



## Foundation Investigation and Design Report

*Sanitary Sewer Installation at Station 17+460, QEW Widening from West of Mississauga Road to West of Hurontario Street, Mississauga  
Ministry of Transportation, Ontario, GWP 2002-13-00*

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# Table of Contents

## PART A – FOUNDATION INVESTIGATION REPORT

<b>1.0 INTRODUCTION .....</b>	<b>1</b>
<b>2.0 SITE DESCRIPTION .....</b>	<b>1</b>
<b>3.0 INVESTIGATION PROCEDURES .....</b>	<b>1</b>
<b>4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS.....</b>	<b>3</b>
4.1 Regional Geology.....	3
4.2 Subsurface Conditions .....	3
4.2.1 Asphalt / Concrete Pavement .....	4
4.2.2 Fill .....	4
4.2.3 Sandy Silt to Silt and Sand .....	4
4.2.4 Silty Gravelly Sand to Clayey Silt (Till) .....	4
4.2.5 Groundwater Conditions .....	6
4.2.6 Analytical Testing Results.....	6
<b>5.0 CLOSURE .....</b>	<b>7</b>

## PART B – FOUNDATION DESIGN REPORT

<b>6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS .....</b>	<b>8</b>
6.1 Anticipated Ground Conditions Along the Proposed Sanitary Sewer .....	9
6.2 Trenchless Pipe Installations Methods – Overview .....	10
6.2.1 Jack and Bore .....	11
6.2.2 Pipe Ramming.....	11
6.2.3 Micro-Tunnel Boring Machines (MTBM) .....	12
6.2.4 Small Boring Unit (SBU) .....	12
6.2.5 Earth Pressure Balance Tunnelling Systems .....	13
6.3 Construction Considerations .....	14
6.3.1 Jack and Bore Considerations .....	14
6.3.2 Pipe Ramming Considerations .....	15
6.3.3 Microtunnelling Considerations.....	15

6.3.4	Earth Pressure Balance Microtunnelling Systems Considerations.....	16
6.4	Entry / Exit Shafts and Cut and Cover Method .....	16
6.4.1	Open Cut Excavations .....	16
6.4.2	Groundwater Control.....	17
6.4.3	Temporary Protection Systems.....	18
6.4.5	Bedding and Cover .....	20
6.4.6	Backfill .....	20
6.5	Existing Utilities .....	21
6.6	Instrumentation and Monitoring.....	21
6.7	Grouting.....	23
6.8	Analytical Testing for Construction Material.....	23
6.8.1	Potential for Sulphate Attack.....	23
6.8.2	Potential for Corrosion .....	24
<b>7.0</b>	<b>CLOSURE .....</b>	<b>25</b>

## REFERENCES

## TABLES

Table 1 Evaluation of Trenchless Crossing Alternatives for Sanitary Sewer Installation Station 17+460

## DRAWINGS

- Drawing 1 Borehole Locations Plan and Soil Strata  
Drawing 2 Settlement Monitoring Point Locations and Installation Details

## APPENDICES

### APPENDIX A Record of Borehole Sheets and Limestone Cobbles and / or Boulders Core Photograph (Borehole C5-3)

Lists of Symbols and Abbreviations  
Records of Boreholes C5-1, C5-2, C5-3 and NRW3-5

Figure A-1 Limestone Cobbles and / or Boulders Core Photograph - Borehole C5-3

### APPENDIX B Geotechnical Laboratory Test Results

- Figure B-1 Grain Size Distribution – Sandy Silt to Silt and Sand  
Figure B-2A Grain Size Distribution – Gravelly Silt and Sand to Silty Gravelly Sand (Till)  
Figure B-2B Grain Size Distribution – Clayey Silt with Sand to Clayey Silt (Till)  
Figure B-3 Grain Size Distribution – Silty Sand to Sand

Figure B-4      Plasticity Chart – Silt and Sand with slight plasticity / Clayey Silt with Sand / Sandy Clayey Silt / Clayey Silt (Till)

**APPENDIX C   Analytical Laboratory Test Results**

**APPENDIX D   Non-Standard Special Provisions and Notice to Contractor**

NSSP – Pipe Installation by Trenchless Method

NSSP – Removal of Protection Systems

SP 517F01 – Dewatering Systems

Notice to Contractor – Obstructions

# PART A

FOUNDATION INVESTIGATION REPORT  
SANITARY SEWER INSTALLATION AT STATION 17+460  
QEW WIDENING FROM WEST OF MISSISSAUGA ROAD TO WEST OF  
HURONTARIO STREET, CITY OF MISSISSAUGA  
MTO, GWP 2002-13-00



## 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (MH) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the sanitary sewer installation at Station 17+460, associated with the widening of the Queen Elizabeth Way (QEW) from west of Mississauga Road to west of Hurontario Street in the City of Mississauga, Ontario, as shown on the Key Plan on Drawing 1.

The purpose of the foundation investigation is to explore the subsurface soil, bedrock (where present) and groundwater conditions along the alignment of the proposed sanitary sewer installation by borehole drilling / rock coring and geotechnical laboratory testing and analytical chemistry laboratory testing on selected soil and rock samples.

The Terms of Reference (TOR) and the scope of work for the foundation investigation are outlined in MTO's Request for Proposal, dated July 2016, and the approved Change Request letters, which forms part of the Consultant's Assignment Number (2015-E-0033) for this project. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for this project, dated February 3, 2017.

## 2.0 SITE DESCRIPTION

The proposed sanitary sewer installation at Station 17+460 is located approximately 600 m east of the Credit River and extends from Premium Way to the south side of the QEW, in the City of Mississauga, Ontario (see Drawing 1). The QEW and Premium Way are oriented in a southwest-northeast direction which at this location and for the purpose of this report, is referred to as west-east orientation.

The QEW consists of three eastbound lanes (to Toronto) and three westbound lanes (to Hamilton), while Premium Way consists of one lane in each direction. Residential areas are located on the north side of Premium Way and between the south side of the QEW and Pinetree Way. The existing ground surface along the sanitary sewer alignment varies from about Elevation 93.5 m at the north end of the sanitary sewer alignment, to about Elevation 95.0 m on the pavement surface of the QEW (eastbound lanes), to about Elevation 90.0 m at the south end of the alignment.

## 3.0 INVESTIGATION PROCEDURES

Field work was carried out between February 19, 2019 and March 8, 2019, during which time a total of three sampled boreholes, designated as Boreholes C5-1, C5-2 and C5-3 were advanced along or adjacent to the proposed sanitary sewer alignment approximately at the locations shown on Drawing 1. This information was supplemented with Borehole NRW3-5 advanced on June 25, 2018 for the proposed Noise Barrier Wall.

Field drilling for Boreholes C5-1, C5-2 and NRW3-5 was carried out using a truck-mounted CME 55 drilling rig supplied and operated by Aardvark Drilling Inc. of Guelph, Ontario, a truck-mounted CME 75 drilling rig supplied and operated by Davis Drilling Ltd. of Milton Ontario, and a truck-mounted CME 75 drilling rig supplied and operated by Geo-Environmental Drilling Inc. of Halton Hills, Ontario. Borehole C5-3 was advanced using a Portable Tripod drilling rig with a manual hammer drive system supplied and operated by OGS Inc. from Almonte, Ontario. Boreholes C5-1, C5-2 and NRW3-5 were advanced through the overburden using 50 mm, 70 mm, and 83 mm inner diameter (I.D.) hollow-stem augers and soil samples were obtained at 0.60 m, 0.75 m and 1.5 m

intervals of depth, using a 50 mm O.D. split-spoon sampler driven by an automatic hammer in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586-11)<sup>1</sup>. Borehole C5-3 was advanced using portable drilling and a combination of wash boring techniques using 75 mm O.D. casings and coring with an approximately 55 mm O.D. core barrel to advance through the overburden soils. Samples of cobbles / boulders were obtained using the core barrel where encountered in the borehole. Soil samples were obtained in Borehole C5-3 using a 50 mm O.D. split-spoon sampler driven by a manual hammer, one third of the weight of the standard hammer used in the ASTM SPT test procedure. The boreholes were advanced to depths between 6.3 m and 11.5 m below existing ground surface in the overburden soils.

Groundwater conditions and water levels in the open boreholes were observed during and immediately following the drilling operations. A standpipe piezometer was installed in Boreholes C5-1 and C5-3 to permit monitoring of the water level at these borehole locations. The installed piezometers consist of a 32 mm or 50 mm diameter PVC pipe, with a slotted screen. The annulus surrounding the piezometer screens was backfilled with a filter sand pack. The section of borehole below the standpipe piezometers was backfilled with bentonite to the underside of the sand pack level, and the remainder of the borehole above the sand pack was backfilled with bentonite to near the ground surface and topped with cold patch asphalt or sand and gravel to match the adjacent ground surface material. All Boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903, Wells (as amended).

Field work was observed by members of Golder's engineering and technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in-situ testing operations, logged the boreholes, and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to Golder's Mississauga geotechnical laboratory where the samples underwent further visual examination and laboratory testing. All of the geotechnical laboratory tests were carried out to MTO and / or ASTM Standards, as appropriate. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected soil samples.

Selected soil samples were submitted to Maxxam Analytics (Maxxam) of Mississauga, Ontario, which is a Standards Council of Canada (SCC) accredited laboratory, for chemical analysis of a suite of characteristics that indicate corrosivity potential including pH, resistivity, conductivity, chloride content and sulphate content.

The as-drilled borehole locations and the ground surface elevations were obtained using a GPS Trimble Geo 7X, having an accuracy of approximately 0.1 m in the vertical and 0.1 m in the horizontal directions. The locations given on the Record of Borehole sheets and shown on Drawing 1 are positioned relative to MTM NAD 83 (Zone 10) CSRS CBNV6-2010.0 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations, geographic coordinates, ground surface elevations and drilled depths are summarized below.

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<sup>1</sup> ASTM D1586-11 – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of the soil.



