



## Foundation Investigation and Design Report

*Trenchless Culvert Installations, Highway 48 and Bloomington Road Roundabout  
(Lat. 44.000847, Long. -79.289013), York Region, Ontario, Ministry of  
Transportation, Ontario, G.W.P. 2086-16-00*

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1671430-O9-2

July 12, 2018

**GEOCRETS No.: 31D-704**



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# PART A

FOUNDATION INVESTIGATION REPORT  
TRENCHLESS CULVERT INSTALLATIONS  
HIGHWAY 48 AND BLOOMINGTON ROAD ROUNDABOUT, YORK REGION,  
ONTARIO  
G.W.P. No. 2086-16-00

## 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the proposed trenchless culvert installations associated with the proposed Highway 48 / Bloomington Road Roundabout between Bloomington and Lemonville, Ontario, under G.W.P. 2086-16-00 (refer to the Key Plan on Drawing 1).

The Terms of Reference and scope of work are outlined in MTO's Work Item Order No. 2016-E-0029-009, dated December 2017, which forms part of the Consultant's Assignment for the Central Region Large Value Retainer under Agreement No. 2016-E-0029-009.

## 2.0 SITE DESCRIPTION

The proposed culverts are located within 50 m of the Highway 48 and Bloomington Road intersection, in the Town of Whitchurch-Stouffville. Culverts 4 and 15 will cross under Bloomington Road, west and east of Highway 48, respectively; and culvert 11 will cross under Highway 48, south of Bloomington Road.

A gas station is located on the southwest quadrant of the site adjacent to the Bloomington Road side of the intersection. Residential areas and farmland are located on both sides of Highway 48 north and southeast of the intersection. The topography of the site is generally flat-lying but rises from south to north, from about Elevation 314 m at the southernmost project limit to about Elevation 340 m at the northernmost project limit. The road grade at the Highway 48 and Bloomington Road intersection is at about Elevation 325.5 m.

The existing embankments at the Highway 48 / Bloomington Road intersection are about 3 m to 5 m high constructed with side slopes at inclinations of about 2H:1V and grass covered. The embankment side slopes were in good condition showing no signs of instability at the time of the field investigation.

## 3.0 INVESTIGATION PROCEDURES

Field work for the foundation investigation for the trenchless culverts was carried out between March 6 and 20, 2018, during which time eight boreholes (designated as Boreholes C4-1 to C4-3, C11-2, C11-3, and C15-1 to C15-3) were advanced at the site, approximately at the locations shown on Drawing 1.

Boreholes C4-1, C4-2, C11-2, C15-1 and C15-2 were advanced through the overburden using 153 mm outside diameter (O.D.) hollow stem augers using a CME 75 truck mounted drill rig, supplied and operated by Geo-Environmental Drilling Inc. of Acton, Ontario. Boreholes C4-3, C11-3 and C15-3 were advanced through the overburden using 60 mm inner diameter BW casing and wash boring technique with a portable tripod drill rig supplied and operated by OGS Inc. of Almonte, Ontario; water for the wash boring operations was brought to site in a large mobile tank by the drilling subcontractor. 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 on the truck-mounted drill rig and driven by a manual hammer on the portable tripod drill rig, in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586)<sup>1</sup>.

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<sup>1</sup> ASTM D1586 – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of Soils.

Boreholes C4-2, C11-2, C15-1 and C15-2 were advanced through the Highway 48 and Bloomington Road surface and C4-1 was advanced from the Bloomington Road shoulder to depth ranging from 6.1 m to 9.8 m below existing ground surface. Borehole C4-3 was advanced within the grassed area in the southwest quadrant of the highway / road intersection to a depth of 5.5 m, while Boreholes C11-3 and C15-3 were advanced along the road embankment slope within the southeast quadrant of the intersection to depths of 3.1 m and 3.7 m, respectively. Traffic protection was required for all the boreholes and consisted of either a shoulder closure for boreholes advanced in the roadways (ditches) or lane closures for boreholes advanced from the roadways platforms, consistent with Book 7 requirements.

Groundwater conditions in the open boreholes were observed during and immediately following the drilling operations. A standpipe piezometer was installed in each of Boreholes C4-2, C11-2 and C15-2 to permit monitoring of the water level at the site. The installed piezometers consist of a 50 mm diameter PVC pipe, with a 1.5 m to 3 m slotted screen sealed within a filter sand pack. The borehole and annulus surrounding the piezometer pipe above the filter sand pack were backfilled to the ground surface with bentonite pellets, and piezometers installed on the road surface were protected with flush mounted casing. Piezometer installation details and water level readings are described on the borehole records in Appendix A. Boreholes C4-1, C4-3, C11-3, C15-1 and C15-3 were backfilled to ground surface with bentonite in accordance with Ontario Regulation 903, Wells (as amended), and Boreholes C4-2, C15-1 and C15-2 were sealed at the surface with cold patch asphalt upon completion.

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.

One soil sample obtained during the field investigation from each three boreholes, using appropriate sampling protocols, were submitted to a specialist analytical laboratory under chain of custody procedures for chemical analysis of conductivity / resistivity, pH, and sulphate and chloride concentrations to assess the potential for the soil to cause deterioration to buried concrete and corrosion to steel.

Borehole locations were marked in the field by Golder personnel relative to the existing road features and using a hand-held GPS. The locations given on 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.

Borehole No.	MTM NAD83 (Zone 10)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m) (Latitude)	Easting (m) (Longitude)		
C4-1	4,873,452.1 (44.000869)	321,665.4 (-79.289704)	325.6	6.1
C4-2	4,873,442.1 (44.000779)	321,684.7 (-79.289463)	325.9	6.1



Borehole No.	MTM NAD83 (Zone 10)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m) (Latitude)	Easting (m) (Longitude)		
C4-3	4,873,421.2 (44.000590)	321,698.3 (-79.289294)	324.1	5.2
C11-2	4,873,415.5 (44.000539)	321,732.9 (-79.288863)	325.2	7.3
C11-3	4,873,429.9 (44.000667)	321,767.5 (-79.288431)	321.4	3.1
C15-1	4,873,476.8 (44.001089)	321,786.5 (-79.288193)	325.6	9.8
C15-2	4,873,456.8 (44.000909)	321,784.9 (-79.288214)	325.4	9.8
C15-3	4,873,442.5 (44.000780)	321,789.7 (-79.288154)	321.1	3.7

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

The site is located at the boundary of the Oak Ridges Moraine and South Slope physiographic regions, according to *The Physiography of Southern Ontario* (Chapman and Putnam, 1984)<sup>2</sup>

The Oak Ridges Moraine is hilly, with a knob-and-basin relief typical of end moraines and Rame moraines. The hills are mostly composed of sand and gravel, however; some are formed of till which protrudes above the sand and gravel deposits. The South Slope is a smooth and drumlinized till plain that has formed as a result of glacial action and deposition of till materials just south of the Oak Ridges Moraine.

### 4.2 Subsurface Conditions

Subsurface soil and groundwater conditions as encountered in the boreholes advanced during this investigation and the results of the geotechnical laboratory tests carried out on selected soil samples are presented on the Record of Borehole sheets provided in Appendix A. The results of in situ field tests (i.e., SPT “N”-values) as presented on the Record of Borehole sheets, on the stratigraphic profiles and in Section 4.2 are uncorrected. Results of the geotechnical laboratory testing on soil samples are also presented in Appendix B. Results of the analytical testing of three soil samples are summarized in Section 4.4 and the laboratory test report is provided in Appendix C.

Stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profiles on Drawing 2 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

<sup>2</sup> 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.



of geological change. Furthermore, subsurface conditions will vary between and beyond the borehole locations; however, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions.

In general, the stratigraphy encountered at the various borehole locations typically consists of surficial layers of asphalt / concrete pavement and / or non-cohesive fill underlain by a cohesive till deposit, further underlain by a sand to sand and gravel deposit or a non-cohesive till deposit. The water level at this site was encountered between Elevation 318.1 m and 322.1 m in the open boreholes upon completion of drilling and the stand pipe piezometers installed were found to be dry about one week after installation.

Detailed descriptions of the subsurface conditions are provided in the following sections of this report. Where relatively significant thicknesses of overburden were encountered, the various soil types are described in detail for each main deposit.

#### **4.2.1 Topsoil**

Approximately 25 mm to 50 mm of topsoil was encountered at ground surface in Boreholes C4-3, C11-3 and C15-3, which were advanced away from the highway / roadway.

#### **4.2.2 Asphalt**

An approximately 64 mm to 180 mm of asphalt pavement was encountered at ground surface in Boreholes C4-2, C11-2, C15-1 and C15-2, which were advanced from the highway / roadway.

#### **4.2.3 Fill**

A 0.4 m to 1.5 m thick layer of fill was encountered at ground surface in Borehole C4-1, underlying the topsoil layer in Boreholes C4-3, C11-3 and C15-3, and underlying the asphalt pavement in Boreholes C4-2, C11-2, C15-1 and C15-2. The surface of the fill layer was encountered between Elevations 325.7 m and 321.1 m, and the base of the fill layer was encountered between Elevations 325.3 m and 319.9 m.

The fill is mainly non-cohesive and varies in composition from sand containing trace to some gravel, trace to some silt, trace clay and trace to some rock fragments to gravelly sand containing trace silt to sandy gravel to sand and gravel containing trace to some silt. The cohesive fill was encountered in Boreholes C4-3 and C15-3 and is comprised clayey silt containing some sand and trace gravel to sandy clayey silt containing trace gravel. Trace organics and rootlets were encountered within the cohesive fill in Boreholes C4-3 and C15-3 and within the non-cohesive fill in Borehole C11-3.

The Standard Penetration Test (SPT) "N"-values measured within the non-cohesive fill deposit range from 3 blows to 62 blows per 0.3 m of penetration, indicating a very loose to very dense level of compactness. The SPT "N"-values measured within the cohesive fill range from 3 blows to 11 blows per 0.3 m of penetration, suggesting a soft to stiff consistency.

The natural water content measured on one selected sample of the non-cohesive fill was about 5 per cent. The natural water content measured on one selected sample of the cohesive fill is 28 per cent.

#### **4.2.4 Clayey Silt**

A 2.5 m and 0.3 m thick clayey silt deposit was encountered underlying the fill in Boreholes C4-3 and C15-2, respectively. The surface of the clayey silt deposit was encountered at Elevations 323.5 m and 324.0 m.

The SPT “N”-values measured within the clayey silt deposit range from 13 blows to 125 blows per 0.3 m of penetration, suggesting a stiff to hard consistency.

A grain size distribution test was carried out on one sample of the clayey silt and the result is shown on Figure B-1 in Appendix B. An Atterberg limits test was carried out on one sample of the clayey silt deposit and measured a liquid limit of 30 per cent, a plastic limit of 15 per cent, and a corresponding plasticity index of 15 per cent. The result, which is plotted on a plasticity chart on Figure B-2 in Appendix B, indicates that the deposit consists of clayey silt of low plasticity. The natural water content measured on two selected samples of the clayey silt is about 15 per cent and 18 per cent.

#### **4.2.5 Clayey Silt to Clayey Silt with Sand Till**

A 1.6 m to 6.5 m thick cohesive till deposit was encountered underlying the fill layer in Boreholes C11-2, C11-3, and C15-3, underlying the sand till in Borehole C15-1 and underlying the gravelly sand in Borehole C15-2. The surface of the cohesive till deposit was encountered between Elevations 324.1 m and 319.9 m. The cohesive till is comprised of clayey silt containing some sand to clayey silt with sand, trace gravel and trace cobble/rock fragments, though the sampler could not obtain larger fragments of rock given the sampler size. A hydrocarbon odour was noted in Boreholes C11-2 and C15-2 in select samples from the till deposit. Boreholes C11-2 and C11-3 were terminated within the cohesive till deposit, penetrating it for a thickness of 6.2 m and 2.5 m, respectively.

The SPT “N”-values measured within the cohesive till deposit, generally range from 4 blows to 57 blows per 0.3 m of penetration, with discrete “N”-values of 28 blows and 50 blows per 0.15 m of penetration on inferred cobbles, suggesting a generally firm to hard consistency.

Grain size distribution testing was carried out on 10 samples of the cohesive till and the results are shown on Figures B-3A and B-3B in Appendix B. Atterberg limits testing was carried out on 10 samples of the cohesive till deposit and measured liquid limits between 16 per cent and 33 per cent, plastic limits between 11 per cent and 24 per cent, and plasticity indices between 5 per cent and 10 per cent. These results, which are plotted on a plasticity chart on Figures B-4A and B-4B in Appendix B, indicate that the cohesive till consists of clayey silt of low plasticity. An organic content test was carried out on one sample of the cohesive till deposit and measured 5.3 per cent organics. The natural water content measured on selected samples of the cohesive till ranges from about 9 per cent to about 32 per cent.

#### **4.2.6 Sand to Silt and Sand to Silty Gravelly Sand Till**

A 0.9 m to 2.4 m thick non-cohesive till deposit was encountered underlying the fill in Borehole C15-1, underlying the clayey silt deposit in Borehole C4-3, the cohesive till in Borehole C15-3, and the sandy gravel to sand and gravel deposit in Boreholes C4-1 and C4-2. The surface of the non-cohesive till was encountered between Elevations 322.2 m and 318.3 m. Boreholes C4-1, C4-2 and C15-3 were terminated within this deposit, penetrating it for thickness between 0.9 m and 2.4 m. The non-cohesive till is comprised of sand to silt and sand to silty gravelly sand containing trace to some clay. The non-cohesive till contains trace cobble/rock fragments, though the sampler could not obtain larger fragments of rock given the sampler size.

The SPT “N”-values measured within the non-cohesive till deposit, range from 5 blows to 55 blows per 0.3 m of penetration, with discrete “N”-values of 116 blows and 148 blows per 0.3 m of penetration and 100 blows per 0.05 m of penetration in Borehole C4-3 on inferred cobbles, indicating a loose to very dense level of compactness. In general the SPT “N”-values in the non-cohesive till are greater than 20 blows per 0.3 m of penetration.

Grain size distribution testing was carried out on six samples of the non-cohesive till and the results are shown on Figure B-5 in Appendix B. Atterberg limits testing was carried out on two samples of the non-cohesive till deposit and measured liquid limits of 13 per cent and 16 per cent, plastic limits of 11 per cent and 12 per cent, and plasticity indices of 2 per cent and 4 per cent. These results, which are plotted on a plasticity chart on Figure B-6 in Appendix B, indicate that the non-cohesive till is a silt of low plasticity. The natural water content measured on selected samples of the non-cohesive till ranges from about 2 per cent to about 12 per cent.

#### 4.2.7 Sand to Sand and Gravel

A 0.3 m to 3.1 m thick sand to sand and gravel deposit was encountered underlying the fill in Boreholes C4-1 and C4-2, the clayey silt deposit in Borehole C15-2, and was found underlying the till in Boreholes C4-3, C15-1 and C15-2. The surface of the deposit was encountered between Elevations 325.3 m and 316.7 m. Boreholes C4-3, C15-1 and C15-2 were terminated within this deposit, penetrating it for thicknesses between 0.3 m and 1.1 m.

The deposit consists of sand containing trace clay, trace to some silt and some gravel (Borehole C15-2 and C4-2) to gravelly sand to sand and gravel containing trace to some silt, trace clay and trace cobble fragments (Boreholes C4-1, C4-2, C4-3, C15-1 and C15-2). Grinding of the augers was observed within the sandy gravel to sand and gravel layer in Boreholes C4-1, on inferred cobbles or boulders.

The SPT “N”-values measured within the sand to sand and gravel deposit range from 10 blows to 93 blows per 0.3 m of penetration, with one discrete “N”-value of 186 blows per 0.2 m of penetration, indicating a compact to very dense level of compactness.

Grain size distribution testing was carried out on four samples of the sand to silty gravelly sand to sand and gravel deposit and the results are shown on Figures B-7 in Appendix B. The natural water content measured on selected samples of the sand to silty gravelly sand to sand and gravel deposit ranges from about 1 per cent to about 9 per cent.

### 4.3 Groundwater Conditions

The water levels in the open boreholes were measured upon completion of drilling operations. A standpipe piezometer was installed in each of Boreholes C4-2, C11-2 and C15-2 to permit monitoring of the groundwater level at this site; water level recorded in the open boreholes and piezometers are summarized below.

Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)	Date	Comments
C4-1	325.6	Dry	-	Mar. 9, 2018	Open borehole
C4-2	325.9	Dry	-	Mar. 12, 2018	Open borehole
		Dry	-	Mar. 21, 2018	Piezometer
C4-3	324.1	2.0	322.1	Mar. 19, 2018	Open borehole
C11-2	325.2	Dry	-	Mar. 8, 2018	Open borehole
		Dry	-	Mar. 20, 2018	Piezometer

Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)	Date	Comments
C11-3	321.4	Dry	-	Mar. 20, 2018	Open borehole
C15-1	325.6	Dry	-	Mar. 6, 2018	Open borehole (borehole caved to 8.2 m depth)
C15-2	325.4	Dry	-	Mar. 11, 2018	Open borehole
		Dry	-	Mar. 20, 2018	Piezometer
C15-3	321.1	3.0	318.1	Mar. 20, 2018	Open borehole

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

#### 4.4 Analytical Testing Results

Three soil samples were submitted 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)	Chlorides (ug/g)	Soluble Sulphates (ug/g)
C4-2 / 4	8.14	1,500	684	340	<20
C11-2 / 5	7.68	420	2,400	1,300	130
C15-1 / 7	7.68	850	1,170	630	<20

## 5.0 CLOSURE

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

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# PART B

FOUNDATION DESIGN REPORT  
TRENCHLESS CULVERT INSTALLATIONS  
HIGHWAY 48 AND BLOOMINGTON ROAD ROUNDABOUT, YORK REGION,  
ONTARIO  
G.W.P. NO. 2086-16-00

## 6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides discussion and foundation engineering recommendations for the proposed trenchless culvert installations associated with the proposed Highway 48 / Bloomington Road Roundabout between Bloomington and Lemonville, 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 installations. 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

This report addresses potential construction concerns and geotechnical problems associated with the installation of three non-structural culverts to be installed by means of trenchless methods. The proposed alignments for the trenchless culverts are shown on Drawing 1, and the vertical alignments, including stratigraphic profiles and shown on Drawing 2. Based on the design drawings provided by AECOM on April 13, 2018, a summary of the proposed non-structural culverts is provided below.

Culvert No. (Location)	Proposed Culvert Diameter (mm)	Assumed Bore Diameter (mm)	Approximate Culvert Length (m)	Culvert / Tunnel* Upstream Invert Elevation (m)	Culvert / Tunnel* Downstream Invert Elevation (m)	Approximate Depth of Cover to Tunnel Obvert (m)
4 (Bloomington Road West of Roundabout)	800	1,200	49.5	323.56 / 323.36	322.42 / 322.22	0.9 – 2.2
11 (Highway 48 South of Roundabout)	800	1,200	65	321.95 / 321.75	320.90 / 320.70	1.4 – 3.1
15 (Bloomington Road East of Roundabout)	900	1,200	53.5	320.52 / 320.32	319.22 / 319.02	0.9 – 4.9

\* Assumes 1.2 m diameter tunnel bore/casing.



Based on the alignment drawings provided by AECOM, the final depth of cover will vary as described above. The depth of cover used in this report has been estimated relative to the overt of the cut diameter of the tunnel crossings and the culvert being centrally positioned within the 1,200 mm diameter tunnel bore/casing. However, depending on the final equipment selected for construction, the depth of cover to the top of the cut diameter of the trenchless/tunnel bore / casing may be different and should be evaluated again once additional information becomes available as to the trenchless method, casing size ultimately chosen by the contractor and positioning of the culvert within the bore / casing.

