797627	99	2	5797627
Available (CaCl2) pH	pH				6.22		5796193
Soluble (20:1) Sulphate (SO4)	ug/g				<20	20	5799807

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

APPENDIX C

Non-Standard Special Provisions and Notice to Contractor

OBSTRUCTIONS – Item No.

Notice to Contractor

The contactor shall be alerted to the presence of cobbles and potentially boulders within the fill deposits along the alignment of the Highway 65, at about Station 15+380, Township of James. Consideration of the presence of these obstructions must be made in the selection of appropriate equipment and procedures for open cut excavations, installation of temporary protection systems.

TEMPORARY PROTECTION SYSTEM – Item No.

Non-Standard Special Provision

Amendment to OPSS 539, November 2014

593.07.02 Removal of Protection Systems

Subsection 539.07.02 od OPSS 539 is deleted in its entirety and replaced with the following:

Protection systems shall be removed from the right-of-way unless it is specified in the Contract Documents that the protection system may be left in place.

Where piles are left in place, the top shall be removed to at least 1.2 m below the finishing grade or ground surface.

The method and sequence of removal shall be such that there shall be no damage to the new work, existing work or facility being protected.

All distributed areas shall be restored to an equivalent to better condition than existing prior to the commencement of construction.

GOLDER

golder.com