Borehole No.	Location (MTM NAD 83 Zone 10)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (Latitude)	Easting (Longitude)		
C5-1	4,824,657.1 (43.561802)	296,188.7 (-79.606597)	93.7	9.8
C5-2	4,824,641.8 (43.561664)	296,221.4 (-79.606192)	95.0	11.1
C5-3	4,824,619.4 (43.561463)	296,238.7 (-79.605978)	89.8	6.3
NRW3-5	4,824,661.4 (43.561832)	296,190.9 (-79.606567)	93.7	11.5

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

The project area is located within the Iroquois Plain physiographic region, as delineated in *The Physiography of Southern Ontario* (Chapman and Putman, 1984)<sup>2</sup>. The glacial Iroquois Plain stretches along the northern shoreline of Lake Ontario, extending from the Niagara Escarpment in the west to the Scarborough Bluffs in the east. The Iroquois Plain soils consist of glaciolacustrine sediments deposited in Lake Iroquois, primarily sands, silts and gravels, with a shallow cover of till remaining over the bedrock. Bedrock of the Georgian Bay Formation that underlies the study area consists mainly of blue-grey shale, containing siltstone, sandstone and limestone interbeds. Outcrops of this formation are commonly found along water courses on the west side of Toronto and in Mississauga, notably in the Humber River, Mimico Creek, Etobicoke Creek and Credit River valleys.

### 4.2 Subsurface Conditions

Subsurface soil and groundwater conditions as encountered in the boreholes, the details of the piezometer installations and water level readings, and the results of the geotechnical laboratory tests carried out on selected soil samples are presented on the Records of Borehole sheets provided in Appendix A. Photographs of the cobbles and/or boulders recovered as core samples from Borehole C5-3 are presented on Figure A-1, in Appendix A. The results of the in-situ field tests (i.e., SPT “N”-values) as presented on the Record of Borehole sheets and in sub-sections of Section 4.2 are uncorrected. Lists of abbreviations and symbols and lithological and geotechnical rock description terminology are also included in Appendix A to assist in the interpretation of the borehole records. The results of the geotechnical laboratory testing on the soil samples are presented in Appendix B. The analytical laboratory test report is included in Appendix C and the test results are summarized in Section 4.2.6.

The stratigraphic boundaries shown on the Record of Borehole sheets and on the stratigraphic profile on Drawing 1 are inferred from non-continuous sampling, observations of drilling progress and the results of the Standard Penetration Tests. These boundaries, therefore, represent transitions between soil types rather than exact planes

<sup>2</sup> Chapman, L.J. and Putman, D.F., 1984, *The Physiography of Southern Ontario*, Ontario Geological Society, 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 borehole records governs any interpretation of the site conditions. It should be noted that the interpreted stratigraphy shown on Drawing 1 is a simplification of the subsurface conditions.

In general, the stratigraphy encountered at the various borehole locations typically consists of surficial layers of asphalt / concrete pavement underlain by fill, underlain by a sandy silt to silt and sand deposit, underlain by a till deposit interlayered with sandy silt to sand deposits. 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 Asphalt / Concrete Pavement**

An approximately 150 mm, 100 mm and 150 mm thick layer of asphalt pavement was encountered at ground surface in Boreholes C5-1, C5-2 and NRW3-5, respectively. A 510 mm thick layer of concrete was encountered underlying the asphalt pavement in Borehole C5-2.

#### **4.2.2 Fill**

An approximately 1.0 m to 4.3 m thick layer of fill comprised of silty sand to silt and sand to sand, trace to some gravel was encountered underlying the asphalt / concrete pavement in Boreholes C5-1, C5-2 and NRW3-5 at depths of between 0.2 m to 0.6 m below ground surface (between Elevations 94.4 m and 93.5 m) and extends to depths of between 1.2 m and 4.9 m below ground surface (between Elevations 92.5 m and 90.1 m).

The Standard Penetration Test (SPT) “N”-values within the fill layers range from 3 blows to 13 blows per 0.3 m of penetration, suggesting a very loose to compact compactness condition.

The water content measured on four samples of the fill ranges from about 3 per cent to about 25 per cent.

#### **4.2.3 Sandy Silt to Silt and Sand**

A 0.4 m to 3.4 m thick granular deposit comprised of sandy silt to silt and sand was encountered at ground surface in Borehole C5-3 and underlying the fill in Boreholes C5-1, C5-2 and NRW3-5 at depths of between about 0.0 m and 4.9 m below ground surface (between Elevations 92.5 m and 89.8 m) and extends to depths of between about 0.8 m and 5.3 m below ground surface (between Elevations 90.7 m and 89.0 m).

The SPT “N”-values within the sandy silt to sand deposit range from 2 blows to 36 blows per 0.3 m of penetration, suggesting a very loose to dense compactness condition.

Grain size distribution testing was carried out on five samples of the sandy silt to silt and sand deposit and the results are shown on Figure B-1 in Appendix B. Atterberg limits testing was carried out on one sample of the silt and sand deposit and the results indicated that the sample was non-plastic.

The water content measured on seven samples of the sandy silt to sand deposit ranges between 28 per cent and 27 per cent.

#### **4.2.4 Silty Gravelly Sand to Clayey Silt (Till)**

Underlying the granular deposit in Boreholes C5-1 to C5-3 and NRW3-5, a 5.3 m to greater than 8.5 m thick till deposit consisting of clayey silt with sand to sandy clayey silt to clayey silt, and coarser material consisting of gravelly silt and sand to silty gravelly sand was encountered at depths of between about 0.8 m and 4.6 m below ground surface (between Elevations 90.7 m and 89.0 m). Boreholes C5-1, C5-2 and NRW3-5 terminated in this till

deposit at depths of about 9.8 m, 11.1 m and 11.5 m below ground surface (Elevations 83.9 m, 83.9 m and 82.2 m), respectively. In Borehole C5-3 the till deposit extended to a depth of about 6.1 m below ground surface (Elevation 83.7 m) where it was underlain by a sand deposit of unknown thickness; Borehole C5-3 was terminated in this sand deposit.

Although the till deposit is predominately cohesive and ranges in composition from clayey silt with sand to clayey silt, there are portions that consist of gravelly silt and sand to silty gravelly sand. These granular portions of the till deposit were encountered in Borehole NRW3-5 at a depth of 8.7 m below ground surface (Elevation 85.0 m) and in Borehole C5-1 where an approximately 2.3 m thick layer of gravelly silt and sand was encountered at a depth of 4.9 m below ground surface (Elevation 88.8 m). In Borehole C5-3, which was advanced with a Portable Tripod rig and a manual hammer drive system, limestone cobbles and boulders were encountered at the following depths and elevations:

Depth Below Ground Surface (m)	Elevation (m)	Cobble and/or Boulder Thickness (mm)
2.2	87.6	300
3.7	86.1	280
4.0	85.8	230
4.9	84.9	150

Due to the presence of cobbles, the sample recovery within the till on Borehole C5-3 was limited; however, based on geotechnical laboratory testing, zone(s) of silt and sand till with slight plasticity are present within the clayey silt till. In addition, in Borehole C5-1, a 1.5 m thick interlayer of silty sand was encountered within the till at a depth of 7.2 m below ground surface (Elevation 86.5 m).

The SPT “N”-values the cohesive till deposit in Borehole C5-2 from a depth of about 5.3 m to 8.2 m (Elevations 89.7 m to 86.8 m) range from 2 blows to 9 blows per 0.3 m of penetration, suggesting a soft to stiff consistency. The SPT “N”-values within the till deposit in Boreholes C5-1, C5-2, NRW3-5 and below Elevation 86.8 m in Borehole C5-2 range from 12 blows per 0.3 m of penetration to 100 blows for 0.25 m of penetration, suggesting a stiff to hard consistency.

Grain size distribution testing was carried out on nine selected samples of the till deposit and the results are shown on Figures B-2A and B-2B in Appendix B. Grain size distribution testing was carried out on two samples of the silty sand to sand interlayers and the results are shown on Figure B-3 in Appendix B. Atterberg limits testing was carried out on the finer fraction of eight samples of the till deposit and measured liquid limits between about 14 per cent and 27 per cent, plastic limits between about 12 per cent and 21 per cent, and plasticity indices ranging between about 2 per cent and 12 per cent. These results, which are plotted on a plasticity chart on Figure B-4 in Appendix B, indicate that the finer fraction of the till deposit is comprised of clayey silt of low plasticity and silt and sand of slight plasticity.

The water content measured on sixteen samples of the till deposit range between about 7 per cent and 22 per cent.

## 4.2.5 Groundwater Conditions

Details of the water levels observed in the open boreholes at the time of drilling are presented on the Records of Boreholes in Appendix A. A standpipe piezometer was installed in Boreholes C5-1 and C5-3 to monitor the groundwater level at the borehole locations. The water levels measured in the open boreholes and the piezometers are summarized below. It should be noted that the groundwater level in the area is subject to seasonal fluctuations and precipitation events and should be expected to be higher during wet periods of the year.

Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)	Date	Comments
C5-1	93.7	7.9	85.8	February 19, 2019	Upon completion of drilling
		3.5	90.2	February 19, 2019	Within piezometer – sealed into sandy clayey silt till / Gravelly Silt and Sand / Silty Sand
		2.2	91.5	March 19, 2019	
C5-2	95.0	Dry	-	March 3, 2019	Dry upon completion of drilling
C5-3	89.8	At ground surface	89.8	March 8, 2019	Borehole advanced with wash boring, therefore water level not reflective of in-situ conditions.
		2.7	87.1	March 13, 2019	Within piezometer – sealed into Clayey Silt Till / Silt and Sand Till
NRW3-5	93.7	1.5	92.2	June 25, 2018	Upon completion of drilling

## 4.2.6 Analytical Testing Results

As noted in Section 3.0, three soil samples collected were submitted to Maxxam Analytics (Maxxam), a Standards Council of Canada (SCC) accredited laboratory, of Mississauga, Ontario, 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 D and the following table summarizes the results of the testing:

Borehole No.	Borehole NRW3-5 Sample 4 Elev. 91.1 m	Borehole C5-1 Sample 6 and 9 Elev. 90.3 and 88.2 m	Borehole C5-2 Samples 8 and 9 Elev. 88.2 m
pH	8.04	7.78	7.85
Resistivity (ohm-cm)	3,000	3,100	1,700
Electrical Conductivity (umho/cm)	337	323	578
Chlorides (ug/g)	<20*	<20*	240
Soluble Sulphates (ug/g)	240	220	130

**Notes:**

\* Lower than Reportable Detection Limit

## 5.0 CLOSURE

This report was prepared by Ms. Alex MacMillan, E.I.T., a geotechnical Engineer-In-Training with Golder and reviewed by Ms. Sandra McGaghran, M.Eng., P.Eng. an Associate and Senior Geotechnical Engineer with Golder. Mr. Paul Dittrich, Ph.D., P.Eng., an MTO Foundations Designated Contact and Principal with Golder, conducted a technical and quality control review of the report.