For the proposed Culvert Nos. 4 and 11 the depth of cover outlined above ranges from 0.9 m to 3.1 m. At these locations, it is recommended that the tunnel diameter be minimized, as an oversize in the tunnel diameter will reduce the depth of cover and increase the risk of ground loss. Alternatively, consideration can be given to lowering of the tunnel alignment; however this may not be feasible from a hydraulics perspective. For the proposed Culvert No. 15, the depth of cover ranges from about 0.9 m at the upstream and to about 4.9 m under the roadway and is considered sufficient to allow for a two phase tunnelling approach.

The contractor should be fully responsible for the selection of the trenchless technology which best suits 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" dated March 2014, a copy of which is included in Appendix D; and as may be modified by recommendations provided in this report and / or by an experienced specialist contractor employing only qualified workers skilled in their trade under the direction of an experienced foreman. The standpipe piezometers installed during the field investigation program have been left operational to allow for monitoring of groundwater levels up to the time of trenchless construction. The standpipe piezometers are to be decommissioned by the contractor immediately prior to construction operations in accordance with Ontario Regulation 903, Wells (as amended); this requirement is to be specified in the Contract Documents and details should be provided in the Contractor's Work Plan. The work plan should include a provision for grouting around the outside of any temporary or permanent ground support systems 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 Frost Penetration

As per Ontario Provincial Standard Drawing (OPSD) 3090.101 (Foundation Frost Depths for Southern Ontario), the frost penetration depth in the area is interpreted to be 1.5 m.

## 6.3 Pipe Materials

Installation of the culvert pipes by either conventional jack and bore or pipe ramming methods will require that a steel casing be installed during boring or ramming. Steel casings installed using these methods would remain permanently in place, with a smaller diameter culvert pipe installed within the casing. If steel casings are used along with smaller internal pipes, grout should be injected in the annular space between the culvert pipe and the steel casing, as is discussed further in Section 6.8. It has been assumed that the steel casing will, as a minimum, be one

standard pipe diameter larger than the proposed culvert diameter to address the potential for alignment challenges during casing installation and construction and to permit suitable annular gap grouting, although because of the ground conditions on this project and the requirement to maintain gravity flow, this oversizing of the diameter may not be sufficient.

If the micro-tunnelling method is selected for this project, it is likely that the stormsewer pipe will be jacked into place behind the micro-tunnelling cutter head. Different pipe materials could be used, ranging 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 as the final culvert pipe, depending on materials and installed diameter. 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<sup>3</sup>; the unit weight of water may be taken as 9.8kN/m<sup>3</sup>.

## 6.4 Trenchless Pipe Installation Methods – Overview

The contractor will be responsible for choosing the method and equipment for the culvert installations unless specific methods are otherwise prohibited by the contract. 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. It should not be construed that the contractor is restricted to the particular methods considered herein, and in the event of alternative methods, the contractor must make their own interpretation of the anticipated ground behaviour, based on the factual information provided in Part A (i.e., Foundation Investigation Report).

Based on the culvert information provided by AECOM, it is understood that it is preferable that the culverts be installed under Highway 48 and Bloomington Road using trenchless methods to reduce the potential effects of construction on traffic flow. Trenchless methods that might be contemplated for this site include conventional jack and bore, pipe ramming, using a microtunnel boring machine (MTBM), small boring units (SBU), open face shield tunnelling and horizontal directional drilling (HDD). Tunnelling methods noted above, except for HDD, will require entry and exit shafts / pits and control of seepage into the excavations.

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 sanitary sewer at this site. Furthermore, 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 locations at this site to minimize the risk of hydraulic fracturing of the ground and loss of drilling fluid to the surface ("frac-out"). Additionally, due to the longer entrance / exit bore curvature, the entry and exist point would extend into private property at the proposed crossing locations. Therefore the HDD method is not considered suitable and is not considered further herein.

Conventional Tunnel Boring Machines (TBM) must be large enough to allow person-entry and operation of the TBM; due to the proposed culvert sizes and the depth of cover, a conventional TBM is not considered feasible for this size, as a TBM with a diameter on the order of 1.5 m or larger would be required and this option is not discussed further.

### 6.4.1 Jack and Bore

Conventional jack and bore is a method of forming a near horizontal bore from a jacking/drive (i.e., entry) pit; and a continuous welded casing is jacked through reaction against a thrust block located within the jacking pit and boring is undertaken with a rotating cutter head at the lead end of continuous flight augers within the steel casing. Spoil from the bored excavation is transported to the jacking pit along the helical auger flights and the new pipe is then installed once the casing is fully in place. The casing may be lubricated to reduce the frictional forces between casing and the surrounding soil. The jack and bore method is generally suitable for penetrating cohesive soils (clayey silt and clay) and wet but unsaturated granular soils that are well-graded (i.e., broadly graded) with sufficient silt and clay size particles. Jack and bore methods can lead to excessive ground losses, settlement and development of sinkholes extending to the surface when passing through saturated (flowing) or dry (running) sand, silt and/or gravel. The presence of boulder and cobble sized materials can obstruct augering operations, damage the equipment and require manual interventions that slow progress. The removal of obstructions may also result in loss of ground at the face and ground settlement at the ground surface, depending on the soil conditions. Difficulties may also be encountered in maintaining alignment control of the tunnel as it advances due to the presence of stiffer or more compact/dense soils ahead of the face, cobbles or boulders at the face or due to mixed face conditions. Because the steel casing is jacked from the rear, there is little opportunity to adjust the alignment if deviations begin to occur as a result of obstructions or variability in the ground conditions at the tunnel face.

The size of the jacking pit is controlled by the equipment size and the length of the casing sections which are being installed. Typically, a work area of about 10 m long by about 3 m to 5 m wide is required to accommodate the jacking/drive pit for jack and bore operations. The receiving pit is typically about 3 m square.

### 6.4.2 Pipe Ramming

Pipe ramming involves the use of a percussive hammer to advance a steel casing with a cutting shoe attached at the front end of the casing, much like horizontal pile driving. The casing is generally advanced open-ended and the soil within the casing is typically removed only after the casing has been driven the entire length of the installation, thereby reducing the potential for ground loss into the casing during driving. As each casing length is installed the rammer is removed, the next casing is welded in place and the rammer replaced and restarted. On completion of the bore, compressed air or water, pressure jetting or augering is used to remove the spoil from within the casing. In some cases, depending on the ground conditions and length of the pipe, soil can be removed periodically from within the pipe to reduce the total mass being driven and the resistance to driving. Periodic removal of soils from within the casing can, however, result in significant ground losses in some soil conditions (e.g., saturated and poorly graded sand).

Pipe ramming is best suited for soft to firm clays and loose to compact sand above the water table. Pipe ramming methods are also better suited for penetrating through/displacing potential obstructions such as cobbles and boulders in comparison to jack and bore installation method, though this method can still be obstructed by cobble and boulder size material depending on their overall size, number and position in the ground as compared to the pipe. Difficulties in maintaining alignment control of the tunnel as it advances can still occur if cobbles and boulders are encountered. Vibrations from the pipe ramming operations may also result in settlement of loose materials in the immediate vicinity of the installation. Furthermore, a “plug” of soil may form at the head of the casing inducing surficial heave as the pipe is advanced. Heave can sometimes be controlled by stopping the operation and removing spoil from within the pipe/casing before advancing further. Compared to the jack and bore method the single most important advantage of pipe ramming is that the soil is typically removed from the pipe only after the pipe has fully passed beneath overlying infrastructure. Another advantage of pipe ramming is there is no need for a thrust block in the entrance pit, therefore a smaller pit size is required for pipe ramming.

### 6.4.3 Micro-Tunnel Boring Machines (MTBM)

Microtunnelling is a method of installing pipes (concrete) behind a steerable remote controlled shielded microtunnel boring machine (MTBM) that is pressurized with a bentonitic fluid to minimize ground losses. The process is essentially remotely controlled pipe jacking where all operations are controlled from the surface, cuttings are removed by the circulating slurry and the necessity for personnel to enter the bore is eliminated. Typically, settlement can be controlled well with this method, if the face pressure and cutting tools are appropriate for the ground and are maintained over the length of the drive. The outer pipe / casing is typically installed while the bore is being advanced.

Overcut should be minimized by selection of a casing diameter which is similar to that of the shield. If over excavation occurs, the annulus between the outside of the pipe and the ground should be immediately filled with bentonite slurry of an appropriate viscosity. The slurry should be appropriately formulated, using suitable additives if necessary for the anticipated ground conditions. 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 slurry into the pits.

Microtunnelling can be fully obstructed if sufficient numbers and/or sizes of cobbles and boulders are encountered due to the lack of access to the face and the smaller diameter of the equipment precluding manual removal of obstructions from the face. As such, the selected cutting tools and methods should be compatible with the very dense glacial till soils. Properly selected rock cutter discs should be used to cut the glacial tills and break cobbles and boulders at the face into smaller fragments to pass through the apertures in the face. Alternatively, depending on the particular MTBM configuration, slurry properties and advance rate, some MTBMs can incorporate a crushing head which can draw cobbles and boulders into the shield and crush them. However, large boulders or many cobbles can choke internal crushers and jam the head rotation such that the obstructions cannot be cleared or ingested by the machine and the alignment will have to be either abandoned or a rescue shaft advanced to free the MTBM and remove the obstructions. Construction specifications for the installation of the tunnel by the use of a MTBM are given in the NSSP for "Pipe Installation by Trenchless Method" in Appendix D.

### 6.4.4 Small Boring Units (SBU)

In the greater Toronto area, some trenchless contractors use "small boring units" and present this system as "micro-tunnelling". In general, the small boring units often consist of a rotating cutter head system that is temporarily welded to the lead end of a steel casing. The ground is cut using a variety of face tools (similar to MTBMs described above), but the spoil is transported to the surface using an auger system, much like conventional jack and bore systems. Face openings on the small boring units are typically much smaller than the auger opening on conventional jack and bore systems and the risk of uncontrolled ingress of ground into the lead end of the casing is lower for this system as compared to jack and bore methods. These systems do not, however, provide consistent and positive support to the ground at all face openings with any slurry or cuttings, unlike the slurry-based MTBMs described above. Therefore, while the small boring units are more suitable and advantageous for cutting through stiff to hard cohesive glacial till and weathered rock materials, they should only be used with great caution if granular soils may be encountered along the alignment.

The "small boring units" are often highly effective in penetrating the glacial till in the area (depending on face tool configuration), the openings in the cutting head are not well protected against uncontrolled ingress of running or flowing ground. However, microtunnelling should not be undertaken using a "small boring unit" if there is a risk that saturated or dry granular soils (native or highway and pavement fill materials) is encountered. Similar to the other

trenchless methods, entry and exit shafts are required for microtunnelling operations. Dewatering may be required at both shaft/pit locations to prevent flooding.

#### 6.4.5 Open Face Shield Tunnelling

Open face shield tunnelling involves excavating the soils using a hydraulic excavator arm, working within a full-circumference tunnelling shield. Alternatively, hand mining (i.e., manual and mechanically-assisted excavation) within the tunnelling shield may be carried out whereby the soil would be excavated using manual equipment with workers at the face. Typically, the liner / steel casing is jacked in sections from the launching shaft. Unlike auger jack and bore, this method allows personnel to enter the tunnel to remove obstructions, or control of groundwater seepage or localized instabilities. Similar to jack and bore, however, groundwater lowering is necessary to control non-cohesive soils below the groundwater level from flowing into the tunnel. Manual or machine-assisted excavation generally requires a tunnel diameter greater than 1.2 m.

### 6.5 Anticipated Ground Conditions and Feasibility of Tunnelling Methods

Trenchless construction methods described in Section 6.4 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.

Based on the subsurface data, the subsurface conditions along the proposed culvert alignments vary from very loose to compact sand fill to dense to very dense sand and gravel / sand till to soft to hard clayey silt till. Cobbles and / or boulders are present within the fill and till materials at Culverts 4, 11 and 15 as inferred from auger grinding, very little penetration by the split-spoon and / or the recovery of broken rock (fragments) by the split spoon sampling operations and therefore may be encountered within the tunnel horizon. The groundwater level is generally below the proposed tunnel invert, ranging from about Elevation 322 m to 318 m; however it should be noted that the majority of the boreholes were dry on completion of drilling.

The behaviour of the anticipated subsurface materials can be classified using Terzaghi's Tunnelman's Ground Classification system as modified by Heuer (1974). 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.

Culvert No. (Approx. Tunnel Invert)	Borehole No.	Anticipated Subsurface Conditions at Culvert Alignment	Groundwater Elevation (m)	Soil Behaviour
4 (323.36 m to 322.22 m)	C4-1	<ul style="list-style-type: none"> <li>■ Compact sand FILL / Dense to very dense sandy gravel to sand and gravel</li> <li>■ Augers grinding at tunnel invert level</li> </ul>	Dry	Running
	C4-2	<ul style="list-style-type: none"> <li>■ Dense to very dense sand / Very dense sand and gravel</li> </ul>	Dry	Running
	C4-3	<ul style="list-style-type: none"> <li>■ Stiff to hard clayey silt</li> <li>■ Potential cobbles at tunnel invert</li> </ul>	322.1	Firm to slow ravelling

Culvert No. (Approx. Tunnel Invert)	Borehole No.	Anticipated Subsurface Conditions at Culvert Alignment	Groundwater Elevation (m)	Soil Behaviour
11 (321.75 m to 320.70 m)	C4-3	<ul style="list-style-type: none"> <li>■ Hard clayey silt</li> <li>■ Cobbles at tunnel invert</li> </ul>	322.1	Firm to slow ravelling
	C11-2	<ul style="list-style-type: none"> <li>■ Firm to very stiff clayey silt to clayey silt with sand TILL</li> <li>■ Cobbles at base of tunnel</li> <li>■ Hydrocarbon odour noted about 1.2 m above obvert</li> </ul>	Dry	Firm to slow ravelling
	C11-3	<ul style="list-style-type: none"> <li>■ Very loose sand FILL / Firm clayey silt with sand TILL</li> </ul>	Dry	Running
15 (320.32 m to 319.02 m)	C15-1	<ul style="list-style-type: none"> <li>■ Firm to hard sandy clayey silt TILL, trace rock fragments</li> </ul>	Dry*	Firm to slow ravelling
	C15-2	<ul style="list-style-type: none"> <li>■ Firm to hard clayey silt to clayey silt with sand TILL</li> <li>■ Hydrocarbon odour notes at about tunnel obvert level</li> </ul>	Dry	Firm to slow ravelling
	C15-3	<ul style="list-style-type: none"> <li>■ Firm sandy clayey silt FILL / Soft to firm clayey silt to clayey silt with sand TILL</li> </ul>	318.1	Squeezing

\* Borehole caved to Elevation 317.4 m

The fills and native sand to sand and gravel soils will likely collapse and flow in an unsupported excavation. The cohesive till deposit would have a stand-up time ranging from a few minutes to several hours depending on the degree of seepage, disturbance and localized grain size distribution. The stand-up time of this material will likely be unpredictable.

The presence of cobbles or boulders within the fill, sand till, sand and gravel, clayey silt and clayey silt till deposits has been inferred from auger grinding and refusal to split spoon penetration, as noted on the Record of Borehole Sheets. The advance of microtunneling and jack and bore equipment can be hindered by cobble nests or boulders; however, the machine face can be equipped with cutters that have the capability to cut boulders that may be encountered along the proposed tunnel alignment. The potential for ground loss using jack and bore and open face shield tunnelling methods, through running soils (i.e., the sand fill, sand till and sand and gravel material) high and would render these methods not feasible at the location of Culvert 4 and at locations where running soils and low depths of cover are present. The very stiff to hard nature of the cohesive till, where encountered, will offer significant resistance for pipe ramming and vibrations caused by ramming operations may induce settlement of the loose fill materials, where encountered.

Man entry into confined spaces where the diameter is less than 1.5 m, as is the case for all there culvert installations, is not recommended. As such, open face shield tunnelling and pipe ramming is not recommended unless the tunnel diameter is increased to a minimum of 1.5 m, which would decrease the depth of cover significantly at Culverts 4



and 11. Based on the subsurface conditions encountered and the proposed tunnel dimensions and alignment, either microtunneling or SBUs is the recommended trenchless installation method at Culverts 4, 11 and 15.

The Contract Documents should contain a NSSP warning the contractor of obstructions within the fill materials, sand till, sand and gravel, clayey silt and glacial till and the difficulties associated with tunneling along the interface between soils of differing composition such as within the till material and along the interface of the fill and native soils. An example NSSP is provided in Appendix D.

### 6.5.1 Jack and Bore Considerations

Jack and bore operations can be carried out at sites where the soils exhibit suitable “stand-up” time; however, given the soil conditions encountered at these culvert sites, the specifications should require that a plug of spoil material remain in the lead end of the casing at all times. A plug of soil can be achieved by forcing the casing into the ground ahead of the cutting tools and maintaining the cutting head at the appropriate distance behind the leading edge of the casing. However, at the Culvert 4 site, the soil deposits are sufficiently dense / hard that maintaining a plug of soil at the lead edge of the casing will likely not be possible. Jack and Bore installations are suitable for lengths typically up to about 75 m, depending on soil conditions, and hence potentially feasible at the locations of Culverts 11 and 15.

If obstructions, such as a boulder, a nest of cobbles or large bedrock fragments, are encountered, it would be necessary to remove the augers and soil plug where a soil plug is present. Depending on the soil conditions at the location of the obstructions, this may result in loss of ground at the face and ground settlement at the ground surface. The very stiff to hard cohesive materials will likely be difficult to penetrate using only jacking forces. In such cases, contractors frequently prefer to have the lead end of the auger at or ahead of the lead edge of the casing. While in some cohesive soil ground conditions this may be acceptable, this practice could lead to excessive ground losses if saturated or dry granular fills are encountered, as are present at some of the culvert locations. Further, difficulties may also be encountered in maintaining alignment control of the tunnel as it advances due to the presence of cobbles/boulders/bedrock fragments, stiffer soils ahead of the face or mixed face conditions. In this case, contingency planning for ground loss events would need to include highway closure to protect the travelling public. Dewatering will likely be required at the locations of the maintenance hole connection at Culvert 4 and Culvert 11.

It may be feasible to use a small boring unit head mounted on the lead end of the casing in order to facilitate jacking a steel pipe section into the ground. A small boring unit head, configured with appropriate rock cutting tools, may be suitable for cutting the glacial till and any rock encountered along the alignment. However, the small boring units can be susceptible to excessive ground losses in saturated conditions and when the soils are of a primarily granular nature, such as the existing fill materials. Depending on local undulations in the interface between highway fill and native soils, tunnelling for this project could encounter granular fill materials. Any successful use of a small boring unit on this project would require rapid and continuous construction (24 hours per day), continuously maintaining a dry access shaft and bore, close monitoring and control of soil volumes removed during tunnelling and the provision of grout pipes and ports along the bore length of the casing should ground losses be suspected or discovered.

### 6.5.2 Pipe Ramming Considerations

The feasibility of pipe ramming is questionable at the culvert locations where very stiff to hard cohesive till and cohesive soils were encountered within the tunnel horizon as significant resistance to pipe advance can be expected and will increase as the pipe is advanced. Also, when the pipe is not being advanced (during welding of casing extensions) the stresses around the circumference of the pipe may increase which will further increase the friction around the pipe, making it more difficult to advance the pipe. The casing may be lubricated to reduce the frictional



forces between casing and the surrounding soil and/or the contractor may utilize a higher energy hammer and thicker wall pipe in such conditions. The length of the pipe and subsurface conditions may also lead to the need to periodically remove materials from within the pipe. Pipe ramming installations are suitable for lengths typically up to about 45 m to 50 m, depending on site conditions. At this site where the bore lengths are 50 m to 65 m, a central shaft would likely be required to allow for the installation in two sections, which would likely result in impacts to traffic flow. Further, it should be noted that the excavation area at the maintenance hole at the connection of Culvert 4 and Culvert 11 will need to be enlarged adequately to allow for pipe ramming of Culvert 4.

