GOLDER

Foundation Investigation and Design Report

McIntyre Creek Relief Culvert, (Site No. 30-522/C), Highway 26, County of Simcoe, Ontario, GWP. No.: 2444-15-00, Assignment No. 4016-E-0029, W.O. #4

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PART A

FOUNDATION INVESTIGATION REPORT
MCINTYRE CREEK RELIEF CULVERT, SITE 30-522/6
HIGHWAY 26, COUNTY OF SIMCOE, ONTARIO
GWP 2444-15-00

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 detail foundation investigation and engineering services for the proposed McIntyre Creek relief culvert (MTO Structure Site No. 30-522/C), located on Highway 26 in the County of Simcoe, Ontario, at approximately the location shown on the Key Plan on Drawing 1.

The scope of work for this assignment is outlined in Golder's Change Request dated February 26, 2018; the original Terms of Reference for the foundation engineering services are outlined in MTO's Work Item Order No. 2016-E-0029-004, dated August 2017, which forms part of the Consultant's Assignment for the Central Region Large Value Retainer under Agreement No. 2016-E-0029-004.

2.0 SITE DESCRIPTION

The existing McIntyre Creek culvert is located across Highway 26 between Stayner and Sunnidale Corners, about 135 m east of Sideroad 3&4 Sunnidale, in the County of Simcoe, Ontario. The site is surrounded by farmland, with the ground generally flat-lying. The McIntyre Creek channel is at approximately Elevation 197.8 m at the existing culvert site, and the creek water level within the existing culvert was at approximately Elevation 197.9 m on November 21, 2017. The natural ground surface to the west and east of the creek channel rises to about Elevation 200 m to 202 m. The Highway 26 grade is at about Elevation 203.7 m at the culvert site.

The existing McIntyre Creek culvert is a flat bottomed, corrugated steel pipe (CSP) arch that was constructed in 1976. The culvert is approximately 38.5 m long, 5.1 m wide and 3.0 m high, with about 4 m of fill above the culvert. The creek water flow is from south to north under Highway 26.

3.0 INVESTIGATION PROCEDURES

Field work at the McIntyre Creek culvert was carried out on November 20 and 21, 2017 and April 24 to 26, 2018, during which time four boreholes (designated as Boreholes 17-1 to 17-4) were advanced at the site. The borehole locations as shown on Drawing 1: Boreholes 17-1 and 17-3 were advanced from the roadway platform in the eastbound and westbound lanes of Highway 26, respectively; and Boreholes 17-2 and 17-4 were advanced at the south and north toe of the embankment of Highway 26, respectively.

Borehole 17-1 was drilled using 203 mm outer diameter hollow-stem augers by a D90 truck-mounted drill rig and Borehole 17-4 was drilled using 152 mm outer diameter hollow stem augers advanced by a D20 truck-mounted drill rig, both supplied and operated by Walker Drilling Ltd. of Utopia, Ontario. Borehole 17-2 was advanced using 80 mm outer diameter casing with a portable tripod drill rig supplied and operated by OGS Inc. of Almonte, Ontario. Borehole 17-4 was initially advanced using "NW" casing with a portable tripod drill rig, but due to the near surface hard soil conditions, the drill methods were changed at a depth of 3.1 m to 152 mm outer diameter hollow stem augers by a D25 track-mounted drill rig, both supplied and operated by Walker Drilling Ltd. of Utopia, Ontario. Soil samples were obtained at 0.75 m and 1.5 m intervals of depth using a 50 mm outer diameter split-spoon sampler driven by an automatic hammer in Boreholes 17-1, 17-3 and below a depth of 3.1 m in Borehole 17-4, and driven by a half-weight manual hammer in Borehole 17-2 and the upper 3.1 m of Borehole 17-4 in accordance with

Standard Penetration Test (SPT) procedures (ASTM D1586)[1]. The SPT "N"-values for the upper 3.1 m in Borehole 17-2 have been adjusted to those that would be expected to be measured using a full weight Hammer

Boreholes 17-1 and 17-3 were advanced through the road embankment to depths of about 18.9 m and 12.8 m, respectively, below existing ground surface. Borehole 17-2 was advanced on the south side of Highway 26 at the base of the embankment beside the southeast gabion wall and terminated upon casing refusal at a depth of about 8.2 m below existing ground surface Borehole 17-4 was advanced at the base of the embankment on the north side of Highway 26 at the proposed shaft location to a depth of about 9.8 m below ground surface.

The groundwater conditions in the open boreholes were observed during and immediately following the drilling operations. A standpipe piezometer was installed in each of Boreholes 17-2 and 17-3 to permit monitoring of the water level. The installed piezometer in Borehole 17-2 consists of a 20 mm diameter PVC pipe, with a 1.5 m slotted screen sealed within a filter sand pack with the bottom of the piezometer within the borehole at about 8 m below ground surface. The installed piezometer in Borehole 17-3 consists of a 50 mm diameter PVC pipe, with a 1.5 m slotted screen sealed within a filter sand pack with the bottom of the piezometer within the borehole at about 6 m below ground surface. The borehole and annulus surrounding the piezometer pipe above the filter sand pack were backfilled to the ground surface with bentonite pellets. Piezometer installation details and water level readings are described on the borehole record in Appendix A. Boreholes 17-1 and 17-4 were backfilled to ground surface with bentonite and Borehole 17-1 was sealed at the surface with cold patch asphalt upon completion, in accordance with Ontario Regulation 903, Wells (as amended).

The field work was monitored on a full-time basis by a member of Golder's technical staff who located the boreholes in the field, directed the sampling and in situ testing 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 laboratory in Mississauga for further visual review and geotechnical laboratory testing on selected samples, consisting of natural moisture content, Atterberg limits and grain size distribution analyses conducted in accordance with MTO and / or ASTM Standards as applicable.

The borehole locations were marked in the field by Golder personnel relative to the existing culvert, gabion walls and other site features. The locations given in the Record of Borehole sheets and shown on Drawing 1 are positioned relative to MTM NAD 83 (Zone 10) northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations, ground surface elevations and drilled depths are summarized below.

[1] ASTM D1586 – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of Soils.

Borehole No.	MTM NAD83		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m) (Latitude)	Easting (m) (Longitude)		
17-1	4,920,915.2 (44.426970)	261,849.4 (-80.039439)	203.7	18.9
17-2	4,920,900.0 (44.426835)	261,865.9 (-80.039231)	198.6	8.2
17-3	4,920,917.8 (44.427002)	261,846.3 (-80.039482)	203.7	12.8
17-4	4,920,923.7 (44.427055)	261,836.6 (-80.039604)	201.5	9.8

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

This section of Highway 26 is located in the Stayner Clay Plain within the Simcoe Lowlands physiographic region, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984)[2].

The Simcoe Lowlands physiographic region covers the central portion of the County of Simcoe. Following the retreat of the last glacial ice sheet, the lowlands were flooded by the now extinct post-glacial Lake Algonquin. This post lacustrine environment is marked by deep sand, silt and clay beds overlying glacial ground moraine material. The Stayner Clay Plain is partly a bevelled till plain with pebbly till appearing at or near the surface. Some areas are floored with deeper beds of clay, while in other places the clay is covered with up to several feet of sand.

4.2 General Overview of Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of the in situ and laboratory tests are provided on the borehole records in Appendix A. The results of the in situ field tests (i.e., SPT "N"-values) as presented on the borehole records, on the stratigraphic profiles and in Section 4 are uncorrected. The results of the laboratory test are presented on the borehole records in Appendix A and in the laboratory test plots in Appendix B.

The stratigraphic boundaries shown on the borehole records and on the interpreted stratigraphic profile on Drawing 1 are inferred from non-continuous sampling, observations of drilling progress and the results of Standard Penetration Tests. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Variation in the stratigraphic boundaries between and beyond boreholes will exist and is to be expected; however, the factual data presented on the borehole records governs any interpretation of the site conditions.

In general, the native subsurface soils encountered near the proposed McIntyre Creek Relief Culvert consist of predominantly non-cohesive deposits of sand and silt separated by interlayers of clayey silt. A detailed

[2] Chapman, L.J. and Putnam, D,F. 1984. *The Physiography of Southern Ontario*, Ontario Geological Survey, Special Volume 2, Third Edition. Accompanied by Map P. 2715, Scale 1:600,000.

description of the subsurface conditions encountered in the boreholes is presented in the following sections of this report.

4.2.1 Fill

Boreholes 17-1 and 17-3 were advanced from the Highway 26 platform and penetrated approximately 200 mm of asphalt pavement in Borehole 17-1. Approximately 1.2 m and 1.5 m of granular fill material comprised of gravelly sand was encountered underlying the asphalt in Borehole 17-1 and from ground surface in Borehole 17-3, respectively. The granular fill below Elevations 202.3 m and 202.2 m in Boreholes 17-1 and 17-3 is underlain by a 4.2 m and 3.2 m thick fill deposit comprised of clayey silt with sand and sandy clayey silt containing a trace of gravel and trace of organics, extending to about Elevations 198.1 m and 199.0 m respectively.

Borehole 17-4 advanced at the north toe of the roadway embankment encountered an approximately 1.2 m thick deposit of fill material comprised of an upper 0.6 m thick layer of silty sand and a lower 0.6 m thick layer of clayey silt from ground surface, extending to Elevation 200.3 m.

Standard Penetration Tests (SPT) “N”-values measured within the non-cohesive portion of the fill layer from 8 blows to 34 blows per 0.3 m of penetration, with one discrete value of 100 blows per 0.08 m of penetration, indicating that the non-cohesive fill has a compact to very dense relative density. SPT “N”-values measured within the cohesive portion of the fill range from 3 blows to 16 blows per 0.3 m of penetration, suggesting that the cohesive fill has a soft to stiff consistency.

A grain size distribution test was carried out on two samples of the cohesive fill layer and the results are shown on Figure B1 in Appendix B. Atterberg limits testing was carried out on two samples of this cohesive fill layer and measured liquid limits of about 28 per cent and 30 per cent, plastic limits of about 15 per cent and 17 per cent, and plasticity indices of about 13 per cent and 14 per cent. These results, which are plotted on a plasticity chart on Figure B2 in Appendix B, indicate that the cohesive fill layer is clayey silt of low plasticity. A natural water content of 6 per cent was measured on one sample of the gravelly sand fill material, while natural water contents ranging between about 11 and 33 per cent were measured on samples of the clayey silt to clayey silt with sand fill.

4.2.2 Clayey Silt (Upper Deposit)

A clayey silt upper deposit was encountered in Boreholes 17-1, 17-2 and 17-4. In Boreholes 17-1 and 17-4 the deposit was encountered beneath the cohesive fill material at Elevations 198.1 m and 200.3 m and is approximately 1.6 m to 1.9 m thick, respectively. In Borehole 17-2, the deposit was encountered immediately below ground surface at Elevation 198.6 m and is 1.5 m thick.

SPT “N”-values ranging from 2 blows to 76 blows per 0.3 m of penetration and two “N”-values of 50 blows for 0.08 m and 0.10 m of penetration were measured within the clayey silt deposit. The SPT “N”-value of 2 blows per 0.3 m of penetration was measured immediately below surface in Borehole 17-2, and this portion of the deposit is considered to have a very soft to soft consistency. The remaining SPT “N”-values suggest a hard consistency.

A grain size distribution test was carried out on two samples of the clayey silt deposit and the results are shown in Figure B3 of Appendix B. The deposit consists of clayey silt containing trace to some sand, as well as trace to some rootlets in Borehole 17-2. Atterberg limits testing was carried out on two samples of the cohesive deposit and measured liquid limits of about 22 and 24 per cent, plastic limits of about 16 and plasticity indices of about 6 and 9 per cent. These results, which are plotted on a plasticity chart on Figure B4 in Appendix B, indicate that the cohesive deposit is a clayey silt of low plasticity. The natural water content measured on three samples of this deposit are between 14 and 21 per cent.

4.2.3 Silt to Silty Sand to Sand

A deposit consisting of interlayers of silt containing trace to some sand, silt and sand to silty sand, and sand containing trace to some silt, was encountered underlying the fill in Borehole 17-3 and underlying the clayey silt upper deposit in the remaining boreholes at between Elevations 199.0 m and 196.5 m. Boreholes 17-1, 17-3 and 17-4 terminated within this deposit after penetrating it for between approximately 6.7 m and 11.7 m, to between Elevations 191.7 m and 184.8 m. Borehole 17-2 penetrated through 5.7 m of this deposit before encountering a lower clayey silt deposit (described below).

SPT “N”-values ranging from 22 blows to120 blows per 0.3 m of penetration and “N”-values up to 100 blows for 0.1 m of penetration were recorded within the silt to sand deposit, indicating a compact to very dense relative density. One SPT “N” value of 6 blows per 0.3 m was measured at the surface of the silt deposit in Borehole 17-3.

Grain size distribution tests were carried out on eight samples of the silt to sandy silt portion of the deposit and two samples of the silty and sand to silty sand portion of the deposit, and the results are shown on Figures B5A and B5B and B6, respectively, in Appendix B. Atterberg limits tests were carried out on five samples of the silt deposit; two of the results show that the silt deposit is non-plastic, while three tests measured liquid limits between about 16 and 18 per cent, plastic limits between 14 and 16 per cent and plasticity indices between about 2 and 3 per cent. These latter results, which are plotted on a plasticity chart on Figure B7 in Appendix B, indicate that this layer consists of a silt of slight plasticity. The natural water content measured on samples of the silt to silt sand to sand deposit range from about 15 to 23 per cent.

4.2.4 Clayey Silt (Lower Deposit)

A lower deposit of clayey silt was encountered below the sandy silt layer of the non-cohesive deposit in Borehole 17-2 at a depth of 7.2 m, corresponding to Elevation 191.4 m. Borehole 17-2 terminated within this deposit/layer, penetrating it for a thickness of 1.0 m. The deposit consist of clayey silt containing some sand.

An SPT “N”-value of 41 blows per 0.3 m was measured within the lower clayey silt deposit, suggesting a hard consistency.

The natural water content measured on one sample of this deposit is about 16 per cent.

4.3 Groundwater Conditions

The groundwater levels in the open boreholes were measured upon completion of drilling operations. A standpipe piezometer was installed in each of Boreholes 17-2 and 17-3 to permit monitoring of the groundwater level at this site. Details of the piezometer installation and the measured groundwater levels are shown on the borehole records in Appendix A. The groundwater level recorded in the open boreholes and piezometer are summarized below.

Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)	Date	Comments
17-1	203.7	7.9	195.8	Nov. 20, 2017	Open borehole
17-2	198.6	1.5	197.1	Nov. 21, 2017	Open borehole
		4.0*	194.6	Jan. 26, 2018	Piezometer
		0.9	197.7	July 6, 2018	
17-3	203.7	4.2	199.5	April 24, 2018	Piezometer
		4.3	199.4	June 22, 2018	
17-4	201.5	-	-	-	Water level was not taken due to use of drilling mud

* Water was apparently frozen within the standpipe piezometer at a depth of 4.0 m below ground surface and may not be representative of the groundwater level.

The groundwater level observations at this site will be subject to seasonal fluctuations and precipitation events; the water levels should be expected to be higher during the spring season or during and following periods of heavy precipitation.

4.4 Analytical Testing Results

A soil samples was submitted to MAXXAM Analytical Laboratory for analysis of parameters used to assess the potential corrosivity of the site soil to steel and concrete. Detailed analytical test results are included in Appendix C and the test results are summarized below.

Borehole No. / Sample No.	pH	Resistivity (ohm-cm)	Electrical Conductivity (umho/cm)	Soluble Chloride (ug/g)	Soluble Sulphates (ug/g)
17-3 / 7B	7.81	490	2040	1200	<20

5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Nikol Kochmanová, P.Eng., a geotechnical engineer with Golder. Jorge Costa, P.Eng., a MTO Foundations Designated Contact and Senior Consultant for Golder, conducted a quality control review of the report.

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PART B

FOUNDATION DESIGN REPORT
MCINTYRE CREEK RELIEF CULVERT, SITE 30-522/6
HIGHWAY 26, COUNTY OF SIMCOE, ONTARIO
GWP. 2444-15-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides discussion and foundation engineering recommendations for the proposed trenchless culvert installation associated with the proposed McIntyre Creek relief culvert (MTO Structure Site No. 30-522/C) works, located on Highway 26 in the County of Simcoe, Ontario. These recommendations are based on interpretation of the factual data obtained from the boreholes and sampling. The discussion and recommendations presented are intended to provide the design engineers with sufficient information to assess the feasible alternatives of trenchless culvert installation.

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. The contractor must make their own interpretation of the factual information provided in Part A (Foundation Investigation). 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 or operational constraints 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

It is understood that the new culvert will consist of a 2 m diameter steel pipe with a wall thickness of 25 mm. The invert varies from Elevation 197.95 m at the upstream (south) end to 197.92 m at the downstream (north) end. It is recommended that the casing/liner, if utilized to advance the trenchless bore have as small a diameter as possible to still allow installation of the storm carrier pipe within it, such as diameter of 2.1 m, resulting in an approximately 2.9 m cover depth thickness Highway 26 (See Section 6.3).

The contractor should be fully responsible for the selection of the trenchless technology which best fits the Contract requirements and subsurface conditions. All trenchless work should be carried out in accordance with MTO's Non-Standard Special Provision (NSSP), titled "Pipe Installation by Trenchless Method", included in Appendix D, as modified by the recommendations provided in this report, and by an experienced specialist contractor employing only qualified workers skilled in their trade under the direction of an experienced foreman. The work plan should include a provision for grouting around the outside of any temporary or permanent ground support systems (e.g. liner) should the need arise. It is recommended that the geotechnical aspects of the contractor's work plan for the trenchless undercrossing be reviewed by a qualified geotechnical engineer prior to construction.

In general, when crossing beneath highways, trenchless operations should be carried out continuously (i.e. 24 hours per day) from the start until the installation is complete. Continuous operations assist with minimizing risks of equipment becoming bound in the excavation by time-dependent increases in friction and/or adhesion, uncontrolled ground losses, and other critical problems that may occur while the work area is unattended. Recommendations specific to the methodologies appropriate for this site are provided in the following report sections.

6.2 Pipe Materials

Installation of the culvert by either conventional jack and bore or pipe ramming methods will require that a steel casing be installed during boring or ramming. The steel casing would remain in place, with a smaller diameter culvert pipe installed within the casing. It is recommended that grout be injected into the annular space between the culvert pipe and the steel casing, as discussed further in Section 6.9. It has been assumed that the steel casing will, as a minimum, be sufficiently large in diameter as compared to the proposed culvert pipe outside diameter to allow for final adjustment of the final pipe invert alignment since construction tolerances and misalignment during installation of the steel casing could otherwise jeopardize proper gravity-flow of the culvert.

If micro-tunnelling methods are selected for this project, it is likely that the culvert pipe will be jacked into place behind the micro-tunnelling cutter head. Different pipe materials could be used from interlocking steel pipe to glass-fibre reinforced concrete (mortar) pipe specially made for micro-tunnelling. In such cases, the jacking pipe may be used for the final culvert pipe, depending on materials and installed diameter requirements. It will be essential to specify appropriate hydraulic, joint integrity and long-term abrasion resistance performance requirements in the event that alternative pipe materials are proposed by the trenchless contractor.

The pipe must be selected to withstand the overburden and highway loads, hydrostatic pressures (if present), and the installation forces and grouting pressure. The overburden pressure may be calculated using a unit weight of 21 kN/m^3. The unit weight of water may be taken as 9.8kN/m^3.

6.3 Culvert Tunnel Alignment

A summary of the proposed culvert and estimated casing pipe diameter, invert elevations, the cover thickness at the highway shoulders, and the corresponding estimated range of overburden cover expressed as a function of the tunnel diameter (i.e., the number of tunnel diameters between the crown of the tunnel and the overlying/highway ground surface) is provided below:

Proposed Culvert Diameter (m)	Estimated Liner / Casing Pipe Min. Diameter (D) (m)	Existing Pavement / Shoulder Crest Elevation (m)	Proposed Culvert Invert Elevation (m) (Upstream / Downstream)	Estimated Liner / Casing Pipe Obvert Elevation (m) (Upstream / Downstream)	Estimated Cover Thickness on Liner / Casing (m) (Upstream / Downstream)	Approx. Minimum Cover Thickness on Liner / Casing (Upstream / Downstream)
2.0	2.1	203	197.95 / 197.92	200.1 / 200.07	2.9 / 2.93	1.38D / 1.39D

For tunnels under highways, MTO typically requires that the minimum overburden cover shall not be less than 1.5 m or generally two tunnel diameters, whichever is greater, at any point along the entire length of the tunnel crossing. Based on the vertical alignment drawings provided by AECOM, the estimated tunnel obvert is less than two tunnel diameters equivalent cover thickness along the culvert alignment; however the requirement for a minimum 1.5 m thickness of cover is met. In order to increase the cover thickness consideration may be given to lowering the invert at this location, which this may not be feasible due to hydraulic constraints, or alternatively, twin smaller diameter pipes could be used at these locations to provide over burden cover of a thickness that is at least two tunnel diameters.

The proposed pipe invert is also at or just below the approximate interface of the roadway embankment fill and native material which suggests that the carrier pipe alignment could be deflected upwards at this interface because of the different character of these materials which could lead to reduced thickness of overburden cover. Typically it is recommended that the tunnel obvert be a minimum of 0.5 m below the fill/native interface so that the tunnel horizon is primarily within the native soil deposits; however, it is understood that other constraints, such as the existing creek elevation, may not allow the depth of cover to be increased at this location.

Typically, trenchless construction (and tunnelling) is undertaken in the direction of increasing elevation to allow for gravity drainage of groundwater seepage; therefore the entry shaft would be located at the lower elevation end and the exit shaft would be located at the higher elevation end. Based on the General Arrangement drawings provided by AECOM, the proposed installation direction is from the downstream (north) end to the upstream (south) end. It will be necessary that where the base of the shafts is below the anticipated groundwater level the shaft be dewatered to maintain stability of the excavation base.

6.4 Anticipated Ground Conditions

Based on the subsurface data, the subsurface conditions along the proposed culvert alignment vary from firm to very stiff clayey silt with sand fill to hard clayey silt to loose to dense silt to dense to very dense silt and sand to silty sand. Organic material was encountered within the fill material and wood debris may be encountered within the fill/native soil interface. The groundwater level is generally at the creek level, which is within the proposed tunnel horizon (i.e. above the invert level), at about Elevation 199.4 m; however this conditions may represent a perched water table on the clayey silt stratum underlying the embankment fill.