### Golder Associates Ltd.



Sandra McGaghran, M.Eng., P.Eng.  
*Associate, Senior Geotechnical Engineer*

A handwritten signature in blue ink, appearing to read 'Paul Dittrich', written over the seal of the second engineer.



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

ACM/DM/SMM/JPD/SJB/rb

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# PART B

**FOUNDATION DESIGN REPORT  
SANITARY SEWER INSTALLATION AT STATION 17+460  
QEW WIDENING FROM WEST OF MISSISSAUGA ROAD TO WEST OF  
HURONTARIO STREET, CITY OF MISSISSAUGA  
MTO, GWP 2002-13-00**



## 6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation engineering design recommendations for the proposed Region of Peel sanitary sewer installation (UTL-6 (SAN-1)) at approximately Station 17+460, associated with the widening of the Queen Elizabeth Way (QEW) from west of Mississauga Road to west of Hurontario Street in the City of Mississauga, Ontario (see Key Plan on Drawing 1). These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation. The discussion and recommendations presented are intended to provide the designer with sufficient information to assess the alternative / feasible trenchless and open cut installation methods and to provide the designers with sufficient information to assess the feasible protection system alternatives for the shafts. 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 based on the factual data in Part A (Foundation Investigation) of the report. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project and for which special provisions may be required in the Contract Documents. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling, and the like.

This report addresses geotechnical considerations associated with the installation of the 375 mm diameter sanitary sewer by means of a trenchless and cut-and-cover methods. The proposed alignment for the sanitary sewer, and the vertical alignment, including other pertinent features is shown in plan and profile on Drawing 1. Based on the design drawings provided by MH on January 8, 2019 and updated drawings provided on March 22, 2019, the proposed sanitary sewer construction will consist of the following major elements:

- The proposed entry shaft at Station 0+080 to 0+090 will be located within the MTO right-of-way south of the noise barrier wall located south of the existing QEW eastbound lanes (to Toronto). From the entry shaft the new sanitary sewer will connect to an existing maintenance hole. South of the QEW eastbound lanes (to Toronto) the ground surface slopes down over a distance of about 10 m to 15 m from about Elevation 95 m on the QEW to about Elevation 90 m at the proposed entry shaft.
- From entry shaft the proposed 375 mm diameter PVC pipe is to be installed by a trenchless method in a 50 m long 1200 mm diameter casing under the QEW and will connect to the proposed exit shaft at about Sta 0+030 located north of the noise barrier wall on the north side of the existing QEW westbound lanes (to Hamilton) and south of Premium Way. The proposed widening of the QEW will result in a grade raise of about 1.5 m between the north side of the QEW and the realigned Premium Way over a distance of about 20 m.
- Cut-and-cover methods will be used from approximately Sta 0+010 to Sta 0+030 (exit shaft) to connect the proposed new sanitary sewer and the existing 250 mm sanitary sewer to a new 1800 mm diameter maintenance hole located north of the existing alignment of Premium Way. It is understood that Premium Way will be realigned to the north and that the maintenance hole will be located within the realigned Premium Way.

Based on the alignment drawings provided by MH, where trenchless methods are proposed the invert of the proposed approximately 1200 mm diameter casing will vary from Elevation 88.3 m to 87.3 m and the depth of cover to the obvert of the casing will vary from approximately 5.2 m at the exit shaft to 6.0 m beneath the QEW to about 2.8 m at the entry shaft. The depth of cover used in this report is measured to the obvert of the inside

diameter of the tunnel crossing (approximately 1200 mm diameter), as shown on the latest design drawings provided by MH; however, depending on the final equipment selected for construction and thickness of casing pipe the depth of cover to the top of the trenchless / tunnel cut may be different and should be evaluated again once additional information becomes available as to the trenchless method and casing size ultimately chosen by the contractor.

The invert of the proposed sanitary sewer for the portion installed using cut-and-cover methods will be at about Elevation 88.5 m (between approximately 5 m depth below ground surface). The proposed shaft locations are shown on Drawing 1 and the base of the proposed exit and entry shaft will be at a depth of about 7.1 m and 3.3 m below ground surface (Elevation 87.4 m and 86.7 m), respectively.

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 November 2018, a copy of which is included in Appendix D; and has been modified by recommendations provided in this report. It is assumed that the work will be carried out by an experienced specialist contractor employing only qualified workers skilled in their trade. 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.

## 6.1 Anticipated Ground Conditions Along the Proposed Sanitary Sewer

Based on the subsurface data, the subsurface conditions along within the proposed tunnel alignment will consist of a heterogeneous glacial till with proportions (by weight) of fine-grained silt and clay varying from 20 to more than 80 per cent with no clear stratigraphic pattern to the fines content variability. During drilling of Borehole NRW3-5 (near the exit shaft) the augers were grinding within the till deposit, which is indicative of the potential for cobble nests / boulders. Limestone cobbles (up to 300 mm thickness) were cored within the till deposit at a Borehole C5-3, advanced near the proposed entry shaft. Groundwater levels measured in the standpipe piezometers installed within Boreholes C5-1 and C5-3 were at depths of 2.2 and 2.7 m below ground surface (at Elevation 91.5 m and 87.1 m), respectively, which is generally about 2.0 m above the invert of the tunnel (casing).

The behaviour of the anticipated subsurface materials can be classified using Terzaghi's Tunnelman's Ground Classification system as modified by Heuer (1974). The behaviour of the materials anticipated to be present within the tunnel alignment is summarized in the table below.

Material	Tunnelman's Ground Classification	
	Above Groundwater Level	Below Groundwater Level
Sandy silt to silt and sand	Running	Cohesive-Running to Flowing
Glacial Till (clayey silt with sand to clayey silt)	Firm to Slow Ravelling	Fast Ravelling
Glacial Till (gravelly silt and sand)	Cohesive Running to Running	Cohesive-Running to Flowing

In the absence of dewatering, the sandy silt to silt and sand, and granular zones within the glacial till deposits will flow in an unsupported excavation. The cohesive glacial till deposits should 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 and will be degraded by underlying layers or zones of glacial till that are primarily granular and saturated. The stand-up time of this material will likely be variable and unpredictable. Further, the upper one to two metres of the glacial till that are within the planned vertical tunnel alignment appears to have either been deposited as a glacial "mud" or weathered and softened. Where these soils are relatively soft, they will tend to squeeze, similar to the overlying silty clay/clayey silt layers.

Cobbles and boulders were encountered in the clayey silt till in Borehole C5-3 and inferred based on grinding of the augers in Borehole NRW3-5. "Nests" or groups of boulders should also be anticipated within the glacial till deposits given the prevalence of such indications during drilling.

The Contract Documents should contain an NSSP warning the contractor of obstructions within the glacial till and the difficulties associated with tunneling along the interface between soils of differing behaviour / stand-up time such as within the dense saturated sandy silt and the variable consistency and gradation of the glacial till deposits (ranging from firm to stiff to hard and ranging from cohesive to granular). An NSSP is provided in Appendix D for inclusion in the Contract Documents.

## 6.2 Trenchless Pipe Installations Methods – Overview

The contractor will be responsible for choosing the method and equipment for sanitary sewer installation 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 trenchless 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 of this report (i.e., Foundation Investigation Report).

Based on the information provided by MH, it is understood that it is preferable that the sanitary sewer be installed under the QEW using trenchless methods to reduce the potential effects of construction on traffic flow. The following trenchless methods have been considered for this site:

- conventional "jack and bore";
- pipe ramming;
- microtunnelling with a micro-tunnel boring machine (MTBM);

- pipe jacking using a small boring unit cutting head;
- earth pressure balance machine (EPB); and,
- horizontal directional drilling (HDD).

The selected method must be able to install the casing pipe as the tunnel advances to reduce the risk of ground losses and settlement around the tunnel excavation.

### 6.2.1 Jack and Bore

Conventional “jack and bore” is a method of forming a near-horizontal bore from a jacking / drive (i.e., entry) pit; using a continuous welded casing jacked into the ground and 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 helical auger flights. Either the steel casing can form the final pipe or separate 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 clays) and, in some cases moist but unsaturated granular soils that are well-graded (i.e., broadly graded) with sufficient silt and clay size particles to assist with maintaining stability. Jack and bore methods can; however, 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.

### 6.2.2 Pipe Ramming

Pipe ramming involves the use of a pneumatic 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 section 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 water levels. 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 or mixed-face conditions 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.

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

Microtunnelling is a method of installing pipes 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 anticipated site soils. Properly selected rock cutter discs should be used to cut any 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.

### 6.2.4 Small Boring Unit (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, construction 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 use of this method.

### 6.2.5 Earth Pressure Balance Tunnelling Systems

Earth pressure balance (EPB) tunnelling machines range in diameter between about 1.2 m to well over 2 m and can accomplish drive lengths of as much as 1,000 m under the right conditions for the larger diameters using intermediate pipe jacking stations and single-pass or two-pass lining methods. These systems rely on using a mix of the soil cuttings and groundwater within a closed chamber at the lead end of the machine to support the face of the ground as it is cut. The cuttings are removed under controlled rates from the forward chamber using either a screw conveyor (auger) or pressure-relieving “gates”/“doors” and the cuttings are transported to the surface using either a conveyor bucket system or small rail car system. These machines can be fitted with a wide range of face tools for cutting different materials and are used in a wide variety of ground conditions. Some of the older, small diameter EPB tunnelling machines that use relieving gates for control of face pressures and discharge of cuttings can pass larger materials including some cobbles and boulders, depending on the relative size of the stones and openings through the machine. However, EPB systems are not as suited for dry or flowing granular soils as the slurry MTBM. Those machines equipped with screw augers for pressure and cuttings discharge control are also not as capable of passing cobbles and boulders as older machines with the pressure relieving gates. Depending on the soil types, additional water, bentonite, polymers, or foaming agents may be required to achieve the proper soil consistency for maintaining productivity and settlement control. As with other systems the EPB system bores a slightly larger diameter hole as compared to the pipe or liner (annular gap). With some systems, bentonite slurry is injected into the annular gap to lubricate the pipe and reduce jacking forces as well as control settlement. Earth pressure balance tunnelling systems can control horizontal and vertical alignment similarly to slurry MTBM systems.