As with the “jack and bore” method, tunnel alignment would be difficult to control due to the presence of cobbles/boulders, or mixed face conditions. If cobbles/boulders or bedrock fragments are encountered, the casing may be cleaned out, allowing access for equipment to break up the obstructions. Cleaning out the spoils from inside the casing may result in the loss of ground at the face of the casing for these reasons, pipe ramming is not considered suitable for this site.

### 6.5.3 MTBM Considerations

Microtunneling uses bentonite slurry to counterbalance the earth and water pressures acting at the tunnel face. If the slurry pressure at the face is allowed to become too high, hydraulic fracture (typically referred to as “frac-out”) of the ground can occur, allowing bentonite slurry to exit at ground surface. “Frac-out” can then result in a sudden drop in face pressure, creating face instability if tunnelling through non-cohesive soils below the groundwater table. To minimize the risk of “frac-out”, slurry microtunneling should not be used for tunnelling construction if the cover is less than 2.5 m, as is the case for Culvert 4, and potentially Culvert 11. Further, to both properly support ground at the cutting face and along the pipe if an over-cut is used, slurries should have a Marsh funnel viscosity between about 50 second and 70 seconds.

An advantage of the MTBM is that lowering of the groundwater level in non-cohesive soils is not required. Another advantage is the MTBM can also be specified to have the capability to cut and crush boulders that may be encountered along the proposed tunnel alignments. For tunnelling in the anticipated ground conditions on this project, any MTBMs that might be used for this project should be specified to include rock disc cutters and/or roller bit cutters as well as soft-ground excavation tools on the MTBM face. Typical drag bits or carbide cutting teeth are often broken from the face of tunnel boring machines when encountering boulders or potentially larger bedrock fragments within the residual soils and should not be solely relied upon for cutting rock on this project.

### 6.5.4 Open Face Shield Tunnelling Considerations

Successful tunnelling using an open-face shield and manual or mechanically-assisted methods (i.e., no rotating cutter head) will be dependent on control of the excavation process. If the open face shield tunnelling method is selected, the contractor should have a means to readily secure the face if inward ground deformation is encountered or if unanticipated work stoppages are necessary (pre-fabricated breasting boards, etc.). Further, the tunnelling work should be continuous from start to finish (24 hours per day, 7 days per week). If it is necessary to stop the tunnelling operations, the contractor should be prepared to immediately support the face. Filling of the annular space between the liner and native ground should be carried out as soon as the liner is installed (bentonitic grout/lubricant in the case of jacked pipes, with cementitious grout provided at the completion of construction).

## 6.6 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 and native sand to sand and gravel deposits are classified as Type 3 soils; the native clayey silt and till deposit are classified as Type 2 soils, and saturated granular fills and native sand to sand and gravel would be Type 4 materials.

Dewatering will be required at the entry and exit shafts since, these excavations are expected to extend below the groundwater level measured in the piezometers at about Elevation 322.1 m at Culvert 4 and Elevation 318.1 m at Culvert 15. Groundwater control using sumps may be adequate if the groundwater is encountered within the clayey silt till; however may not be adequate if the groundwater level is encountered within the granular fill and sand to sand and gravel deposit and 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 shaft and below the base of the maintenance holes. Based on the subsurface information available which indicates 'dry' conditions in the standpipe piezometers (March 20 or 21, 2018) and wet soil conditions or water levels during drilling at about Elevation 322.1 m in Borehole CH-3 and Elevation 318.1 m in Borehole C15-3, it is anticipated that minor dewatering will be required at the entry and exit shafts, to lower the groundwater levels by about 2 m within the clayey silt and possibly the till materials. It is expected that such minor groundwater lowering will have negligible to minor impacts on the highway/roadway conditions. 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 NSSP 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 these materials. 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 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 very dense sand and gravel and hard till, as well as potential presence of cobbles and boulders 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/m <sup>3</sup> )
	Active, $K_a$	At Rest, $K_o$	Passive, $K_p$		
Existing Sand to Gravelly Sand (Fill)	0.33	0.50	3.0	30	19
Existing Clayey Silt (Fill)	0.36	0.53	2.77	28	19
Stiff to Hard Clayey Silt	0.31	0.47	3.25	32	20
Compact to Dense Sand to Sand and Gravel	0.31	0.47	3.25	32	20
Very Dense Sand to Sand and Gravel	0.28	0.44	3.54	34	20
Stiff to Hard Clayey Silt to Clayey Silt with Sand (Till)	0.31	0.47	3.25	32	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.

## 6.7 Instrumentation and Monitoring

An instrumentation and monitoring program is recommended at the crossing location if trenchless installation methods are to be used in order 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.

The locations of the settlement monitoring points to be installed as part of the settlement monitoring program and details and general specifications pertaining to the monitoring points are shown on Drawing 3.

Monitoring of settlement instruments on this project is constrained by the continuous traffic volume along Highway 48 and Bloomington Road and the limited periods during which access to the highway can be obtained. By necessity, settlement points on the roadway and highway must be read remotely and the use of reflectorless precision surveying methods are recommended. A specialist surveying firm should be retained to confirm the set-up and to carry out the settlement monitoring during construction; their equipment and procedures must be capable of surveying the settlement point elevation to within  $\pm 2$  mm of the actual elevation.

In addition, in-ground settlement points, consisting of a sleeved iron bars, set preferably below the depth of frost penetrated but not closer than 0.3 m above the tunnel invert elevation along the crossing at readily accessible locations (e.g., roadway and highway shoulders) should also be installed. 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 they are unaffected by frost heave, thaw settlement or the bridging action of the pavement structure.

All monitoring points should be read at least three times (on separate days) before the start of the culvert installations to establish a pre-construction baseline. All monitoring points behind the face of the trenchless excavation and those within 10 m of the front of the face should be read every 4 hours over the duration of the tunnel drive. The effectiveness of this monitoring method could be impacted by weather conditions if the work is undertaken during the winter months.

The following procedure should be followed if settlement levels of 10 mm (Review Level) and 15 mm (Alert Level) are reached:

- If the Review Level is reached, the contractor should be required to provide a formal plan that states actions that will be implemented to ensure that the Alert Level is not reached.
- If the Alert Level is reached, the contractor should be required to stop all work, make the site secure, and proposed methods for remediating the excess ground displacements and completing the necessary remedial work at the Contractor's own cost. In this case, the Contractor should also bear all costs associated with delays until the MTO is satisfied that pipe installation can proceed without endangering the travelling public.

In addition to settlement monitoring, line and grade should be carefully monitored during construction. To the extent that is practical, measurement of the volumes and/or weights of cuttings on a regular basis (e.g., every 3 m length of casing or pipe installed) could provide a secondary means of monitoring ground control during tunnelling.

The plotting and interpretation of the survey results and preparation of monitoring reports should be the responsibility of Golder on behalf of and reporting to the owner or its representative. The specialist surveying firm should provide the survey results to Golder within 24 hours (or sooner) for comparison against allowable settlement limits. However, if the Review/Alert Level is exceeded, survey results should be provided to Golder within two hours. Golder will review the survey results on a daily basis and notify AECOM within 24 hours if any exceedances occur. Golder will prepare weekly summary reports during tunnelling and monthly after tunnelling, for the duration of the monitoring program. The weekly reports will be submitted to AECOM, each Monday of the monitoring program. AECOM should forward the reports to MTO in a timely manner as determined in advance with MTO.

A settlement monitoring plan consistent with the requirements in the "Appendix: Settlement Monitoring Guideline – Tunnelling" of MTO's "Guideline for Foundation Engineering – Tunnelling Speciality for Corridor Encroachment Permit Application", should be established as part of the Contract Administration for construction.

Where sections of concrete pavement exists, these may temporarily bridge over and mask underlying ground loss or settlement. High traffic volumes and the need to preserve the integrity of pavements further inhibit installation of monitoring points through the concrete pavement. Therefore, to the extent practicable and possible, it will be important to measure the volume of tunneled/bored ground removed from beneath paved areas as compared to the theoretical cut hole volume on a frequency of at least once per 3 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.

## 6.8 Grouting

After the permanent sewer pipe is installed within the casing (i.e., reinforced concrete pipe being proposed for this project), post installation grouting to fill the annular space between the pipes should be carried out as noted in the NSSP for "Pipe Installation by Trenchless Method", included in Appendix D. For any installations at which the settlement monitoring or excavation volume monitoring indicates that pavement settlement or ground loss might have occurred, or where signs of ground loss have been noted, provision should be made for a program of compensation grouting above the casing pipe and/or repair of the pavements.

## 6.9 Corrosion Assessment and Protection

Soil corrosivity may affect the 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 samples submitted for testing are summarized in Section 4.4 and the test report by the analytical laboratory is included in Appendix C.

### 6.9.1 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 concentrations measured in the samples are less than 0.1 per cent, which is below the exposure class of moderate. Therefore, based on the test results from the boreholes at the culvert locations the effects of sulphates from within the existing native deposits may not need to be considered.

### 6.9.2 Potential for Corrosion

The soil has a pH of between about 7.7 and 8.1 and a resistivity between about 420 ohm-cm and 1,500 ohm-cm based on the three soil samples tested. According to the Gravity Pipe Design Guidelines (MTO, 2014), the pH is not considered detrimental to concrete durability. However, the resistivity is in 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 these results some level of protection may be required depending on the pipe material specified. Further, given that the culverts are 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 Costa, P.Eng., a MTO Foundations Designated Contact and Senior Consultant with Golder, conducted a quality control review of the report.

**Golder Associates Ltd.**



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*Geotechnical Engineer*



Jorge M.A. Costa, P.Eng.  
*MTO Foundations Designated Contact, Senior Consultant*

NK/JMAC/rb

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<https://golderassociates.sharepoint.com/sites/15994g/6.deliverables/wo009-hwy48-bloomington/2.culverts/3.final/1671430wo92018jul12bloomingtontrenchlessculverts.docx>

## REFERENCES

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.

CSA Group. 2014. A23.1-14/A23.2-14 - Concrete materials and methods of concrete construction / Test methods and standard practices for concrete.

Heuer, Ronald E., 1974 "Important Ground Parameters in Soft Ground Tunneling", Proceedings Specialty Conference on Subsurface Explorations for Underground Excavations and Heavy Construction, ASCE, NY.

Ministry of Transportation Ontario. 2014. *Gravity Pipe Design Guideline*. Drainage and Hydrology Design and Contract Standards Office.

### **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

### **Ontario Water Resources Act**

Ontario Regulation 903 Wells (as amended)

### **Ontario Occupational Health and Safety Act**

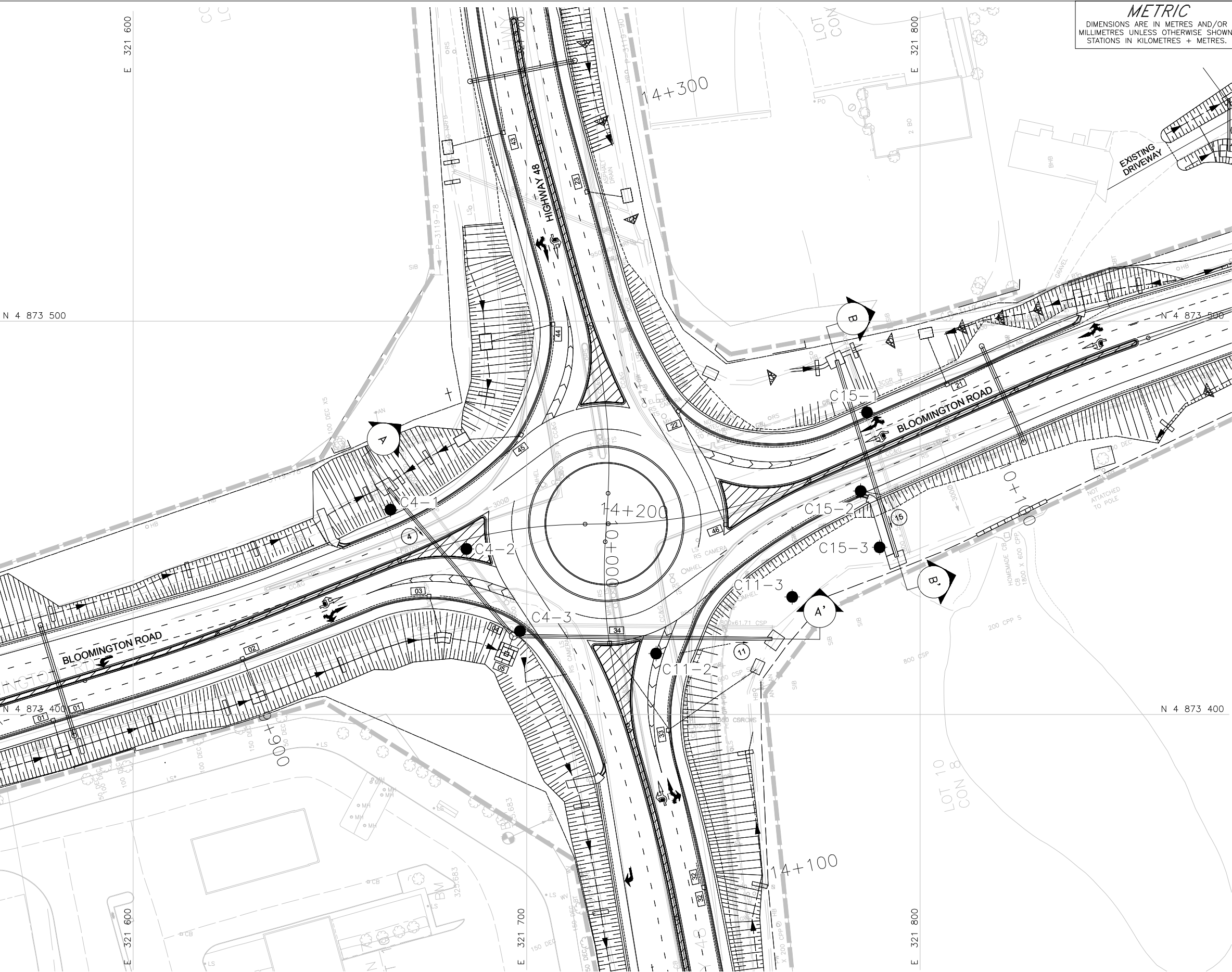
Ontario Regulation 213 Construction Projects (as amended)



TABLE 1 – EVALUATION OF TRENCHLESS CROSSING ALTERNATIVES FOR TRENCHLESS CULVERT INSTALLATIONS

Installation Method	Feasibility	Advantages	Disadvantages	Relative Costs	Relative Risks	Mitigation Options
Jack and Bore or Jack and Bore with SBU	<ul style="list-style-type: none"><li>■ Culvert 4 – Jack and Bore by itself Not Feasible due to presence of running soils; SBU Potentially feasible but may encountered cobbles at invert level of tunnel</li><li>■ Culvert 11 – Potentially feasible but may encountered cobbles at invert level of tunnel</li><li>■ Culvert 15 – Feasible</li></ul>	<ul style="list-style-type: none"><li>■ Widely used method.</li><li>■ The line and grade can be maintained with moderate accuracy.</li><li>■ Equipment can be withdrawn and bore can be restarted at different location if obstructions are encountered.</li><li>■ Reduced level of vibrations.</li><li>■ Use of SBU mounted at the lead end of the casing can improve face stability control and with improved face tools, can be better suited to cutting through cobbles.</li></ul>	<ul style="list-style-type: none"><li>■ Large work areas required for jacking pits.</li><li>■ Obstructions (e.g. cobbles and boulders) may deflect and/or halt bore. Removal of augers and man entry would be required to remove boulders.</li><li>■ Can lead to ground loss in running soils, i.e., sand to sand and gravel fill materials.</li><li>■ Unstable water-bearing granular interlayers can go undetected until ground loss and settlement has occurred.</li><li>■ Requires settlement monitoring program to assess for ground loss along the alignment</li></ul>	Relatively low cost.	<ul style="list-style-type: none"><li>■ Risk of encountering refusal on obstructions; difficult to penetrate very stiff to hard cohesive soils</li><li>■ Obstructions can result in deflection of the casing resulting in misalignment of the culverts</li><li>■ Potential for loss of ground into casing if running soils are encountered</li><li>■ Potential need to excavate pits to remove obstructions</li><li>■ A change in soil conditions occurs over the proposed alignments for Culvert 4 and 11, which could lead to either loss of ground if running soils are unexpectedly encountered, or can hinder penetration if soils with obstructions are encountered.</li></ul>	<ul style="list-style-type: none"><li>■ Use of SBU mounted at the lead end of the casing can improve face stability control and with improved face tools, can be better suited to cutting through cobbles.</li><li>■ The tunnel bore diameter can be increased to a minimum of 1.5 m to allow for man-entry to remove any obstructions that may be encountered; however, this would decrease the depth of cover and is not recommended at Culverts 4 and 11.</li><li>■ The tunnel bore and casing can be oversized to allow for misalignment – the carrier pipe can be grouted into place at the required alignment within the casing. This is not recommended at Culverts 4 and 11 due to the already small thickness of cover present.</li><li>■ Deepening of the culvert alignment would increase the depth of cover at Culverts 4 and 11; but may not be feasible due to hydraulic considerations.</li></ul>
Pipe Ramming	Not Feasible for all culverts due to bore length	<ul style="list-style-type: none"><li>■ Better suited for penetrating through cobbles and boulders than Jack-and-Bore (depending on size and strength of obstructions).</li><li>■ Continuous casing installation.</li><li>■ Where conditions warrant, spoil can be removed once the exit pit is reached minimizing subsidence and overcut</li></ul>	<ul style="list-style-type: none"><li>■ Suitable for installation length typically up to about 45 m, depending on soil conditions; therefore not suitable for these sites where the crossing extend from 50 m to 65 m unless a central shaft is used to stage in two sections resulting in impacts to traffic flow.</li><li>■ Large work area required for ramming pit.</li><li>■ Large obstructions/ boulders can result in deflection or refusal.</li><li>■ Potential for heave at ground surface.</li><li>■ Potential for settlement of near surface fills due to vibration.</li><li>■ Removal of spoil may be required after advancing the pipe partway due to the weight of and drag on the pipe.</li><li>■ Very dense granular soil strata and hard cohesive zones will make ramming difficult and subsequent augering of spoil from inside the pipe.</li><li>■ Pneumatic ramming can be annoying to public.</li></ul>	Least expensive – likely less than Jack-and-Bore	<ul style="list-style-type: none"><li>■ Cobbles and boulders can hinder/stop penetration requiring open excavation to remove obstructions as hand mining not possible for this size of bore.</li><li>■ Misalignment of tunnel may occur if large obstructions are encountered and this cannot be corrected.</li><li>■ Significant jacking/ramming forces would be required to advance through zones of very dense / hard overburden and the proposed length of the pipe.</li><li>■ Vibration from pipe ramming may be experienced by the users of the roadway / highway.</li><li>■ A change in soil conditions occurs over the proposed alignments for Culvert 4 and 11, which could lead to either a loss of ground if running soils are unexpectedly encountered, or can hinder penetration if soils with obstructions are encountered.</li></ul>	<ul style="list-style-type: none"><li>■ The tunnel bore diameter can be increased to a minimum of 1.5 m to allow for man-entry to remove any obstructions that may be encountered; however, this would decrease the depth of cover and is not recommended at Culverts 4 and 11.</li><li>■ The tunnel bore and casing can be oversized to allow for misalignment – the carrier pipe can be grouted into place at the required alignment within the casing. This is not recommended at Culverts 4 and 11 due to the already small thickness of cover present.</li><li>■ Deepening of the culvert alignment would increase the depth of cover at Culverts 4 and 11; but may not be feasible due to hydraulic considerations</li></ul>