The behaviour of the anticipated subsurface materials can be classified using Terzaghi's Tunnelman's Ground Classification system as modified by Heuer (1974). This system is commonly used to describe the expected behaviour of an unsupported tunnel face during excavation and uses qualitative "stand-up time" criteria to classify the ground at and above the tunnel face into the following principal categories: firm, slowly ravelling, fast ravelling, cohesive-running, running and flowing. The subsurface conditions along the tunnel horizon of the proposed culvert alignments, the ground water conditions, as well as the classification of the behaviour of these soils based on Terzaghi's Tunnelman's Ground Classification system is summarized below.

Borehole Nos.	Anticipated Subsurface Conditions at Culvert Alignment	Soil Behaviour	* Groundwater Elevation (m)	Distance between Groundwater and Invert of Culvert (m) (Upstream / Downstream)
17-1 17-2 17-3* 17-4	■ Firm to very stiff clayey silt with sand fill	■ Firm to slow ravelling	199.4	1.45 / 1.48 above invert
	■ Hard clayey silt	■ Firm		
	■ Loose to dense silt	■ Cohesive running to flowing		
	■ Dense to very dense silt and sand to silty sand	■ Cohesive running to flowing		

* Highest measured groundwater elevation in closest piezometer (subject to fluctuation).

Stand-up time will range from about one hour to approximately one day for the clayey silt fill and native clayey silt deposit if properly dewatered or above the groundwater level and will be less than 1 hour for the native silt, silt and sand to silty sand deposits. Below the groundwater level the native silt, silt and sand to silty sand deposits in an unsupported excavation would flow with little to no stand-up time. The remaining materials would have a stand-up time of approximately one day for the cohesive fill and native deposits.

Trenchless installations will be primarily affected by five factors associated with the subsurface and groundwater conditions, namely:

- The nature of the embankment fill: the fill, particularly at the ground surface, may be granular and can be excavated with several trenchless methods provided that the appropriate precautions are taken to preserve face stability, prevent void formation and potential loss of ground. Most of the fill along the alignment is anticipated to be cohesive and favourable for most types of trenchless technologies.
- Remnants of the original construction buried in the fill particularly along the original ground interface: Our recent experience with trenchless crossings of major MTO highways suggests that there may be debris consisting of abandoned temporary works associated with the original construction; such as logs, stumps and brush from the clearing and grubbing operations; and cobbles and boulders buried in the fill. Such obstructions have the potential to damage/clog/obstruct machinery and halt trenchless operations, particularly if there is no person-access to the excavation face to clear the obstruction.
- Mixed Face Tunnelling: the vertical alignment will encounter a mixed face consisting of firm to very stiff clayey silt with sand fill, hard clayey silt, loose to dense silt and dense to very dense silt and sand to silty sand. In addition to the potential for encountering obstructions buried in the fill, the selected trenchless methodology must be adaptable to varying subsurface conditions which can change from firm to hard in the cohesive fills and native deposits to cohesive running or flowing in the granular materials. The selected methods and equipment must provide sufficient face support for the granular materials. In general, the native materials are denser/harder than the overlying fill. There is the potential, particularly with jack and bore or pipe ramming methods, for the casing/pipe to ride-up on the more resistant materials and into the softer overlying fills.
- Groundwater: the groundwater was encountered at the surface of the cohesive deposit which is above the non-cohesive deposits, and those trenchless technologies/methods that do not provide effective face support to prevent flowing or running of the native non-cohesive materials should be prohibited.

The Contract Documents should contain a NSSP warning the contractor of obstructions within the fills and the difficulties associated with tunneling along the interface of the embankment fill and the underlying native soils; an example NSSP is provided in Appendix D.

6.5 Review of Trenchless Installation Methods

For typical MTO construction contracts, the contractor is responsible for choosing the method and equipment for culvert installation unless specific methods are otherwise prohibited. Ground behaviour will be, in part, dependent on the installation method adopted and this report provides guidance on the influence of ground behaviour on some possible culvert installation methods. While in general, it should not be construed that the contractor is restricted to the particular methods considered herein, this report does recommend that some trenchless construction methods be specifically prohibited or mandated at select locations. For any construction method, the contractor must make his own interpretation of the anticipated ground behaviour, based on the factual information provided in Part A, Foundation Investigation Report.

Based on the culvert profile provided by AECOM, it is understood that it is preferable that the culvert be installed using trenchless methods under Highway 26. Trenchless methods that might be contemplated for this site include conventional jack and bore, pipe ramming, horizontal directional drilling (HDD), microtunnel boring machine (MTBM), conventional tunneling with tunnel boring machine (TBM) and hand or mechanically-assisted mining. Tunnelling methods noted above, except for HDD, will require entry and exit shafts / pits and control of seepage into the excavations.

Jack and bore and pipe ramming are susceptible to deflection at this site due to the differing densities present along the proposed culvert alignment. Additionally, there are very few contractors in Ontario with jack and bore and pipe ramming equipment capable of installing larger diameter (2.0 m diameter or greater) bores. Given the subsurface conditions and the limited availability of contractors capable of installing the proposed culvert, jack and bore and pipe ramming methods are not considered practical for this site and is not considered further herein.

HDD uses drilling fluid under pressure to create the pilot hole and is typically used for smaller diameter crossings below embankments or rivers, where the installed carrier pipe will be conveying fluid under pressure and therefore is not dependant on gravity drainage as is the case for the culvert at this site. However, HDD would require a long entrance / exit bore curvature to achieve the required vertical alignment at the ends of the crossing and would typically require greater thickness of cover than is present at the culvert location at this site to minimize the risk of hydraulic fracturing of the ground and loss of drilling fluid to the surface (“frac-out”). Therefore the HDD method is not considered suitable and is not considered further herein.

6.5.1 Microtunnel Boring Machine (MTBM)

Microtunnelling is a guided pipe-jacking process which uses a remotely controlled TBM to provide continuous support to the excavation face. It relies on a horizontal jacking force applied to the pipe to propel the remotely controlled microtunnel boring machine (MTBM) along with the pipe string through the ground. The pipe is typically installed while the bore is being advanced and serves both as temporary ground support and the final culvert. Specially designed jacking pipe made from steel, glass fibre reinforced plastic (GFRP) or reinforced concrete, and capable of transferring the jacking forces from the jacking reaction frame in the shaft to the MTBM, will be required. Entry and receiving shafts are required for microtunnelling operations. Dewatering will be required only at the shafts since MTBMs can operate in saturated soils below the groundwater level. Microtunnelling is typically able to maintain high accuracy (± 25mm) with line and grade control.

There are two main types of microtunnelling tunnel boring machines (MTBMs), classified by the cuttings transport equipment: auger type; and slurry type. A slurry type MTBM operation is recommended for this project. A slurry MTBM has a full-face rotating cutting head with openings through which the spoil enters a pressurized slurry chamber behind the head. The slurry is used to balance the hydrostatic pressure and convey suspended cuttings away from the face. Typically, MTBMs are limited to passing boulders one third of the machine diameter, but some models have a crusher chamber which breaks down the obstructions to a size which can be pumped with the cuttings. However, the volume or size of the boulders may be such that the capacity of the crusher could be exceeded resulting in either abandonment of the bore or advancement of a rescue shaft to remove the obstructions and permit resumption of tunnelling. If woody debris is encountered in the fill, it will likely clog the machine, also necessitating a rescue shaft and possibly repairs.

Generally, it is recommended that a minimum of two tunnel diameters equivalent cover thickness is present along the culvert alignment when using a slurry system due to the risk of hydraulic fracturing of the ground and loss of drilling fluid to the surface. The cover thickness at the site is only about 1.38D along the proposed culvert alignment, increasing the risk of a “frac-out”.

An overcut will be required to: reduce frictional forces along the pipe string; reduce jacking forces; and facilitate steering. The overcut should be minimized by selection of an excavated diameter which results in an annular space between the excavated hole and outer diameter of the jacking pipe no greater than 40 mm. The annulus between the outside of the pipe and the ground should be immediately filled with bentonite slurry of an appropriate viscosity using lubrication ports in the pipes installed at regular intervals.

Care during operation is required to maintain adequate support at the face of the MTBM especially in loose non-cohesive deposits. In highly permeable deposits where the groundwater level is below the obvert, there is the potential for loss of the slurry away from the machine face. The bentonite based slurry should be appropriately formulated, using suitable polymers and additives if necessary for the anticipated ground conditions to prevent fluid loss and maintain a stable ground condition at the face and around the MTBM. When installing the culvert in non-cohesive deposits, the slurry should be sufficiently viscous to create a “filter-cake” to support the granular material. A seal will be required to close the annular space between the wall of the entry/exit shaft and the shield and pipes to retain soil behind the temporary shoring and stop backflow of the slurry into the pits.

The MTBM should be equipped for mixed face conditions. The selected cutting tools and methods should be compatible with variable ground conditions, including firm to hard cohesive deposits, loose to very dense non-cohesive materials, and potential debris material within the fill, including cobbles and boulders. Properly selected rock cutter discs should be used to cut the hard/very dense deposits and break cobbles and boulders at the face into smaller enough fragments to pass through the apertures in the face. Only closed-face machines equipped with rock cutters and a crusher changer should be used at this site. In addition to cobbles and boulders, the contractor’s work plan should include a method of dealing with debris in the fill materials.

The embankment fill deposits along the tunnel alignment are generally softer/less dense than the native deposits encountered along the alignment and below the invert. Noting the varying material consistencies/densities, and that the fill materials may contain cobbles and boulders and/or debris material, the contractor should be prepared for steering difficulties, deflection of the machine and increased wear or damage to the cutters or cutter housings due to high impact forces.

Person-entry to remove obstructions is generally not available for MTBMs. Even if equipped with a crusher chamber and rock cutting tools, the MTBM will be stopped by boulders greater than one third of the diameter. Given the potential for encountering obstructions in the embankment fill and native deposit, there is a risk of these obstructions either impeding or halting the machine. Additionally, the cover thickness along the culvert alignment is less than the recommended two tunnel diameters equivalent, increasing the risk of a “frac-out”. For these reasons, a microtunnelling installation at this site is considered to be only marginally feasible.

6.5.2 Conventional Tunnelling with Tunnel Boring Machine

Depending on the selected equipment, it might be possible to install the culvert using a tunnel boring machine (TBM). Since the ground conditions require continual support of the face only closed-face TBMs that provide support to the face to balance hydrostatic and earth pressures should be employed. Dewatering will be required at the entry and receiving shafts.

Depending on the contractor’s available equipment and experience, the size of this installation allows for small diameter conventional (man-entry) TBMs to be used. In this case, face control and cuttings transport may be accomplished using “earth pressure balance” (EPB) technologies in which discharge from the chamber is controlled by pressure relieving gates or doors that open at pre-set pressures or loads. Another system uses a screw conveyor to remove materials from the chamber at rates that maintain specified pressures within much of the excavated chamber. While older relieving gate EPB systems are not as controlled as with screw conveyor systems, the combination of face opening sizes and relieving gate opening size allows for passage of cobbles, boulders and smaller debris without clogging and damaging the machine and, providing flowing ground is controlled, can allow access to the face to remove larger obstructions. Some TBM systems are promoted as being "earth pressure balance" when they do not actually achieve the goals of the EPB technology. Such unacceptable systems rely only on doors that close the face or rely on jacking forces being transmitted to the steel sections of the machine face where this is then interpreted as "face pressure." Such systems should be prohibited for this project since they could result in significant ground losses and the consequential safety risks and claims. Also, older TBMs that do not include a secondary bulkhead and controlled muck discharge system should be prohibited for this project.

The machine should must be equipped with hardened disc cutters (as well as soft ground spade, drag bits and picks) to handle the hard/very dense deposits. The contractor should be prepared to deal with obstructions in the fill and native deposits.

Face stability should be constantly monitored. Overexcavation above or ahead of the TBM and lining should be avoided to maintain face stability. The overcut should be minimized by selection of a lining diameter which is similar to that of the TBM. Face pressure should be selected and maintained at values no less that the active earth pressure at the tunnel vertical centreline. If over excavation or ground losses occur, the annulus between the outside of the pipe and the ground and any voids at the face should be immediately filled with bentonite slurry of an appropriate viscosity and/or low strength grout.

As with MTBMs, it is generally recommended that a minimum of two tunnel diameters equivalent cover thickness is present along the culvert alignment when using a slurry system due to the risk of hydraulic fracturing of the ground and loss of drilling fluid to the surface. The cover thickness at the site is only about 1.38D along the proposed culvert alignment, increasing the risk of a "frac-out".

The selected equipment, face tooling and methods must be able to adapt to changing ground conditions which include the presence of flowing or running non-cohesive materials. Alignment may be affected by the presence of layers/deposit with varying consistencies/densities, as well as potential debris within the fill materials. Due to the cover thickness along the culvert alignment being less than the recommended two tunnel diameters equivalent, increasing the risk of a "frac-out", a TBM installation at this site is considered to be only marginally feasible.

6.5.3 Hand or Mechanically-Assisted Mining

Hand mining or mechanically assisted excavation within a shield with jacked pipe, steel liner plate, or steel ribs and lagging is considered a feasible method for the culvert installation provided groundwater pressures and seepage are adequately controlled. In this method, the tunnelling process is carried out by removing excavated soil from the front cutting face and installing a liner to form a continuous ground support structure. The liner may be installed using a two-pass system or a single pass where the culvert pipe is jacked in during excavation and provides both temporary and permanent support. With a two-pass system, a conduit is installed between the entry and exit shaft by first installing a segmental temporary or primary liner. Once the full length of the primary liner has been constructed, a permanent or secondary liner is installed. The primary liner may consist of steel ribs and wooden lagging or steel liner plates. The secondary liner is typically of cast-in-place concrete construction but may be a smaller primary conduit (carrier) pipe of any suitable material. If the carrier pipe option is used, the annulus between the primary and secondary liners is grouted. The soil may be excavated using hand mining techniques and shields that include the capability of closing the face with breasting boards, plates or mechanical systems. The most economical option would be to install the culvert in a single pass using a steel pipe. Higher costs would be incurred for concrete pipes and two-pass systems.

In hand mining, excavation is conducted at the face using picks, shovels, or pneumatic hand held tools. Using conventional tunnelling or pipe jacking techniques, a protective shield, which may have a forward hood projection to provide additional face stability during soil excavation is usually required. If an articulated shield is used, line and grade corrections can be accomplished by activating the hydraulic propulsion cylinders. In a fixed shield, minor line and grade changes are accomplished by differential excavation in the desired direction.

Mechanically-assisted excavation is accomplished by using special shields equipped with power excavation devices. Such soil cutting devices can be rotary cutter booms mounted on the front of the shield, modified hydraulic backhoes, or rotary boom cutters. The soil excavation rate of open-face mechanical excavation is much faster than that of hand mining.

Dewatering at the entry and receiving shafts will likely be required. Since the groundwater level is above the springline, dewatering of the native materials with horizontal drainage lances/pipes from the exit and entry shafts and the tunnel face will be required.

The contractor's selected equipment and methods must provide effective control of the stability of the face soils which are prone to flowing or cohesive running. Fore-poling or spiles driven into the ground ahead of the face will be necessary to prevent loss of ground and improve support for the tunnel crown. Use of a hooded shield where the top of the shield extends beyond the invert by providing an angled profile to the leading edge of about 60 degrees from the horizontal is recommended. This angle must be measured from the top of the shield to the invert. As noted above, the shield should have doors which can close off the entire face and retractable breast plates or horizontal bench plates when additional support of the face is necessary, such as in zones with loose materials.

Overexcavation can lead to ground losses and should be limited to a maximum of 15 mm. It is important that care be taken with the installation of the liner in order to minimize settlements.

The materials along the proposed alignment are variable in texture and consistency/relative density. In addition, the alignment will proceed along the interface between the embankment fill and native materials and between looser and significantly denser materials. As such, the jacking forces will be variable and high jacking pressures and difficulty maintaining line and grade may be experienced when transiting through hard/very dense deposits along the invert. For each separate jack, it will be necessary to use varying hydraulic pressures and travel movements to improve or correct steering.

Lubricants should be used where high jacking pressures are encountered. The use of bentonite based lubricants is recommended due to the predominance of granular and low plasticity cohesive materials. The spacing and number of grout ports should be optimized to result in even distribution of lubricant over the entire length of pipe and facilitate post-installation grouting of the annulus, if necessary.

Face access facilitates removal of cobbles, boulders and obstructions in the embankment fill if encountered. The appropriate health and safety precautions associated with confined spaces as outlined in the current Ontario Regulation 213 in the Occupational Health and Safety Act (OSHA) must be observed by the contractor. Hand mining is considered to be feasible only if proper dewatering measures are employed. Line and grade accuracy comparable to microtunnelling.

6.6 Comparison of Tunneling Methods

Trenchless construction methods described in Section 6.5 include various advantages and disadvantages depending on soil conditions, depth of cover, vertical and horizontal alignment, length of pipe installation, cost and availability of equipment, and carry varying levels of risk of successfully completing the installation. The advantages, disadvantages and relative costs and risks are compared in Table 1, following the text of this report.

Jack-and-bore and pipe ramming are not considered feasible due to the pipe diameter and site conditions. Microtunnelling is marginally feasible since the MTBM may be stopped by woody debris in the fill. Both microtunnel and conventional tunnel boring machines use a slurry to balance the hydrostatic and earth pressures at the face, as would be required at this site due to the presence of running / flowing non-cohesive soils; however, due to the cover depth being less than the recommended two tunnel diameters equivalent, there is a potential for hydraulic fracturing of the ground and loss of drilling fluid to the surface. The most feasible methods of installing the new culvert are hand mining or mechanically assisted excavation within a shield, and conventional tunneling with a TBM. These two methods are less risky than microtunnelling since person-entry is possible to facilitate removal of obstructions. Hand mining and mechanically assisted excavation is the preferred technical alternative from a foundations engineering perspective since it requires the least work area and support equipment, is less costly compared to use of MTBMs or TBMs, does not have the same risk of frac-outs as MTBMs and TBMs and is readily adapted to the changing ground conditions.

6.7 Entry/Exit Shafts – Temporary Excavation and Groundwater Control

The trenchless methods under consideration require entry and exit pits as part of the tunnel installation. Temporary excavations may be carried out using open cut methods. All excavation work should be carried out in accordance with the Occupational Health and Safety Act and Regulations (OSHA), with local regulations and as outlined in Ontario Provincial Standard Specification (OPSS) 902 (*Excavation and Backfilling – Structures*). Properly dewatered granular fill, cohesive fill and native silt to sand deposits are classified as Type 3 soils; the native clayey silt deposit is classified as Type 2 soils, and saturated granular fills and native silt to sand deposits would be Type 4 materials.

Dewatering will be required at the entry and exit shafts since these excavations are expected to extend to, or to below the groundwater level measured in the piezometer in Boreholes 17-2 and 17-3 at about Elevations 197.7 m and 199.4 m, respectively. Groundwater control using sumps may be adequate if the groundwater is encountered within the clayey silt fill and native clayey silt deposit; however pumping from sumps may not be adequate if the groundwater level is encountered within the granular fill and silt to sand deposit, wherein it may be necessary to use well points, eductors or the like. The groundwater level should be lowered to at least 0.5 m below the base of the entry / exit shafts and carried out consistent with OPSS.PROV 517 (Dewatering) and SSP 517 FO1 (Dewatering System). Based on the subsurface information available, it is anticipated that minor dewatering will be required at the entry and exit shafts during the construction period. The excavations should be protected from ingress of surface water. The appropriate NSSP should be included in the Contract Documents to alert the Contractor for the need for effective dewatering and control of surface water; an example Special Provision is included in Appendix D. Provided proper groundwater control is in place, conventional temporary type open cuts may be developed with side slopes not steeper than 1 horizontal to 1 vertical (1H:1V) in Types 2 and 3 soils. However, depending upon the construction procedures adopted by the contractor, actual groundwater seepage conditions, the success of the contractor's groundwater control methods and weather conditions at the time of construction, some flattening and/or blanketing of the slopes may be required. Care should be taken to direct surface water runoff away from the open excavations and all excavations should be carried out in accordance with the OHSA. Stockpiles of excavated material should be set back from the edge of the excavation by a distance at least equal to the excavation depth.

The base of all entry/exit shafts should be designed to the loading associated with the weight of the pipe and selected tunneling equipment. It should be covered with a (an OPSS 1860 (Geotextiles) Class II geotextile with a Fabric Opening Size (FOS) less than or equal to 212 μm), overlain by a minimum 300 millimetre thick layer of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II material and a 100 millimetre thick concrete working slab, with concrete having a 28-day compressive strength not less than 20 MPa as specified in the NSSP included in Appendix D.

The shafts could be constructed using soldier piles and lagging or a slide rail system, or a steel liner / casing provided that groundwater control systems are fully operational and demonstrated to be effective prior to excavation, including prior to install lagging or below the edge of the slide rail panels if such a system is adopted. Due to the presence of hard clayey silt and dense to very dense silt to sand, it may be difficult to install sheet piles. Steel H-piles for soldier piles should be installed in pre-drilled holes. As noted above, the use of trench boxes and any system which does not provide continuous support to the excavation walls should be prohibited.

The temporary excavation support system should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*). The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS.PROV 539.

The design of internally braced soldier pile and lagging walls or other temporary support systems is the responsibility of the contractor. For design considerations, the system design should be based on trapezoid-shaped apparent earth pressure distributions using the design parameters given below. Where the support to the wall is provided by anchors or rakers, the wall design should be based on conventional active and passive earth pressure distributions using the design parameters given below. The internal bracing or raker/anchor supports must be designed to accommodate the loads applied from earth pressures and surcharge pressures from area, line or point loads as well as the effects of sloping ground behind the system. Passive toe restraint to the soldier piles may be determined using conventional passive earth pressure distribution acting over an equivalent width equal to three times the soldier pile socket diameter provided that the soldier piles are separated by more than three times the socket diameter.