The term “earth pressure balance” is sometimes used to describe microtunnelling systems and should be interpreted with caution. Some manufacturers and operators promote that the pressure exerted by the steel components of a rotating and open cutting head or the lead augers on an auger boring system provide earth pressure balance. However, such systems do not control the ground through true balancing of earth pressures over the entire cut face and do not represent true EPB systems.

### 6.2.6 Horizontal/Directional Drilling (HDD)

Typically, HDD is used for relatively small diameter crossings below roadways, embankments or rivers, where the installed pipe will be conveying fluid under pressure and is therefore not dependent on gravity drainage. Often, HDD requires a long entrance / exit bore curvature to achieve the required vertical alignment at the ends of the crossing (i.e., at tie-ins to existing sanitary sewers) and may require a greater thickness of cover as compared to other systems to reduce the risk of hydraulic fracturing of the ground and loss of drilling fluid to the surface (“frac-



out”). In general, HDD is not suitable for installing relatively large diameter (e.g., 0.5 m to 1 m or more) steel carrier casings when these are required to reduce the risk of pipeline failures causing losses of ground that could jeopardize overlying highways. Therefore, the HDD method is not considered further within this report.

## 6.3 Construction Considerations

Trenchless construction methods described in Section 6.2, 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. From a geotechnical perspective the preferred alternative is to use a micro-tunnelling boring machine for the trenchless installation portion of the proposed sanitary sewer as it is able to provide appropriate alignment control, ground support, management of cuttings, and pressure to the face of the tunnel in order to minimize groundwater control and ground loss concerns. The methods, construction recommendations and limitations for Jack and Bore, pipe ramming, micro-tunnelling using a MTBM and earth pressure balance machine are discussed in the following sections.

### 6.3.1 Jack and Bore Considerations

“Jack and bore” operations can sometimes be carried out below groundwater levels in soils that have high fines (silt and clay) content and exhibit suitable “stand-up” time; however, under such conditions the specifications typically require that a plug of spoil material remain in the lead end of the casing at all times. When possible, 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. At this site, the tunnel is expected to pass through ground that includes saturated granular soils that will likely exhibit flowing behaviour. Traditional jack and bore systems are incapable of appropriately managing such conditions and could readily lead to excess ground losses and sinkholes, regardless of whether attempts are made to create or maintain a “plug” of soil within the lead end of the casing.

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 plug can be developed). Depending on the soil conditions at the location of the obstructions, this may also result in loss of ground at the face and settlement at the ground surface. The compact to very dense gravelly silt and sand till deposit and generally stiff to hard cohesive till deposit, 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 conditions this may be acceptable, this practice could lead to excessive ground losses when saturated granular / non-cohesive soils are encountered. Further, difficulties may also be encountered in maintaining alignment control of the tunnel as it advances due to the presence of cobbles / boulders, stiffer soils ahead of the face or mixed face conditions. Cobbles and boulders are anticipated to be relatively prevalent in the glacial till soils at this site and cutting through and removing cobbles and boulders can be problematic for traditional jack and bore systems, especially if there are more concentrated groups of cobbles and boulders. In this case, contingency planning for ground loss events would need to include highway closure to protect the travelling public. At this site, dewatering will be required at the exit pit location to appropriately control groundwater and ground stability throughout construction. Given the various risks that could produce excessive ground losses beneath the highway, conventional “jack and bore” systems should not be used for this project.

### 6.3.2 Pipe Ramming Considerations

The feasibility of pipe ramming is marginal at the sanitary sewer crossing location where firm to hard clayey silt with sand, compact to dense gravelly silt and sand till with saturated sandy silt within a portion of the tunnel and above the obvert were encountered within the tunnel horizon. Significant resistance to pipe advance can be expected and will increase as the pipe is advanced. To facilitate ramming long pipes, the casing may include a larger diameter leading edge (overcut) and 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. Similar to Jack and Bore, the pipe ramming installation are suitable for lengths typically up to about 45 m to 50 m, depending on site conditions and local contractor capabilities. At this site where the bore length is about 50 m, a central shaft may be used to allow for completion of such pipe lengths in two sections, a central shaft at this site is likely not practical or possible given the likely interference with traffic flow that a central shaft could create. As with the jack and bore method, tunnel alignment may be difficult to control due to the presence of cobbles / boulders, and mixed face conditions. If cobbles / boulders are encountered to a degree that inhibits ramming, the typical manner of clearing the obstruction would be to remove soils from within the casing, allowing access for equipment to break up the obstructions. However, cleaning out the spoils from inside the casing will likely result in the loss of ground at the face of the casing particularly if the face of the tunnel is within the saturated sand silt soils. For these reasons, pipe ramming is not considered suitable at this site.

### 6.3.3 Microtunnelling Considerations

Microtunnelling 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, which are anticipated at this site. To minimize the risk of “frac-out” slurry microtunnelling should not be used for tunnelling construction if the cover is less than 2.5 m. 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 and 70 seconds.

Slurry MTBMs do not require that the groundwater level in granular soils be lowered, which is an advantage for this site where compact to very dense saturated gravelly silt and sand till deposit and compact to dense saturated sandy silt deposit will likely be encountered. Often MTBMs can also be equipped to cut boulders that may be encountered along the proposed tunnel alignments. For tunnelling in the anticipated ground conditions on this crossing, it may be appropriate that the MTBMs be equipped with rock disc 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 and should not be solely relied upon for cutting rock for this crossing. Disc cutting tools may, however, also become plugged with the firm glacial till soils. The contractor should evaluate the capabilities of their particular equipment in light of these competing risks when choosing face tool configurations and the associated performance risks. .

Similar to the other trenchless methods, entry and exit shafts are required for microtunnelling operations. Dewatering will be required at the exit shaft and may be required at the entry shaft to appropriately control groundwater, depending on the type of shaft used for access. Some local contractors have adapted “shaft sinking”

methods that effectively eliminate the need for dewatering. Dewatering recommendations are provided in Section 6.4.2 of this report.

### 6.3.4 Earth Pressure Balance Microtunnelling Systems Considerations

Similar to slurry microtunnelling, earth pressure balance machines rely on using a mix of the soil cuttings and groundwater within a closed chamber at the lead end of the machine to support the face of the ground as it is cut. The soil within the alignment of the tunnel is anticipated to consist predominately of clayey silt with sand till; however, towards the exit shaft the face conditions are anticipated to consist of compact to dense saturated sandy silt in upper portion of the tunnel and gravelly silt and sand till near the invert. Foaming agents, bentonite or polymers will likely be required to achieve the proper soil consistency for maintaining productivity and settlement control. The machine can be equipped with face tools for breaking down cobbles and boulders; however, although the earth pressure balance machine permits person-entry (for the larger diameters in the order of 1.5 m), dewatering ahead of the face would be required prior to entering the chamber due to the presence of the overlying sandy silt and gravelly silt and sand till below the groundwater level and installation of dewatering wells within the QEW highway is not practical. Earth pressure balance systems are also susceptible to excess excavation (i.e., ground losses) when tunnelling through a face that consists of materials with very different behaviours such as saturated granular soils overlying cohesive soils as expected towards the exit shaft. In such conditions, it is difficult to control the propensity for the more fluid-like soils to enter the face of the machine faster than the machine can excavate the harder materials below. For these reasons earth pressure balance machine is not the preferred tunnelling method for the installation of the proposed sanitary sewer beneath the QEW.

## 6.4 Entry / Exit Shafts and Cut and Cover Method

Open cut construction involves trench excavation and excavation sidewall support, bedding and pipe installation, trench backfilling and pavement restoration. The cut-and-cover method offers the best control of horizontal and vertical alignment, reduces the potential for delays resulting from encountering obstructions.

The proposed invert of the sanitary sewer is at about 2.5 m below ground surface (at the entry shaft only) between about 6.2 m and 7.2 m below ground surface along the portion under the QEW and depending on construction staging, the sanitary sewer could be installed using cut-and-cover methods. The major disadvantages with cut-and-cover installation include the requirement for complex construction staging to minimize traffic disruption, the need for relatively deep excavations at some locations, groundwater control systems where excavation will extend below groundwater levels, and the potential for post construction settlement of the backfill materials especially in areas requiring deep trenches. Furthermore, stacked trench box systems for excavation support do not provide for intimate contact with the excavation sidewalls leading to loss of lateral stability and ground movement, and further can be problematic / impractical as temporarily stable unsupported vertical trench sidewalls cannot be maintained due to “firm” to “slow ravelling” of the cohesive deposit, the “cohesive running” to “flowing” of the saturated sandy silt deposit and gravelly silt and sand till deposit.

### 6.4.1 Open Cut Excavations

Based on the design drawings cut-and-cover construction methods are planned for two sections of the sanitary sewer installation, from Maintenance Hole 8 to the proposed exit shaft (approximately Sta. 0+010 to Sta. 0+023 - about 13 m in length) and from the entry shaft to connect to the existing 375 mm sanitary sewer at Maintenance Hole 4 (approximately Sta. 0+090 to Sta. 0+097 – about 7 m in length). Based on the drawings received from MH, the entry and exit shafts are proposed to be constructed at the following locations:

- Entry shaft located at about Station 0+080 to 0+090 in the wooded area south of the noise barrier wall and QEW eastbound lanes (to Toronto); and,
- Exit shaft located at about Station 0+020 to 0+030, in the area north of the existing noise barrier wall located north of the QEW westbound lanes (to Hamilton).

Based on the most recent design drawings provided by MH on March 22, 2019, the tunnel invert will be about between about 6.2 m and 7.2 m and the cut-and-cover portion north of the exit shaft will be about 5.0 m below ground surface and at the entry shaft about 2.5 m below ground surface. Due to space constraints and the anticipated subsurface conditions encountered in the boreholes advanced adjacent to the alignment, temporary protection systems will be required for these two sections of the open cut alignment.

Excavations for the entry shaft and the cut-and-cover section south of the entry shaft will extend through very loose saturated silt and sand and into stiff to very stiff clayey silt till. Limestone cobbles were encountered Borehole C5-3, in the vicinity of the entry shaft and Maintenance Hole 4. Excavations for the exit shaft and the cut-and-cover section north of the exit shaft will extend through fill material consisting of loose to compact silty sand to sand, underlain by compact to dense saturated sandy silt and into stiff to hard clayey silt till with sand and compact to very dense gravelly silt and sand till deposits.