Installation Method	Feasibility	Advantages	Disadvantages	Relative Costs	Relative Risks	Mitigation Options
Microtunnelling (MTBM)	<ul style="list-style-type: none"><li>■ Culvert 4 - Not Feasible due to depth of cover less than 2.5 m</li><li>■ Culvert 11 – Potentially feasible if depth of cover can be maintained above 2.5m</li><li>■ Culvert 15 – Feasible</li></ul>	<ul style="list-style-type: none"><li>■ Continuous support to excavation face is provided.</li><li>■ Final pipe can be installed while bore is being advanced.</li><li>■ More accurate than pipe ramming and jack-and-bore methods.</li><li>■ For hard soils, cobbles and boulders (of limited size) can often be cut and penetrated provided appropriate disc cutter face tools are utilized.</li><li>■ An SBU of the required size to accommodate a 1,200 mm diameter concrete pipe line likely available - see above.</li></ul>	<ul style="list-style-type: none"><li>■ Will require a machine capable of cutting boulders, or allow for man-entry for removal of such obstructions.</li><li>■ Greater cost for muck handling and disposal.</li><li>■ 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.</li><li>■ Lack of readily available machines.</li><li>■ Relatively expensive – high mobilization costs for short crossings.</li><li>■ Not suitable where depths of cover are less than 2.5 m due to potential for “frac-out”.</li><li>■ Susceptible to hydraulic fracture depending on slurry viscosity and pressure.</li><li>■ Requires settlement monitoring program to assess for ground loss along the alignment</li></ul>	Most expensive method.	<ul style="list-style-type: none"><li>■ Low to moderate risk of ground loss for culvert installations where the depth of cover is greater than 2.5 m provided appropriate equipment and slurry properties are selected and controlled.</li><li>■ Hydraulic fracture is possible at culvert locations with cover less than 2.5 m and any slurry exiting onto the pavements could be a significant hazard to traffic.</li><li>■ 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.</li><li>■ Potential schedule delay in obtaining a suitable MTBM.</li></ul>	<ul style="list-style-type: none"><li>■ Use of appropriate equipment and slurry properties can improve face stability and allow to penetrate through any obstructions encountered.</li><li>■ Deepening of the culvert alignment would increase the depth of cover and reduce the potential for hydraulic fracture; but may not be feasible due to hydraulic considerations</li></ul>
Open Face Shield Tunnelling	<ul style="list-style-type: none"><li>■ Culvert 4 - Not Feasible due to presence of running soils and low depth of cover</li><li>■ Culvert 11 – Feasible</li><li>■ Culvert 15 – Feasible</li></ul>	<ul style="list-style-type: none"><li>■ Minimal traffic disruption.</li><li>■ Better suited for penetrating through potential obstructions such as cobble and boulder size material than jack and bore methods.</li></ul>	<ul style="list-style-type: none"><li>■ Risk of ground subsidence of highway but more control than jack and bore methods.</li><li>■ Requires groundwater lowering if saturated granular soils are to be penetrated.</li><li>■ Requires diameter sufficient for person entry (≥1.2 m)</li><li>■ Requires settlement monitoring program to assess for ground loss along the alignment.</li><li>■ Additional health and safety concerns</li></ul>	Comparable to pipe ramming installation methods	<ul style="list-style-type: none"><li>■ Potential for loss of ground into shield particularly if granular materials are encountered.</li><li>■ Risk of ground surface subsidence increases with decreasing cover thickness.</li><li>■ A change in soil conditions occurs over the proposed alignments for Culvert 4 and 11, which could lead to either a loss of ground if granular soils are unexpectedly encountered.</li></ul>	<ul style="list-style-type: none"><li>■ The tunnel bore diameter can be increased to a minimum of 1.5 m to allow for man-entry; however, this would decrease the depth of cover and is not recommended at Culverts 4 and 11.</li><li>■ Deepening of the culvert alignment would increase the depth of cover at Culverts 4 and 11; but may not be feasible due to hydraulic considerations</li><li>■ A means of securing the face, i.e., using a pre-fabricated breasting board, in case of loss of ground at the face.</li></ul>

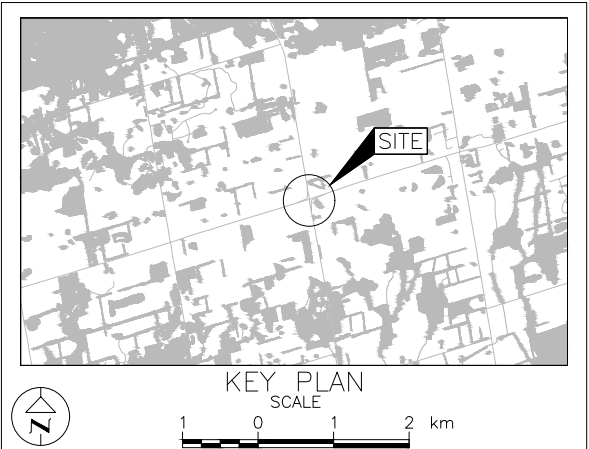


**METRIC**  
DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.

CONT No. 2017-2042  
GWP No. 2086-16-00

HWY 48 AND BLOOMINGTON ROAD ROUNDABOUT  
(LAT. 44.000847, LONG. -79.289013)  
NON-STRUCTURAL CULVERT REPLACEMENTS  
BOREHOLE LOCATIONS

SHEET



LEGEND

Borehole - Current Investigation

BOREHOLE CO-ORDINATES (MTM NAD 83 ZONE 10)			
No.	ELEVATION	NORTHING	EASTING
C4-1	325.6	4873452.1	321665.4
C4-2	325.9	4873442.1	321684.7
C4-3	324.1	4873421.2	321698.3
C11-2	325.2	4873415.5	321732.9
C11-3	321.4	4873429.9	321767.5
C15-1	325.6	4873476.8	321786.5
C15-2	325.4	4873456.8	321784.9
C15-3	321.1	4873442.5	321789.7

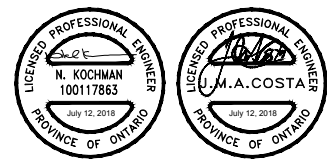
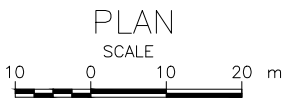
**NOTES**

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

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

**REFERENCE**

Base plans provided in digital format by AECOM, drawing file nos. Hwy48 Bloom\_bgd\_PH 150409\_Hwy48N.dwg, Hwy48 Bloom\_bgd\_PH 150410\_Hwy48S.dwg and Hwy48 Bloom\_plan.dwg, received February 15, 2018 and Hwy48 Bloom\_bgd.dwg, received April 12, 2018.

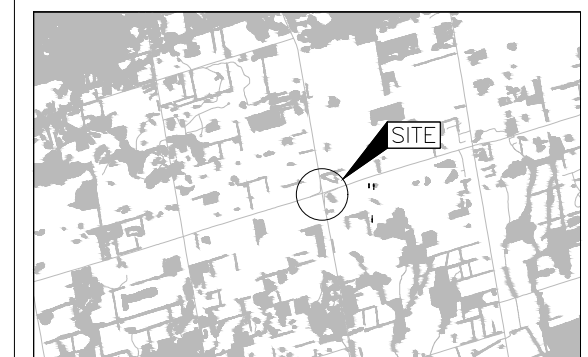


NO.	DATE	BY	REVISION
Geocres No. 31D-704			
HWY. 48	PROJECT NO. 1671430		DIST. .
SUBM'D. NK	CHKD. NK	DATE: 07/12/2018	SITE: .
DRAWN: DD	CHKD. NK	APPD. JMAC	DWG. 1






SHEET







KEY PLAN  
SCALE



1 0 1 2 km

## LEGEND

- |   |  |
|---|--|
|  | Borehole – Current Investigation                                   |
| N   | Standard Penetration Test Value                                    |
| 16  | Blows/0.3m unless otherwise stated<br>(Std. Pen. Test, 475 j/blow) |
|  | WL upon completion of drilling                                     |
|  | Seal   |
|  | Piezometer   |

BOREHOLE CO-ORDINATES (MTM NAD 83 ZONE 10)			
No.	ELEVATION	NORTHING	EASTING
C4-1	325.6	4873452.1	321665.4
C4-2	325.9	4873442.1	321684.7
C4-3	324.1	4873421.2	321698.3
C11-2	325.2	4873415.5	321732.9
C11-3	321.4	4873429.9	321767.5
C15-1	325.6	4873476.8	321786.5
C15-2	325.4	4873456.8	321784.9
C15-3	321.1	4873442.5	321789.7

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NO.	DATE	BY	REVISION		
Geocres No. 31D-704					
HWY. 48		PROJECT NO. 1671430		DIST. .	
SUBM'D. NK		CHKD. NK		DATE: 07/12/2018 SITE:	
DRAWN: DD/SD		CHKD. NK		APPD. JM/C DWG. 2	




CONT No. 2017-2042  
GWP No. 2086-16-00



# HWY 48 AND BLOOMINGTON ROAD ROUNDABOUT (LAT. 44.000847, LONG. -79.289013) NON-STRUCTURAL CULVERT REPLACEMENTS SETTLEMENT MONITORING POINT LOCATIONS AND INSTALLATIONS DETAILS



## 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
C4-1	325.6	4873452.1	321665.4
C4-2	325.9	4873442.1	321684.7
C4-3	324.1	4873421.2	321698.3
C11-2	325.2	4873415.5	321732.9
C11-3	321.4	4873429.9	321767.5
C15-1	325.6	4873476.8	321786.5
C15-2	325.4	4873456.8	321784.9
C15-3	321.1	4873442.5	321789.7

## NOTES

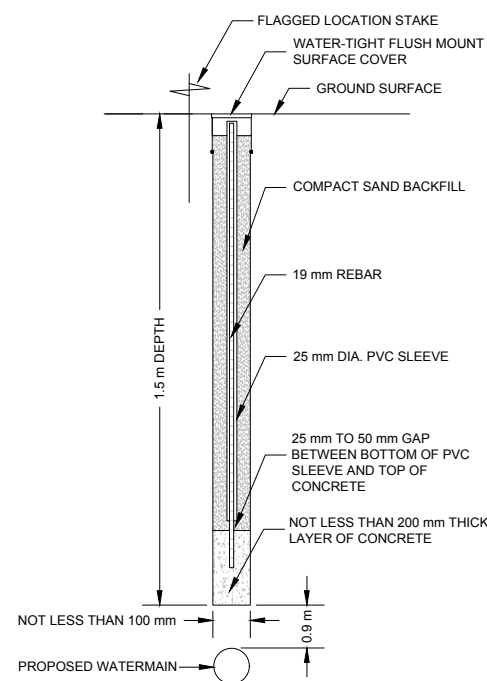
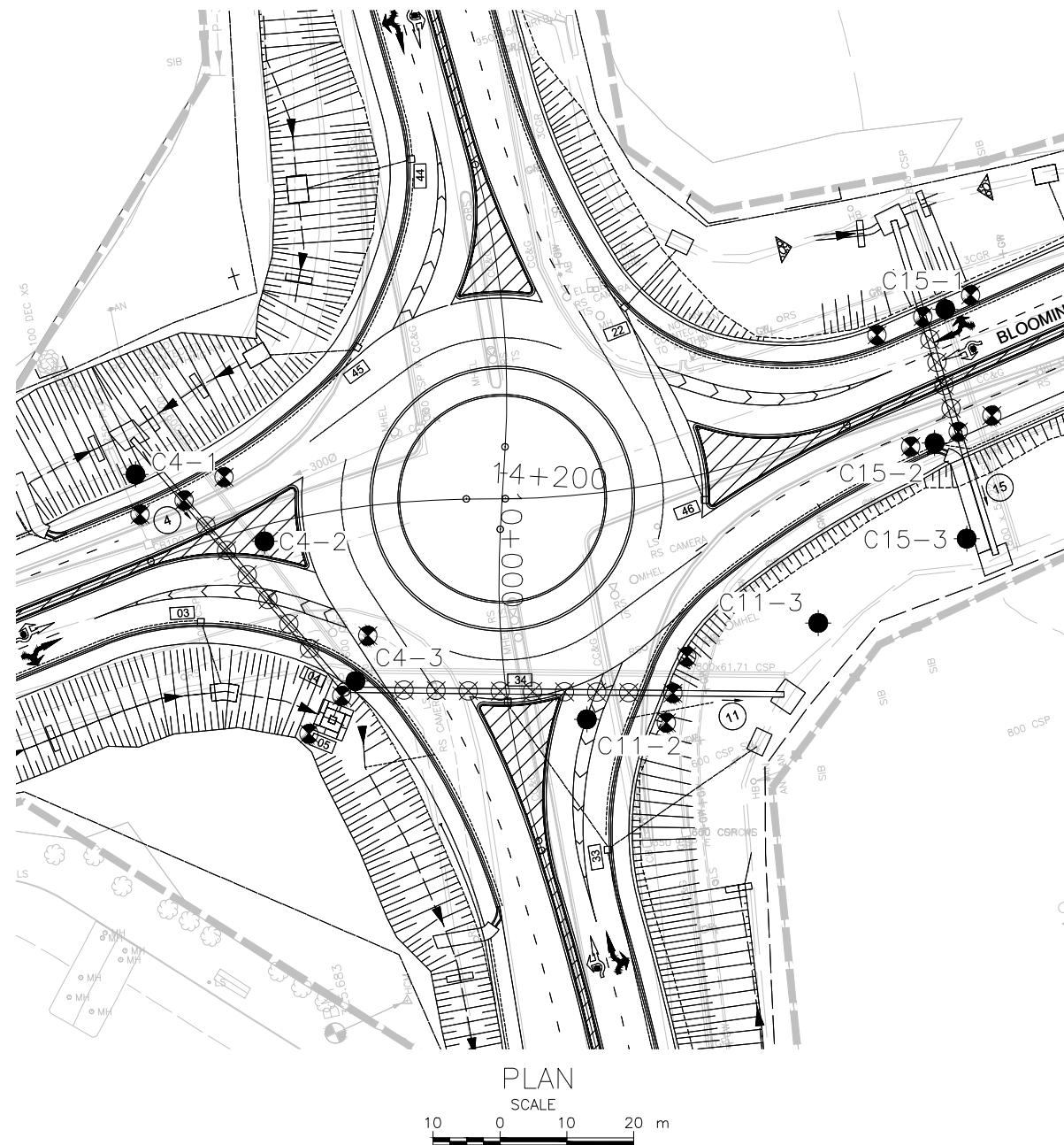
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NO.	DATE	BY	REVISION		
Geocres No. 31D-704					
HWY. 48		PROJECT NO. 1671430		DIST. .	
SUBM'D. NK	CHKD. NK	DATE: 07/12/2018		SITE: .	
DRAWN: DD	CHKD. NK	APPD. JM/C		DWG. 3	



### IN-GROUND MONITORING POINT INSTALLATION DETAIL

N.T.S.



**APPENDIX A**

# Record of Borehole Sheets

## LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

### I. GENERAL

$\pi$	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

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\varepsilon$	linear strain
$\varepsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	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
$\gamma'$	unit weight of submerged soil ( $\gamma' = \gamma - \gamma_w$ )
$D_R$	relative density (specific gravity) of solid particles ( $D_R = \rho_s / \rho_w$ ) (formerly $G_s$ )
e	void ratio
n	porosity
S	degree of saturation

#### (a) Index Properties (continued)

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

#### (b) Hydraulic Properties

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

#### (c) Consolidation (one-dimensional)

$C_c$	compression index (normally consolidated range)
$C_r$	recompression index (over-consolidated range)
$C_s$	swelling index
$C_{\alpha}$	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
$\sigma'_p$	pre-consolidation stress
OCR	over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$

#### (d) Shear Strength

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

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

Notes: 1  
2

$\tau = c' + \sigma' \tan \phi'$   
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, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

**WH:** Sampler advanced by static weight of hammer

**WR:** Sampler advanced by weight of sampler and rod

#### Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm<sup>2</sup> 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	N
Condition	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

#### (b) Cohesive Soils Consistency

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

### IV. SOIL TESTS

w	water content
$w_p$	plastic limit
$w_l$	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
$D_R$	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)
$\gamma$	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

<b>PROJECT</b> 1671430		<b>RECORD OF BOREHOLE No C4-1</b>		SHEET 1 OF 1		<b>METRIC</b>	
<b>G.W.P.</b> 2086-16-00		<b>LOCATION</b> N 4873452.1; E 321665.4 MTM NAD 83 ZONE 10 (LAT. 44.000869; LONG. -79.289704)		<b>ORIGINATED BY</b> JS			
<b>DIST</b> Central HWY 48		<b>BOREHOLE TYPE</b> 153 mm O.D., 70 mm I.D. Hollow Stem Augers		<b>COMPILED BY</b> ACM			
<b>DATUM</b> Geodetic		<b>DATE</b> March 9, 2018		<b>CHECKED BY</b> NK			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								○ UNCONFINED   + FIELD VANE ● QUICK TRIAXIAL   × REMOULDED	20	40	60	80	100	w <sub>p</sub>	w		w <sub>L</sub>			
325.6	GROUND SURFACE																			
0.0	Gravelly sand, trace silt, trace rootlets (FILL)		1A	SS	14															
325.2	Compact Brown Moist		1B																	
0.4	Sand, some gravel, trace silt (FILL)		2	SS	28								○							
324.2	Compact Brown Moist																			
1.5	Sandy GRAVEL to SAND and GRAVEL, trace silt, trace clay, some rock fragments from 2.9 m to 3.7 m		3	SS	41															
	Dense to very dense Grey to brown Dry to moist - Grinding between depths of about 2.3 m and 2.9 m below ground surface																			
			4	SS	85								○					56 37 6 1		
			5	SS	71								○					69 26 4 1		
321.4			6A	SS	55															
4.2	SAND, trace to some silt, trace gravel, trace clay (TILL)		6B																	
	Loose to very dense Brown Moist																			
			7	SS	52								○					1 94 4 1		
319.5			8	SS	5															
6.1	END OF BOREHOLE																			
	NOTE:  1. Open borehole dry upon completion of drilling.																			

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PROJECT 1671430		RECORD OF BOREHOLE No C4-2				SHEET 1 OF 1		METRIC								
G.W.P. 2086-16-00		LOCATION N 4873442.1; E 321684.7 MTM NAD 83 ZONE 10 (LAT. 44.000779; LONG. -79.289463)				ORIGINATED BY JS										
DIST Central HWY 48		BOREHOLE TYPE 153 mm O.D., 70 mm I.D. Hollow Stem Augers				COMPILED BY ACM										
DATUM Geodetic		DATE March 12, 2018				CHECKED BY NK										
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)			
325.9	GROUND SURFACE															
0.0	ASPHALT (180 mm)		1A	AS	-											
	Gravelly sand, trace silt (FILL)		1B													
0.6	Brown Moist Sand, trace silt, trace gravel (FILL)		2	SS	93											
	Brown Moist SAND, some gravel, trace silt, trace clay															
	Dense to very dense		3	SS	44											
	Brown Moist															
323.6																
2.3	SAND and GRAVEL, trace to some silt, trace clay		4	SS	67											
	Very dense															
	Brown Moist		5	SS	71											45 46 7 2
322.2																
3.7	SAND, trace to some gravel, trace to some silt, trace clay (TILL)		6	SS	32											7 85 7 1
	Dense to very dense															
	Brown to grey Moist		7	SS	39											
			8	SS	51											
319.8																
6.1	END OF BOREHOLE															
NOTES:																
1. Open borehole dry upon completion of drilling.																
2. Water levels measured in standpipe piezometer:																
	Date Depth(m) Elev.(m)															
	12/03/18 Dry -															
	21/03/18 Dry -															

PROJECT		1671430		RECORD OF BOREHOLE No C4-3		SHEET 1 OF 1		METRIC								
G.W.P.		2086-16-00		LOCATION		N 4873421.2; E 321698.3 MTM NAD 83 ZONE 10 (LAT. 44.000590; LONG. -79.289294)		ORIGINATED BY								
DIST		Central HWY 48		BOREHOLE TYPE		73 mm O.D., 60 mm I.D. BW Casing		COMPILED BY								
DATUM		Geodetic		DATE		March 19, 2018		CHECKED BY								
								NK								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
324.1	GROUND SURFACE															
0.0	TOPSOIL (25 mm)		1	SS	11											
323.5	Clayey silt, some sand, trace gravel, trace organics, rootlets (FILL)		2	SS	13											
0.6	Stiff Brown Moist		3	SS	35											
	CLAYEY SILT, trace to some sand, trace gravel		4	SS	33											
	Stiff to hard Brown Moist		5	SS	125											
321.0	- Cobbles encountered between 1.8 m and 3.1 m depths - Sand seam between 2.3 m and 2.9 m depths		6	SS	148											
3.1	Silty Gravelly SAND, trace to some clay, trace cobble fragments (TILL)		7	SS	100/ 0.05											
	Very dense Brown to brown/grey mottled Moist to wet		8	SS	116											
	- Cobbles encountered between 3.1 m and 3.7 m depths		9	SS	186/ 0.20											
319.2	SAND and GRAVEL, some silt, cobbles fragments, sand seams, clayey silt pocket															
318.9	Very dense Grey/brown, mottled Wet															
5.2	END OF BOREHOLE															
NOTE: 1. Water level in open borehole at a depth of about 2.0 m below ground surface (Elev. 322.1 m) upon completion of drilling.																