Soil Type	Coefficient of Lateral Earth Pressure			Internal Angle of Friction (Degrees)	Unit Weight (kN/m3)
	Active, Ka	At Rest, Ko	Passive, Kp		
Existing gravelly sand fill	0.31	0.47	3.25	32	20
Existing silty sand / clayey silt fill	0.33	0.5	3.0	30	19
Hard clayey silt	0.31	0.47	3.25	32	20
Loose to compact silt to sand	0.33	0.5	3.0	30	20
Compact to dense silt to sand	0.31	0.47	3.23	32	20

Soil Type	Coefficient of Lateral Earth Pressure			Internal Angle of Friction (Degrees)	Unit Weight (kN/m3)
	Active, Ka	At Rest, Ko	Passive, Kp		
Very dense silt to sand	0.28	0.44	3.54	34	21

Notes:
1) The lateral earth pressure coefficients presented above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are expected, the coefficients showed need to be corrected accordingly.
2) The total passive resistance below the base of the excavation (i.e., within the shored excavation and / or adjacent to the temporary protection system, may be calculated based on the value 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.

6.8 Instrumentation and Monitoring

A settlement monitoring plan is required for monitoring of ground stability, as stated in the "Appendix: Settlement Monitoring Guideline – Tunnelling" of MTO's "Guideline for Foundation Engineering – Tunnelling Speciality for Corridor Encroachment Permit Application". The requirements of a settlement monitoring program are outlined in the NSSP titled "Installation of Pipes by Trenchless Methods", included in Appendix D and should be established as part of the Contract Administration for construction.

The instrumentation and monitoring program is recommended at trenchless crossing locations to:

- document the effects of the culvert installation on the overlying roadways, adjacent structures or services lines/pipes;
- identify adverse movement trends;
- measure the Contractor's compliance with the settlement limits specified in the Contract; and
- provide information to support adaptation of the culvert installation methods to observed behaviour and ground conditions toward compliance with the settlement limits.

Monitoring of settlement instruments on this project is constrained by the continuous and high traffic volume and the limited periods during which access to Highway 26 can be obtained. By necessity, settlement points on the road must be read remotely and the use of electromagnetic distance measuring equipment reading reflectors installed on the highway may be required, instead of the standard surface settlement points. A specialist surveying firm should be retained by the contractor to confirm the set-up and to carry out the settlement monitoring during construction.

The requirements for the installation of in-ground settlement points (SPs), consisting of a sleeved iron bar set below the depth of frost penetration, which for this site is 1.5 m as interpreted from OPSD 3090.101 (Foundation, First Penetration Depths for Southern Ontario), or 0.3 m above the tunnel obvert elevation, whichever is higher, at accessible locations (on the highway/roadway shoulders), and surface settlement markers (SSMs) beyond the roadway surface are shown on Drawing 2. The elevation of the top of the bar would be read using conventional precision levelling equipment. The in-ground monitoring points provide the best measure of the ground settlement effects of tunnelling as tunnelling progress, as they are unaffected by frost heave, thaw settlement or the bridging action of the pavement structure.

Further, to the extent practicable and possible, it will be prudent to measure the volume of ground removed from beneath paved areas as compared to the theoretical cut hole volume on a frequency of at least once per 6 m section of pipe installed. Measuring excavated ground volumes will be difficult because of bulking that occurs when excavating soils and the spoil discharge systems on some systems are not readily conducive to such measurements (e.g., jack and bore, MTBM). However, on-site observation of construction operations and measurement of grout and/or lubricant volumes should assist in identifying atypical conditions that could be indicative of unacceptable ground losses.

6.9 Grouting

After the permanent culvert pipe is installed within the casing, post installation grout to fill the annular space between the pipes should be carried out, as required in the NSSP provided in Appendix D for culvert installation via trenchless methods.

For any installations at which the settlement monitoring indicates that pavement settlement has occurred, or where signs of ground loss have been noted, provision should be made for a program of compensation grouting above the pipe and/or repair of the pavements.

6.10 Corrosion Assessment and Protection

Soil corrosivity may affect concrete pipes, steel pipes and reinforced steel and other concrete elements buried in the soil. The long-term performance and durability of the structures are directly related to their respective corrosion resistance. Generally, the corrosivity of a structure depends on the soil resistivity, hydrogen ion concentration, salts (chloride and sulphate) concentrations and redox potential. The analytical results for the soil sample submitted for testing are summarized in Section 4.4 and the test report by the analytical laboratory is included in Appendix C.

6.10.1 Potential for Sulphate Attack

The analytical test results were compared to CSA Standard, CAN/CSA-A23.1-14 Table 3 *("Additional requirements for concrete subjected to sulphate attack")* for potential sulphate attack on concrete. The sulphate concentration measured in the sample is less than 0.1 per cent, which is below the exposure class of moderate. Therefore, based on the test result for this parameter from the boreholes at the culvert location the effects of sulphates from within the existing native deposits may not need to be considered.

6.10.2 Potential for Corrosion

The soil has a pH of about 7.81 and a resistivity of about 490 ohm-cm based on the one soil sample tested. According to the Gravity Pipe Design Guidelines (MTO, 2014), the pH is not considered detrimental to concrete durability. However, the resistivity is less than 2,000 ohm-cm, which indicates that the soil corrosiveness is severe (R < 2,000 ohm-cm), as per Table 3.2 of the Gravity Pipe Design Guidelines (MTO, 2014). Based on the resistivity results some level of protection may be required depending on the pipe material specified. Further, given that the culvert is located adjacent to the roadway shoulder and will be exposed to de-icing salt, consideration should be given to selection of a “C” type exposure class as defined by CSA A23.1 Table 1.

It is ultimately up to the designer to determine the appropriate exposure class and to ensure that all aspects of CSA A23.1 Section 4.1.1 “Durability Requirements” are followed.

7.0 CLOSURE

This Foundation Design Report was prepared by Ms. Nikol Kochmanová, P.Eng., a geotechnical engineer with Golder. Mr. Jorge M.A. Costa P.Eng., a MTO Foundations Designated Contact and Senior Consultant for Golder, conducted a quality control review of the report.

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ASTM International

ASTM D1586 Standard Test Method for Standard Penetration Test (SPT) and Split Barrel Sampling of Soils

Ontario Provincial Standard Specification:

OPSS.PROV 539	Construction Specifications for Temporary Protection Systems
OPSS 902	Construction Specifications for Excavating and Backfilling – Structures
OPSS.PROV 517	Construction Specification for Dewatering
OPSS 1860	Material Specification for Geotextile

Special Provisions

SSP 517FO1	Dewatering System / Temporary Flow Passage System
Special Provision	Construction Specification for the Installation of Pipes by Trenchless Methods. November 2018

Ontario Provincial Standard Drawings (OPSD)

OPSD 3090.101 Foundation, Frost Penetration Depths for Southern Ontario

Ontario Water Resources Act

Ontario Regulation 903 Wells (as amended)

Ontario Occupational Health and Safety Act

Ontario Regulation 213 Construction Projects (as amended)

TABLE 1 – EVALUATION OF CULVERT INSTALLATION METHODS

Installation Method	Feasibility	Advantages	Disadvantages	Relative Costs	Relative Risks
Jack and Bore	Not Feasible	Subsurface conditions and diameter preclude the use of jack and bore[1]			
Pipe Ramming	Not Feasible	Subsurface conditions and diameter preclude the use of pipe ramming[1]			
Microtunnelling (MTBM)	Marginally Feasible	■ Continuous support to excavation face is provided. ■ Final pipe can be installed while bore is being advanced. ■ For hard soils, cobbles and boulders (of limited size) can often be cut and penetrated provided appropriate disc cutter face tools are utilized. ■ High accuracy for line and grade ■ Dewatering required at shafts only ■ Fastest rate of advance without obstructions ■ May not require a casing lines, thus allowing for a greater depth of soil cover.	■ No person access to face ■ Greater cost for muck handling and disposal. ■ Woody debris and gabion wire if encountered will likely clog the machine; pit at outlet should be moved closer to the highway to avoid identified rock fill and gabion wire ■ Advance of MTBM may be halted by large numbers of cobbles or large boulders; only method of removing obstruction may be shaft excavated from surface as size of bore does not permit for man entry. ■ Lack of readily available machines. ■ Relatively expensive – high mobilization costs for short crossings. ■ Not suitable where depths of cover are less than 2.5 m, or two tunnel diameter equivalents due to potential for "frac-out". ■ Susceptible to hydraulic fracture depending on slurry viscosity and pressure. ■ Where fill is much softer than the underlying hard / dense to very dense native materials, the machine may be deflected by boulders requiring correction in line or grade ■ Requires settlement monitoring program to assess for ground loss along the alignment	Most expensive method.	■ Hydraulic fracture is possible at culvert locations with cover less than 2.5 m or two tunnel diameter equivalents and any slurry exiting onto the pavements could be a significant hazard to traffic. ■ Use of small boring units or low viscosity slurries could contribute to excessive ground losses when cutting through granular soils that result in pavement damage and a significant hazard to traffic. ■ Encountering woody debris, gabion wire and oversized cobble nests or boulders - high to very high risk of not completing installation ■ Tunnel invert along interface between embankment fill and native materials - low to moderate risk of not achieving line and grade if machine deflected by hard/very dense soils ■ Groundwater above springline – low risk of ground loss due to flowing of sands if slurry MTBM selected and proper dewatering carried out at shafts ■ Potential schedule delay in obtaining a suitable MTBM.
Conventional Tunnelling with Tunnel Boring Machine (TBM)	Feasible	■ Face access possibility can facilitate removal of cobbles, boulders and obstructions in the fill, sand and gravel and glacial till ■ Closed-face machine must be used to provide effective control of face stability ■ High accuracy with line and grade	■ Older TBMs that do not include a secondary bulkhead and controlled muck discharge system (e.g., discharge gates controlled by load or pressure sensors) should be prohibited ■ Machines can become jammed or clogged with wood and/or cobbles and boulders; particularly	More expensive than hand mining but less than microtunneling.	■ Encountering woody debris, gabion wire and oversized cobble nests or boulders - moderate to high risk of not completing installation ■ Tunnel invert along interface between embankment fill and native materials - low to moderate risk of not achieving line and grade if

Installation Method	Feasibility	Advantages	Disadvantages	Relative Costs	Relative Risks
		■ Dewatering required at shafts only if EPB TBM used and can be enhanced with localized use of horizontal drainage lances from entry and exit shafts/pits ■ Compared to hand mining methods, conventional tunnelling may achieve more consistent and effective support of the face	machines that rely on screw conveyors for pressure control and muck transport. ■ Requires a work area at the entry shaft somewhat smaller than that needed for microtunnelling ■ Would likely require a casing / liner within which the carrier storm pipe would be installed, depending on machine site available.		machine deflected by boulders in glacial till or hard/very dense soils ■ Groundwater controlled/lowered to the tunnel invert – low to moderate risk of ground loss due to flowing of sands if closed-face machine selected ■ Moderate to high risk of ground losses in saturated granular soils when removing or mining through boulders or other obstructions if groundwater is not controlled by other means
Open Face Shield Tunnelling (Hand Mining or Mechanically Assisted Excavation)	Feasible	■ Minimal traffic disruption. ■ Better suited for penetrating through potential obstructions due to face access. ■ Good accuracy for line and grade ■ Most economical solution with line and grade accuracy comparable to microtunnelling ■ Smallest footprint required for entry shaft ■ Potentially the most economical method of installing the culvert at low end of cost range. ■ Likely will not require a casing / liner, thus allowing for a greater thickness of soil cover.	■ Risk of ground subsidence of highway but more control than jack and bore methods. ■ Labour intensive: Due to the potential presence of sandy deposit at and near the invert level which may be saturated, the contractor's selected equipment and methods must provide effective control of the stability of the face (e.g., use of hooded shield, stiffeners, forepoling, retractable breast plates with doors etc.) ■ Requires groundwater lowering if saturated granular soils are to be penetrated. ■ Requires settlement monitoring program to assess for ground loss along the alignment. ■ Additional health and safety concerns ■ Slowest rate of advance ■ Cost may approach conventional tunneling with TBM option due to dewatering requirements. Minimizing tunnel length by placing entry/exit pits as close as possible to the roadway should facilitate reduction of dewatering effort	Least expensive option	■ Potential for loss of ground into shield particularly if granular materials are encountered. ■ Risk of ground surface subsidence increases with decreasing cover thickness. ■ Encountering woody debris, gabion wire and oversized cobble nests or boulders - low to moderate risk of not completing installation ■ Groundwater controlled/lowered to the tunnel invert – moderate to high risk of ground loss due to flowing of sands depending on dewatering methods; risk can be minimized with proper horizontal drainage within tunnel, shortening tunnel length and effective dewatering at shafts

1. The availability of contractors in Ontario with large-scale jack and bore or pipe ramming equipment and experience installing pipes with diameters of 2.0 m or greater is rare or non-existent. The typical maximum casing sizes are about 1.8 m for jack and bore and less than 2.5 m for pipe ramming. Pipe ramming and jack-and-bore in particular are considered high risk due to the presence of a groundwater level above the springline and non-cohesive materials along the alignment which can only be dewatered using horizontal drainage lances/pipes from the entry and exit pits.

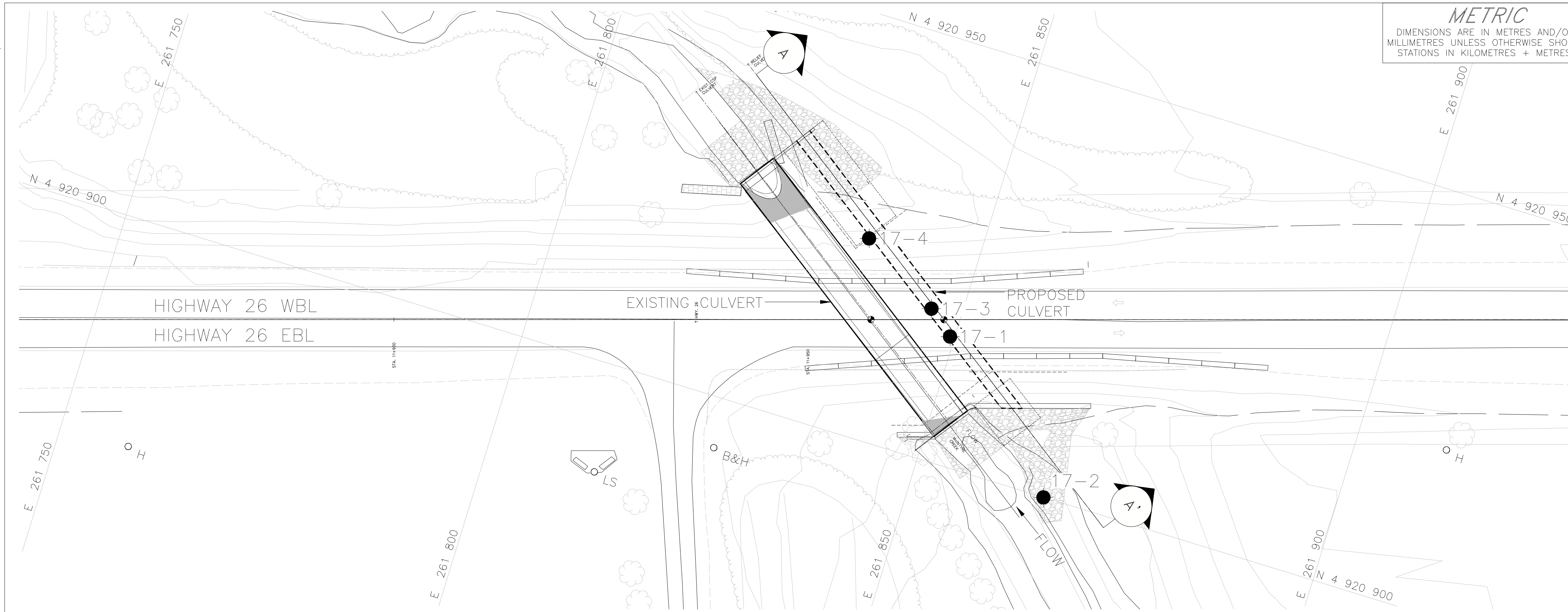
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No. 2018–2006
GWP No. 2444–15–00

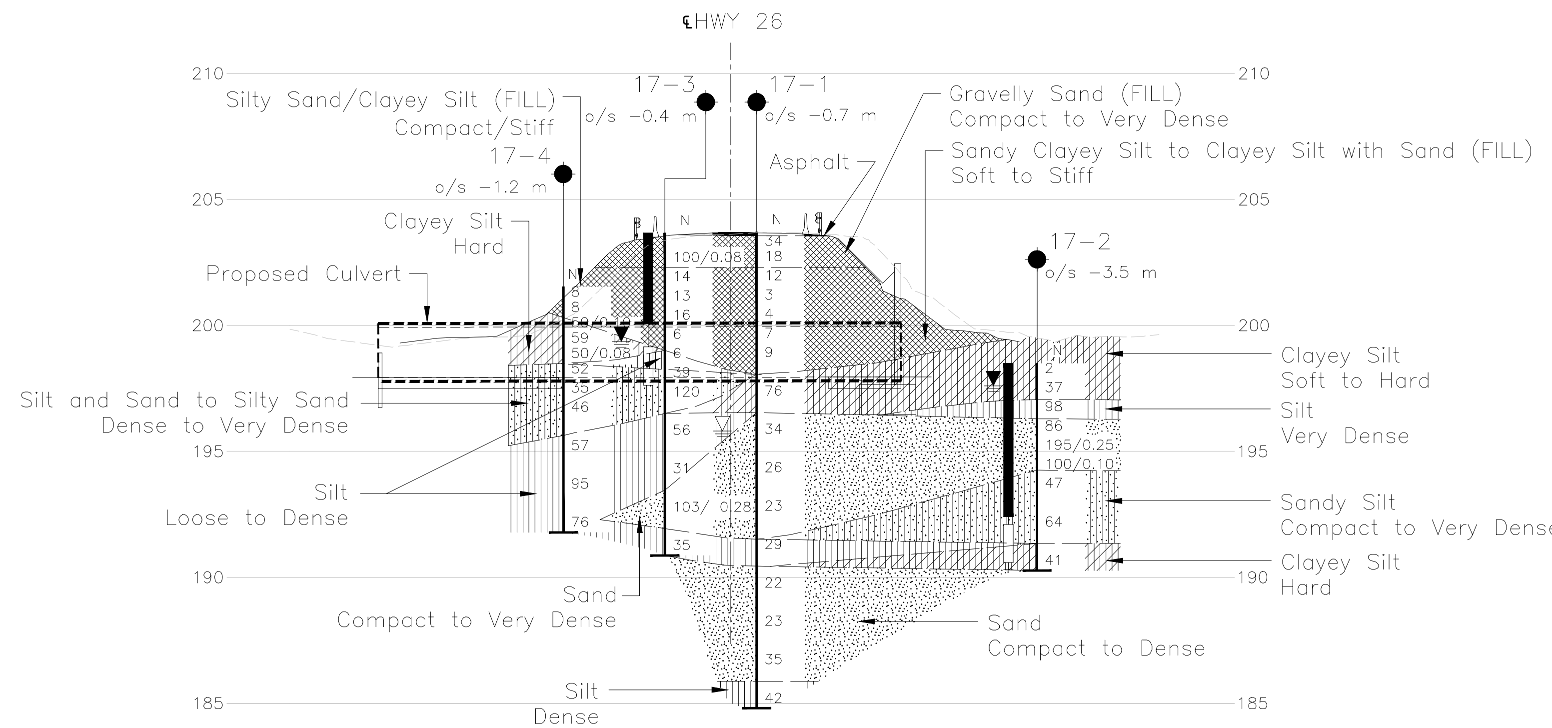
HIGHWAY 26
MCINTYRE CREEK RELIEF CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Golder Associates



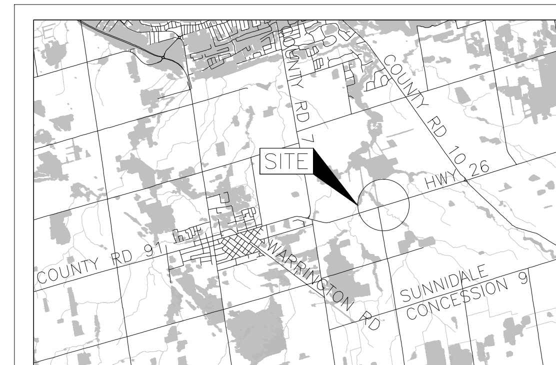
PLAN
SCALE
6 0 6 12 m



PROFILE A – A'

HORIZONTAL SCALE
6 0 6 12 m

VERTICAL SCALE
3 0 3 6 m



KEY PLAN
SCALE
2 0 2 4 km

LEGEND

- Borehole – Current Investigation
- Seal
- Piezometer
- N — Standard Penetration Test Value
- 16 — Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL upon completion of drilling
- WL in piezometer on June 18 (BH 17–3) and July 6 (BH 17–2), 2018

BOREHOLE CO-ORDINATES (MTM NAD 83 ZONE 10)			
No.	ELEVATION	NORTHING	EASTING
17–1	203.7	4920915.2	261849.4
17–2	198.6	4920900.0	261865.9
17–3	203.7	4920917.8	261846.3
17–4	201.5	4920923.7	261836.6

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. SITE 30–522C FOR INROADS.DWG, SITE 30–522C.DWG, received November 28, 2017, 4–60555407_McINTYRE CREEK_SITE_30–522_CSP_LINER_GA.dwg, received February 16, 2018 and 4–60555407_McINTYRE CREEK_SITE_30–522_CSP_LINER_GA.dwg, received March 5, 2018. Ground surface provided in digital format by AECOM, file no. SITE 30–522C––from CALLON DIETZ.DWG, received June 1, 2018.