All temporary and permanent excavations, including trenches and shafts should be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act and Regulations (OHSA), with local regulations and as outlined in Ontario Provincial Standard Specification (OPSS) 402 (*Excavating, Backfilling, and Compacting for Maintenance Holes, Catch Basins, Ditch Inlets and Valve Chambers*), OPSS 407 (*Maintenance Hole, Catch Basin, Ditch Inlet and Valve Chamber Installation*) and OPSS.PROV 410 (*Pipe Sewer Installation in Open Cut*). The loose to compact granular fill materials and compact to dense silty sand, above the groundwater level would likely be categorized as Type 3 soils and temporary excavations (i.e., those which are open for a relatively short time period) above groundwater levels should be made with side slopes no steeper than 1 horizontal to 1 vertical (1H:1V). The clayey silt with sand till and gravelly silt and sand till deposits would likely be categorized as Type 3 soils above and below the groundwater level and temporary excavations (i.e., those which are open for a relatively short time period) above groundwater levels should be made with side slopes no steeper than 1 horizontal to 1 vertical (1H:1V). Appropriately dewatered compact to dense granular soils would likely be categorized as Type 2 and 3 soils and temporary excavations should be made with side slopes no steeper than 1 horizontal to 1 vertical (1H:1V). Saturated granular soils below groundwater levels will be inherently unstable if they are not properly dewatered in advance of excavation and likely categorized as Type 4 soils, and temporary excavations (i.e., those which are open for a relatively short time period) should be made with side slopes no steeper than 3 horizontal to 1 vertical (3H:1V). All soil OHSA type categories should be reviewed in the field in conjunction with the contractor's operations before a final soil type categorization can be determined. 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. Excavated material must be stockpiled at a distance away from the excavation equal to or greater than the depth of the open cut excavation.

#### 6.4.2 Groundwater Control

Groundwater levels measured in the standpipe piezometers were at between about Elevation 91.5 m (north of the QEW) to Elevation 87.1 m (south of the QEW) and excavations are expected to extend about 4.1 m below the groundwater level at the exit shaft and open cut area to the north. At the entry shaft and open cut area to the

south, excavations are expected to extend about 0.5 m below the groundwater level. Dewatering will be required for the exist shaft and the cut-and-cover sections adjacent to the exit shaft. The groundwater level should be lowered to at least 0.5 m below the base of the exit shaft and 0.5 m below the underside of the cut-and-cover excavations. Groundwater control using sumps may be adequate if the groundwater is encountered solely within the clayey silt till deposit and where the thickness of cohesive soils below the base of the excavation is at least twice the depth of excavation below groundwater levels. Use of sumps will not be adequate where excavations penetrate below the granular deposits or granular interlayers within the clayey silt till as encountered in Boreholes NRW3-5 and C5-1 on the north end of the proposed sanitary sewer alignment. Further, where excavations are expected to terminate within the glacial till, water pressure control may be required to achieve an appropriate factor of safety against hydraulic uplift failure of the excavation base. In these cases, it is expected that a combination of well points, eductors and pressure relief will likely be necessary.

Dewatering should be carried out in accordance with OPSS.PROV 517 (*Construction Specification for Dewatering*) and SP517F01 (*Dewatering System*); it is recommended that the requirement for a dewatering design engineer be specified and that an inspection radius of 50 m be used in Table A contained in SP517F01. Construction water takings in excess of 50 m<sup>3</sup>/day are regulated by the Ministry of the Environment, Conservation and Parks (MECP). Certain takings of groundwater and stormwater for construction dewatering purposes with a combined total less than 400 m<sup>3</sup>/day qualify for self-registration on the MECP's Environmental Activity and Sector Registry (EASR). Registry on the EASR replaces the need to obtain a PTTW for water taking less than 400 m<sup>3</sup>/day and a Section 53 approval for discharge of water to the environment. A "Water Taking Plan" and a "Discharge Plan" are required by the MECP if water is taken in accordance with an EASR. In all cases, discharge under the EASR must be in accordance with a Discharge Plan. A Category 3 PTTW would be required for water takings in excess of 400 m<sup>3</sup>/day. The construction water taking permit and registration should be prepared adequately in advance of site excavation works so as not to unduly affect the construction schedule.

### 6.4.3 Temporary Protection Systems

Where the side slopes of cut-and-cover excavations are required to be steepened to limit the extent of the excavation, then some form of trench support will be required. The cut-and-cover and shaft excavations could be carried out using a vertically unsupported (using a properly engineered prefabricated support system for personnel protection, certified by an experienced engineer) in open areas which can tolerate lateral movement of the soil deposits; or by a supported excavation (discussed below) if in close proximity to adjacent structures or underground services where restriction of lateral movements is required. It must be emphasized that a prefabricate support system (trench liner box) provides protection for construction personnel but does not provide any lateral support for adjacent excavation walls, underground services or existing structures. It is imperative that underground services and existing structures adjacent to the trench and shaft excavations be accurately located prior to construction and adequate support provided where required. Steepened excavations should be left open for as short a duration as possible and completely backfilled at the end of each working day.

The shafts could be constructed using soldier piles and lagging, a slide rail system, a contiguous reinforced concrete cast-in-place secant pile wall provided that groundwater control systems are fully operational and demonstrated to be effective prior to excavation, including prior to installing lagging or below the edge of the slide rail panels if such a system is adopted. Due to the presence of hard / very dense till as well as the presence of cobbles and boulders, it is expected to be difficult to install sheet piles to the degree that sheet pile systems are not considered practical for this construction. 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 is not recommended. Depending on the experience and expertise of the contractor, sunken caisson shafts may also be utilized to reduce the need for dewatering.

The temporary excavation support system should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*) as amended by SP 105S09. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS.PROV 539 (*Temporary Protection Systems*) as amended by SP 105S09. The design of 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 corner bracing and wales or rakers, the wall design should be based on conventional active and passive earth pressure distributions using the design parameters given below as well as applicable groundwater pressures. The internal bracing or raker supports must be designed to accommodate the loads applied from earth pressures, water 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. In the event that circular shaft support systems are planned, the lateral earth pressure coefficients provided below will require modification and Golder should be provided the opportunity to address such designs accordingly.

Soil Type	Unit Weight (kN/m <sup>3</sup> )	Internal Angle of Friction (Degrees)	Undrained Shear Strength (kPa)	Coefficient of Lateral Earth Pressure		
				Active, Ka	At Rest, Ko	Passive, Kp
Existing Silty Sand (Fill)	19	30		0.33	0.50	3.0
Compact to dense sandy silt to silt and sand	20	30		0.33	0.50	3.0
Stiff to hard Clayey Silt with Gravel to clayey silt (Till)	21	32		0.31	0.47	3.25
Compact to very dense gravelly silt and sand (Till)	21	34		0.28	0.44	3.54

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 Kp 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.



For all shaft excavations with groundwater seepage, the formation of ice on the shaft walls should be expected during the winter months. The accumulation of ice on the walls should be closely monitored and periodic removal will be required to prevent ice from falling into the excavation and endangering workers in the shaft.

Consideration could be given to either partial or full removal of the protection system upon completion of construction or each stage of construction (as required). Where possible, full removal of the protection system should be considered to mitigate potential impediments to future rehabilitation/reconstruction work on the highway. An NSSP is included in Appendix D which addressed the removal or cut-off of the protection system.

#### 6.4.4 Pipe Bedding, Cover and Trench Backfill

The bedding, cover, and backfill for the concrete storm sewer pipe should be compatible with the type and class of pipe, the surrounding subsoil conditions and anticipated loading conditions and should be designed in accordance with OPSD 802 (*Rigid Pipe Bedding, Cover, and Backfill*), as presented in OPSD 802.030 and 802.031, for construction in Type 2 soil and Type 3 soil, respectively, adopting Class B bedding.

#### 6.4.5 Bedding and Cover

The bedding and cover material should consist of the material as specified in OPSS.PROV 401 (*Trenching, Backfilling, and Compacting*). Clear stone should not be used as bedding or cover material. Bedding shall consist of OPSS.PROV1010 (*Aggregates*) Granular 'A' or OPSS 1359, unshrinkable fill. All bedding and cover material should be placed in loose lifts and uniformly compacted to at least 98 per cent of the material's Standard Proctor Maximum Dry Density (SPMDD), in accordance with OPSS.PROV 501 (*Compacting*), as amended by SP 105S22.

#### 6.4.6 Backfill

Native site soils or excavated cohesive and non-cohesive fills may be used for trench backfill, provided they are free of topsoil, organic material or other deleterious materials. If water contents of the site soils at the time of construction are too high, or if there is a shortage of suitable in-situ material, then an approved imported material which meets the requirements for OPSS.PROV 1010 (*Aggregates*) Select Subgrade Material (SSM) or Granular B" Type I could be used. It should be placed and compacted as indicated above for granular materials and to 95 per cent of the materials SPMDD for native soils/excavated fills. Backfilling operations during cold weather should avoid inclusions of frozen lumps of material, snow and ice, and backfilling with fine grained (i.e. silts and/or clays) materials should not be undertaken.

Settlement of the compacted trench backfill should be anticipated, and the majority of such settlement should take place within about 6 months following the completion of trench backfilling operations. This settlement will be reflected at the ground surface and may be compensated for, where necessary, by placing additional granular material as required. Alternatively, if the asphalt binder course is placed shortly following the completion of trench backfilling operations in these areas, any settlement that may be reflected by subsidence of the surface of the binder asphalt should be compensated for by placing an additional thickness of binder asphalt or by padding.

The design frost depth in the area is estimated to be 1.2 m below ground surface, as interpreted from OPSD 3090.101 (*Frost Penetration Depths for Southern Ontario*). To avoid undue differential movements or settlement of ground surface adjacent to and over the trench, the general backfill materials should match, as practically as possible, to the native or fill material exposed in the trench walls, or granular materials should be used as backfill as it will undergo most of the settlement during construction. Backfill within the zone of frost

penetration below the bedrock surface should consist of non-frost susceptible material such as OPSS.PROV 1010 (*Aggregates*) Granular “A” or Granular “B” Type 1.