PROJECT 1671430		<b>RECORD OF BOREHOLE No C11-2</b>		SHEET 1 OF 1		<b>METRIC</b>																	
G.W.P. 2086-16-00		LOCATION N 4873415.5; E 321732.9 MTM NAD 83 ZONE 10 (LAT. 44.000539; LONG. -79.288863)		ORIGINATED BY JS																			
DIST Central HWY 48		BOREHOLE TYPE 153 mm O.D., 70 mm I.D. Hollow Stem Augers		COMPILED BY ACM																			
DATUM Geodetic		DATE March 8, 2018		CHECKED BY NK																			
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ			GR SA SI CL				
325.2	GROUND SURFACE							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					W <sub>p</sub> — W — W <sub>L</sub> 10 20 30			kN/m <sup>3</sup>							
0.0	ASPHALT (152 mm)		1A	AS	-		325																
324.7	Gravelly sand, trace silt (FILL)		1B																				
0.5	Brown Moist																						
324.1	Sand, trace to some gravel, trace to some silt (FILL)		2A	SS	23		324																
1.1	Compact Brown Moist		2B																				
	CLAYEY SILT, some sand to with SAND, trace to some gravel (TILL)		3	SS	28/0.15																		
	Firm to hard																						
	Brown to black at 1.1 m to grey at 6.4 m to 7.3 m		4	SS	17		323													4	38	45	13
	Moist																						
	- Hydrocarbon odour noted at 1.5 m depth		5	SS	8		322																
	-split spoon refusal at 1.7 m																						
			6	SS	6		321																
			7	SS	14		320													3	29	50	18
			8A	SS	22		319																
			8B																				
			9A	SS	35		318													7	36	44	13
			9B																				
317.9	END OF BOREHOLE																						
7.3	NOTES:																						
	1. Open borehole dry on completion of drilling.																						
	2. Water level measured in standpipe piezometer:																						
	Date Depth (m) Elev. (m)																						
	08/03/18 Dry -																						
	20/03/18 Dry -																						

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PROJECT		1671430		RECORD OF BOREHOLE No C11-3		SHEET 1 OF 1		METRIC									
G.W.P.		2086-16-00		LOCATION		N 4873429.9; E 321767.5 MTM NAD 83 ZONE 10 (LAT. 44.000667; LONG. -79.288431)		ORIGINATED BY									
DIST		Central HWY 48		BOREHOLE TYPE		73 mm O.D., 60 mm I.D. BW Casing		COMPILED BY									
DATUM		Geodetic		DATE		March 20, 2018		CHECKED BY									
								NK									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
321.4	GROUND SURFACE																
0.9	TOPSOIL (50 mm)		1A	SS	3												
320.8	Sand, some gravel, some silt, trace organics (FILL)		1B	SS	3												
0.6	Very loose Brown/grey mottled Moist		2	SS	6												
	CLAYEY SILT with SAND, trace gravel, trace organics, trace sand seams (TILL)		3	SS	6												
	Firm to very stiff Brown Moist		4	SS	10												
			5	SS	20												
318.4	END OF BOREHOLE																
3.1	NOTE: 1. Borehole dry upon completion of drilling.																

PROJECT		1671430		RECORD OF BOREHOLE No C15-1		SHEET 1 OF 1		METRIC					
G.W.P.		2086-16-00		LOCATION		N 4873476.8; E 321786.5 MTM NAD 83 ZONE 10 (LAT. 44.001089; LONG. -79.288193)		ORIGINATED BY JS					
DIST		Central HWY 48		BOREHOLE TYPE		153 mm O.D., 70 mm I.D. Hollow Stem Augers		COMPILED BY ACM					
DATUM		Geodetic		DATE		March 6, 2018		CHECKED BY NK					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>p</sub>	W		
325.6	GROUND SURFACE												
0.0	ASPHALT (152 mm)												
0.2	Sand to gravelly sand, trace silt (FILL)		1A	AS	-								
324.9	Brown Moist		1B										
0.7	SAND, trace to some silt, trace to some gravel, trace clay (TILL)		2	SS	48								7 80 11 2
	Compact to dense		3	SS	23								
	Brown Moist		4	SS	20								
322.6	Sandy CLAYEY SILT, trace to some gravel (TILL)		5A	SS	57								
3.0	Firm to hard		5B										
	Brown Moist		6	SS	36								3 29 52 16
			7	SS	8								
			8	SS	8								1 25 56 18
			9	SS	10								
316.9	SAND and GRAVEL, trace to some silt, trace clay												
8.7	Loose to compact												
	Brown Moist		10	SS	10								49 42 8 1
315.8	END OF BOREHOLE												
9.8	NOTES: 1. Borehole caved to a depth of 8.2 m below ground surface on removal of augers. 2. Open borehole dry upon completion of drilling.												



+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3%</sup> STRAIN AT FAILURE

PROJECT <u>1671430</u>		<b>RECORD OF BOREHOLE No C15-3</b>		SHEET 1 OF 1		<b>METRIC</b>	
G.W.P. <u>2086-16-00</u>		LOCATION <u>N 4873442.5; E 321789.7 MTM NAD 83 ZONE 10 (LAT. 44.000780; LONG. -79.288154)</u>		ORIGINATED BY <u>EG</u>			
DIST <u>Central</u> HWY <u>48</u>		BOREHOLE TYPE <u>73 mm O.D., 60 mm I.D. BW Casing</u>		COMPILED BY <u>ACM</u>			
DATUM <u>Geodetic</u>		DATE <u>March 20, 2018</u>		CHECKED BY <u>NK</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					w <sub>p</sub>	w	w <sub>L</sub>						
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× REMOULDED	WATER CONTENT (%)									
321.1	GROUND SURFACE						20	40	60	80	100										
0.0	TOPSOIL (25 mm)		1	SS	3		321														
	Sandy clayey silt, trace gravel, trace organics/rootlets, sand seams (FILL) Firm		2	SS	6		320														
319.9	Dark brown to brown, black staining Moist		3	SS	4		319														
1.2	CLAYEY SILT with SAND, trace to some gravel (TILL) Soft to very stiff Brown Moist to wet		4	SS	4																
			5A	SS	29																
318.3	SILT and SAND, trace to some gravel, trace to some clay (TILL) Compact to very dense Brown Moist		5B	SS	29		318														
2.8	- Sand seams and oxidation present below 3.1 m END OF BOREHOLE		6	SS	52																
317.4																					
3.7																					
	NOTE:  1. Water level recorded in open borehole at a depth of about 3.0 m below ground surface (Elev. 318.1 m) upon completion of drilling.																				

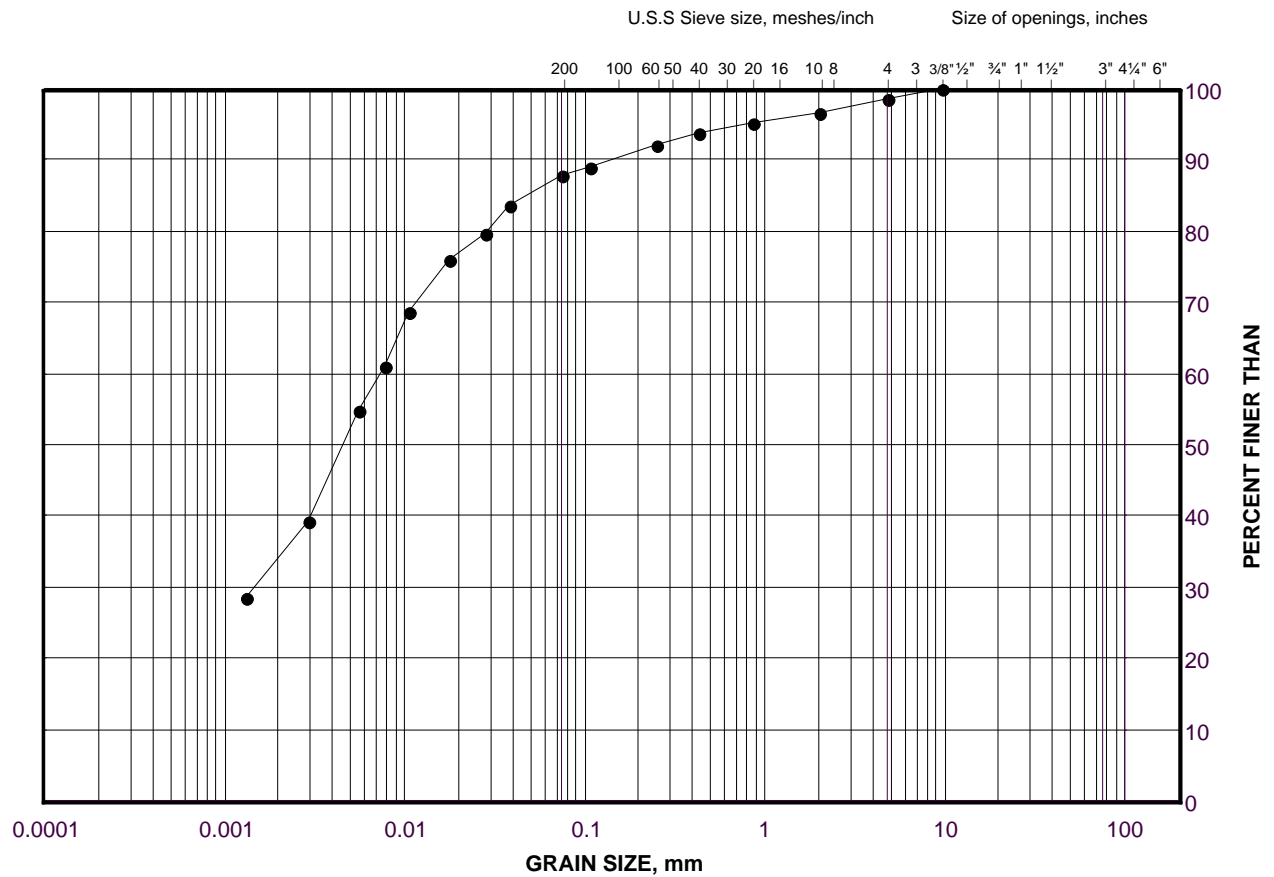
**APPENDIX B**

# Geotechnical Laboratory Test Results

# GRAIN SIZE DISTRIBUTION

Clayey Silt

FIGURE B-1



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

## LEGEND

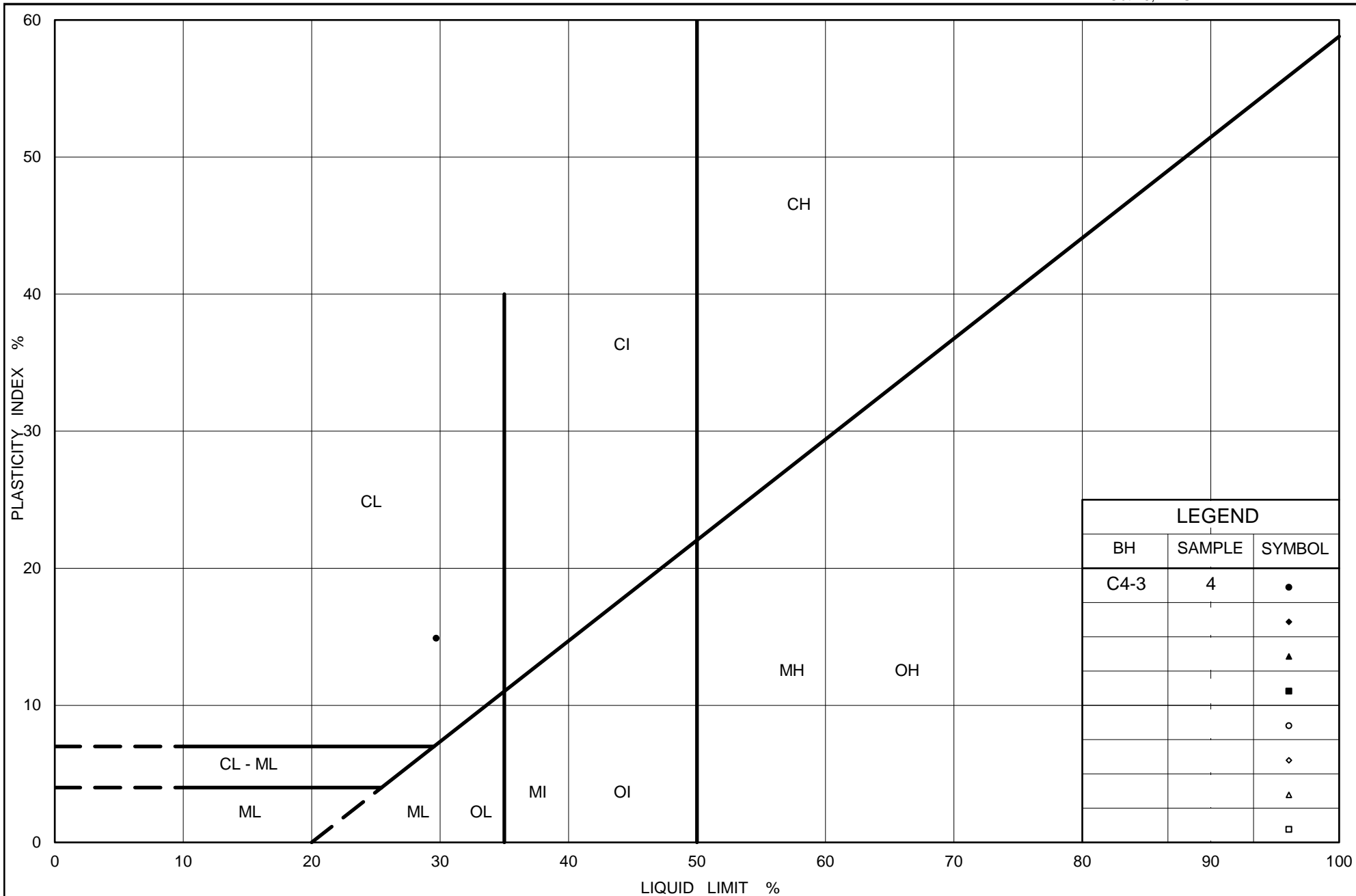
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	C4-3	4	322.0

Project Number: 1671430

Checked By: NK

**Golder Associates**

Date: 17-Apr-18



Ministry of Transportation

Ontario

# PLASTICITY CHART Clayey Silt

Figure No. B-2

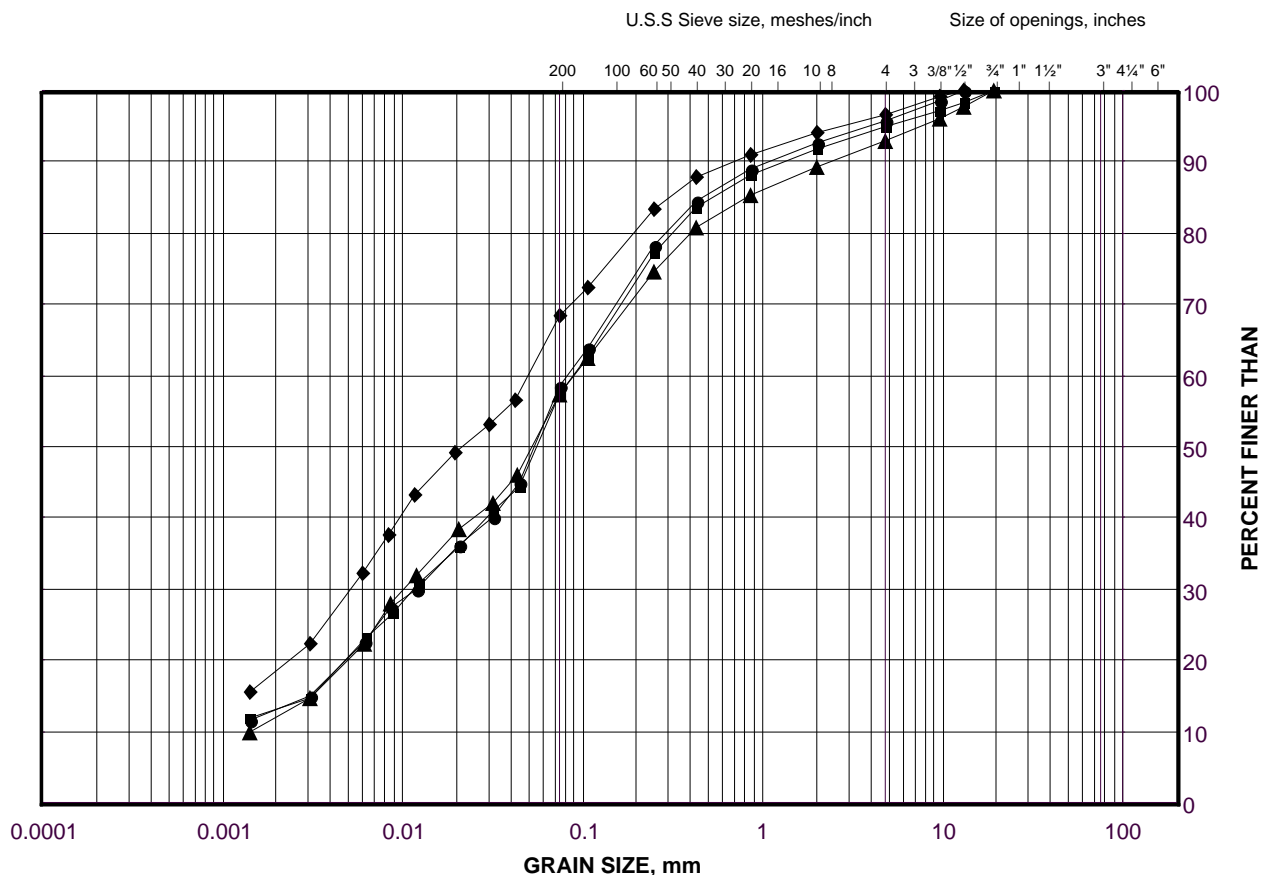
Project No. 1671430 WO9

Checked By: NK

# GRAIN SIZE DISTRIBUTION

Sandy Clayey Silt to Clayey Silt with Sand (Till)