LICENSED PROFESSIONAL ENGINEER N. KOCHMAN 100117863 Jan. 24, 2019 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER J.M.A.COSTA Jan. 24, 2019 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 41A–249

HWY. 26		PROJECT NO. 1671430	DIST.
SUBM'D. NK	CHKD. NK	DATE: 01/24/2019	SITE: 30–522/C
DRAWN: DD	CHKD. NK	APPD. JMAC	DWG. 1

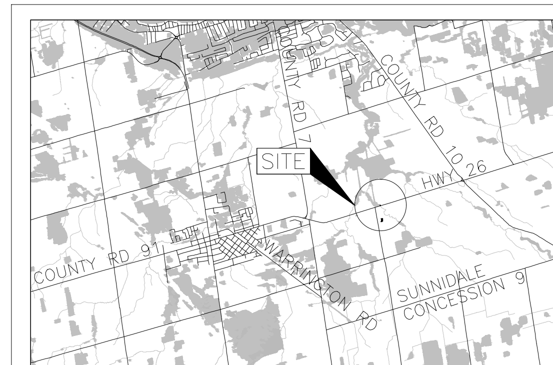
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No. 2018–2006
WP No. 2444–15–00

SHEET

HIGHWAY 26
MCINTYRE CREEK RELIEF CULVERT
SETLEMENT MONITORING POINT LOCATIONS AND INSTALLATION DETAILS

Golder Associates

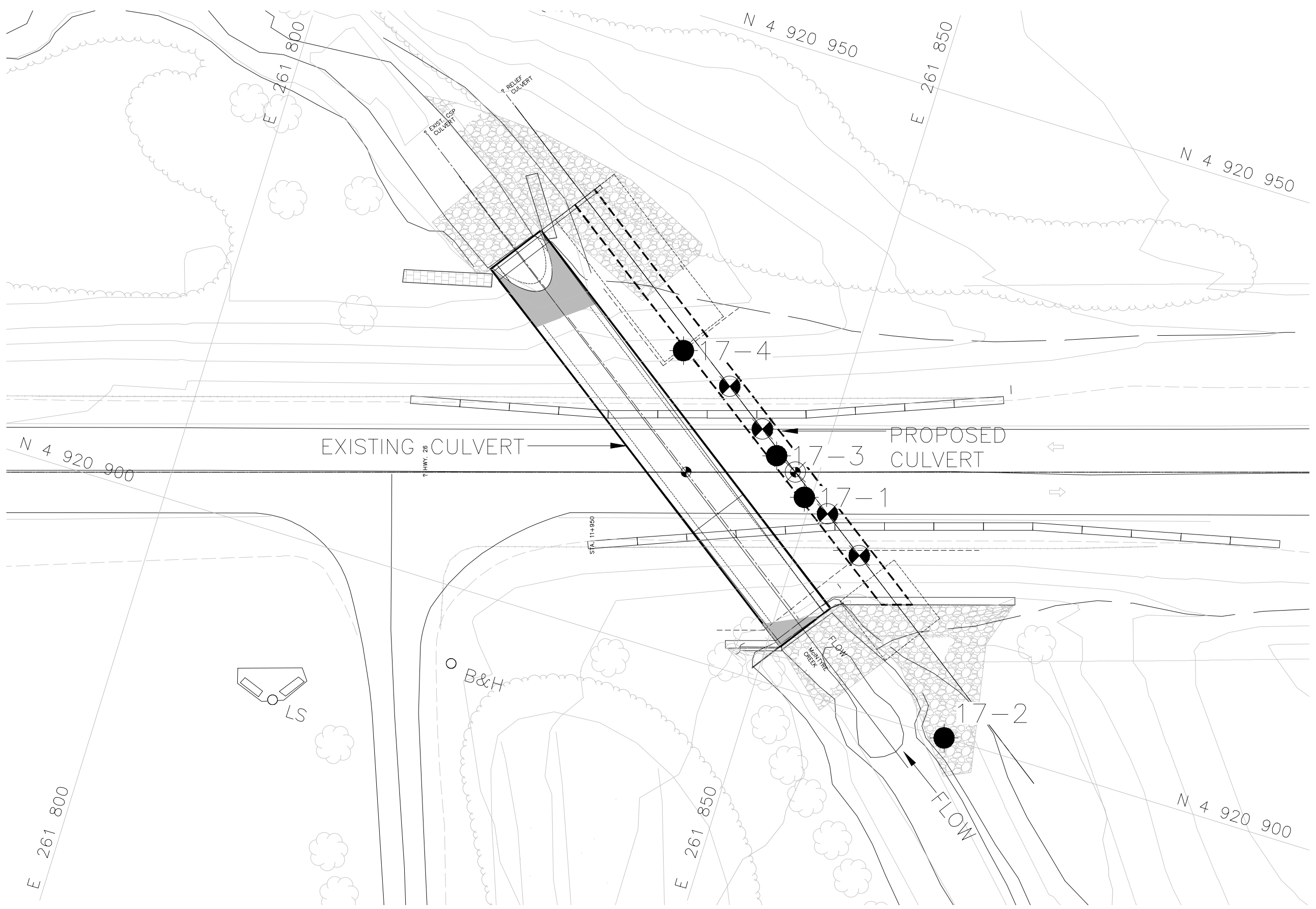


KEY PLAN
SCALE
2 0 2 4 km

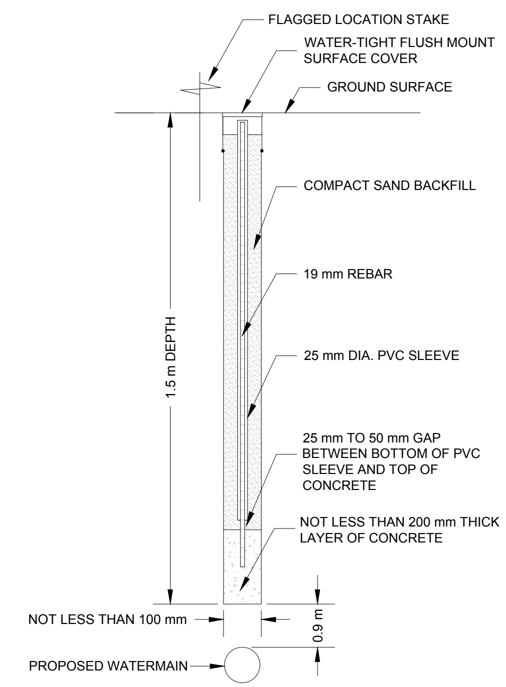
LEGEND

- ● Borehole – Current Investigation
- ⊗ Surface Monitoring Point
- In–ground Monitoring Point (1.2m depth)

BOREHOLE CO–ORDINATES (MTM NAD 83 ZONE 10)			
No.	ELEVATION	NORTHING	EASTING
17–1	203.7	4920915.2	261849.4
17–2	198.6	4920900.0	261865.9
17–3	203.7	4920917.8	261846.3
17–4	201.5	4920923.7	261836.6



PLAN
SCALE
6 0 6 12 m



IN–GROUND MONITORING POINT INSTALLATION DETAIL
N.T.S.

NOTES

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REFERENCE

Base plans provided in digital format by AECOM, drawing file nos. SITE 30-522C FOR INROADS.DWG, SITE 30-522C.DWG, received November 28, 2017, 4-60555407_McINTYRE CREEK_SITE_30-522_CSP_LINER_GA.dwg, received February 16, 2018 and 4-60555407_McINTYRE CREEK_SITE_30-522_CSP_LINER_GA.dwg, received March 5, 2018. Ground surface provided in digital format by AECOM, file no. SITE 30-522C--from CALLON DIETZ.DWG, received June 1, 2018.

LICENSED PROFESSIONAL ENGINEER N. KOCHMAN 100117863 Jan. 24, 2019 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER J.M.A.COSTA Jan. 24, 2019 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 41A–249

HWY. 26	PROJECT NO. 1671430		DIST.
SUBM'D. NK	CHKD. NK	DATE: 07/17/2018	SITE:
DRAWN: DD	CHKD. NK	APPD. JMAC	DWG. 2

PLOT DATE: January 24, 2019
FILENAME: S:\Clients\MTO\Hwy_26\99_PROJ\1671430_Aecom\40_PROD\0002_Relief_Culvert\1671430-0002-BG-0002.dwg

APPENDIX A

Borehole Records

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

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c'	effective cohesion
c_u, s_u	undrained shear strength (ϕ = 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

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 With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

RECORD OF BOREHOLE No 17-1

SHEET 1 OF 2 **METRIC**

PROJECT 1671430

G.W.P. 2016-E-0029 LOCATION N 4920915.2; E 261849.4 MTM NAD 83 ZONE 10 (LAT. 44.426970; LONG. -80.039439) ORIGINATED BY DMF

DIST Central HWY 26 BOREHOLE TYPE 203 mm O.D., Hollow Stem Augers, Truck-mounted Drill Rig COMPILED BY DH

DATUM Geodetic DATE November 20, 2017 CHECKED BY NK

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
203.7	GROUND SURFACE										
0.0	ASPHALT										
0.2	Gravelly sand, some silt, trace cobble fragments (FILL) Compact to dense Brown Moist	1	SS	34		203					
		2	SS	18			○				
202.3 / 1.4	Clayey silt with sand, trace gravel, trace organics (FILL) Soft to stiff Mottled dark brown to grey Moist	3	SS	12		202					
		4	SS	3		201	├─○─┤	3	38	35	24
		5	SS	4		200					
		6	SS	7			○				
		7	SS	9		199					
198.1 / 5.6	CLAYEY SILT, trace sand Hard Grey Moist					198					
		8	SS	76		197	○				
196.5 / 7.2	SAND, trace to some silt Compact to dense Grey/brown Moist					196					
		9	SS	34	∇						
						195					
		10	SS	26		194	○				
		11	SS	23		193					
						192					
191.5 / 12.2	SILT, trace to some clay, trace sand Compact Grey Moist	12	SS	29		191	├○┤	0	4	85	11
190.4 / 13.3	SAND, trace to some silt Compact to dense Grey Moist to wet					190					
		13	SS	22		189					

Plot legend: 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 (%) 10, 20, 30; UNIT WEIGHT γ kN/m^3; REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

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

GOLDER

RECORD OF BOREHOLE No 17-1

SHEET 2 OF 2 **METRIC**

PROJECT 1671430

G.W.P. 2016-E-0029

LOCATION N 4920915.2; E 261849.4 MTM NAD 83 ZONE 10 (LAT. 44.426970; LONG. -80.039439)

ORIGINATED BY DMF

DIST Central HWY 26

BOREHOLE TYPE 203 mm O.D., Hollow Stem Augers, Truck-mounted Drill Rig

COMPILED BY DH

DATUM Geodetic

DATE November 20, 2017

CHECKED BY NK

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	--- CONTINUED FROM PREVIOUS PAGE ---												
	SAND, trace to some silt Compact to dense Grey Moist to wet		14	SS	23		188	~20					
			15	SS	35		187						
185.9 17.8	SILT, trace to some clay, trace sand Dense Grey Moist						186						
184.8			16	SS	42		185	~21	NP	0	1	94	5
18.9	END OF BOREHOLE NOTES: 1. Borehole caved to 7.9 m below ground surface upon completion of drilling. 2. Water level in open borehole observed at a depth of 7.9 m below ground surface (Elev. 195.8 m) upon completion of drilling.												

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (20, 40, 60, 80, 100): O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10, 20, 30; REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

GOLDER

Foundation Design

RECORD OF BOREHOLE No 17-2

SHEET 1 OF 1 **METRIC**

PROJECT 1671430

G.W.P. 2016-E-0029 LOCATION N 4920900.0; E 261865.9 MTM NAD 83 ZONE 10 (LAT. 44.426835; LONG. -80.039231) ORIGINATED BY DMF/DH

DIST Central HWY 26 BOREHOLE TYPE 76 mm O.D Casing Portable Tripod Drill Rig COMPILED BY DH

DATUM Geodetic DATE November 20 to 21, 2017 CHECKED BY NK

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
198.6	GROUND SURFACE										
0.0	CLAYEY SILT, some sand, trace gravel, trace to some rootlets, oxidation staining; Soft to hard; Brown to grey; Moist to wet	1	SS	2	198			1	19	67	13
		2	SS	37		Wp–w–WL plotted					
197.1 / 1.5	SILT, trace to some sand, trace to some clay, oxidation staining; Very dense; Grey/brown; Moist	3	SS	98	197	○	NP	0	7	92	1
196.4 / 2.2	SAND, trace to some silt; Very dense; Grey/brown; Moist	4	SS	86	196						
		5	SS	195/0.25	195	○					
		6	SS	100/0.10							
194.3 / 4.3	Sandy SILT, some sand, trace clay; Dense to very dense; Grey/brown; Moist	7	SS	47	194	○		0	28	70	2
					193						
		8	SS	64	192						
191.4 / 7.2	CLAYEY SILT, some sand; Hard; Grey; Moist				191						
		9	SS	41		○					
190.4 / 8.2	END OF BOREHOLE										

NOTES:

1. Water level measured at a depth of 1.5 m below ground surface (Elev. 197.1 m) upon completion of drilling.

2. Water in monitoring well frozen at a depth of 4.0 m below ground surface (Elev. 194.6 m) on January 26, 2018.

3. Water level in monitoring well at a depth of 0.9 m below ground surface (Elev. 197.7 m) on July 6, 2018.

Column headers: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; STRAT PLOT; 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 (%) 10 20 30; REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

GOLDER

Foundation Design

RECORD OF BOREHOLE No 17-3

SHEET 1 OF 2 **METRIC**

PROJECT 1671430
G.W.P. 2016-E-0029
LOCATION N 4920917.8; E 261846.3 MTM NAD 83 ZONE 10 (LAT. 44.427002; LONG. -80.039482)
ORIGINATED BY CC
DIST Central HWY 26
BOREHOLE TYPE 152 mm O.D., Hollow Stem Augers, Truck-mounted Drill Rig
COMPILED BY KAW
DATUM Geodetic
DATE April 24, 2018
CHECKED BY NK

ELEV / DEPTH (m)	SOIL PROFILE DESCRIPTION
203.7	GROUND SURFACE
0.0	Gravelly sand, trace cobble fragments, trace asphalt fragments (FILL) Very dense Brown Moist
202.2 / 1.5	Sandy clayey silt (FILL) Firm to very stiff Grey Moist - 152 mm thick sand seam at a depth of approximately 2.5 m
199.0 / 4.7	SILT, some clay, trace sand Loose to dense Grey Wet - 203 mm thick silty sandy gravel seam at a depth of approximately 4.8 m
198.1 / 5.6	Silty SAND, trace gravel, trace clay Dense to very dense Grey Wet
196.5 / 7.2	SILT, some sand, trace clay Dense to very dense Brown Wet - Oxidation stains between depths of approximately 7.6 m and 8.2 m
193.5 / 10.2	SAND, some silt Very dense Brown Wet
192.0 / 11.7	SILT, some clay, trace to some sand Dense Grey Wet
190.9 / 12.8	END OF BOREHOLE

SAMPLE NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	SS	100/0.08				
2	SS	14				
3A, 3B	SS	13				
4	SS	16				
5	SS	6	0	28	45	27
6A, 6B, 6C	SS	6				
7A, 7B	SS	39	0	1	82	17
8	SS	120	5	67	24	4
9	SS	56				
10	SS	31	0	19	77	4
11	SS	103/0.28				
12	SS	35	0	9	77	14

ELEVATION SCALE: 203, 202, 201, 200, 199, 198, 197, 196, 195, 194, 193, 192, 191

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 (%) 10 20 30

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

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

GOLDER

Foundation Design

RECORD OF BOREHOLE No 17-3

SHEET 2 OF 2 **METRIC**

PROJECT 1671430			
G.W.P. 2016-E-0029	LOCATION N 4920917.8; E 261846.3 MTM NAD 83 ZONE 10 (LAT. 44.427002; LONG. -80.039482)		ORIGINATED BY CC
DIST Central HWY 26	BOREHOLE TYPE 152 mm O.D., Hollow Stem Augers, Truck-mounted Drill Rig		COMPILED BY KAW
DATUM Geodetic	DATE April 24, 2018		CHECKED BY NK

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 (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										

NOTES:

1. Borehole 17-3 was advanced to a depth of 6.05 m at which time a standpipe piezometer was installed. After the installation of the standpipe was complete, a second borehole was advanced approximately 1.8 m to the east of the original location and sampling was continued from 7.6 m.

2. Water level measured in standpipe piezometer:

Date	Depth (m)	Elev. (m)
24/04/18	4.2	199.5
22/06/18	4.3	199.4

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

RECORD OF BOREHOLE No 17-4

SHEET 1 OF 1 **METRIC**

PROJECT 1671430

G.W.P. 2016-E-0029

LOCATION N 4920923.7; E 261836.6 MTM NAD 83 ZONE 10 (LAT. 44.427055; LONG. -80.039604)

ORIGINATED BY CC

DIST Central HWY 26

BOREHOLE TYPE 'N' Casing, Portable Rig,152 mm O.D., Hollow Stem Augers, Truck-mounted Drill Rig

COMPILED BY KAW

DATUM Geodetic

DATE April 25-26, 2018

CHECKED BY NK

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
201.5	GROUND SURFACE						
0.0	Silty sand, some clay, trace gravel, trace organics/rootlets (FILL) Compact Brown Wet	1	SS	8	201		
200.9 / 0.6	Clayey silt, some sand, trace organics/rootlets (FILL) Stiff Brown Wet	2	SS	8			
200.3 / 1.2	CLAYEY SILT, trace to some sand, trace gravel Hard Grey Wet	3	SS	50/0.10	200		
		4	SS	59			1 5 66 28
		5	SS	50/0.08	199		
198.4 / 3.1	SILT and SAND, trace clay Dense to very dense Brown Wet	6	SS	52	198		
		7	SS	35	197		0 58 40 2
		8	SS	46	196		
195.6 / 5.9	SILT, some sand, trace clay Very dense Grey Wet	9	SS	57	195		0 18 79 3
		10	SS	95	194, 193		
		11	SS	76	192		
191.7 / 9.8	END OF BOREHOLE						

NOTES:

1. Borehole 17-4 was advanced to a depth of 3.1 m using a portable washbore drill when casing refusal was encountered. A second borehole was advanced approximately 1.8 m west of the original location using a D25 track-mounted drill rig.

2. SPT 'N' values for Samples 1 to 5 have been corrected to account for half-weight hammer used to drive split spoon sampler.

3. No water level reading taken upon completion of drilling due to the addition of water/drill mud.

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; 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 (%) 10 20 30; UNIT WEIGHT γ kN/m³

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

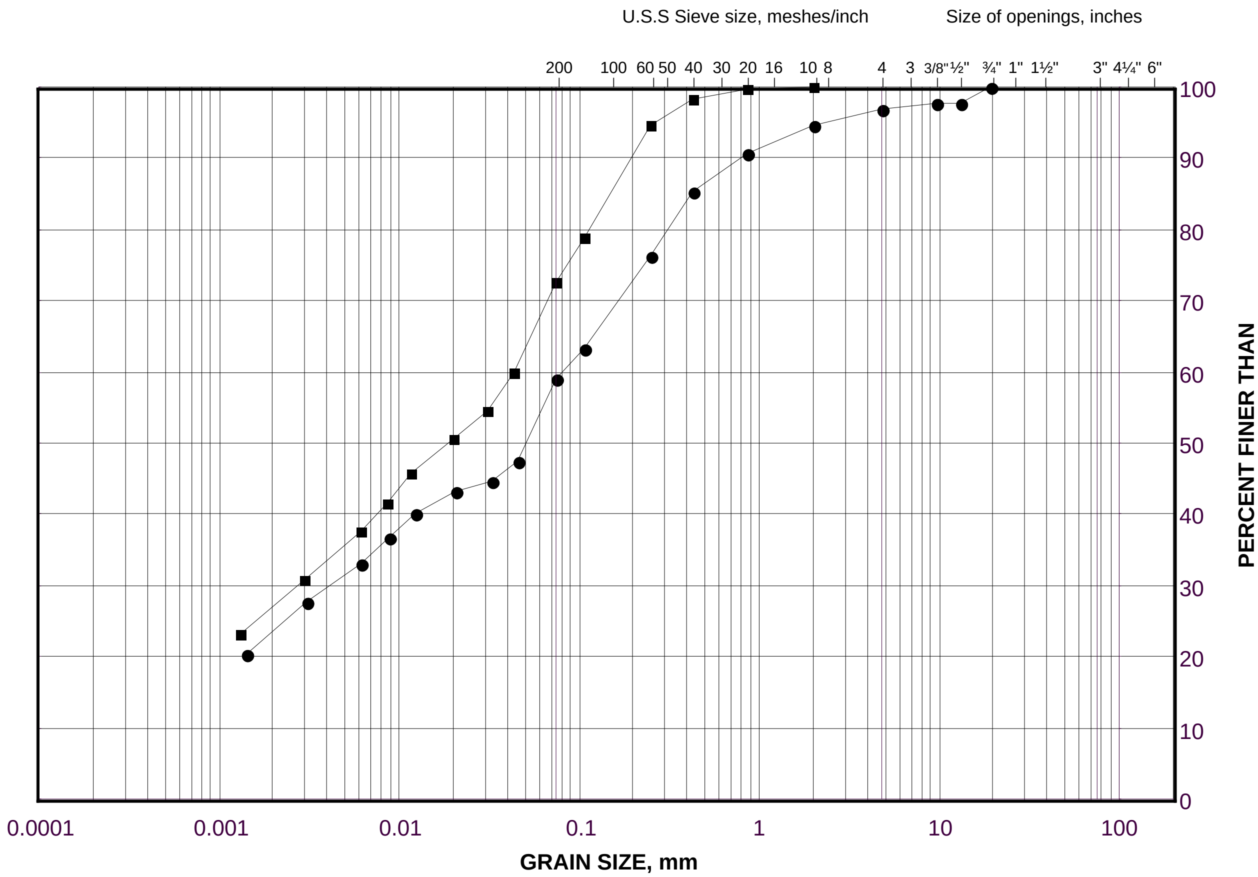
APPENDIX B

Geotechnical Laboratory Test Results

GRAIN SIZE DISTRIBUTION

Sandy Clayey Silt to Clayey Silt with Sand (Fill)