## 6.5 Existing Utilities

Within the section of the sanitary sewer to be installed using trenchless methods, the plan portion of the design drawings provided by MH indicate that there is an existing 375 mm diameter sanitary sewer within a 4800 mm diameter tunnel that is about 9 m west of and parallel to the proposed sanitary sewer and extends under the QEW. The vertical alignment of the existing sanitary sewer under the QEW is not shown in profile on the MH drawings; however, based on the invert shown south of the proposed entry shaft it is assumed that the invert of the existing sanitary sewer is at about the same elevation of the proposed sanitary sewer. It is recommended that an utility monitoring point above the top of the existing sanitary sewer to confirm that the existing sanitary sewer does not experience undue distress.

## 6.6 Instrumentation and Monitoring

In accordance with MTO's Guidelines for Foundation Engineering-Tunnelling Specialty for Corridor Encroachment Permit Application, dated April 3, 2008 and NSSP Pipe Installation by Trenchless Method, and it is recommended that provisions for settlement monitoring should be made in the Contract Documents for monitoring the response of the highway prior to, during and after the sanitary sewer installation to:

- document the effects of the sanitary sewer 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 sanitary sewer 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 are shown on Drawing 2; and details and general specifications pertaining to the monitoring points are also presented on the drawing.

Monitoring of settlement instruments on this project is constrained by the continuous and high traffic volume along the QEW and the limited periods during which access to the highway can be obtained. By necessity, settlement points on the surface of the highway must be read remotely and the use of reflectorless precision surveying methods are recommended. A specialist surveying firm should be retained by the Contractor to confirm the set-up and to carry out the settlement monitoring pre-construction baseline, during construction and post construction; their equipment and procedures must be capable of surveying the settlement point elevation with sufficient accuracy and precision to meet a repeatability of  $\pm 2$  mm of the actual elevation. In general, the owner should also survey the monitoring points to an equivalent repeatability as an independent confirmation of the baseline and monitoring data at a surveying frequency decided upon by the owner.

In addition, in-ground settlement points, consisting of sleeved reinforcing steel bars, set at just below frost depth along the crossing centreline and one instrument on either side of the alignment at readily accessible locations (e.g., highway shoulders) should also be installed. The elevation of the top of the bar would be read using conventional precision levelling equipment and this would require lane closure and traffic protection. Alternatively,

a vertical extensometer (with wireless readout) could be installed on the north and south shoulder and in the median or a shape-accelerometer could be installed at a depth of about 1.2 m below QEW surface. 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.

In addition, it is recommended that two deep settlement points consisting of sleeved iron bars, set not closer than 1.0 m above the tunnel obvert elevation, be installed between the entry shaft and the QEW and between the exit shaft and the QEW. The elevation of the top of the bar would be read using conventional precision levelling equipment. The deep settlement points provide an indication of the settlement of the soil just above the obvert of the tunnel. It is recommended to install an utility monitoring point above the existing 375 mm diameter storm sewer to confirm that the existing storm sewer does not experience undue distress.

All monitoring points should be read at least three times (on separate days) before the start of the sanitary sewer installation 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. For in-ground settlement points on the QEW the frequency of the readings could be reduced to a reading at the start and end of the permitted closure window. 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.

Plotting and interpretation of the survey results for the purposes of controlling construction should be by the Contractor with interpretation of data for the purposes of monitoring contract compliance by the owner's representative. Surveying data prepared by all parties should be provided to the owner's representative within 24 hours (or sooner) for comparison against settlement tolerances identified above. If the Review / Alert Level is exceeded, the surveying frequency and communication of results should be altered to provide data to the owner every two hours.

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", and NSSP Pipe Installation by Trenchless Method and should be established as part of the Contract Administration for construction.

Where sections of concrete pavement exist, 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 tunnelled / 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.

## 6.7 Grouting

All voids between the primary lining and the wall of the excavated tunnel shall be filled with cement grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground. This requirement is included in the NSSP for "Pipe Installation by Trenchless Method", see 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.

After the permanent sanitary sewer pipe is installed within the casing, post installation grouting to fill the annular space between the pipes may be carried out as noted in the NSSP for "Pipe Installation by Trenchless Method", included in Appendix D.

## 6.8 Analytical Testing for Construction Material

Soil corrosivity may affect the concrete pipes, steel pipes and reinforced steel and other concrete elements buried in the soil. Generally, the corrosivity of a structure depends on the soil resistivity, hydrogen ion concentration, salts (chloride and sulphate) concentrations and redox potential. The results of analytical test on two soil samples from Boreholes C5-1, C5-2 and NRW3-5 are summarized in Section 4.2.6 and the analytical testing reports are presented in Appendix C. The potential for sulphate attack and corrosion are discussed in the following sub-sections. However, it is ultimately up to the designer to determine the appropriate construction materials, including the exposure class and ensuring that all aspects of CSA A23.1-14 Section 4.1.1 "Durability Requirements" are followed when designing concrete elements.

### 6.8.1 Potential for Sulphate Attack

The analytical test results were compared to CSA A23.1 14 Table 3 ("Additional requirements for concrete subjected to sulphate attack") for the potential sulphate attack on concrete. The sulphate concentrations measured in all samples of the native soils range from less than 0.024 per cent to about 0.013 per cent, which are below the exposure class of "S-3" (Moderate - 0.1 – 0.2 per cent) and the sulphate concentrations are considered negligible according to the Gravity Pipe Design Guidelines Table 7.2 (MTO, 2014). Therefore, based on the samples tested, when the designer is selecting the exposure class for the structure, the effects of sulphates from within the native soil deposits around the tunnel alignment may not need to be considered.

### 6.8.2 Potential for Corrosion

Based on the test results from the soil sample and bedrock core sample the pH ranges from about 7.8 to 8.0 and the resistivity ranges from 1,700 to 3,100 ohm-cm. According to the MTO Gravity Pipe Design Guidelines (2014), the pH is not considered detrimental to pipe durability. The soil corrosiveness is generally moderate ( $2,000 \text{ ohm-cm} < R < 4,500 \text{ ohm-cm}$ ) to severe ( $R < 2,000 \text{ ohm-cm}$ ), as per Table 3.2 of the MTO Gravity Pipe Design Guidelines (2014). As the sanitary sewer will be located under the roadway / highway shoulders and will be exposed to de-icing salt, concrete should be designed for a "C" type exposure class as defined by CSA A23.1-14 Table 1. The sanitary sewer should be designed with consideration given to Table 7.1 of the MTO Gravity Pipe Design Guidelines (2014).

## 7.0 CLOSURE

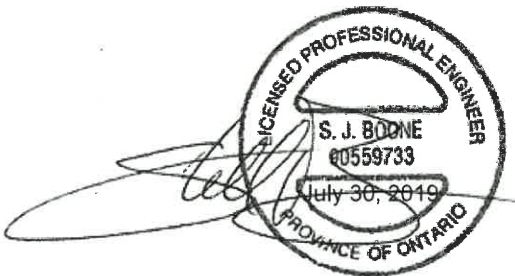
This report was prepared by Mr. David Marmor, E.I.T., a geotechnical engineer-in-training with Golder and reviewed by Ms. Sandra McGaghran, M.Eng., P.Eng., an Associate and senior geotechnical engineer with Golder. Mr. Storer Boone, Ph.D., P.Eng., a Principal with Golder and MTO's RAQS recognized specialist for high complexity tunnelling assignments, reviewed the report.

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DM/SMM/SJB/rb

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## 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.

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.

### Ontario Provincial Standard Drawings:

OPSD 802.030	Rigid Pipe Bedding, Cover and Backfill, Type 1 or 2 Soil – Earth Excavation
OPSD 802.031	Rigid Pipe Bedding, Cover and Backfill, Type 3 Soil – Earth Excavation
OPSD 3090.101	Foundation Frost Penetration Depth for Southern Ontario

### Ontario Provincial Standard Specifications (OPSS)

OPSS 402	Excavating, Backfilling, and Compacting for Maintenance Holes, Catch Basins, Ditch Inlets and Valve Chambers
OPSS 407	Maintenance Hole, Catch Basin, Ditch Inlet and Valve Chamber Installation
OPSS.PROV 410	Pipe Sewer Installation in Open Cut
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

### Special Provision (SP)

SP 517F01	Dewatering Systems
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### ASTM International:

ASTM D1586	Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
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### Ontario Water Resources Act:

Ontario Regulation 903	Wells (as amended)
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### Ontario Occupational Health and Safety Act:

Ontario Regulation 213	Construction Projects (as amended)
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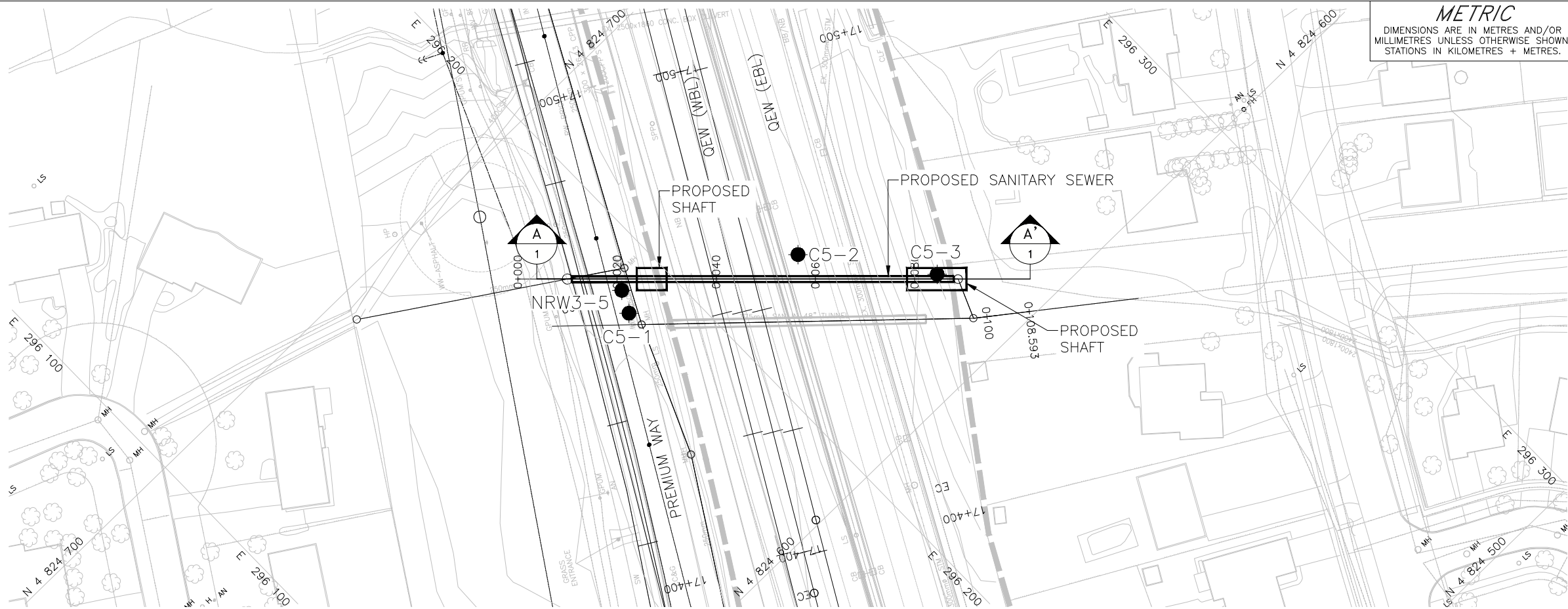
**TABLE 1 – EVALUATION OF TRENCHLESS CROSSING ALTERNATIVES FOR SANITARY SEWER REPLACEMENT**