FIGURE B-3A



## LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	C11-2	4	322.6
■	C11-3	5	318.7
◆	C11-2	7	320.3
▲	C11-2	9A	318.3

Project Number: 1671430

Checked By: NK

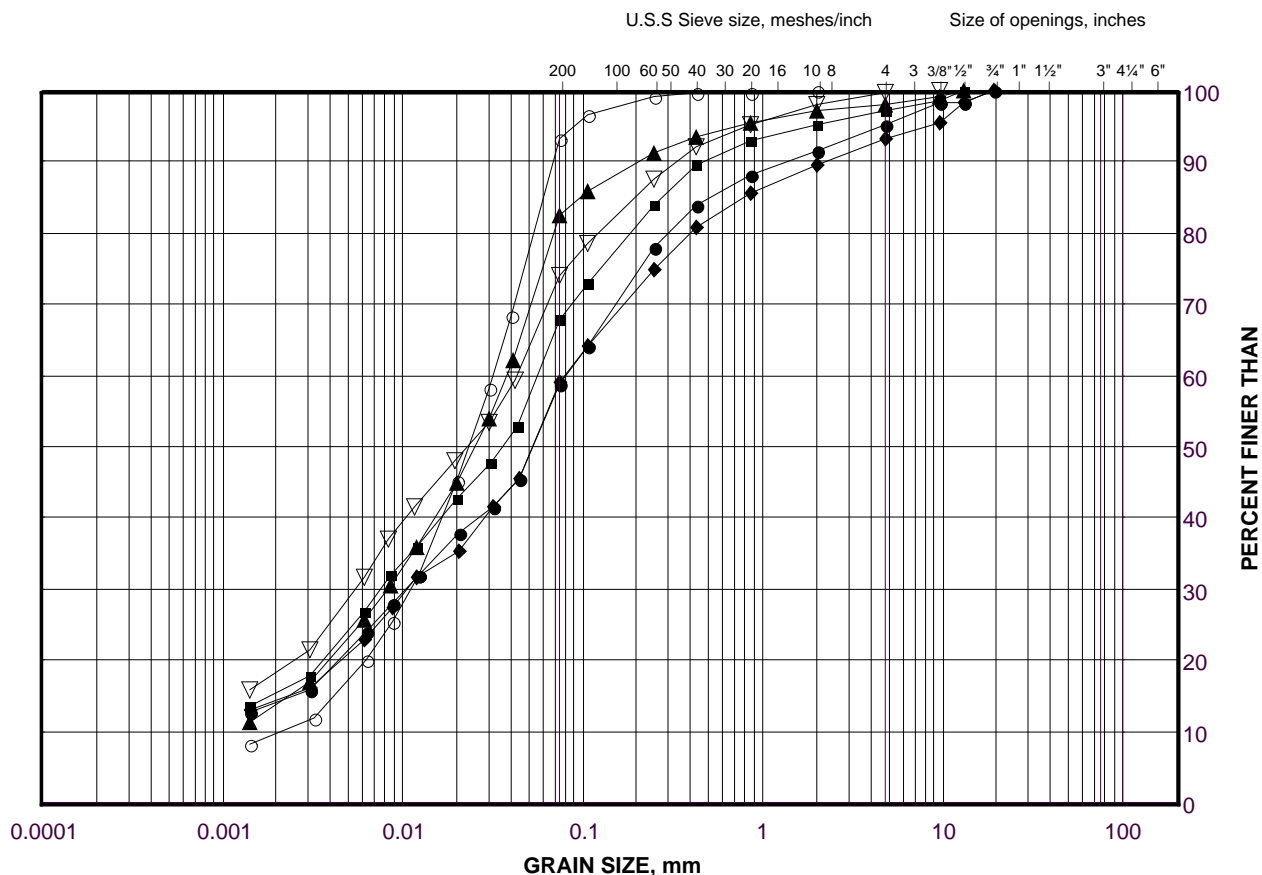
**Golder Associates**

Date: 27-Apr-18

# GRAIN SIZE DISTRIBUTION

Sandy Clayey Silt to Clayey Silt with Sand (Till)

FIGURE B-3B



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

## LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	C15-3	4	319.0
■	C15-1	6	321.5
◆	C15-2	7	320.6
▲	C15-2	8	319.0
▽	C15-1	8	319.2
○	C15-2	9A	317.6

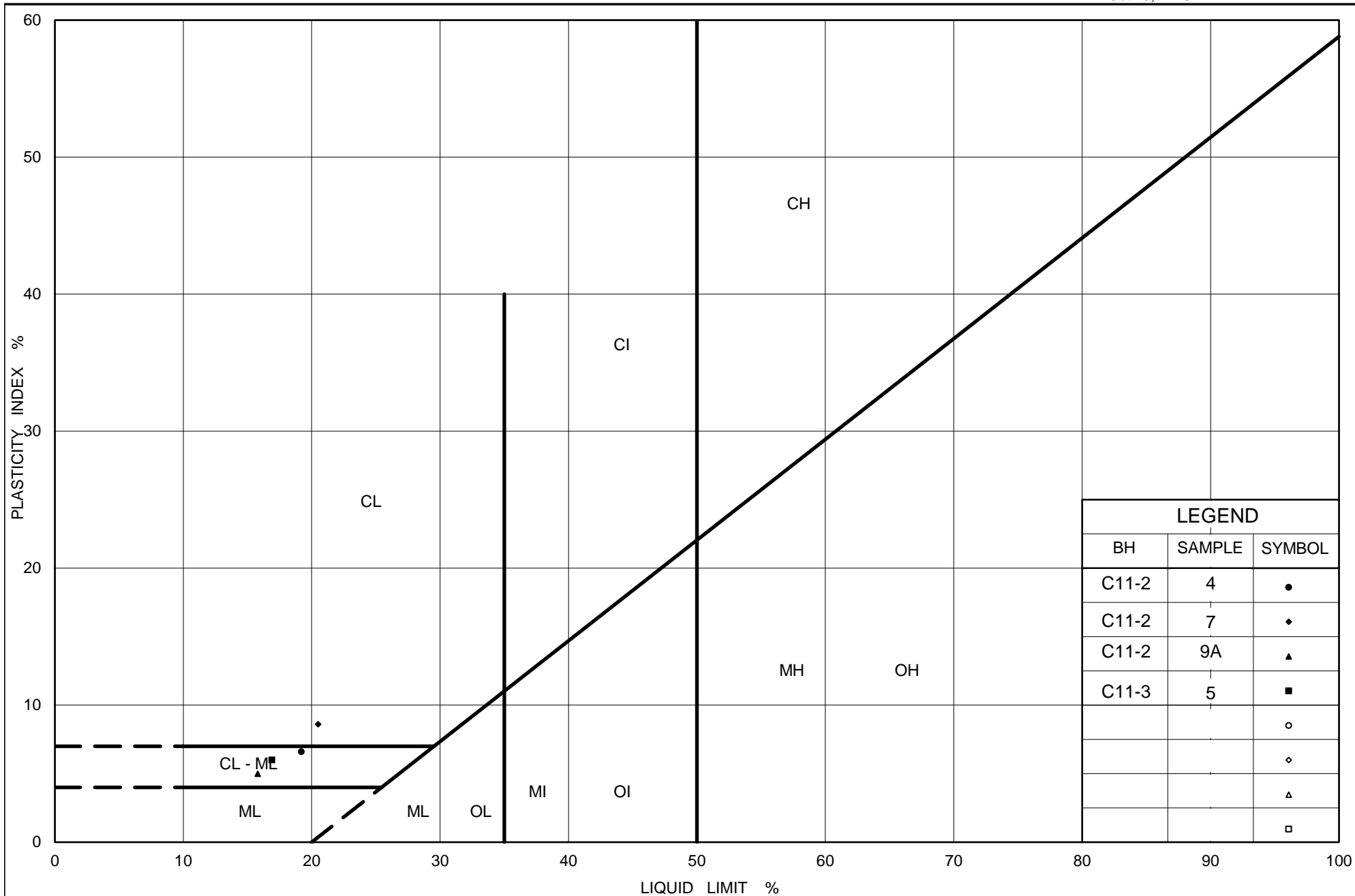
Project Number: 1671430

Checked By: NK

**Golder Associates**

Date: 27-Apr-18





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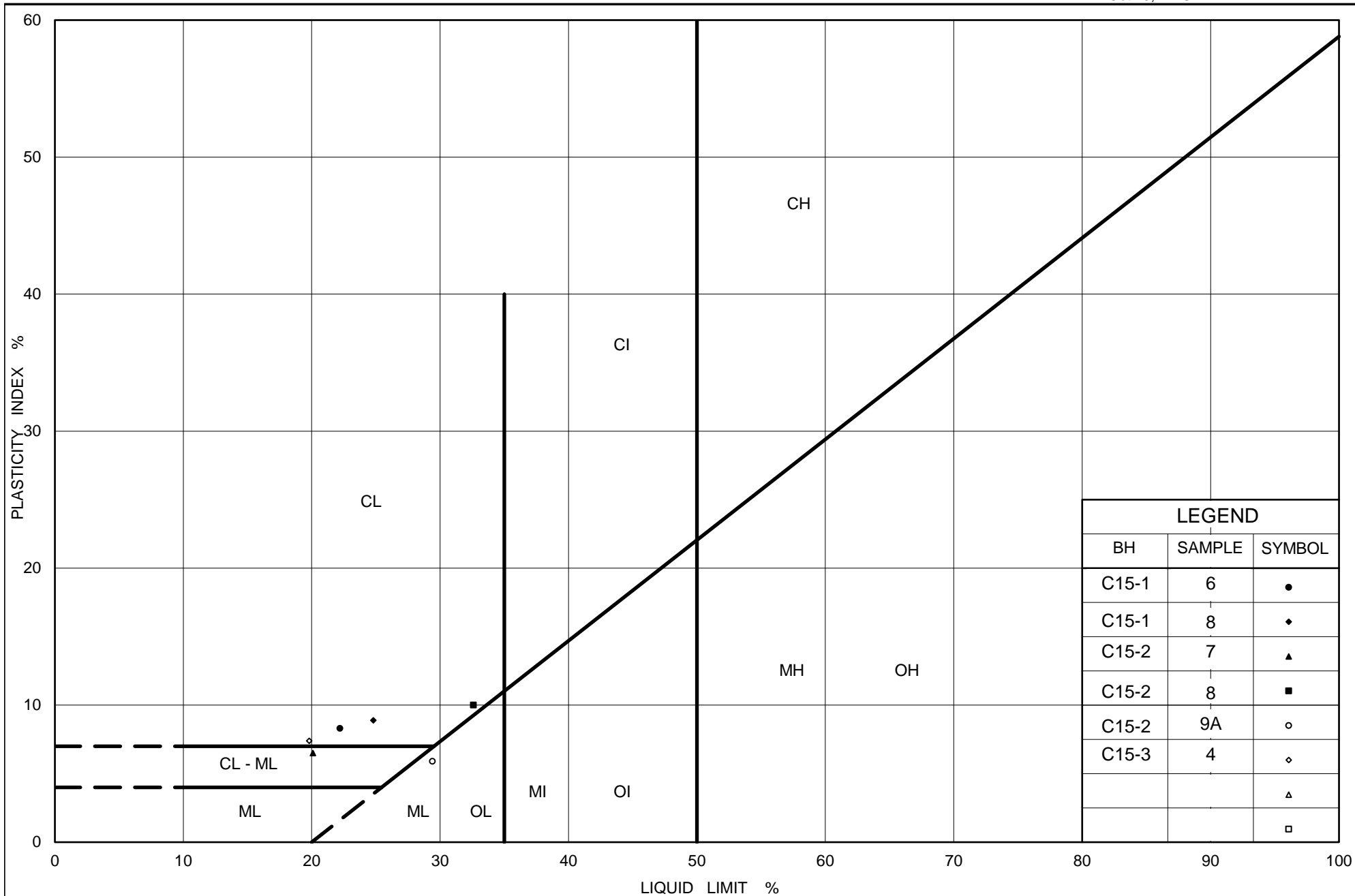
# PLASTICITY CHART Sandy Clayey Silt to Clayey Silt with Sand (Till)

Ontario

Figure No. B-4A

Project No. 1671430 WO9

Checked By: NK



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# **PLASTICITY CHART** Sandy Clayey Silt to Clayey Silt with Sand (Till)

Ontario

Figure No. B-4B

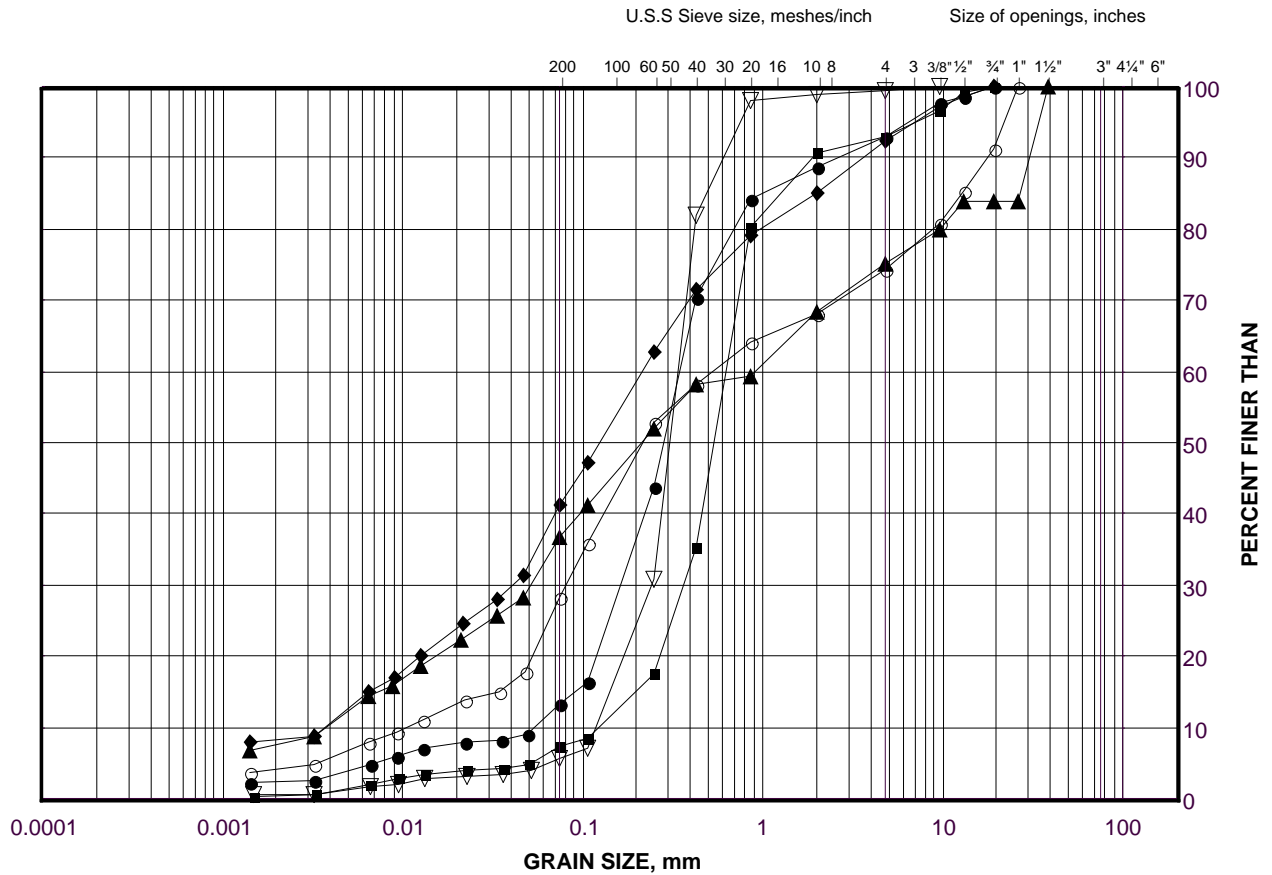
Project No. 1671430 WO9

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# GRAIN SIZE DISTRIBUTION

Sand to Silt and Sand to Gravelly Silty Sand (Till)

FIGURE B-5



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

## LEGEND

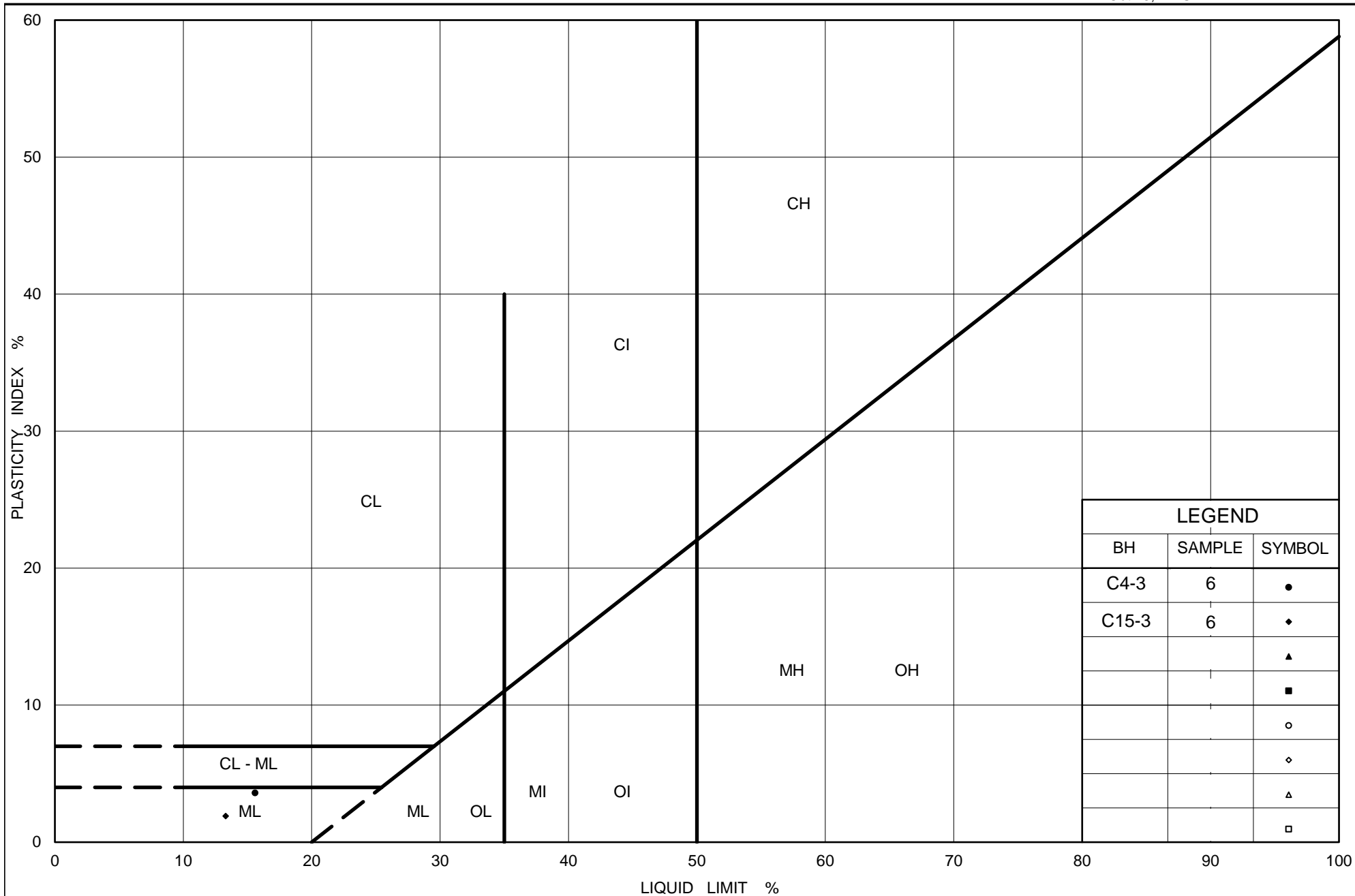
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	C15-1	2	324.6
■	C4-2	6	321.8
◆	C15-3	6	317.8
▲	C4-3	6	320.8
▽	C4-1	7	320.8
○	C4-3	8	319.5