FIGURE B1



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

LEGEND

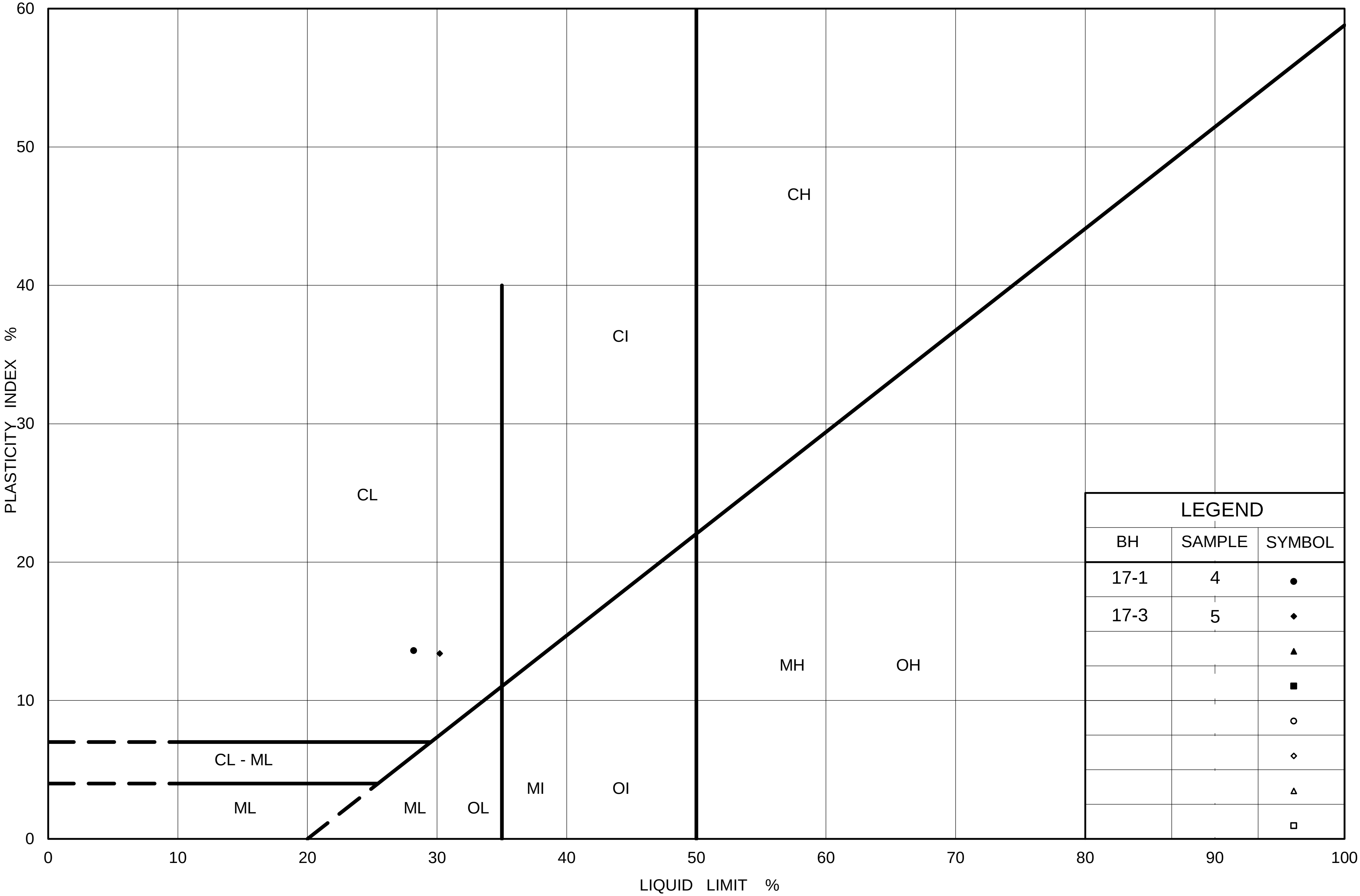
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	17-1	4	201.1
■	17-3	5	199.6

Project Number: 1671430

Checked By: NK

Golder Associates

Date: 18-Jun-18



Ministry of Transportation

Ontario

PLASTICITY CHART

Sandy Clayey Silt to Clayey Silt with Sand (Fill)

Figure No. B2

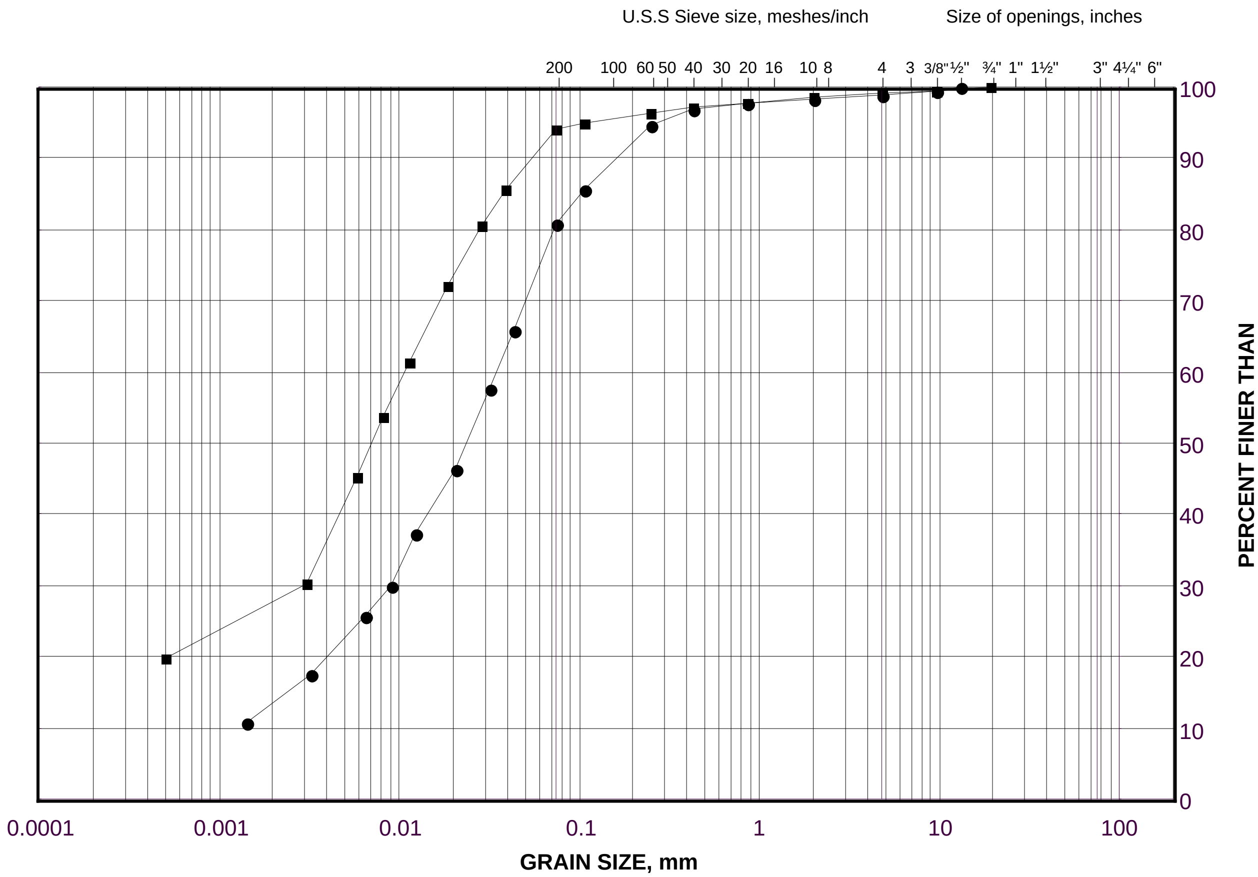
Project No. 1671430

Checked By: NK

GRAIN SIZE DISTRIBUTION

Clayey Silt (Upper Deposit)

FIGURE B3



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	17-2	1	198.3
■	17-4	4	199.4

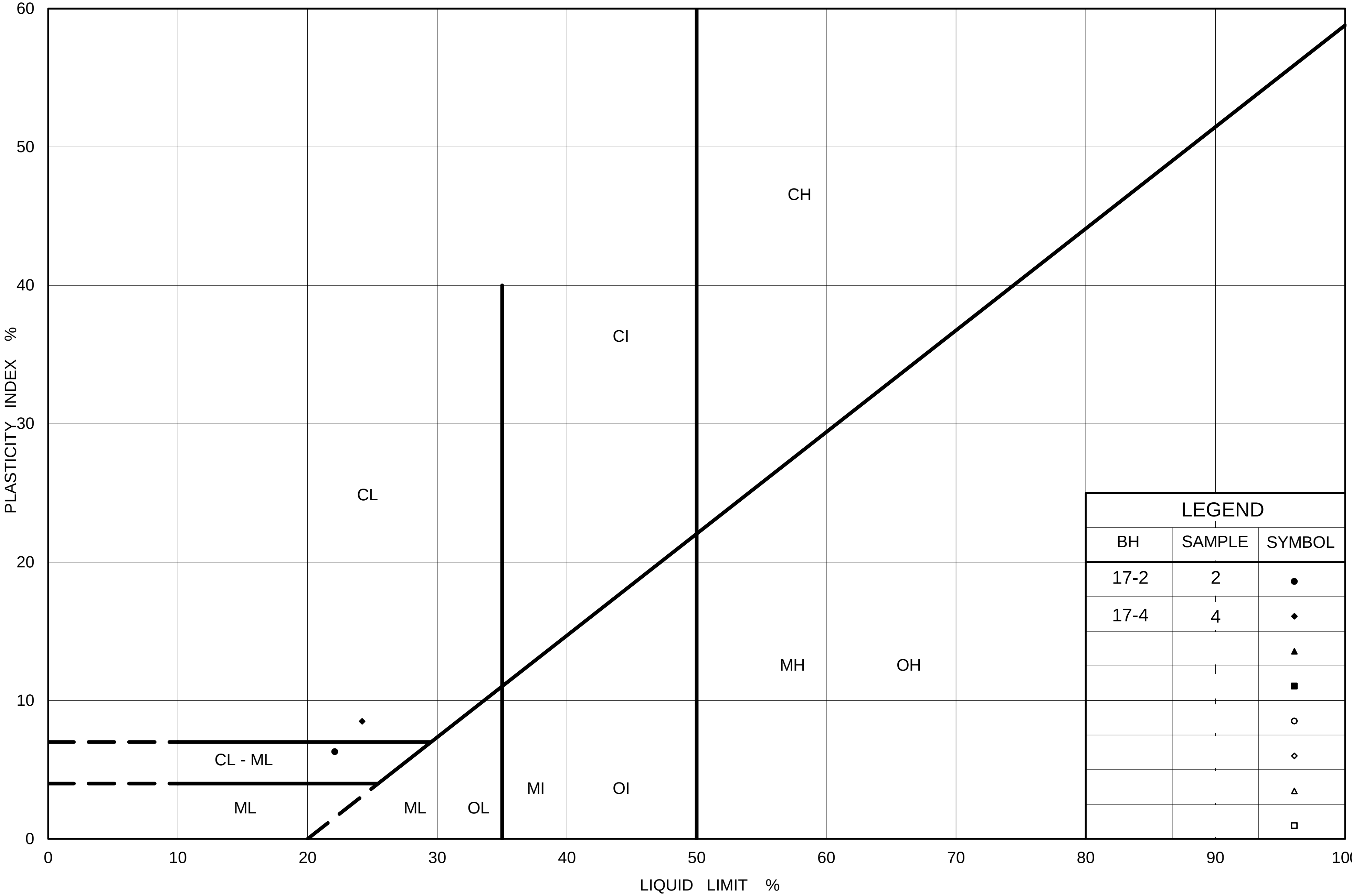
Project Number: 1671430

Checked By: NK

Golder Associates

Date: 18-Jun-18

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART
Clayey Silt (Upper Deposit

Figure No. B4

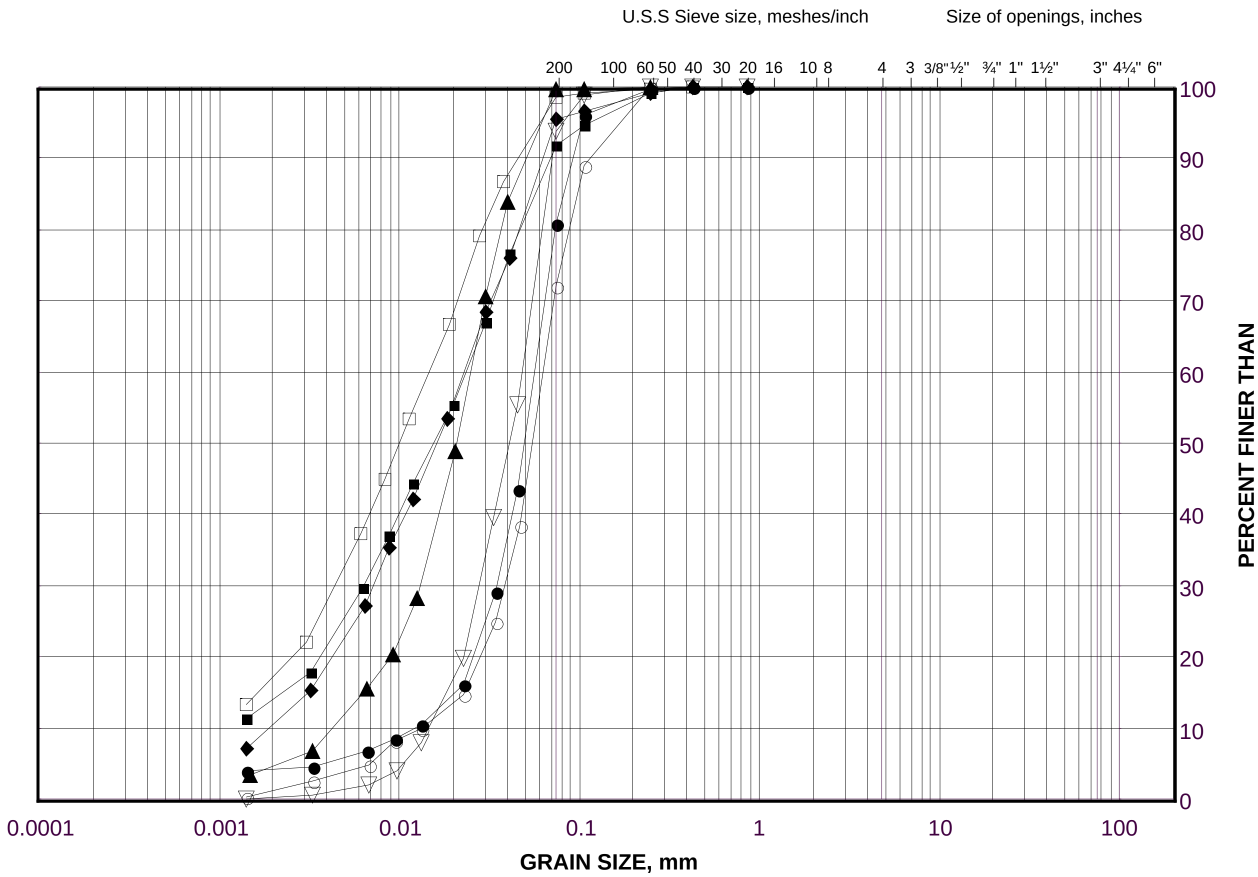
Project No. 1671430

Checked By: NK

GRAIN SIZE DISTRIBUTION

Silt to Sandy Silt

FIGURE B5A



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	17-3	10	194.2
■	17-3	12	191.2
◆	17-1	12	191.2
▲	17-1	16	185.1
▽	17-2	3	196.7
❍	17-2	7	193.7
□	17-3	7A	198.2

Project Number: 1671430

Checked By: NK

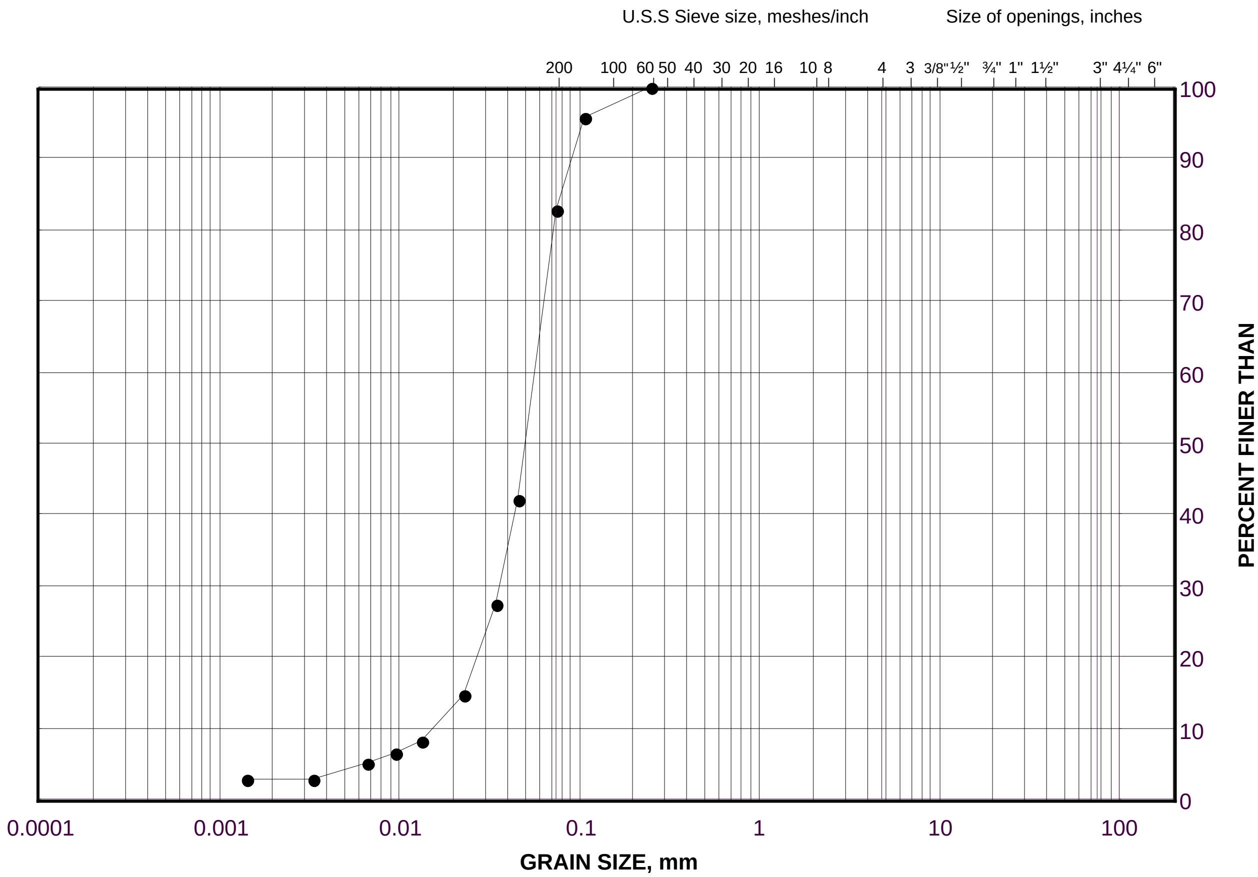
Golder Associates

Date: 18-Jun-18

GRAIN SIZE DISTRIBUTION

Silt

FIGURE B5B



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	17-4	9	195.1

Project Number: 1671430

Checked By: NK

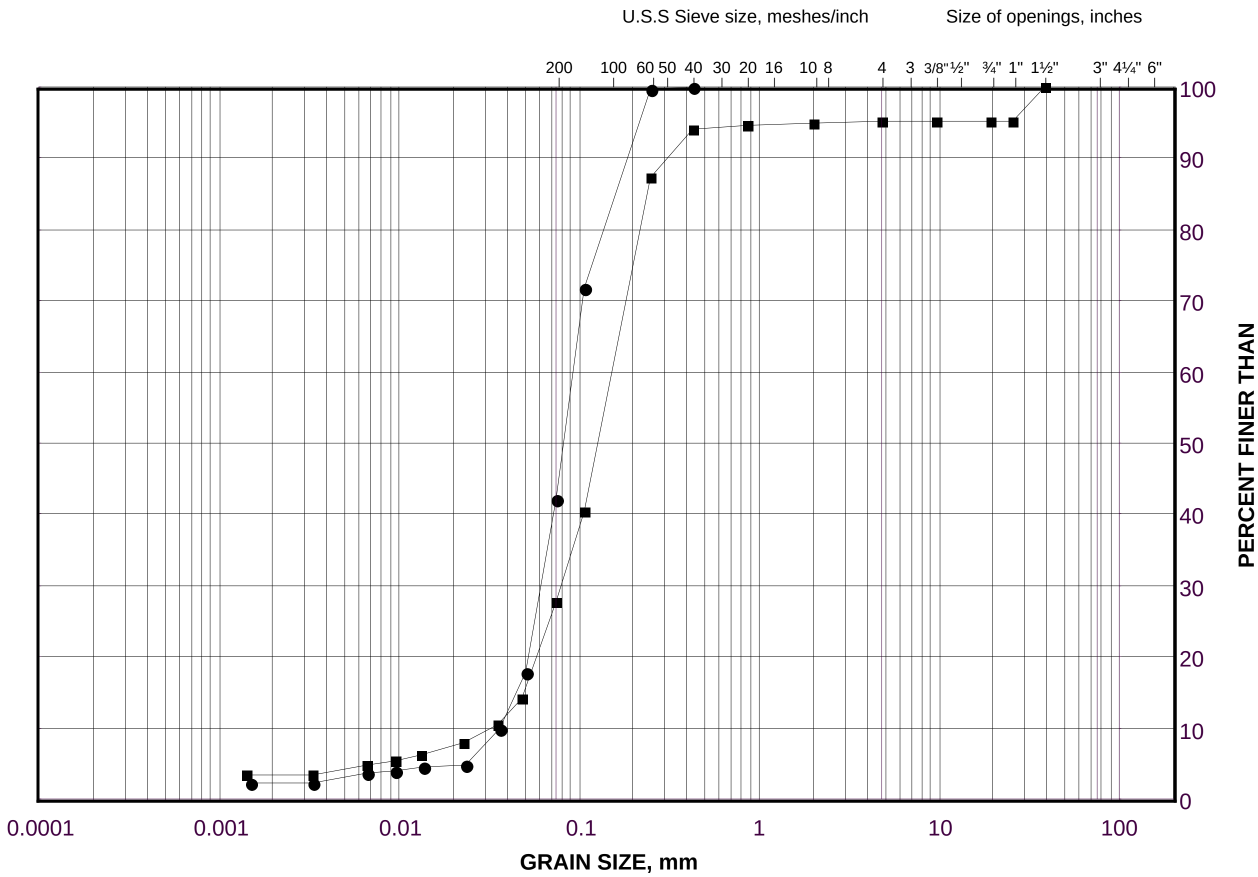
Golder Associates

Date: 18-Jun-18

GRAIN SIZE DISTRIBUTION

Silt and Sand to Silty Sand

FIGURE B6



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	17-4	7	197.4
■	17-3	8	197.3