Installation Method	Feasibility	Advantages	Disadvantages	Relative Costs	Relative Risks
Jack-and-Bore or Jack and Bore with SBU	Not Suitable	<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 sometimes be withdrawn and bore can be restarted at different location if obstructions are encountered.</li> <li>Reduced level of vibrations.</li> <li>Use of a SBU mounted at the lead end of the casing can improve face stability control and, with appropriate face tools, can be better suited to cutting through cobbles, boulders, and hard / very dense till.</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 person-entry would be required to remove boulders.</li> <li>Unstable water-bearing granular interlayers can go undetected until ground loss and settlement has occurred.</li> <li>Bore through sandy silt to silt and sand clayey silt till with granular interlayers below water level; zones of hard / very dense till make augering difficult.</li> </ul>	Relatively low cost.	<ul style="list-style-type: none"> <li>Risk of encountering refusal on obstructions; difficult to penetrate hard / very dense TILL</li> <li>Obstructions can result in deflection of the casing resulting in misalignment of the sanitary sewer</li> <li>Potential for loss of ground into casing when saturated layers are encountered.</li> <li>Potential need to excavate pits to remove obstructions.</li> </ul>
Pipe Ramming	Not Suitable	<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</li> </ul>	<ul style="list-style-type: none"> <li>Suitable for installation length typically up to about 45 m, depending on soil conditions; therefore, marginally suitable for this site where the crossing extends about 47 m length unless a central shaft is used to stage in two sections resulting in impacts to traffic flow. Large work area required for ramming pit.</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> </ul>

Installation Method	Feasibility	Advantages	Disadvantages	Relative Costs	Relative Risks
		removed once the exit pit is reached minimizing subsidence and overcut	<ul style="list-style-type: none"> <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>■ Hard / very dense till zones will make ramming difficult and subsequent augering of spoil from inside the pipe.</li> <li>■ May require groundwater lowering – likely affecting a large area.</li> <li>■ Pneumatic ramming can be a nuisance to public.</li> </ul>		<ul style="list-style-type: none"> <li>■ Significant jacking / ramming forces would be required to advance through zones of hard glacial TILL and the proposed length of the pipe.</li> </ul>
Microtunnelling (MTBM)	Feasible	<ul style="list-style-type: none"> <li>■ Continuous support to excavation face is provided.</li> <li>■ Does not require groundwater lowering, only at the shaft locations.</li> <li>■ Final pipe can be installed while bore is being advanced.</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.</li> </ul>	<ul style="list-style-type: none"> <li>■ Most expensive method.</li> </ul>	<ul style="list-style-type: none"> <li>■ Low to moderate risk for sanitary sewer installation provided appropriate equipment and slurry properties are selected and controlled.</li> <li>■ Potential schedule delay in obtaining a suitable MTBM.</li> </ul>

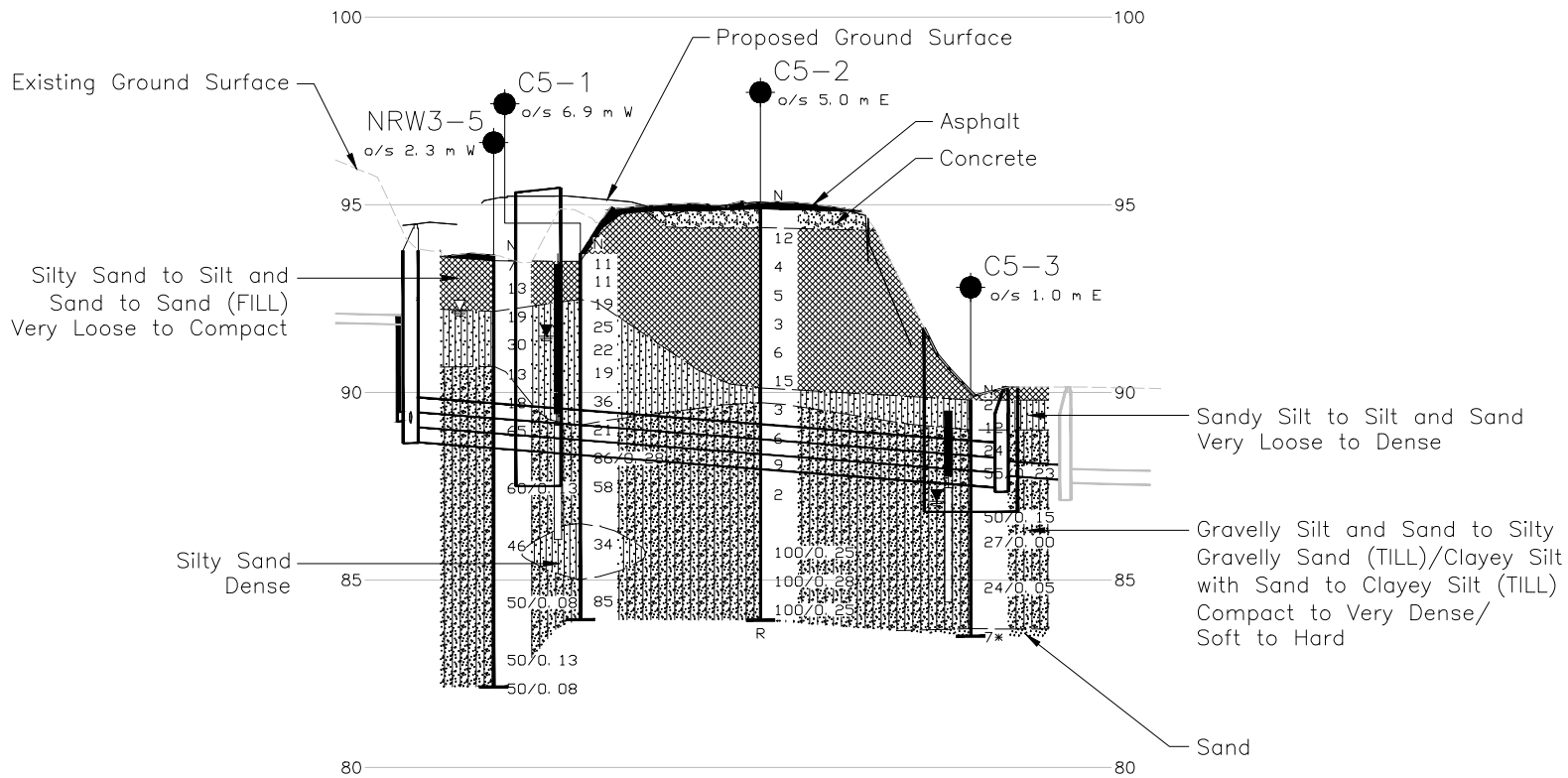
Installation Method	Feasibility	Advantages	Disadvantages	Relative Costs	Relative Risks
		<ul style="list-style-type: none"> <li>More accurate than pipe ramming and jack-and-bore methods.</li> <li>For hard / very dense soils, cobbles and boulders (of limited size) can often be cut and penetrated provided appropriate disc cutter face tools are utilized.</li> <li>An MTBM of the required size to accommodate a 1200 mm diameter concrete pipe line likely available.</li> </ul>	<ul style="list-style-type: none"> <li>Lack of readily available machines.</li> <li>Relatively expensive – high mobilization costs for short crossings.</li> </ul>		
Tunnelling with EPB TBM	Feasible, but would require larger diameter tunnel and dewatering in order to permit removal of large boulders, if encountered.	<ul style="list-style-type: none"> <li>EPB TBM is able to counterbalance earth and groundwater pressures in a controlled manner, providing continuous face support and eliminating need for dewatering at the tunnel face along the alignment.</li> <li>Can be steered continuously, providing good control over line and grade.</li> <li>Tunnel is fully lined as excavation progresses (i.e., casing pipe is installed behind the TBM during forward advancement).</li> </ul>	<ul style="list-style-type: none"> <li>A larger diameter in the order of 1.5 m minimum would be required in order to permit person-entry to remove large boulders if encountered. A larger diameter results in increased cost and potential conflicts with existing utilities.</li> <li>If person-entry is required to remove boulders, the sandy silt to sand below the groundwater will be required to be dewatered; which is not feasible beneath the QEW</li> <li>Near the exist shaft the soils are expected to consist of mixed face (saturated sands and silts with cohesive till at the invert). It is anticipated to be difficult to control the propensity for the more fluid-</li> </ul>	Relatively expensive, can be less costly than slurry MTBM methods	Relatively low risk of ground loss during tunnelling when a counterbalancing face pressure is used and conditioning agents may be required; no advantage over slurry microtunnelling with respect to removal of boulders with screw-conveyor EPB systems, older relieving gate systems permit passage of cobbles and some boulders depending on sizes relative to TBM opening dimensions.