Project Number: 1671430

Checked By: NK

**Golder Associates**

Date: 01-May-18



Ministry of Transportation

Ontario

# PLASTICITY CHART Silt and Sand to Gravelly Silty Sand (Till)

Figure No. B-6

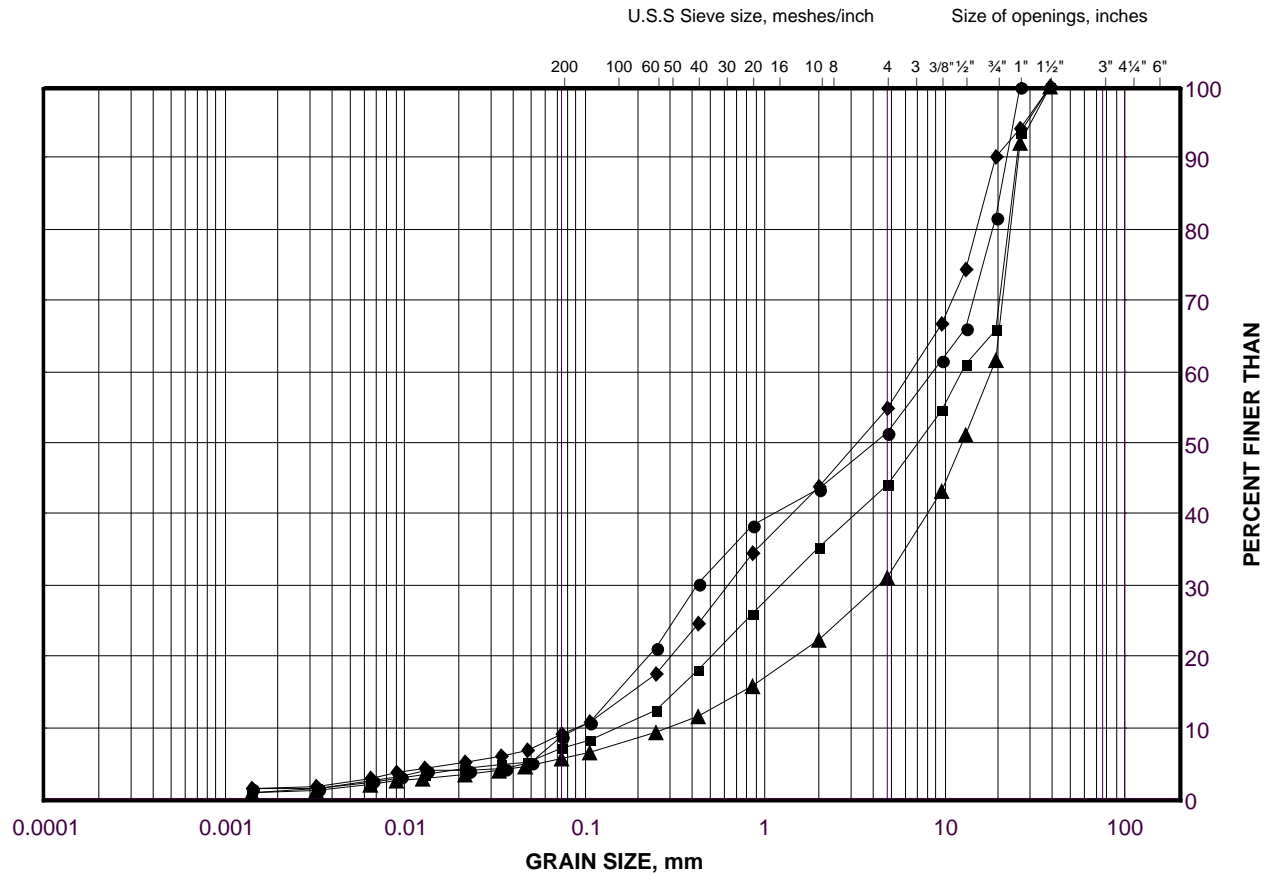
Project No. 1671430 WO9

Checked By: NK

# GRAIN SIZE DISTRIBUTION

Silty Gravelly Sand to Sand and Gravel

FIGURE B-7



## LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	C15-1	10	316.1
■	C4-1	4	323.0
◆	C4-2	5	322.6
▲	C4-1	5	322.2

Project Number: 1671430

Checked By: NK

**Golder Associates**

Date: 01-May-18

**APPENDIX C**

# Analytical Test Results

Your Project #: 1671430-W09

Site Location: HWY 48

Your C.O.C. #: 107476

**Attention: Nikol Kochmanova**

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

**Report Date: 2018/03/23**

Report #: R5052467

Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**MAXXAM JOB #: B862098**

**Received: 2018/03/20, 12:06**

Sample Matrix: Soil  
# Samples Received: 3

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Chloride (20:1 extract)	3	N/A	2018/03/22	CAM SOP-00463	EPA 325.2 m
Conductivity	3	N/A	2018/03/22	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl <sub>2</sub> EXTRACT	3	2018/03/23	2018/03/23	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	3	2018/03/20	2018/03/22	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	3	N/A	2018/03/22	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.



Your Project #: 1671430-W09

Site Location: HWY 48

Your C.O.C. #: 107476

**Attention: Nikol Kochmanova**

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

**Report Date: 2018/03/23**

Report #: R5052467

Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**MAXXAM JOB #: B862098**

**Received: 2018/03/20, 12:06**

**Encryption Key**

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

Ema Gitej, Senior Project Manager

Email: EGitej@maxxam.ca

Phone# (905)817-5829

=====

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### SOIL CORROSIVITY PACKAGE (SOIL)

Maxxam ID		GHG284		GHG285		GHG286			GHG286		
Sampling Date		2018/03/12		2018/03/08		2018/03/06			2018/03/06		
COC Number		107476		107476		107476			107476		
	UNITS	C4-2-SA4	RDL	C11-2-SA5	RDL	C15-1-SA7	RDL	QC Batch	C15-1-SA7 Lab-Dup	RDL	QC Batch
Calculated Parameters											
Resistivity	ohm-cm	1500		420		850		5448848			
Inorganics											
Soluble (20:1) Chloride (Cl)	ug/g	340	20	1300	60	630	20	5450392			
Conductivity	umho/cm	684	2	2400	2	1170	2	5451899	1170	2	5451899
Available (CaCl2) pH	pH	8.14		7.68		7.68		5452126			
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	130	20	<20	20	5450427	<20	20	5450427
RDL = Reportable Detection Limit											
QC Batch = Quality Control Batch											
Lab-Dup = Laboratory Initiated Duplicate											

## TEST SUMMARY

**Maxxam ID:** GHG284  
**Sample ID:** C4-2-SA4  
**Matrix:** Soil

**Collected:** 2018/03/12  
**Shipped:**  
**Received:** 2018/03/20

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5450392	N/A	2018/03/22	Alina Dobreanu
Conductivity	AT	5451899	N/A	2018/03/22	Tahir Anwar
pH CaCl2 EXTRACT	AT	5452126	2018/03/23	2018/03/23	Neil Dassanayake
Resistivity of Soil		5448848	2018/03/22	2018/03/22	Cristina Carriere
Sulphate (20:1 Extract)	KONE/EC	5450427	N/A	2018/03/22	Alina Dobreanu

**Maxxam ID:** GHG285  
**Sample ID:** C11-2-SA5  
**Matrix:** Soil

**Collected:** 2018/03/08  
**Shipped:**  
**Received:** 2018/03/20

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5450392	N/A	2018/03/22	Alina Dobreanu
Conductivity	AT	5451899	N/A	2018/03/22	Tahir Anwar
pH CaCl2 EXTRACT	AT	5452126	2018/03/23	2018/03/23	Neil Dassanayake
Resistivity of Soil		5448848	2018/03/22	2018/03/22	Cristina Carriere
Sulphate (20:1 Extract)	KONE/EC	5450427	N/A	2018/03/22	Alina Dobreanu

**Maxxam ID:** GHG286  
**Sample ID:** C15-1-SA7  
**Matrix:** Soil

**Collected:** 2018/03/06  
**Shipped:**  
**Received:** 2018/03/20

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5450392	N/A	2018/03/22	Alina Dobreanu
Conductivity	AT	5451899	N/A	2018/03/22	Tahir Anwar
pH CaCl2 EXTRACT	AT	5452126	2018/03/23	2018/03/23	Neil Dassanayake
Resistivity of Soil		5448848	2018/03/22	2018/03/22	Cristina Carriere
Sulphate (20:1 Extract)	KONE/EC	5450427	N/A	2018/03/22	Alina Dobreanu

**Maxxam ID:** GHG286 Dup  
**Sample ID:** C15-1-SA7  
**Matrix:** Soil

**Collected:** 2018/03/06  
**Shipped:**  
**Received:** 2018/03/20

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Conductivity	AT	5451899	N/A	2018/03/22	Tahir Anwar
Sulphate (20:1 Extract)	KONE/EC	5450427	N/A	2018/03/22	Alina Dobreanu

### GENERAL COMMENTS

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

Package 1	15.0°C
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**Results relate only to the items tested.**

## QUALITY ASSURANCE REPORT

Golder Associates Ltd  
Client Project #: 1671430-W09  
Site Location: HWY 48  
Sampler Initials: JLS

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
5450392	Soluble (20:1) Chloride (Cl)	2018/03/22	NC	70 - 130	103	70 - 130	<20	ug/g	2.4	35
5450427	Soluble (20:1) Sulphate (SO4)	2018/03/22	114	70 - 130	102	70 - 130	<20	ug/g	NC	35
5451899	Conductivity	2018/03/22			100	90 - 110	<2	umho/cm	0.35	10
5452126	Available (CaCl2) pH	2018/03/23			99	97 - 103			0.89	N/A

N/A = Not Applicable

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

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

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

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

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

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

### VALIDATION SIGNATURE PAGE

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

*Cristina Carriere*

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Cristina Carriere, Scientific Service Specialist

---

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

## CHAIN OF CUSTODY RECORD

107476

Page 3 of 3

Invoice Information		Report Information (if differs from invoice)		Project Information (where applicable)		Turnaround Time (TAT) Required	
Company Name: <b>Goldier Associates Ltd.</b>		Company Name: _____		Quotation #: _____		<input checked="" type="checkbox"/> Regular TAT (5-7 days) Most analyses	
Contact Name: <b>Nikol Kachmanova</b>		Contact Name: _____		P.O. #/ A/E#: _____		PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS	
Address: <b>6925 Century Ave #100 Mississauga ON</b>		Address: _____		Project #: <b>1671430-W09</b>		Rush TAT (Surcharges will be applied)	
Phone: <b>905-567-4444</b> Fax: _____		Phone: _____ Fax: _____		Site Location: _____		<input type="checkbox"/> 1 Day <input type="checkbox"/> 2 Days <input type="checkbox"/> 3-4 Days	
Email: <b>Nikol.Kachmanova@golider.com</b>		Email: _____		Site #: <b>HWY 48</b>		Date Required: _____	
Sampled By: <b>JLS</b>		Sampled By: _____		Rush Confirmation #: _____			
MDE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY							
Regulation 153		Other Regulations		Analysis Requested			
<input type="checkbox"/> Table 1 <input type="checkbox"/> Res/Park <input type="checkbox"/> Med/ Fine <input type="checkbox"/> Table 2 <input type="checkbox"/> Ibd/Comm <input type="checkbox"/> Coarse <input type="checkbox"/> Table 3 <input type="checkbox"/> Agri/ Other <input type="checkbox"/> Table _____ FOR RSC (PLEASE CIRCLE) Y / N		<input type="checkbox"/> CCME <input type="checkbox"/> Sanitary Sewer Bylaw <input type="checkbox"/> MISA <input type="checkbox"/> Storm Sewer Bylaw <input type="checkbox"/> PWQO <input type="checkbox"/> Region _____ <input type="checkbox"/> Other (Specify) _____ <input type="checkbox"/> REG 558 (MIN. 3 DAY TAT REQUIRED)		Analysis Requested FIELD FILTERED (CIRCLE) Metals / Hg / CrVI BTEX/ PHC F1 PHG F2 - F4 VOCs REG 153 METALS & INORGANICS REG 153 ICPMS METALS REG 153 METALS (Hg, Cr VI, ICPMS Metals, HWS - B) Corrosivity Package			
Include Criteria on Certificate of Analysis: Y / N		SAMPLES MUST BE KEPT COOL (< 10 °C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM		LABORATORY USE ONLY			
SAMPLE IDENTIFICATION		DATE SAMPLED (YYYY/MM/DD)	TIME SAMPLED (HH:MM)	MATRIX	CUSTODY SEAL Y / N		
					COOLER TEMPERATURES Present Intact		
					COOLING MEDIA PRESENT: Y / (N)		
					COMMENTS		
1	C4-2-SA4	2018/3/12	PM	Soil	1		
2	C11-2-SA5	2018/3/8	PM	Soil	1		
3	C15-1-SA7	2018/3/6	PM	Soil	1		
4							
5							
6							
7							
8							
9							
10							
RELINQUISHED BY: (Signature/Print)		DATE: (YYYY/MM/DD)	TIME: (HH:MM)	RECEIVED BY: (Signature/Print)		DATE: (YYYY/MM/DD)	TIME: (HH:MM)
Katie Neo Kachmanova		2018/03/20	12:05 PM	Pardeep Puroshok Puroshok		2018/03/20	12:06

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COC-1004 (03/17)

White: Maxxam ~ Yellow: Client

**APPENDIX D**

# Non-Standard Special Provisions



## **PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.**

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Special Provision

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### **CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY TRENCHLESS METHODS**

#### **TABLE OF CONTENTS**

<b>1.0</b>	<b>SCOPE</b>
<b>2.0</b>	<b>REFERENCES</b>
<b>3.0</b>	<b>DEFINITIONS</b>
<b>4.0</b>	<b>DESIGN AND SUBMISSION REQUIREMENTS</b>
<b>5.0</b>	<b>MATERIALS</b>
<b>6.0</b>	<b>EQUIPMENT</b>
<b>7.0</b>	<b>CONSTRUCTION</b>
<b>8.0</b>	<b>QUALITY ASSURANCE- Not Used</b>
<b>9.0</b>	<b>MEASUREMENT FOR PAYMENT</b>
<b>10.0</b>	<b>BASIS OF PAYMENT</b>

#### **1. SCOPE**

This specification covers the general requirements for the installation of pipes by trenchless methods, including Jack & Bore, Pipe Ramming, Directional Drilling, and Tunnelling. The Contractor shall determine the most appropriate method of installation for each of the crossing locations.

This specification shall supersede OPSS 415 (Construction Specification for Pipeline Installation by Tunneling), OPSS 416 (Construction Specification for Pipeline and Utility Installation by Jacking and Boring) and OPSS 450 (Construction Specification for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling).

#### **2. REFERENCES**

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

##### **Ontario Provincial Standard Specifications, General**

OPSS 180      Management and Disposal of Excess Materials

##### **Ontario Provincial Standard Specifications, Construction**

OPSS 401	Trenching, Backfilling, and Compacting
OPSS 404	Support Systems
OPSS 491	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 517	Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS.PROV 539	Temporary Protection Systems

### **Ontario Provincial Standard Specifications, Material**

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

### **American Society for Testing and Materials (ASTM) International Standards**

ASTM A252-93	Welding and Seamless Steel Pipe Piles
ASTM D2657-03	Standard Practice for Heat Fusion Joining of Polyelofin Pipe and Fittings
ASTM D3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
ASTM F894	Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

### **Canadian Standards Association Standards:**

CSA B182.6	Profile Polyethylene Sewer Pipe and Fittings.
CAN/CSA A5-93	Portland Cement
CSA W59	Welded Steel Construction (Metal Arc Welding)

## **3. DEFINITIONS**

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

**Auger Jack & Bore:** a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead and rotating a cutter head, followed by removal of material from inside the bore by using an auger.

**Backreamer:** a cutting head suitably designed for the subsurface conditions that is attached to the end of a drill string to enlarge the pilot bore during a pullback operation.

**Bore Path:** 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 original design and working drawings. 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.

**Digger Shield/Hand Mining:** a method of forming a horizontal bore in the subsurface by essentially

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.

**Drilling Fluids:** 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 Fracture or Frac Out:** a condition where the drilling fluid’s pressure in the bore is sufficient to overcome the in situ confining stress, thereby fracturing the soil and/or rock materials and allowing the drilling fluids to migrate to the surface at an unplanned location.

**Engineer:** a Professional Engineer licensed by the Professional Engineers of Ontario to practice in the Province of Ontario.

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

**Environmentally Sensitive Area (ESA):** areas adjacent to construction that are off limits to the Contractor as specified elsewhere in the Contract.

**Fill:** man-made mixture of previously placed/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.

**Grouting:** injection of grout into voids.

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

**Directional Drilling (DD):** directional boring or guided boring.

**HDPE:** high density polyethylene.

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

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

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

**Pipe Jacking:** a method for installing steel casing or concrete pipe in the subsurface utilizing hydraulically operated jacks of adequate number and capacity to ensure smooth and uniform advancement without overstressing the liner/pipe.

**Pipe Ramming:** 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.

**Primary Liner (Support):** system installed prior to or concurrent with excavation, to maintain stability of an excavation and to support earth or rock and any structure utilities or other facilities in or on the supported earth or rock mass, until the excavation is completed.

**Product:** pipe culverts, pipe sewers, watermain pipe and sanitary pipe.

**Pullback:** that part of the DD method in which the drill string is pulled back through the bore path to the entry point.

**Contractor's Engineer :** an Engineer who has a minimum of five (5) years experience in the field of pipe installation using trenchless methods or alternatively has demonstrated expertise by providing satisfactory quality verification services for the work at a minimum of two (2) projects of similar scope to the contract. The Contractor's Engineer shall be retained by the Contractor to certify that the work is in general conformance with the contract documents and to issue Certificate(s) of Conformance.

**Reaming:** a process for pulling a tool attached to the end of the drill string through the bore path to enlarge the bore and mix the cuttings with the drilling fluid. This typically includes multiple passes.

**Rock:** 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 size equivalent to 0.3 m in diameter or greater.

**Secondary Liner:** concrete pipe, HDPE pipe or un-reinforced cast-in-place concrete, installed subsequent to tunnel excavation.

**Shaft:** vertically sided excavation used as entry and/or exit points from which the trenchless method is initiated or directed for the installation of product.

**Strike Alert:** 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:** a mixture of soil and/or rock cuttings, and drilling fluid.

**Soil:** all materials except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials; includes rock fragments having an equivalent size less than 0.3 m in diameter.

**Trenchless Installation:** an underground method of constructing a passage open at both ends that involves installing a pipe. For the purpose of this specification, the pipe may be installed by any of the various methods defined herein such as Auger Jack & Boring, Pipe Jacking, Pipe Ramming, Directional Drilling, or using a tunnelling machine or hand mining methods.

**Tunnelling:** An underground method of constructing a passage using a tunnel boring machine (TBM), a microtunnel boring machine (MTBM) or hand mining using a shield to support the opening.

## **DESIGN AND SUBMISSION REQUIREMENTS**

### **4.01 General**

The Contractor's documentation, submission requirements and installation methods shall specifically consider and address the subsurface conditions at each pipe crossing as identified in the Foundation Investigation

Report or elsewhere in the Contract Documents.

#### **4.02 Working Drawings**

Three copies of stamped working drawings for portal or shaft construction, primary liner, excavation, secondary lining, dewatering and groundwater control and grouting shall be submitted to the Contract Administrator (CA) at least one week prior to the commencement of the work for information purposes. All submissions shall bear the seal and signature of the Design Engineer and Design Checking Engineer. The Contractor shall have a copy of the stamped working drawings at the site during construction.