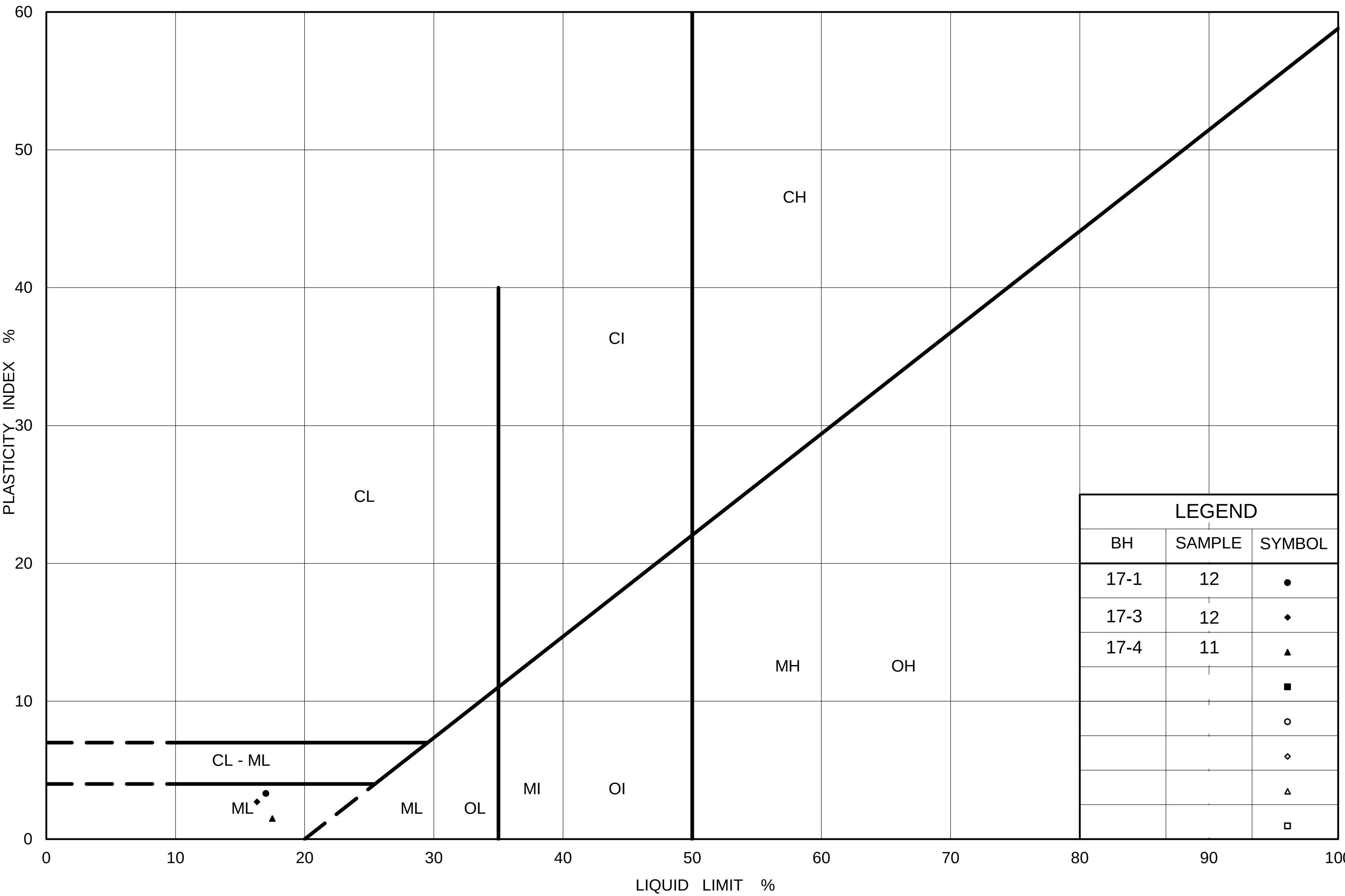
Project Number: 1671430

Checked By: NK

Golder Associates

Date: 18-Jun-18

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART
Silt

Figure No. B7

Project No. 1671430

Checked By: NK

APPENDIX C

Analytical Test Results

Maxxam
A Bureau Veritas Group Company

Your Project #: 1671430 W004
Site Location: HIGHWAY 26
Your C.O.C. #: n/a

Attention: Nikol Kochmanova

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

Report Date: 2018/06/15
Report #: R5243274
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B8E2841
Received: 2018/06/12, 15:59

Sample Matrix: Soil
Samples Received: 1

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Chloride (20:1 extract)	1	N/A	2018/06/15	CAM SOP-00463	EPA 325.2 m
Conductivity	1	N/A	2018/06/15	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl2 EXTRACT	1	2018/06/14	2018/06/14	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	1	2018/06/13	2018/06/15	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	1	N/A	2018/06/15	CAM SOP-00464	EPA 375.4 m

Remarks:

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

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

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

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.
Results relate to samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

Your Project #: 1671430 W004
Site Location: HIGHWAY 26
Your C.O.C. #: n/a

Attention: Nikol Kochmanova

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

Report Date: 2018/06/15
Report #: R5243274
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B8E2841
Received: 2018/06/12, 15:59

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Ema Gitej, Senior Project Manager
Email: EGitej@maxxam.ca
Phone# (905)817-5829
==
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Job #: B8E2841
Report Date: 2018/06/15

Golder Associates Ltd
Client Project #: 1671430 W004
Site Location: HIGHWAY 26
Sampler Initials: CC

SOIL CORROSIVITY PACKAGE (SOIL)

Maxxam ID		GYB548			GYB548		
Sampling Date		2018/04/28			2018/04/28		
COC Number		n/a			n/a		
	UNITS	**17-3 SA#7B**	**RDL**	**QC Batch**	**17-3 SA#7B Lab-Dup**	**RDL**	**QC Batch**
Calculated Parameters							
Resistivity	ohm-cm	490		5578503			
Inorganics							
Soluble (20:1) Chloride (Cl)	ug/g	1200	40	5582214			
Conductivity	umho/cm	2040	2	5582341	2030	2	5582341
Available (CaCl2) pH	pH	7.81		5580453			
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	5582215			

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

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Maxxam Job #: B8E2841
Report Date: 2018/06/15

Golder Associates Ltd
Client Project #: 1671430 W004
Site Location: HIGHWAY 26
Sampler Initials: CC

TEST SUMMARY

Maxxam ID: GYB548
Sample ID: 17-3 SA#7B
Matrix: Soil

Collected: 2018/04/28
Shipped:
Received: 2018/06/12

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5582214	N/A	2018/06/15	Deonarine Ramnarine
Conductivity	AT	5582341	N/A	2018/06/15	Tahir Anwar
pH CaCl2 EXTRACT	AT	5580453	2018/06/14	2018/06/14	Tahir Anwar
Resistivity of Soil		5578503	2018/06/15	2018/06/15	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5582215	N/A	2018/06/15	Deonarine Ramnarine

Maxxam ID: GYB548 Dup
Sample ID: 17-3 SA#7B
Matrix: Soil

Collected: 2018/04/28
Shipped:
Received: 2018/06/12

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Conductivity	AT	5582341	N/A	2018/06/15	Tahir Anwar

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

GENERAL COMMENTS

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

Package 1	22.3°C

Sample GYB548 [17-3 SA#7B] : Sample received and analyzed past the recommended hold time as per client request.

Results relate only to the items tested.

Maxxam Job #: B8E2841
Report Date: 2018/06/15

QUALITY ASSURANCE REPORT

Golder Associates Ltd
Client Project #: 1671430 W004
Site Location: HIGHWAY 26
Sampler Initials: CC

			Matrix Spike		SPIKED BLANK		Method Blank		RPD	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
5580453	Available (CaCl2) pH	2018/06/14			101	97 - 103			0.21	N/A
5582214	Soluble (20:1) Chloride (Cl)	2018/06/15	NC	70 - 130	102	70 - 130	<20	ug/g	2.3	35
5582215	Soluble (20:1) Sulphate (SO4)	2018/06/15	NC	70 - 130	109	70 - 130	<20	ug/g	8.1	35
5582341	Conductivity	2018/06/15			100	90 - 110	<2	umho/cm	0.50	10

N/A = Not Applicable

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

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

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

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

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

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Maxxam Job #: B8E2841
Report Date: 2018/06/15

Golder Associates Ltd
Client Project #: 1671430 W004
Site Location: HIGHWAY 26
Sampler Initials: CC

VALIDATION SIGNATURE PAGE

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

Brad Newman, Scientific Service Specialist

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

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Maxxam A Bureau Veritas Group Company

6740 Campobello Road, Mississauga, Ontario L5N 2L8
Phone: 905-817-5700 Fax: 905-817-5779 Toll Free: 800-563-6266
CAM FCD-01191/3

CHAIN OF CUSTODY RECORD

Page 1 of 1

Invoice Information		Report Information (if differs from invoice)		Project Information (where applicable)	
Company Name:	Golder Associates Ltd.	Company Name:		Quotation #:	
Contact Name:	Nikol Kochmanová	Contact Name:		P.O. #/ AFE#:	
Address:	6925 Century Ave Suite 100 Mississauga ON L5N 7K2	Address:		Project #:	1671430 WD004
				Site Location:	Highway 26
Phone:	905-567-4444 Fax: 905-567-6561	Phone:	Fax:	Site #:	
Email:	Nikol_Kochmanova@golder.com	Email:		Sampled By:	C.C.

Turnaround Time (TAT) Required
- [X] Regular TAT (5-7 days) Most analyses

PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS

Rush TAT (Surcharges will be applied)
- [ ] 1 Day [ ] 2 Days [ ] 3-4 Days

Date Required:
Rush Confirmation #:

MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY

Regulation 153
- [ ] Table 1 [ ] Res/Park [ ] Med/ Fine
- [ ] Table 2 [ ] Ind/Comm [ ] Coarse
- [ ] Table 3 [ ] Agri/ Other
- [ ] Table ____

FOR RSC (PLEASE CIRCLE) Y / N

Other Regulations
- [ ] CCME [ ] Sanitary Sewer Bylaw
- [ ] MISA [ ] Storm Sewer Bylaw
- [ ] PWQO Region
- [ ] Other (Specify)
- [ ] REG 558 (MIN. 3 DAY TAT REQUIRED)

Include Criteria on Certificate of Analysis: Y / N

SAMPLES MUST BE KEPT COOL (< 10 °C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM

Analysis Requested

	SAMPLE IDENTIFICATION	DATE SAMPLED (YYYY/MM/DD)	TIME SAMPLED (HH:MM)	MATRIX	# OF CONTAINERS SUBMITTED	FIELD FILTERED (CIRCLE) Metals / Hg / CrVI	BTEX/ PHC F1	PHCs F2 - F4	VOCs	REG 153 METALS & INORGANICS	REG 153 ICPMS METALS	REG 153 METALS (Hg, Cr VI, ICPMS Metals, HWS - B)	Corrosivity Package (Cl, SO4, pH, Resistivity, EC)	no sulphide and redox potential						HOLD- DO NOT ANALYZE
1	17-3 SA#7B	2018/04/28	AM	SOIL									X							
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				

LABORATORY USE ONLY

CUSTODY SEAL Y / (N)		COOLER TEMPERATURES
Present	Intact	
N	N	22/22/23

COOLING MEDIA PRESENT: Y / (N)

COMMENTS

RELINQUISHED BY: (Signature/Print)	DATE: (YYYY/MM/DD)	TIME: (HH:MM)	RECEIVED BY: (Signature/Print)	DATE: (YYYY/MM/DD)	TIME: (HH:MM)
Alex MacMillan [signature]	2018/06/12	16:00	[signature] Jonathan Usner	18/06/12	15:59

12-Jun-18 15:59
Ema Gitej
B8E2841
VMK ENV-1084

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APPENDIX D

Non-Standard Special Provisions

<u>PIPE INSTALLATION BY TRENCHLESS METHOD</u> – Item No.

Special Provision November 2018

CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY TRENCHLESS METHODS

TABLE OF CONTENTS

1.0 SCOPE

2.0 REFERENCES

3.0 DEFINITIONS

4.0 DESIGN AND SUBMISSION REQUIREMENTS

5.0 MATERIALS

6.0 EQUIPMENT

7.0 CONSTRUCTION

8.0 QUALITY ASSURANCE- Not Used

9.0 MEASUREMENT FOR PAYMENT

10.0 BASIS OF PAYMENT

1.0 SCOPE

This specification covers the requirements for the installation of pipe by a selected trenchless method.

2.0 REFERENCES

This specification refers to the following standards, specifications, or publications:

Ontario Provincial Standard Specifications, General

OPSS 180 Management of Disposal of Excess Material

Ontario Provincial Standard Specifications, Construction

OPSS 401 Trenching, Backfilling, and Compacting
OPSS 402 Excavating, Backfilling, and Compacting for Maintenance Holes, Catch Basins, Ditch Inlets and Valve Chambers
OPSS 403 Rock Excavation for Pipelines, Utilities, and Associated Structures in Open Cut
OPSS 404 Support Systems
OPSS 409 Closed-Circuit Television (CCTV) Inspection of Pipelines

OPSS 491	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 517	Dewatering
OPSS 539	Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

OPSS 1004	Aggregates - Miscellaneous
OPSS 1350	Concrete - Materials and Production
OPSS 1440	Steel Reinforcement for Concrete
OPSS 1802	Smooth Walled Steel Pipe
OPSS 1820	Circular and Elliptical Concrete Pipe
OPSS 1840	Non-Pressure Polyethylene (PE) Plastic Pipe Products

CSA Standards

B182.6	Profile polyethylene (PE) sewer pipe and fittings for leak-proof sewer applications
A3000	Cementitious Materials Compendium
W59	Welded Steel Construction (Metal Arc Welding)

American Society for Testing and Materials (ASTM) International Standards

A 252	Standard Specification for Welded and Seamless Steel Pipe Piles
D 2657	Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings
D 3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
D6910	Standard Specification for Marsh Funnel Viscosity of Clay Construction Slurries
F 894	Standard Specification for Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

International Organization for Standardization/International Electrotechnical Commission (ISO/IEC)

17025	General Requirements for the Competence of the Testing and Calibration Laboratories

3.0 DEFINITIONS

For the purpose of this specification, the following definitions apply:

Auger Jack & Bore means a method of forming a horizontal bore in the subsurface by simultaneously or alternately jacking into the ground a casing pipe and rotating a cutter head at the lead end of an auger flight with removal of material from inside the casing by using continuous-flight augers.

Backreamer or Reamer means a cutting head suitably designed for the subsurface conditions that is attached to drilling equipment and used to enlarge the bore

Bore Path means a drilled path according to the grade and alignment tolerances specified in the Contract Documents.

Design Engineer means the Engineer retained by the Contractor who produces the design and working drawings and other engineering documents required of the Contractor. The Design Engineer shall be licensed to practice in the Province of Ontario.

Design Checking Engineer means the Engineer retained by the Contractor who checks the original design and working drawings. The design checking engineer shall be licensed to practice in the Province of Ontario, shall not be an employee of the Contractor and shall be independent from the Design Engineer.

Digger Shield/Hand Mining means a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking a casing pipe, with or without a protective shield at the lead end, into the ground while tunnelling and removal of earth and rock is completed using manually-operated tools (e.g., pneumatic spades, rams, shovels, breaker bars, etc.) or a "digger" type shield with a hydraulic excavator arm or "road-header" rock cutting machine to remove materials from inside the shield and liner pipe.

Horizontal Directional Drilling (HDD) means horizontal directional boring or guided boring.

Drilling Fluids means a mixture of water and additives, such as bentonite, polymers, surfactants, and soda ash, designed to block the pore space on a bore wall, reduce friction in the bore, and to suspend and carry cuttings to the surface.

Drilling Fluid Hydraulic Fracture or "Frac Out" means a condition where the drilling fluid's pressure in the bore is sufficient to fracture the soil and/or rock materials and allow the drilling fluids to migrate to the surface at an unplanned location.

Earth Pressure Balance (EPB) means a tunnelling system that provides support to the excavated face of the ground and resistance to groundwater inflow through the pressure of mixed earth, rock and any drilling fluids or additives (spoil) as maintained by and in a chamber behind the cutting face of a tunnel boring machine through which spoil can pass only by manner of controlled-load relieving gates or an internal screw-conveyor that is separate from subsequent spoil conveyance systems (e.g., flight augers, belt conveyor, spoil bucket rail cars, etc.). Trenchless systems that apply pressure to the excavated face of the ground only through mechanical and jacking forces on metal parts of the machinery (e.g., steel parts of cutting tools, adjustable gates or doors at cutting face, etc.) will not be considered equivalent to EPB systems.

Excavation means all materials encountered regardless of type and extent and shall include removal of natural soil, boulders, cobbles, wood and fill regardless of means necessary to break consolidated materials for removal.

Environmentally Sensitive Area (ESA) means areas specified in the Contract Documents that are prohibited from entry or use.

Fill means man-made mixture of previously placed or handled materials such as sand, clay, silt, gravel, broken rock, sometimes containing organic and/or deleterious materials, placed in an excavation or other area to raise the surface elevation.

Guidance System means an electronic system capable of indicating the position, depth and orientation of the drill head during the directional drilling process.

Hand Mining means a method of forming a horizontal bore in the subsurface by simultaneously jacking ahead while tunnelling advances using hand–mining (man-entry operation or "Jack and Mine") or a "digger" type shield with a hydraulic excavator arm to remove materials from inside the liner pipe.

Inadvertent Returns means the unexpected flow of fluids, saturated materials (or flowing soil) towards the drilling rig that typically originated from an artesian aquifer encountered during the drilling process.

Loss of Circulation means the discontinuation of the flow of drilling fluid in the bore back to the entry or exit point or other planned recovery points.

Microtunnelling means an underground method of constructing a passage by using a microtunnel boring machine (MTBM) or hand mining using a shield to support the opening.

Pilot Bore means the initial bore to set directional controlled horizontal and vertical alignment between the connecting points.

Pipe Jacking means a method for installing steel casing, concrete pipe or other acceptable material in the subsurface utilizing hydraulically operated jacks of adequate number and capacity for the smooth and uniform advancement of the casing or pipe.

Pipe means pipe culverts, pipe storm and sanitary sewers, watermain pipe, conduits and ducts.

Pipe Ramming means a method for installing steel casings utilizing the energy from a percussion hammer to advance a steel casing with a cutting shoe attached at the front end of the casing.

Project Superintendent means an individual representing the Contractor that oversees the trenchless or tunnelling operation qualified to provide the services specified in the Contract Documents.

Pullback means that part of the HDD method in which the drilling equipment is pulled back through the bore path to the entry point.

Reaming means a process for enlarging the bore path

Rock means natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a volume of 0.5 m^3 or greater.

Shaft means an excavation used as entry and/or exit points, alternatively called entry/exit pits, from which the trenchless method is initiated for the installation of the pipe product.

Slurry Pressure Balance (SPB) means a tunnelling system that provides support to the excavated face of the ground and resistance to groundwater inflow through the pressure of slurry as maintained by and in a chamber behind the cutting face of a TBM or MTBM through which spoil can pass only by manner of controlled-pressure and controlled flow slurry pumping systems.

Strike Alert means a system that is intended to alert and protect the operator in the case of inadvertent drilling into an electrical utility cable. The strike alert system consists of a sensor and an alarm connected to the drill rig and a grounding stake. The alarm may be audio or visual or both.

Slurry means a mixture of soil and/or rock cuttings, and drilling fluid.

Soil means all soils except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials.

Spoil means mix of earth cuttings, rock cuttings, water (groundwater or added water), bentonite, polymers and/or other additives that is discharged from the trenchless construction systems.

Trenchless Installation means an underground method of constructing a passage open at both ends that involves installing a pipe product by auger jack & boring, pipe ramming, horizontal directional drilling, or tunnelling.

Trenchless Contractor means the subcontractor retained by the Prime Contractor qualified to provide the services specified in the Contract Documents.

Tunnelling means an underground method of constructing a passage using a tunnel boring machine (TBM) operated by personnel within the tunnel, a microtunnel boring machine (MTBM) operated by personnel at a remote control station or excavation using a shield to support the opening and protect workers.

Zone of Influence means a zone defined by lines projected outward and upward at 45 degrees from horizontal to the ground surface from the vertical and horizontal alignment of the pipe constructed using trenchless/tunnel methods.

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.01 Design

4.01.01 General

The Contractor shall determine the most appropriate method of installation for each location within the terms of this specification.

The installation method selected for each pipe crossing shall be designed for the subsurface conditions as reported in the Contract Documents.

The detailed design of the installation method selected to carry out the work as specified in the Contract Documents shall be completed.

Jack-and-bore and pipe ramming methods are not considered feasible at the McIntyre Creek site.

4.02 Submission Requirements

4.02.01 Qualifications

At least two weeks prior to construction, the names of the Project Superintendent, Trenchless contractor, Design Engineer, and Design Checking Engineer shall be submitted to the Contract Administrator.

4.02.01.01 Project Superintendent

The Project Superintendent shall have a minimum of five years' experience on projects with similar scope and complexity.

During construction, the project superintendent shall not change without written permission from the Contract Administrator. A proposal for a change in the project superintendent shall be submitted at least one week prior to the actual change in project superintendent.

4.02.01.02 Trenchless Contractor

The Trenchless Contractor shall have a minimum of five years' experience on projects with similar scope and complexity

4.02.01.03 Design Engineer

The Design Engineer shall have a minimum of five years' experience on projects with similar scope and complexity

4.02.01.04 Design Checking Engineer

The Design Checking Engineer shall have a minimum of five years' experience on projects with similar scope and complexity

4.02.02 Working Drawings

Three sets of Working Drawings for the trenchless installation method selected shall be submitted to the Contract Administrator (CA) for purposes of documentation and quality assurance at least two week prior to the commencement of the work. All Working Drawings shall bear the seal and signature of the Design Engineer and Design Checking Engineer.

The working drawings shall be submitted to the Contract Administrator under cover with a Request to Proceed.

The Contractor shall not proceed with the work until a Notice to Proceed has been received from the Contract Administrator

A copy of the Working Drawings shall be kept at the site during construction.