As a minimum, working drawings/details pertaining to the tunnel design and construction shall include the following (as appropriate):

a) Plans, Elevations and Details:

- A work plan outlining the materials, procedures, methods and schedule to be used to execute the work;
- A list of personnel, including backup personnel, and their qualifications and experience;
- A safety plan including the company safety manual and emergency procedures;
- The work area layout;
- An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail;
- 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;
- Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations; and
- Excavated materials disposal plan.

b) Design Criteria:

- Primary liner design details, if applicable;
- Design assumption and material data when materials other than those specified are proposed for use; and
- Drill path design, details of alignment and alignment control, maximum curvature and reaming stages.

c) Materials:

- 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; and
- Material mixture for filling voids and installation procedures.

d) Upstream/Downstream Portal Installation Procedure:

- The access shaft or entry/exit pit details designed and stamped/signed by the Design Engineer, as applicable; and
- Face support and other temporary support details, if applicable.

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

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

f) Excavation and Dewatering:

- Ground control/dewatering details, as applicable, describing the proposed method for control, handling, treatment, and disposal of water.

g) Monitoring Method:

The methods to be employed to monitor and maintain the alignment of the installation.

#### **4.03 Site Survey**

Prior to commencing the work, the Contractor shall, at each pipe location, lay-out the alignment and install settlement monitoring points.

#### **4.04 Certificate of Conformance**

The Contractor shall submit details of the sequence and method of construction to the Contractor's Engineer for review, prepared and stamped by the Design Engineer. The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Contractor's Engineer a minimum of one week 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 Certificate of Conformance sealed and signed by the Contractor's 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 Certificate of Conformance shall state that the work has been carried out in general conformance with the contract documents, specifications and/or stamped working drawings.

In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a final Certificate of Conformance sealed and signed by the Contractor's 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.

The Design Engineer will not be permitted to carry out the work of the Contractor's Engineer.

### **5. MATERIALS**

#### **5.01 Product**

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

#### **5.02 Concrete**

Concrete shall be according to OPSS.PROV 1350. The concrete strength shall be as specified in the Contractor's design submission.

#### **5.03 Concrete Reinforcement**

Steel reinforcing for concrete work shall be according to OPSS.PROV 1440.

#### **5.04 Timber**

Timber shall be sound, straight, and free from cracks, shakes and large or loose knots.

#### **5.05 Grout**

The Contractor shall submit the proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces. Purging grout shall consist of a mixture of one part Portland cement conforming to the requirements of CAN/CSA A5-93 and two parts mortar sand conforming to OPSS.PROV 1004 wetted with only sufficient water to make the mixture plastic.

#### **5.06 Auger Jack & Bore Materials**

##### **5.06.01 Pipe Materials**

Steel pipe shall conform with ASTM A252-93 welded joints suitable for jacking operations. The Contractor shall select pipe class for pipe jacking.

Concrete pipe as per OPSS.PROV 1820.

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

#### **5.07 Pipe Ramming Materials**

##### **5.07.01 Pipe Materials**

Steel pipe shall conform with ASTM A 252-93 welded joints.

New steel casing when specified shall be smooth wall carbon steel pipe according to ASTM A252-93 Grade 2.

Used steel casing can be used provided that the steel casing can resist the applicable static and dynamic loadings.

Pipe wall thickness shall be determined by the Contractor based on static and dynamic loads from traffic loading and anticipated ramming forces for selected pipe and driven pipe lengths. The wall thickness shall be increased as required to ensure the casing is not damaged during handling and installation. The pipe minimum wall thickness shall be as per Table 1 of OPSS 1802.

Pipe segments shall be determined by the Contractor.

Steel pipe joints shall be pressure fit type or welded.

All steel casing pipe shall be square cut.

Steel casing pipe shall have roundness such that the difference between the major and minor outside diameters shall not exceed 1% of the specified nominal outside diameter or 6 mm, whichever is less.

Steel casing pipe shall have a minimum allowable straightness of 1.5 mm maximum per metre of length.

### **5.07.02 Mill Certificates**

For permanent casing, the Contractor shall submit to the Contract Administrator at the time of delivery one copy of the mill certificate, indicating that the steel meets the requirements for the appropriate standards for casings.

Where mill test certificates originate from a mill outside Canada or the United States of America the Contractor shall have the information on the mill certificate verified by testing by a Canadian laboratory. The laboratory shall be accredited by a Canadian National Accreditation Body to comply with the requirements of ISO/IEC Guide 25 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 and the signature of an authorized officer of the Canadian testing laboratory.

## **5.08 Directional Drilling Materials**

### **5.08.01 Drilling Fluids**

The drilling fluids shall be mixed according to the manufacturer's recommendations and be appropriate for the anticipated subsurface conditions.

### **5.08.02 Pipe Materials**

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

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

The Contractor shall determine the required dimensional ratio (DR) of the HDPE pipe to support all subsurface conditions and hydrostatic pressures, and to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

The Contractor's submission shall demonstrate, in conjunction with the manufacturer's specifications, that the heat resistance of the pipe material is sufficient to tolerate without damage the heat of hydration generated by grout curing.

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

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

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

## **5.09 Tunnelling Materials**

### **5.09.01 Primary Liner**

Tunnelling methods will require installation of a primary liner. The primary liner shall be designed by the



Contractor and the design/drawings shall be stamped/signed by the Design Engineer. The design shall be submitted to the Contract Administrator as specified herein.

## **5.09.02 Secondary Liner**

Concrete or High Density Polyethylene Pipe shall be used according to the following requirements.

### **5.09.02.01 Concrete Pipe**

Concrete pipe as per OPSS.PROV 1820 shall be used. The Contractor shall select the pipe class to withstand grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

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

### **5.09.02.02 High Density Polyethylene (HDPE)**

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

The requirements for fittings shall be according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

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

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

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

## **6. EQUIPMENT**

### **6.01 Auger Jack & Bore Equipment**

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 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 shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

### **6.02 Pipe Ramming Equipment**

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 drive pit through the existing subsurface conditions at the site.

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 pipe shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

### **6.03 Directional Drilling Equipment**

#### **6.03.01 General**

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

#### **6.03.02 Drilling Rig**

The directional drilling rig shall:

- 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;
- contain a guidance system to accurately guide boring operations;
- be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation; and
- 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 Equipment**

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

Specific details of the manner in which rock or boulders will be broken and removed from the tunnel face

shall be submitted to the Contract Administrator information purposes. 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.

## **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 submitted to the Contract Administrator for information purposes prior to commencing the work and shall be subject to the limitations presented in the following subsections.

#### **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 at every 5 m in normal conditions and every 2 m where precise alignment control is necessary;

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

All excavations shall be carried out in accordance with the Occupational Health and Safety Act (OHSA) of Ontario.

For 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 9m 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.

#### **7.01.02 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 OPSS.PROV 539. 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, 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.PROV 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 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. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

#### **7.01.12 Record Keeping**

Verification record requirements of the alignment and depth of the installation shall be as specified in the Contract Documents. A copy of the verification records shall be given to the Contract Administrator at the completion of the installation.

#### **7.01.13 Testing**

Testing of the product installation shall consist of verifying the specified grade between the two ends of the pipe and passing of water from the inlet end of the pipe to the outlet end to confirm gravity flow conditions.

#### **7.01.14 Management and Disposal of Excess Material**

Management and disposal 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.

#### **7.01.16 Supervision**

A qualified individual, who is experienced in the pipe installation by trenchless methods shall supervise the work at all times.

### **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:

Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.

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.

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 conditions at each pipe crossing.

### **7.02.02 Pipe Installation**

Concrete pipe joints shall be water tight and according to OPSS.PROV 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 excavation shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavation shall be filled with grout.

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. But welding of pipe joints shall conform to CAS W59.

Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement 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.

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 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.

#### **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 DD 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 and re-drill from the location along the bore path before the deviation.

In the event that a drilling fluid fracture, inadvertent returns, or loss of circulation occurs during pilot bore drilling operations, the Contract Administrator shall be advised of the event and action shall be taken in accordance with the Contractor's submitted contingency plan.

At the entry and exit points, there is potential for ravelling of the existing soil, fill and or weathered rock areas along the alignment. This is conventionally addressed by the use of drilling fluid. However, casing may be required. The Contractor's methods shall take into consideration the potential need to install sections of casing to manage ravelling at or near ground surface.

If a drill hole beneath the highway must be abandoned, the hole shall be backfilled with grout or bentonite to prevent future subsidence.

The Contractor shall maintain drilling fluid pressure and circulation throughout the DD 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 Fracture (Frac-Out)**

In order to reduce the potential for hydraulic fracturing of the hole during directional drilling, a minimum depth of cover of 5m is normally maintained between the pipe and the ground surface. Sections of the pipe close to the exit pit with less than 5m cover shall be cased. The Contractor shall ensure that drilling fluid pressures are properly set and controlled 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.

Since fluid loss normally occurs in fault zones, fracture zones, or seams of coarse material, fluid migration does not always gravitate to the surface, thus making detection difficult. Once a fluid loss is detected, the Contractor shall halt operations immediately and conduct a detailed examination of the drill path and implement measures to mitigate fluid loss. If no surface migration is evident, resume operation while paying particular attention to fluid monitoring.

In the event of a fluid migration to the surface occurring, the Contractor shall halt all operations immediately, isolate the migration site, and recover fluids. Once the fracture is controlled, continue drilling operations with

the operator paying particular attention to the fracture points

#### **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 exceeded.

Product shall be allowed to recover before connections to new or existing facility are made. Product recovery time shall be according to manufacturer's recommendations.

##### **7.04.06.02 Pullback and Grouting**

After successfully reaming the bore to the required diameter, the product shall be pulled through the bore path. Once the pullback operation has commenced, it shall continue without interruption until the product 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. When specified in the Contract Documents, a weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

The product 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 excavation walls shall be filled with grout.

#### **7.05 Tunnelling Installation**

##### **7.05.01 General**

The method of tunnelling shall be selected by the Contractor and shall be submitted to the Contract Administrator prior to commencement of the work for information purposes.

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 advance the ventilation system as a regular part of the normal excavation cycle.

The Contractor shall provide lighting in accordance with OHSA requirements for the entire length of the tunnel.

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.

In the event that excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation. 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 surface of the excavation shall be filled with cement grout. If an unexpanded liner is used, the space outside the liner plates shall be grouted 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.

### **7.06 Instrumentation and Monitoring**

#### **Settlement Monitoring**

The work specified in this section includes furnishing and installing instruments for monitoring of settlement and ground stability.

Surface settlement markers (SSMs) and settlement points (SPs) for monitoring ground stability shall be installed at the pavement/ground surface level as detailed in the settlement monitoring plan. Two Benchmarks (BM) shall be installed by the contractor as described in this section.

The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within 2 mm of the actual elevation.

#### **BENCHMARKS**

**Number and Locations of Benchmarks** The minimum number of Benchmarks for this crossing is two, and should be located in the field such that:

- Direct sighting is possible from all instruments to at least one Benchmark.
- Benchmarks are located in an area that will not experience ground movement as a result of the boring operations.
- Benchmarks are located in such a way to minimize interference with and damage by construction activities.
- The rod anchor elevation should be determined based on the subsurface conditions at each location and shall extend approximately 6 m into soil, or into soils having Standard Penetration Test 'N' value of greater than 50 blows per 0.3 m of penetration, whichever is less.

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#### **Materials for Benchmarks**

The contractor shall supply all materials and equipment required for the installation of the Benchmarks, as follows:

**Rod:** The contractor shall supply a steel pipe, Schedule 40, with an outside diameter not less than 25.4 mm, supplied in lengths as required to complete the installation. A rounded cap shall be installed at the top of the rod in such a way that a single survey point can be clearly identified and returned to.

**Sand:** The contractor shall supply clean, washed sand for backfilling around the friction reducing sleeve.

**Rod Anchor Grout:** The contractor shall supply cement-bentonite grout suitable for anchoring the rod at the bottom of the borehole

**Friction-Reducing Sleeve:** The contractor shall supply a friction-reducing sleeve consisting of Schedule 40 — 50.8 mm (2") outer diameter PVC pipe cut perpendicular to the axis of the pipe.

### **Installation of Benchmarks**

The Contractor shall install Benchmarks in accordance with the following:

**Borehole:** The borehole shall be advanced to the required depth using suitable drilling techniques. The diameter of the borehole shall be sufficient to fit the rod, friction-reducing sleeve and rod anchor. The sides of the borehole shall be stable and the borehole shall be free of drilling mud and debris.

**Rod:** The coupling of the rods shall be such that all sections have the same axis and no separation or contraction will occur at the couplings.

**Rod Anchor:** The rod shall be installed vertically in the borehole with its bottom end resting at the bottom of the borehole. The bottom portion of the rod shall be fixed against the surrounding native soil by grouting the bottom 300 mm of the borehole to form a concrete/soil anchor. Once grouting is completed and the rod anchor grout has set, the contractor shall pour clean sand in the lower 25 mm to 50 mm length of the borehole above the concrete/soil anchor to create a base for the end of the friction reducing sleeve to rest on. The elevation of the bottom of the rod anchor shall be determined by measuring the length of the rod to the ground surface elevation.

**Friction-Reducing Sleeve:** The friction-reducing sleeve shall be installed over the entire length of the rod above the rod anchor and sand, extending up to ground surface.

### **SURFACE SETTLEMENT MARKERS (SSM)**

The Surface Settlement Markers shall be installed on/within the pavement in a way such that they can be surveyed without the need for traffic protection.

The contractor shall install SSMs at the approximate locations shown on the Instrumentation and Monitoring plan. In general, the Surface Settlement Markers shall be located on the pavement of the highway and shall be installed to be in line with the pavement marking lines where installed within the travelled lanes in order to reduce visual distraction to drivers.

### **Materials for Surface Settlement Markers (SSM)**

The contractor shall supply all materials and equipment required for the installation of the Surface Settlement Markers, as follows:

**Hex-Head Bolt:** The contractor shall supply hardened steel hex-head bolt treated/coated to resist corrosion, with an exposed face of approximately 6 mm height. The face of the hex-head bolt shall be such that a single survey point can be clearly identified and returned to including the use of a scored line or paint marking, to eliminate the need for traffic protection, as may be required depending on the survey equipment used.

**Washer:** An appropriately sized washer shall be placed between the pavement surface and the head of the hex-head bolt, to minimize the potential for the head to be pushed into the pavement due to traffic travelling over the bolt.

**Epoxy:** The contractor shall use an appropriate high-strength, rapid-curing epoxy to secure the hex-head bolts into the asphalt or concrete pavement. The contractor shall ensure that the epoxy selected is non-expansive to ensure that the bolt is not pushed up from the hole.

### **Installation of Surface Settlement Markers (SSM)**

The contractor shall install Surface Settlement Markers at the approximate locations shown on the instrumentation and monitoring plan following the typical installation details as shown in addition to what is stated below:

The SSMs should be installed on the painted divider lines separating the driving lanes (at the approximate spacing shown on the drawings). The hex-head bolts shall be rigidly affixed so as not to move relative to the surface to which it is attached. The hex-head bolts shall be installed in a pre-drilled hole, with a washer placed on the surface of the asphalt pavement below the head of the bolt, and the assembly affixed into place using an appropriate high-strength, rapid-curing, non-expansive epoxy.

## **SETTLEMENT POINTS (SP)**

### **Materials for Settlement Points (SP)**

The Geotechnical Monitoring Consultant shall supply all materials and equipment required for the installation of the Settlement Points, as follows:

Rod: The Geotechnical Monitoring Consultant shall supply a steel pipe, Schedule 40, with an outside diameter not less than 25 mm, supplied in lengths as required to complete the installation. A rounded cap shall be installed at the top of the rod in such a way that a single survey point can be clearly identified and returned to, where required to eliminate the need for traffic protection, and as may be required depending on the survey equipment used.

Sand: The contractor shall supply clean, washed sand suitable for backfilling around the friction reducing sleeve

Rod Anchor Grout: The contractor shall supply cement-bentonite grout suitable for anchoring the rod.

Friction-Reducing Sleeve: The contractor shall supply a friction-reducing sleeve consisting of Schedule 40 — 50.8 mm (2") outer diameter PVC pipe cut perpendicular to the axis of the pipe.

### **Installation of Settlement Points (SP)**

The contractor shall install Settlement Points at the approximate locations shown on the instrumentation and monitoring plan following the typical installation details as shown in addition to what is stated below:

A borehole shall be advanced to the required depth using suitable drilling techniques. The diameter of the borehole shall be sufficient to fit the rod, friction-reducing sleeve and rod anchor. The sides of the borehole shall be stable and the borehole shall be free of drilling mud and debris.

The rod shall be installed vertically in the borehole with its bottom end resting at the bottom of the borehole. The bottom portion of the rod shall be fixed against the surrounding native soil by grouting the bottom 200 mm of the borehole to form a concrete/soil anchor. Once grouting is completed and the rod anchor grout has set, the contractor shall pour clean sand in the lower 25 mm to 50 mm length of the borehole above the concrete/soil anchor to create a base for the end of the friction reducing sleeve to rest on. The elevation of the bottom of the rod anchor shall be determined by measuring the length of the rod to the ground surface elevation.

The friction-reducing sleeve shall be installed over the entire length of the rod above the rod anchor and sand, extending up to ground surface.

### **General Conditions**

The Contractor shall install all instruments a minimum of one week prior to the start of works. The contractor shall determine if an elevated platform is required to be able to have direct siting to the benchmark(s) and the roadway/railway instruments and construct an appropriate platform for use by the surveyor.

All survey work shall be performed by a licensed OLS (Ontario Land Surveyor) and/or OLIP (Ontario Land Information Professional) registered with the Association of Ontario Land Surveyors.

The contractor shall to protect and avoid damaging instrumentation during construction. Instrumentation that is damaged as a result of the Contractor's operation shall be repaired or replaced by the Contractor within one business day. The costs for replacement/repair shall be borne by the Contractor.

At the completion of the job, the contractor shall decommission all instruments installed during the course of the work. For Benchmarks and Settlement Points, the steel rod shall be removed and the hole backfilled with fine sand up to the original ground surface. For Surface Settlement Markers, the hex head bolt shall be removed and the hole filled with a Crack Sealant, Rubberized Asphalt, Hot Poured, from an approved source on the designated source materials list.

### **Reading and Reporting Requirements**

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 recorded at the following time intervals:

- Three consecutive readings at least one week prior to commencement of the work (Baseline Reading)
- Once per shift during tunnelling operations period
- 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 within 24 hours of the reading being taken. 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.

The contractor shall submit biweekly reports to the MTO Pavements and Foundations office through the Contract Administrator during the monitoring period for information purposes. The biweekly report shall consist of a site plan showing the locations of the monitoring points, a geodetic survey of the settlement monitoring points including station, offset and elevation. The report shall also 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. The biweekly reports shall be submitted by the Contract Administrator in digital PDF format by e-mail to the MTO Foundations Section representative.

### **7.07 Criteria for Assessment of Roadway Subsidence/Heave**

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

- 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.

- 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:

- The cause of the settlement has been identified.
- The Contractor submits a corrective/preventive plan.
- Any corrective and/or preventive measure deemed necessary by the Contractor is implemented.
- 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 rigid or flexible pipe conduits installed inside the pipe liners 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/obstructions greater than an equivalent 0.3 m in diameter shall be on a time and materials basis. The Contractor shall inform the Contract Administrator when boulders/obstructions are encountered and prior to removal to allow for proper and accurate tracking of time and material charges.

**EARTH EXCAVATION FOR STRUCTURE – Item No.**

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Non-Standard Special Provision

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**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 cobbles and boulders within the fill and native clayey silt and glacial till deposit. 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.**

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Special Provision No. FOUN0003

March 8, 2018

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### **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.



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