Information and details shown on the Working Drawings shall include, but not be limited to:

a) Plans and Details:

  i. Plans and profiles defining all horizontal and vertical alignment positions and positions of all utilities and other infrastructure within the zone of influence of the work;
  ii. A work plan outlining the materials, procedures, methods and schedule to be used to execute the work.
  iii. A list of personnel, including backup personnel, and their qualifications and experience.
  iv. A safety plan including the company safety manual and emergency procedures.
  v. The work area layout.
  vi. An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail.
  vii. A contingency plan with specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner.
  viii. A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan detailing emergency procedures in the event that the fluid management plan fails.
  ix. Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations.
  x. Excavated materials disposal plan.

xi. Locations of protection systems.

b) Designs

i. Primary liner design (e.g., steel liner plates, steel ribs and wood lagging, steel casing pipe, etc.),
ii. Design assumption and material data when materials other than those specified are proposed for use.
iii. Drill path design, details of alignment and alignment control, maximum curvature and reaming stages.

c) Materials:

i. Certification from the manufacturer that the product furnished on the contract meets the specifications cited in the manufacturer's product specification and that the materials supplied are suitable for the application.
ii. Manufacturer data sheets for all drilling fluids and additives for use in Earth Pressure Balance, Slurry Pressure Balance
iii. Manufacturer data sheets for drilling systems.
iv. Mix designs, target rheology criteria (e.g., viscosity, density, shear strength, gel time, pressure-filtration – fluid losses under pressure, etc.) and additive dosage rates for all slurries and EPB TBM and MTBM operations.
v. The proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces.
vi. Compressive strength of concrete pipe products.
vii. Pipe class for all steel pipe products.
viii. Steel for Permanent Casings
    - One copy of a mill test certificate certifying that the steel meets the requirements for the appropriate standards for permanent casings shall be submitted to the Contract Administrator at the time of delivery.
    - Where mill test certificates originate from a mill outside Canada or the United States of America, the information on the mill certificates shall be verified by testing by a Canadian laboratory. The laboratory shall be certified by an organization accredited by the Standards Council of Canada to comply with the requirements of ISO/IEC 17025 for the specific tests or type of tests required by the material standard specified on the mill test certificate.
    - The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date (i.e., yyyy-mm-dd), and the signature of an authorized officer of the Canadian testing laboratory

ix. The Contractor shall submit the followings to the Contract Administrator two weeks prior to construction:

    - type, source, and physical and chemical properties of bentonite, polymer or other additives;
    - source of water;
    - method of mixing;
    - the water to solids ratio and the mass and volumes of the constituent parts, including any chemical admixtures or physical treatment employed to achieve required physical

properties;

- details of procedure to be used for monitoring physical properties of slurry, drilling fluids and tunnelling fluids or EPB spoil; and method of disposal of the slurry, drilling fluids and associated spoil

d) Upstream/Downstream Portal Installation Procedure:

i. The access shaft or entry/exit pit details, as applicable.
ii. Face support and other temporary support details, if applicable.

e) Primary Liner/Secondary Liner Installation and Grouting Procedure:

i. Excavation and pipe installation procedures, including methods to handle obstructions and prevent soil cave-in.
ii. Details of tunnelling equipment/methods to be used for the works.

f) Excavation and Dewatering:

i. Equipment and methods for control, handling, treatment, and disposal of groundwater and water or fluids introduced by the Contractor;
ii. Equipment and methods for maintaining control of ground inflow at the excavation face during excavation;
iii. Equipment and methods for removal of cobbles and boulders;
iv. Manufacturer data sheets for each TBM, shield, tunnelling system or drilling system noting all intermediate and final cut dimensions, and methods and equipment for controlling and measuring drilling fluid, SPB and EPB pressures;
v. Methods for measuring excavated volumes or weights of earth and rock materials cut from ground on a per meter or per pipe basis up to a maximum of 3 m long intervals per measurement;
vi. Target operating pressures (minimum and maximum) and range of expected pressure variation for slurry or EPB spoil at excavated face or drilling fluids at lead end of drilling equipment and in annular gap between maximum excavated dimensions and outside dimensions of tunnelling equipment, drilling equipment and primary liner systems;
vii. Basis for setting target operating conditions (pressures, flow rates, advance rates) and the relationship of target operating conditions to ground conditions;
viii. Basis for selection of excavation tools (e.g., bits, TBM face tools, MTBM face tools, excavator fittings, etc.) as related to expected ground conditions;
ix. Jacking forces for installation of pipe, for driving of trenchless equipment forward and, in the case of Auger Jack & Bore, for advancing the lead end of the casing ahead of the lead end of the auger cutting tools.

g) Monitoring Method:

Methods, equipment, frequency and repeatability (accuracy and precision) of data collection to be employed for measuring and monitoring shall be submitted for:

i. Maintaining the alignment of the installation;
ii. EPB, SPB and drilling fluid pressures at the leading edge of excavation (face), flow rates and volume or weights of spoil;
iii. Jacking forces on pipes, linings and cutting tools;
iv. Torque, total revolutions and revolution rates on rotating equipment such as TBM or MTBM heads, auger flights, drill bits, etc.
v. Grout injection pressures and volumes;

vi. Longitudinal position of all casings and excavation cutting tools (auger flight heads, TBM face, drill bit position, etc.);
vii. Ground displacements (heave and settlement); and noise and ground vibrations induced by trenchless construction

4.02.03 Quality Control Certificate

The Contractor shall submit a Quality Control Certificate to the Contract Administrator for documentation and quality assurance purposes, prepared and stamped by the Design and Design Checking Engineers, a minimum of two weeks prior to commencement of work under this item. The Certificate shall state that the construction procedures are in conformance with the requirements and specifications of the contract documents.

The Contractor shall submit to the Contract Administrator a Quality Control Certificate sealed and signed by the Design and Design Checking Engineer upon completion of each of the following operations and prior to commencement of each subsequent operation for each pipe installation:

Site Surveying (as noted in Section 4.02)
Excavation for pits including dewatering of excavations
Jacking/Ramming/Directional Drilling of Casing/Liner
Installation of the Product
Grouting Operations

Each Quality Control Certificate shall state that the work has been carried out in general conformance with the contract documents, specifications and/or stamped working drawings.

The Contractor shall submit a Request to Proceed to the Contract Administrator upon completion of each of the milestones.

The Contractor shall not proceed to the subsequent operation until a Notice to Proceed has been received from the Contract Administrator

In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a final Quality Control Certificate sealed and signed by the Design and Design Checking Engineer. The Certificate shall state that the pipe has been installed in general conformance with the Contractor's Submission and Design Requirements, stamped working drawings and contract documents.

5.0 MATERIALS

5.01 Pipe

5.01.01 General

The product shall be concrete pipe, steel pipe or high density polyethylene pipe as specified.

All joints shall be suitable for jacking operations as specified in the working drawings.

Fittings shall be suitable and compatible with the class and type of pipe with which they will be used.

All fittings shall be designed to be watertight.

5.01.02 Steel Pipe

Steel pipe shall be according to ASTM A252.

All steel casing pipe shall be square cut.

Steel casing pipe shall meet a straightness tolerance of 1.5 mm/m. When placed anywhere on the pipe parallel to the pipe axis, there shall not be a gap more than 1.5 mm between a 1 m long straightedge and the pipe.

5.01.03 HDPE Pipe

High density polyethylene (HDPE) pipe according to OPSS 1840 shall be used in accordance with ASTM D3350.

Fittings shall be according to CAN/CSA-B182.6 or ASTM F894 and suitable for the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed according to the manufacturer's recommended procedures and ASTM D2657. Where conflicts exist between the manufacturer's instructions and ASTM D2657, the manufacturer's instructions are to be followed.

Jointing of HDPE piping to other piping materials or appurtenances shall be completed using flanged connections.

5.01.04 Concrete Pipe

Concrete pipe shall be according to OPSS 1820.

5.02 Concrete

Concrete shall be according to OPSS 1350. The concrete strength shall be as specified on the Working Drawings.

5.03 Steel Reinforcement

Steel reinforcement for concrete work shall be according to OPSS 1440.

5.04 Wood

Wood shall be according to OPSS 1601.

5.05 Drilling Fluids

Drilling fluid shall be mixed according to the working drawings.

Selection of drilling fluid type shall be based on the soils encountered in the subsurface investigation.

The drilling fluids shall be mixed according to the manufacturer's recommendations.

Slurry shall be mixed according to the submitted slurry design and be appropriate for the anticipated subsurface conditions. The viscosity of slurry used for SPB tunnelling shall be no less than 40 seconds Marsh Funnel viscosity, as defined by ASTM D6910, measured prior to introduction of groundwater and spoil and as required to ensure:

a) development of appropriate filter cake at excavation face to provide slurry support pressures exceeding ground and groundwater pressures at excavation face;
b) lubricate installation of primary liners as required;
c) transport spoil through pipe systems;

5.06 Grout

Purging grout shall conform to the requirements of OPSS 1004 wetted with only sufficient water to make the mixture plastic

6.0 EQUIPMENT

6.01 Auger Jack & Bore

Except in the case of dewatering to at least 1 m below the tunnel/bore invert for the full length of the pipe alignment, Auger Jack & Bore shall not be used and will not be permitted where subsurface conditions indicate that saturated gravel, sand and silt soils may be encountered at pipe level or within one pipe diameter above or below outside pipe dimensions.

Pipe auger jack & bore equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the equipment with which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

The lead end of the auger shall be maintained at least one pipe diameter inside the lead end of the casing. The auger cutting tools shall not extend to or beyond the lead end of the casing at any time unless specific exception is provided by the Ministry prior to construction. Submittals shall identify anticipated jacking forces for advancing casing ahead of leading edge of auger cutting tools in addition to friction forces that are to be overcome by jacking systems

6.02 Pipe Ramming

Pipe ramming equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

The pipe ramming hammer(s) shall be capable of driving the pipe casing from the entry pit to the exit pit through the existing subsurface conditions at the site without removal of soil from within the casing until the lead end of the pipe is outside the zone of influence for any overlying infrastructure.

Specific details of the equipment with which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the pipe shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

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6.03 Horizontal Directional Drilling

6.03.01 General

The Horizontal Directional Drilling equipment shall consist of a directional drilling rig and a drilling fluid mixing and delivery system to successfully complete the product installation without exceeding the maximum tensile strength of the product being installed.

6.03.02 Drilling Rig

The horizontal directional drilling rig shall:

a) Consist of a leak free hydraulically powered boring system to rotate, push, and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head.

b) Have drill rod that is suitable for both the drill and the product pipe installation.

c) Contain a drill head that is steerable, equipped with the necessary cutting surfaces and fluid jets, and be suitable for the anticipated ground conditions.

d) Have adequate reamers and down-bore tooling equipped with the necessary cutting surfaces and fluid jets to facilitate the product installation and be suitable for the anticipated ground conditions.

e) Contain a guidance system to accurately guide boring operations.

f) Be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation.

g) Be grounded during all operations unless otherwise specified by the drilling rig manufacturer.

6.03.03 Drill Head

The drill head shall be steerable by changing its rotation, be equipped with the necessary cutting surfaces and drilling fluid jets, and be of the type for the anticipated subsurface conditions,

6.03.04 Guidance System

The guidance system shall be setup, installed, and operated by trained and experienced personnel. The operator shall be aware of any magnetic or electromagnetic anomalies and shall consider such influences in the operation of the guidance system when a magnetic or electromagnetic system is used.

6.03.05 Drilling Fluid Mixing System

The drilling fluid mixing system shall be of sufficient size to thoroughly and uniformly mix the required drilling fluid.

6.03.06 Drilling Fluid Delivery System

The delivery system shall have a means of measuring and controlling fluid pressures and be of sufficient flow capacity to ensure that all slurry volumes are adequate for the length and diameter of the final bore and the anticipated subsurface conditions. Connections between the delivery pump and drill pipe shall be leak-free.

6.04 Tunnelling

Tunnelling equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein. Specific details of tunnelling equipment included in the submission shall be provided for:

a) rock or boulder breaking and removal;

b) equipment used within shields for spilling, fore-poling, face drainage, breasting boards/plates and for otherwise maintaining support of the tunnel crown and face under all anticipated conditions;

c) jacking systems;

d) alignment control systems;

Use of rock fracturing chemicals shall only be considered subject to a field demonstration satisfactory to the Ministry prior to its use. Use of explosives is prohibited without specific application and acceptance by the Ministry prior to construction.

6.05 Microtunnelling Equipment

The Contractor shall be responsible for selecting microtunnelling equipment which, based on past experience, has proven to be satisfactory for excavation of the soils that will be encountered.

The Contractor shall employ microtunnelling equipment that will be capable of handling the various anticipated ground conditions.

The MTBM shall also be capable of controlling loss of soil ahead of and around the machine and shall provide continuous pressurized support of the excavated face.

a) Remote Control System – The Contractor shall provide a MTBM that includes a remote control system with the following features:

i. Allows for operation of the system without the need for personnel to enter the microtunnel. Has a display available to the operator, at a remote operation console, showing the position of the shield in relation to a design reference together with other information such as face pressure, roll, pitch, steering attitude, valve positions, thrust force cutter head torque, rate of advance and installed length.

ii. Integrates the system of excavation and removal of spoil and its simultaneous replacement by Product Pipe. As each pipe section is jacked forward, the control system shall synchronize all of the operational functions of the system.

iii. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.

iv. The system shall monitor and continuously balance the soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.
v. The pressure at the excavation face shall be managed by controlling the volume of spoil removal with respect to the advance rate.
vi. The system shall include a separation process designed to provide adequate separation of the spoil from the slurry so that slurry with a sediment content within the limits required for successful microtunnelling, can be returned to the cutting face for reuse. Appropriately contain spoil at the site prior to disposal.
vii. The type of separation process shall be suited to the size of microtunnel being constructed, the soil type being excavated, and the work space available at each work area.
viii. The system shall allow the composition of the slurry to be monitored to maintain the slurry weight and viscosity limits required.

b) Active Direction Control - Provide an MTBM that includes an active direction control system with the following features:

i. Controls line and grade by a guidance system that relates the actual position of the MTBM to a design reference Provides active steering information that shall be monitored and transmitted to the operating console and recorded.
ii. Provides positioning and operation information to the operator on the control console.

6.05.01 Pipe Jacking Equipment

Provide a pipe jacking system with the following features:

a) Has the main jacks mounted in a jacking frame located in the launch shaft.
b) Has a jacking frame that successively pushes towards a receiving shaft, a string of Product Pipe that follows the microtunnelling excavation equipment.
c) Has sufficient jacking capacity to push the microtunnelling excavation equipment and the string of pipe through the ground.
d) The main jack station may be complemented with the use of intermediate jacking stations as required.
e) Has a capacity at least 20 percent greater than the calculated maximum jacking load.
f) Develops a uniform distribution of jacking forces on the end of the casing pipe.
g) Provides and maintains a pipe lubrication system at all times to lower the friction developed on the surface of the pipe during jacking.
h) Jack Thrust Blocking shall adequately support the jacking pressure developed by the main jacking system.
i) Special care shall be taken when setting the pipe guide rails in the jacking shaft to ensure correctness of the alignment, grade, and stability.

6.05.02 Spoil Separation System

The Contractor shall determine the type of spoil separation equipment needed for each drive based on the geotechnical information available and other project constraints.

6.05.03 Electrical Equipment, Fixtures and Systems

Electrical equipment shall be suitably insulated for noise reduction. Noise produced by electrical equipment must comply with local municipal noise by-laws.
Electrical systems shall conform to requirements of the Canadian Electrical Code – CSA C22.1.

7. CONSTRUCTION

7.01 General

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting work. The proposed method of pipe installation to be used by the Contractor shall be subject to the limitations presented in the following subsections.

The Project Superintendent shall supervise the work at all times.

7.01.01 Layout, Alignment and Depth Control

The location of the installation shall be established from the lines, elevations and tolerances specified in the Contract Documents. The pipe installation shall be to the horizontal and vertical alignments specified in the Contract Drawings. Deviations from location, alignment, grades and/or invert levels shall be corrected by the Contractor at no cost to the Ministry.

All reference points necessary to construct the pipe installation and appurtenances shall be laid out.

The Contractor shall calibrate tracking and locating equipment at the beginning of each work day, and shall monitor and record the alignment and depth readings provided by the tracking system every 2 m.

The Contract Administrator shall be provided with the assistance and access necessary to check the layout of the pipe installation and associated appurtenances.

The Contractor shall submit records of the alignment and depth of the installation to the Contract Administrator at the completion of the installation.

7.01.02 Construction Shafts

Construction shafts shall be specified in the Contractor's submission. The boundaries and protection of these shall be as required to contain all disturbances to areas outside of the ESA limits.

Shafts shall be maintained in a drained condition.

A minimum 2.4 m high secure fence shall be installed around the perimeter of the construction shaft area with gates and truck entrances. The fence shall be removed on completion of the work.

7.01.03 Protection Systems

The construction of all protection systems shall be according to OPSS539. Where the stability, safety, or function of an existing roadway, watercourse, other works, proposed works or ESA's may be impaired due to the method of operation, protection shall be provided. Protection may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works.

7.01.04 Settlement or Heave

Any disturbance to the ground surface (settlement or heave) as a result of the pipe installation shall be immediately corrected by the Contractor, at no additional cost to the Ministry.

7.01.05 Stability of Excavation

The construction methods, plant, procedures, and precautions employed shall ensure that excavations are stable, free from disturbance, and maintained in a drained condition.

The construction methods, plant, procedures, and materials employed shall prevent the migration of soil and/or rock material into the excavation from adjacent ground.

7.01.06 Preservation and Protection of Existing Facilities

Preservation and protection of existing facilities shall be according to OPSS 491.

Minimum horizontal and vertical clearances to existing facilities as specified in the Contract Documents shall be maintained. Clearances shall be measured from the nearest edge of the largest cut diameter required to the nearest edge of the facility being paralleled or crossed.

Existing underground facilities shall be exposed to verify its horizontal and vertical locations when the outlet pipe path comes within 1.0 m horizontally or vertically of the existing facility. Existing facilities shall be exposed by non-destructive methods. The number of exposures required to monitor work progress shall be as specified in the Contract Documents.

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer's handling and storage recommendations shall be followed.

7.01.08 Trenching, Backfilling and Compacting

Trenching, backfilling, and compacting for entry and exit points or other locations along the pipe path shall be according to OPSS 401.

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

If any open excavation will encroach into the highway embankment the protection system shall satisfy the requirements for Performance Level 2 as specified in OPSS 539.

7.01.10 Dewatering

The work of this Section includes control, handling, treatment, and disposal of groundwater. The Contractor shall review the foundation investigation report for reference to soil and groundwater conditions on the project site and plan a dewatering scheme accordingly.

The Contractor shall control groundwater inflows to excavations to maintain stability of surrounding ground, to prevent erosion of soil, to prevent softening of ground exposed in the excavation, and to avoid interfering with execution of the work.

The Contractor shall maintain excavations free of standing water at all times during excavation, including while concrete is curing.

Should water enter the excavation in amounts that could adversely affect the performance of the work or could cause loss of ground, the Contractor shall take immediate steps to control the inflow.

The Contractor is alerted that seepage zones of perched water within the fill materials should be expected, particularly where granular materials are excavated.

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Cobbles and Boulders

The Contractor is alerted that cobbles and boulders should be anticipated in the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. Removal of cobbles shall be expected to be routine and will not be considered cause for obstruction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

The Contractor is alerted to the potential presence of wood debris, cobbles and boulders within the fill and hard / very dense native soils at the McIntyre Creek site.

7.01.14 Management of Excess Material

Management of excess material shall be according to OPSS 180. Satisfactory re-usable excavated material required for backfill shall be separated from unsuitable excavated material.

7.01.15 Site Restoration

Site restoration shall be according to OPSS 492.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

The installation procedure to be used shall be subject to the following limitations:

a) Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.
b) A suitably padded jacking head or collar shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
c) The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
d) Selection of the excavation method and jacking equipment shall take into consideration the conditions at each pipe crossing.

7.02.02 Pipe Installation

Concrete pipe joints shall be water tight and according to OPSS 1820 and must withstand jacking forces, determined by the Contractor.

During the jacking of the liner the space between the liner and the wall of the excavated volume (e.g., maximum cut diameter) shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavated volume shall be filled with grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground.

The annular space between the liner and the product shall be fully grouted with a water tight, expandable and stable grout.

7.03 Pipe Ramming Installation

For pipe ramming installation the following requirements apply:

Only smooth walled steel pipe shall be used. Butt welding of pipe joints shall conform to CAS W59.

Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement between the shafts/pits without overstressing of the pipe. Delays shall be avoided between ramming operations.

A ramming head shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.

Two or more lubricated guide rails or sills shall be provided of sufficient length to fully support the pipe at the specified line and grade in the ramming pit. Pipe shall be installed to the line and grade specified.

Removal of materials from within the pipe shall not be undertaken until the lead end of the pipe has passed fully through and beyond the zone of influence of any overlying infrastructure.

Following installation of the liner pipe, all material shall be removed from the pipe to the satisfaction of the Contract Administrator. Any voids remaining between the pipe and the excavation wall shall be grouted as soon as the pipe is rammed. The annular space between the liner pipe and the product shall be fully grouted with a water tight, expandable and stable grout.

7.04 Horizontal Directional Drilling Installation

7.04.01 General

When strike alerts are provided on a drilling rig, they shall be activated during drilling and maintained at all times.

For horizontal directional drilling, the contractor shall ensure that during pilot hole drilling the maximum degree of deviation or “dog-leg” shall be 2.5 degrees per 9 m drill pipe length. Any deviation exceeding 2.5 degrees will necessitate a pull-back and straightening of the alignment at the Contractor’s sole expense. The pilot hole exit location shall be within 0.5m of the target location.

7.04.02 Site Preparation

The work site shall be graded or filled to provide a level working area for the drilling rig. No alterations beyond what is required for HDD operations are to be made. All activities shall be confined to designated work areas.

7.04.03 Pilot Bore

The pilot bore shall be drilled along the bore path in accordance with the grade, alignment, and tolerances as indicated on the Contractor’s submitted drilling plan to ensure that the product is installed to the line and grade shown on the Contract Drawings. The Contractor’s methods shall take into consideration the conditions at each crossing within the pipe alignment and shall be suitable to advance through such obstructions such as cobbles and boulders and address the potential for deflection off these obstruction and/or soil conditions.

In the event the pilot bore deviates from the submitted path, the Contract Administrator shall be notified. The Contract Administrator may require the Contractor to pullback, fill and abandon the hole and re-drill from the location along the bore path before the deviation.

If a drill hole beneath highways, roads, watercourses or other infrastructure must be abandoned, the hole shall be backfilled with grout or bentonite to prevent future subsidence and subsurface water conveyance.

The Contractor shall maintain drilling fluid pressure and circulation throughout the HDD process, including during the initial pilot bore and during the reaming process.

The Contractor shall at all times and for the entire length of the installation alignment be able to demonstrate the horizontal and vertical position of the alignment, the fluid volume used, return rates and pressures.

7.04.04 Drilling Fluid Losses to Surface ("Frac-Out")

To reduce the potential for hydraulic fracturing of the hole during horizontal directional drilling, a minimum depth of cover of 5 m shall be maintained between the top of pipe and the surface of any pavements or beds of water courses. Sections of the pipe close to the entry and exit pit with less than 5 m cover shall be cased. The Contractor shall ensure that drilling fluid pressures are properly set and controlled for the full length of the bore to prevent frac-out for the depth of cover available between the bottom of the pavement structure (bottom of the subbase material) and the top of the bore.

Once a fluid loss or frac-out event is detected, the Contractor shall halt operations immediately and conduct a detailed examination of the drill path and implement measures to collect all fluids discharged to surface, mitigate and prevent additional fluid loss.

7.04.05 Reaming

The bore shall be reamed using the appropriate tools to a diameter at least 50% greater than the outside diameter of the product.

7.04.06 Product Installation

7.04.06.0 General

The product shall be jointed according to manufacturer's recommendations. The length of the product to be pulled shall be jointed as one length before commencement of the continuous pulling operation.

The product shall be protected from damage during the pullback operation.

The minimum allowable bending radius for the product shall not be contravened.

Product shall be allowed to recover to static conditions from thermal and installation stresses before connections to new or existing facility are made. Product recovery time shall be according to manufacturers recommendations.

7.04.06.02 Pullback and Grouting

After successfully reaming the bore to the required diameter, the product pipe shall be pulled through the bore path. Once the pullback operation has commenced, it shall continue without interruption until the product pipe is completely pulled into bore unless otherwise approved by the Contract Administrator.

A swivel shall be used between the reamer and the product being installed to prevent rotational forces from being transferred to the product. A weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

The product pipe shall be inspected for damage where visible at excavation pits and where it exits the bore. Any damage noted shall be rectified to the satisfaction of the Contract Administrator.

The pull back and reaming operations shall not exceed the fluid circulation rate capabilities. Reaming and back pulling operations shall be planned to insure that, once started, all reaming and back pulling operations are completed without stopping and within the permitted work hours.

The space between the pipe and the walls of the excavated volume shall be filled with grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground.

7. 05 Tunnelling Installation

7.05.01 General

Excavation of native soil and fill shall be done in a manner to control groundwater inflow to the excavation and to prevent loss of ground into the excavation.

Methods of excavating the tunnel shall be capable of fully supporting the face and shall accommodate the removal of boulders and other oversize objects from the face. Continuous ground support shall be maintained during excavation.

As the excavation progresses, the Contractor shall continuously monitor (every 2 m) indications of support distress, such as cracking, deflection or failure of support system and subsidence of ground near the excavation.

The Contractor shall provide ventilation and lighting in accordance with OHSA requirements for the entire length of the tunnel installed as tunneling progresses.

The tunnel is to be kept sufficiently dry at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times in tunnels.

If excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation and make the excavation face secure. The Contractor shall then evaluate methods of construction and revise as necessary to ensure the safe continuation of the work.

The Contractor shall maintain tunnel excavation line and grade to provide for construction of final lining within specified tolerances.

7.05.01 Tunnelling Method

The tunnelling method shall be suitable to provide face support in changing ground conditions that may be encountered during the progress of the work. The selection of the tunnelling method should consider the soil conditions at each pipe crossing and the presence of obstructions, such as cobbles and boulders, with respect to the tunnel alignment.

7.05.02 Primary Liner (Support System)

Primary support systems shall prevent deterioration, loosening, or unravelling of ground surfaces exposed by excavation.

The primary liner support system shall be designed and installed to achieve the intended performance requirements.

Primary liner support system shall maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the excavation.

The primary liner shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting, and shall ensure that no ground loading or other loading will be placed on the new work until after design strength has been reached.

The primary liner shall be installed so that the exterior is as tight as possible to the excavated surface of the tunnel and allows the placement of the full design thickness of the secondary lining.

Primary support systems shall be compatible with the encountered ground conditions, with the method of excavation, with methods for control of water, and with placement of the permanent lining.

All voids between the primary lining and the wall of the excavated volume shall be filled with cement grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground. If an unexpanded liner is used, the space outside the liner plates shall be filled at least daily.

7.05.03 Secondary Liner

7.05.03.01 Placing of Grout

The void outside the finished secondary liner shall be filled with cement grout according to the Contractor's submission.

Grout shall not be placed until the lining has achieved 85% of its specified strength or 30 MPa. Grouting shall be limited to such sequences and programs as are necessary to avoid damaging any part of the works or any other structure or property. Grout mix design shall be chemically and thermally compatible with all pipe systems.

7.06 Microtunnelling

7.06.01 General

Excavation of soil, rock and fill shall be done in a manner to control and prevent groundwater inflow to the tunnel.

The MTBM shall be capable of fully supporting the face and shall accommodate the removal of boulders and other obstructions from the face. Continuous ground support shall be maintained during excavation.

The tunnel is to be kept well drained at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times.

In the event that excavation threatens to endanger personnel, the Work, adjacent property, roadways, railways, waterways, or the public in any way, the Contractor shall cease excavation. The Contractor shall then evaluate the methods of construction and revise as necessary to ensure the safe continuation of the Work.

The Contractor shall maintain the tunnel excavation line and grade to provide for construction of the product within the specified tolerances.

7.06.02 Method of Installation

The installation procedure to be used shall be subject to the following limitations:

- The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
- Selection of the excavation method and jacking equipment shall take into consideration the subsurface conditions within the tunnel alignment.
- Perform microtunnelling operations in a manner that will minimize the movement of the ground in front of and surrounding the tunnel in conformance with the limits listed in the Contract Documents.
- Prevent damage to structures and utilities above and in the vicinity of the microtunnelling operations.

- Excavated diameter should be the minimum size required to permit pipe installation by jacking.
- Whenever there is a condition encountered which could endanger the microtunnel excavation or adjacent structures if tunnelling operations cease, continue to operate without intermission including 24-hour working days, weekends and holidays, until the condition no longer exists.
- Maintain an envelope of lubricant around the exterior of the pipe during the jacking and excavation operation to reduce the exterior soil/pipe friction and possibility of the pipe seizing in place.
- In the event a section of pipe is damaged during the jacking operation or a joint failure occurs, as evidenced by inspection, visible ground water inflow or other observations, the Contractor shall submit for approval his methods for repair or replacement of the pipe.

7.06.03 Casing Installation

Casing must withstand the jacking forces determined by the Contractor.

The space between the Casing and the wall of the excavation shall be kept filled with lubricant during the pipe jacking operation. Upon completion of pipe jacking, the space between the Casing and the wall of the excavation shall be filled with grout that is compatible with the Casing.

The Casing shall act as a support system to maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the Casing.

The Casing shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting.

7.07 Instrumentation and Monitoring

The Instrumentation and Monitoring program shall be project specific.
The work specified in this Section includes furnishing and installing instruments for monitoring of settlement (and heave) and ground stability.

7.07.01 Surface Monitoring Points

Surface settlement points for monitoring ground stability shall be installed at the pavement/ground surface level on the shoulder, side slope and pavement at intervals of 5 m or less along the tunnel alignment centreline and as arrays of three points in each shoulder of the highway crossing and centred on the tunnel alignment. The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within a repeatability (combined accuracy and precision of equipment and methods) ± 2 mm of the actual elevation.

Surface settlement markers shall be hardened steel markers treated or coated to resist corrosion, with an exposed convex head having a minimum diameter of 12 mm and similar to surveyor's PK nails. Markers shall be rigidly affixed so as not to move relative to the surface to which it is attached. Traffic shall be managed by the contractor using short-term lane closures in accordance with the Ontario Traffic Manual (OTM). Surface markers shall be recessed or otherwise designed for safe passage of vehicles at highway speeds and protected from snow removal equipment in the event that work occurs during snow removal seasons.

7.07.02 In-Ground Monitoring Points

In-ground settlement monitoring points shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe, set to a depth of 1.5 m below ground surface or below frost penetration depth whichever is greater. The assembly shall be placed in a drill hole, backfilled with uniform sand and provided with protective covers suitable for high vehicular traffic areas.

7.07.03 Installation, Replacement and Abandonment

The Contractor shall install all settlement monitoring points a minimum of two weeks prior to the start of works to permit baseline surveying to be completed. The settlement monitoring points shall be clearly labelled for easy field identification. The Contractor shall submit to the Contract Administrator a site plan showing the locations of the monitoring points, a geodetic survey of the settlement monitoring points including station, offset and elevation. Instruments damaged by the Contractor's operations or other causes shall be replaced and surveyed at the time of installation within 24 hours at no additional cost. At the completion of the job, the Contractor shall abandon all instrumentations installed during the course of the Work and restore the surface at instrument locations.

7.07.03 Monitoring and Reporting Frequency

The Contractor shall survey and otherwise obtain elevations of all settlement monitoring points at the following time intervals:

a) Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);
b) Once per shift or once daily during tunnelling operations period whichever results in the more frequent reading intervals; and
c) Weekly after completion of the work for one month, or until such time at which all parties agree that further movement has stopped.

All readings shall be submitted to the Contract Administrator for information purposes on a weekly basis.

Each report shall include all survey data collected in tabular and graphical format as plots of time versus settlement in comparison to survey data collected prior to commencement of the work.

7.07.03 Benchmarks

Two independent benchmarks shall be used for all settlement monitoring surveying and shall be located sufficiently outside the zone of influence such that the benchmarks are not influenced by any trenchless or other construction activity or weather conditions (e.g., frost heave). All surveying shall be reported using the geodetic datum and coordinate system as defined in the Contract Documents.

7.08 Criteria for Assessment of Roadway Subsidence/Heave

Review and Alert Levels

Based on the monitoring of ground movement as specified in Subsections 4.02 and 7.07, the following represents trigger levels that define magnitude of movement and corresponding action:

a) Review Level: If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate or sequence of construction or ground stabilization measures to mitigate further ground displacement. If this Review Level is exceeded, the Contractor shall immediately notify the CA and review and discuss response actions. The

Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.

b) Alert Level: If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic. No construction shall take place until all of the following conditions are satisfied:

i. The cause of the settlement has been identified.
ii. The Contractor submits a corrective/preventive plan.
iii. Any corrective and/or preventive measure deemed necessary by the Contractor is implemented.
iv. The CA deems it is safe to proceed.

9. MEASUREMENT FOR PAYMENT

Measurement shall be by Plan Quantity Payment as may be revised by Adjusted Plan Quantity Payment in metres, following along the centre line of the pipes from centre to centre of maintenance holes or chambers (catch basins) or from/to the end of the pipe where no maintenance hole or chamber is installed, of the actual length of pipe installed by trenchless methods.

10. BASIS OF PAYMENT

Payment at the contract price shall be full compensation for all labour, equipment and materials required for excavation (regardless of material encountered), dewatering, sheathing and shoring, supply and installation of pipe liners, settlement instrumentation and monitoring, site restoration, and all other work necessary to complete the installation as specified.

Payment for the pipe installed inside the pipe liner shall be paid separately under the appropriate tender items.

Where a protection system is made necessary because of the Contractor’s operations (e.g., choice of trenchless installation method), the cost shall be included in this item and shall be full compensation for all labour, equipment and materials required to carry out the work including subsequently removing the temporary protection system and performing any necessary restoration work.

Payment for connecting intercepted drains and service connections shall be made on the following basis:

(a) Where such drains and service connections are shown on the contract drawings the cost of connections shall be included in the contract price for pipe installation.

(b) Where such drains and service connections are not shown on the contract drawings, the cost of connections will be considered an allowable extra to the contract.

Payment for removal of boulders exceeding Boulder Volume Rations (BVR) and Boulder Number Ration (BNR) shall be by Time and Material.

Notes to Designer

A Foundation Engineering Specialist shall be retained by the Contract Administrator to assist the CA in ensuring that the Design and Submission Requirements are met and to ensure quality management of the work. Terms of Reference for the Foundation Engineering Specialist shall be provided by the Foundations Office and finalized in collaboration with the Regional Operations.

Designer Fill Ins

Design and Submission Requirements

*4.01 Design Requirements

Any method that is not suitable shall be specified. Restrictions on tunnelling methodologies shall be specified

4.02 Qualifications

******4.02.01.01 Project Superintendent

Specify minimum requirements commensurate with complexity as recommended in the FIDR.

***4.02.01.02 Tunnelling/Trenchless Contractor

Specify minimum requirements commensurate with complexity as recommended in the FIDR.

****4.02.01.03 Design Engineer

Specify minimum requirements commensurate with complexity as recommended in the FIDR.

*****4.02.01.04 Design Checking Engineer

Specify minimum requirements commensurate with complexity as recommended in the FIDR.

**********7.01.11 Removal of Cobbles and Boulders

Subsurface Condition Baseline Reporting that includes Boulder Volume Ration (BVR), Boulder Number Ration (BNR) shall be project specific and included in the Foundation Engineering TOR as selected during the scoping of the project.

******7.07 Instrumentation and Monitoring

The Instrumentation and Monitoring program shall be project specific as recommended in the FIDR.

***********7.08 Criteria for Assessment of Roadway Subsidence/Heave

Criteria selection shall be project specific as recommended in the FIDR

WARRANT: Always with this specification

<u>EARTH EXCAVATION FOR STRUCTURE</u> – Item No.

Non-Standard Special Provision

Amendment to OPSS 902, November 2010

Excavating and Backfilling – Structures

902.07 CONSTRUCTION

Section 902.07 of OPSS 902 shall be amended by the addition of the following:

The Contactor is alerted to the potential presence of wood debris, cobbles and boulders within the fill and hard/very dense native soil conditions. Consideration of the presence of these obstructions shall be made in the selection of appropriate equipment and procedures for excavations and temporary protection systems.

DEWATERING STRUCTURE EXCAVATIONS - Item No.

Special Provision No. FOUN0003 March 8, 2018

Amendment to OPSS 902, November 2010

OPSS 902, November 2010, Construction Specification for Excavating and Backfilling - Structures is amended as follows:

902.02 REFERENCES

Section 902.02 of OPSS 902 is amended by the addition of the following:

Ontario Provincial Standard Specifications, Construction

OPSS 517 Dewatering
OPSS 805 Temporary Erosion and Sediment Control Measures

902.03 DEFINITIONS

Section 903.03 of OPSS 902 is amended by the addition of the following:

Automatic Transfer Switch means as defined in OPSS 517.

Cofferdam means as defined in OPSS 539.

Cut-Off Wall means as defined in OPSS 517.

Design Storm Return Period means as defined in OPSS 517.

Dewatering System means as defined in OPSS 517.

Groundwater Control System means as defined in OPSS 517.

Plug means as defined in OPSS 517.

Sediment means as defined in OPSS 517.

Sediment Control Measure means as defined in OPSS 517.

Temporary Flow Passage System means as defined in OPSS 517.

Unwatering means as defined in OPSS 517.

Vegetated Discharge Area means as defined in OPSS 517.

Waterbody means as defined in OPSS 517.

Watercourse means as defined in OPSS 517.

902.04 DESIGN AND SUBMISSION REQUIREMENTS

902.04.01 Design Requirements

902.04.01.01 Dewatering

Clause 902.04.01.01 of OPSS 902 is deleted in its entirety and replaced with the following:

A dewatering system shall be designed to control water and the flow of water into the excavation, prevent disturbance of the foundation, permit the placing of concrete in the dry, and complete the excavating and backfilling for structures work.

When the system includes temporary flow passage system, the system shall be designed, as a minimum, for a two year design storm return period, and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

The dewatering system shall be according to the design requirements specified in OPSS 517.

902.04.02 Submission Requirements

Subsection 902.04.02 of OPSS 902 is deleted in its entirety and replaced with the following:

902.04.02.01 Working Drawings

Working Drawings for the dewatering system shall be according to OPSS 517.

902.04.02.02 Preconstruction Survey

When a groundwater control system by wells or a well point system will be used, a condition survey of property and structures that may be affected by the work shall be carried out. The condition survey shall include the location and condition of adjacent properties, buildings, underground structures, water wells, Utilities, and structures, within a distance of 300 metres from the groundwater control system. In addition, all water wells used as a supply of drinking water and located within this distance shall be tested for compliance with Ontario Drinking Water Quality Standards.

Water wells within the preconstruction survey distance can be located using the website https://www.ontario.ca/environment-and-energy/map-well-records or its successor site.

Copies of the condition survey and water quality test results shall be submitted to the Contract Administrator prior to the operation of the groundwater control system.

902.04.02.03 Milestone Inspections

Clause 902.04.02.03 of OPSS 902 is deleted in its entirety.

902.07 CONSTRUCTION

Subsection 902.07.04 of OPSS 902 is deleted in its entirety and replaced with the following:

902.07.04 Dewatering Structure Excavation

902.07.04.01 General

The dewatering systems shall be constructed and operated according to the Working Drawings.

Activation and deactivation of a temporary flow passage system, if applicable, shall be according to OPSS 517.

The dewatering system shall be continuously operational to control buoyancy forces until such forces can be resisted by backfill and structure self-weight, to keep excavations stable, to avoid erosion impacts from the release of accumulated water, and to keep the work area in the condition required to complete the associated work as specified in the Contract Documents.

When a temporary flow passage system is to remain operational through a seasonal shutdown period, the Contractor shall be responsible for any maintenance or repair costs due to the system during the seasonal shutdown period.

Temporary erosion and sediment control measures, including controlling the discharge of water, shall be according to OPSS 805. Measures not specified in OPSS 805 shall be according to the Working Drawings. Temporary erosion and sediment control measures and cover material to protect exposed soils, as required by the Working Drawings, shall be installed as soon as is practical.

Stranded fish shall be managed as specified in the Contract Documents.

Unwatering shall be carried out as necessary.

Water suspected of being contaminated as indicated by visual or olfactory observations shall be reported to the Contract Administrator.

Dewatering and temporary flow passage systems shall be discontinued in a manner that does not disturb any structure, pipeline, or flow channel. Operation of the dewatering system shall be shut down according to the procedures specified in the Working Drawings, where applicable.

902.07.04.02 Discharge of Water

The discharge of water shall be according to OPSS 517.

902.07.04.03 Monitoring

Monitoring shall be according to OPSS 517.

902.07.04.04 System Amendments

Amendments to stop any displacement, damage, soil loss or erosion due to the operation of the dewatering system shall be according to OPSS 517.

902.07.04.05 Removal

Removal of dewatering system and temporary flow passage system components shall be according to OPSS 517.

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: *				Longitude: *		
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	
**	***	****	****	****	****	*****
Dewatering Systems						
Site Name / Station Reference	Preconstruction Survey Distance (Note 2) (m)					Design Engineer Requirements (Note 1)
**	******					*****

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.

Table A (Sample)

<table>
<tr><td colspan="2">IDF Curve Location</td><td colspan="4">Latitude: 44.974844</td><td colspan="2">Longitude: -79.769339</td></tr>
<tr><td colspan="8">Temporary Flow Passage Systems</td></tr>
<tr><td rowspan="2">Site Name /
Station Reference</td><td rowspan="2">Minimum
Return Period
(Years)</td><td colspan="4">Return Period Flow Estimates (m^3/s)</td><td colspan="2" rowspan="2">Design Engineer
Requirements
(Note 1)</td></tr>
<tr><td>2
Year</td><td>5
Year</td><td>10
Year</td><td>25
Year</td></tr>
<tr><td>Woods Creek Culvert
Rehabilitation</td><td>2</td><td>0.7</td><td>3.5</td><td>7.5</td><td>10.9</td><td colspan="2">N/A</td></tr>
<tr><td>Site 32-145
Robbs Creek Culvert Replacement</td><td>10</td><td>1.6</td><td>7.6</td><td>17.4</td><td>25.2</td><td colspan="2">Yes</td></tr>
<tr><td colspan="8">Dewatering Systems</td></tr>
<tr><td>Site Name /
Station Reference</td><td colspan="5">Preconstruction Survey Distance (Note 2)
(m)</td><td colspan="2">Design Engineer
Requirements
(Note 1)</td></tr>
<tr><td>Site 32-145
Robbs Creek Culvert Replacement</td><td colspan="5">300</td><td colspan="2">Yes</td></tr>
<tr><td colspan="8">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.</td></tr>
</table>

WARRANT: Always with these tender items.

CONCRETE WORKING SLAB - Item No.

Non-Standard Special Provision

1.0 Scope

This Special Provision covers the requirements for the supply and placement of a concrete working slab for the base of the entry/exit shafts associated with the trenchless culvert installation at McIntyre Creek.

2.0 References

This Special Provision refers to the following standards, specifications or publications:

Ontario Provincial Standard Specifications, Construction
OPSS 902 Excavating and Backfilling - Structures

3.0 Definitions - Not Used

4.0 Design and Submission Requirements - Not Used

5.0 Materials

Concrete for working slabs shall have a minimum 28 day strength of 20 MPa.

6.0 EQUIPMENT - Not Used

7.0 CONSTRUCTION

7.01 Excavation

Excavation for the working slab shall be according to OPSS 902.

7.03 Protection of Subgrade

The native subgrade for the entry/exit shaft will be susceptible to disturbance and softening/loosening from construction traffic and ponded water. Following inspection and approval of the prepared subgrade, a concrete working slab with a minimum thickness of 100 mm shall be placed on the foundation subgrade within four hours.

The concrete shall have a compressive strength of at least 20 MPa, and be placed in accordance with OPSS.PROV 904.

7.04 Dewatering

Dewatering shall be carried out according to OPSS 902.

8.0 Quality Assurance - Not Used

9.0 Measurement for Payment - Not Used

10.0 Basis of Payment

10.01 Working Slab - Item

Payment at the Contract price for the above tender item shall be full compensation for all labour, Equipment and Material to do the work.

END OF SECTION

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