Installation Method	Feasibility	Advantages	Disadvantages	Relative Costs	Relative Risks
		<ul style="list-style-type: none"> <li>Potential effects on underground utilities next to the tunnel alignment can be better controlled than most other methods.</li> <li>Machines can include rock-cutting face tools and older systems that use load or pressure-controlled gates for spoil discharge from forward chamber can pass some larger potential obstructions depending on face opening and relieving gate sizes.</li> <li>Considered suitable for site subsurface conditions with caution for mixed face conditions.</li> </ul>	<ul style="list-style-type: none"> <li>like soils to enter the face of the machine faster than the machine can excavate the harder materials below.</li> <li>Addition of appropriate conditioning agents (e.g., bentonite) may be required to modify spoil for appropriate consistency and face pressure control</li> <li>Relatively expensive for short installation length (47 m).</li> </ul>		



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

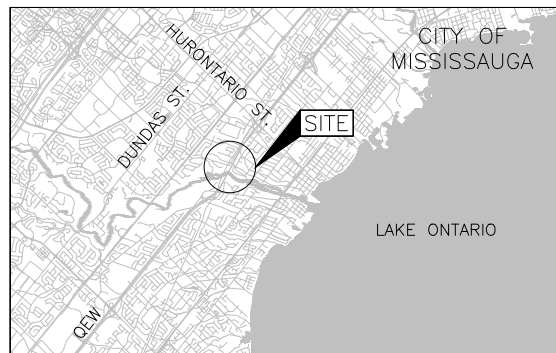
PLAN  
SCALE  
10 0 10 20 m



PROFILE A-A'  
VERTICAL SCALE  
10 0 10 20 m  
HORIZONTAL SCALE  
10 0 10 20 m

CONT No.  
GWP No. 2002-13-00

QEW WIDENING - MISSISSAUGA RD TO HURONTARIO ST  
SANITARY SEWER INSTALLATION STATION 17+460  
BOREHOLE LOCATIONS PLAN AND  
SOIL STRATA



KEY PLAN  
SCALE  
2 0 2 4 km

LEGEND

- Borehole - Current Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- R Split-Spoon Refusal
- WL in piezometer, March 19, 2019
- WL upon completion of drilling

BOREHOLE CO-ORDINATES (MTM NAD 83 ZONE 10)

No.	ELEVATION	NORTHING	EASTING
C5-1	93.7	4824657.1	296188.7
C5-2	95.0	4824641.8	296221.4
C5-3	89.8	4824619.4	296238.7
NRW3-5	93.7	4824661.4	296190.9

NOTES

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

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

REFERENCE

Base plans provided in digital format by MH, drawing file nos.  
X11609340Base.dwg, X-Final Merged Util.dwg, X-PROP-UTIL.dwg, Existing Property.dwg, 11609340 - QEW Prop Util-Dickson & Lynchmere - C3D 2017.dwg, 11609340 - QEW Prop Util-IndianGroveAve - C3D 2017.dwg, 11609340 - QEW Prop Util-Stavebank Rd - C3D 2017.dwg, 11609340 - QEW Prop Util-Knareswood Dr - C3D 2017.dwg, and x1160934\_Align.dwg, received March 25, 2019.

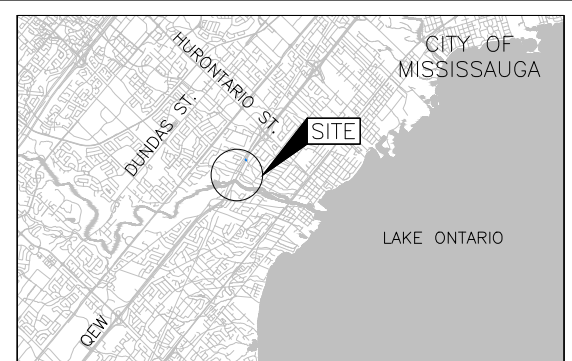


NO.	DATE	BY	REVISION
Geocres No. 30M12-451			
HWY. QEW	PROJECT NO. 1662333		DIST. CENTRAL
SUBM'D. AB/EJ	CHKD. DM	DATE: 7/30/2019	SITE: .
DRAWN: DD	CHKD. SMM	APPD. JPD	DWG. 1






QEW WIDENING - MISSISSAUGA RD TO HURONTARIO ST  
 SANITARY SEWER INSTALLATION STATION 17+460  
 SETTLEMENT MONITORING  
 INSTALLATION LOCATION AND DETAILS






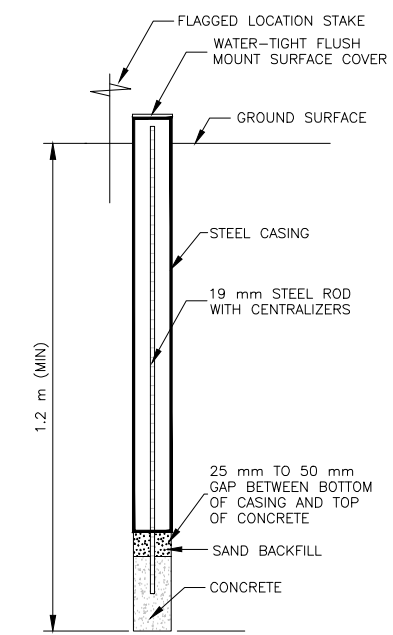
KEY PLAN  
SCALE



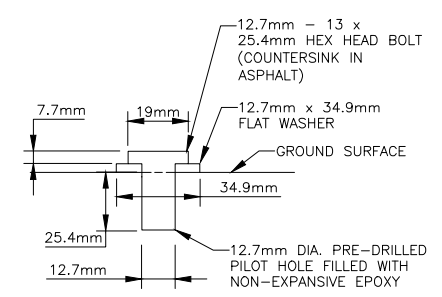
2 0 2 4 km

## LEGEND

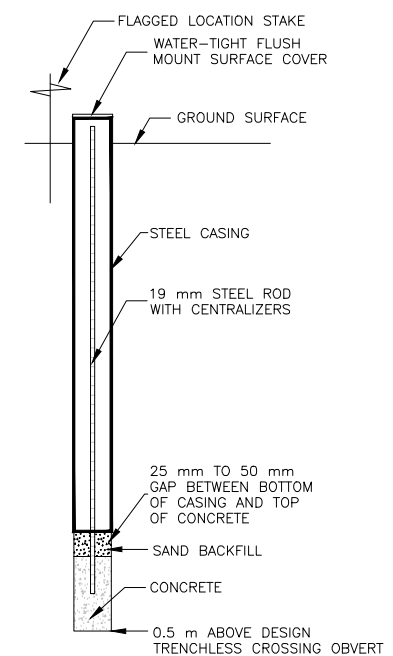
- |   |                           |
|---|---------------------------|
|  | Surface Settlement Marker |
|  | Settlement Point          |
|  | Deep Settlement Point     |



### SETTLEMENT POINT (SP) INSTALLATION DETAIL



SURFACE SETTLEMENT MARKER  
(SSM) INSTALLATION DETAIL  
NOT TO SCALE



DEEP SETTLEMENT POINT (DSP)  
INSTALLATION DETAIL

## 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.

## REFERENCE

Base plans provided in digital format by MH, drawing file nos.  
X11609340Base.dwg, X-Final Merged Util.dwg, X-PROP-UTIL.dwg, Existing  
Property.dwg, 11609340 – QEW Prop Util-Dickson & Lynchmere – C3D  
2017.dwg, 11609340 – QEW Prop Util-IndianGroveAve – C3D 2017.dwg,  
11609340 – QEW Prop Util-Stavebank Rd – C3D 2017.dwg, 11609340 –  
QEW Prop Util-Knoreswood Dr – C3D 2017.dwg, and x1160934\_Align.dwg,  
received March 25, 2019.

-	-	-	-
NO.	DATE	BY	REVISION
Geocres No. 30M12-451			
HWY. QEW		PROJECT NO. 1662333	DIST. CENTRAL
SUBM'D. AB/EJ		CHKD. DM	DATE: 7/30/2019
DRAWN: DD		CHKD. SMM	SITE: .
		APPD. SJB	DWG. 2



**APPENDIX A**

**Record of Borehole Sheets and Limestone Cobbles and  
/ or Boulders Core Photograph (Borehole C5-3)**

## 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: $\Delta \sigma$
$\epsilon$	linear strain
$\epsilon_v$	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 <sub>4</sub>	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

PROJECT 1662333		RECORD OF BOREHOLE No C5-1		SHEET 1 OF 1		METRIC															
G.W.P. 2002-13-00		LOCATION N 4824657.1; E 296188.7 MTM NAD ZONE 10 (LAT. 43.561802; LONG. -79.606597)		ORIGINATED BY EJ																	
DIST Central HWY QEW		BOREHOLE TYPE CME 55, 83 mm I.D. Hollow Stem Augers		COMPILED BY KN																	
DATUM Geodetic		DATE February 19, 2019		CHECKED BY SEMP/SMM																	
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		
93.7	GROUND SURFACE							20 40 60 80 100					W <sub>p</sub> W W <sub>L</sub>			kN/m <sup>3</sup>					
0.0	ASPHALT (150mm)							20 40 60 80 100					10 20 30								
0.2	Silty sand, trace to some gravel (FILL) Compact Brown Moist		1	SS	11		93														
92.5			2	SS	11																
1.2	Sandy SILT, trace to some clay, trace gravel Compact to dense Brown to grey Moist to wet  - Grey below a depth of 2.4 m		3	SS	19		92						o								
			4	SS	25		91						o								
			5	SS	22		90						o						1 26 66 7		
			6	SS	19		89						o						0 21 73 6		
			7	SS	36								o								
89.1																					
88.8	Sandy CLAYEY SILT, trace to some gravel (TILL) Very stiff Grey Moist		8A	SS	21		89						o						27 43 23 7		
4.9	Gravelly SILT and SAND to Silty Gravelly SAND, trace to some clay (TILL) Compact to very dense Grey Dry to moist - 0.3 m of sand and gravel at 6.1 m depth		9	SS	86/0.28		88						o			Non-plastic			26 32 34 8		
			10A	SS	58		87														
			10B	SS			86														
86.5																					
7.2	Silty SAND, trace to some clay Dense Grey Wet		11	SS	34		86						o						0 65 25 10		
85.0							85														
8.7	CLAYEY SILT and GRAVEL, trace to some sand (TILL) Hard Grey Wet		12	SS	85		84						o								
83.9																					
9.8	END OF BOREHOLE																				
NOTES:																					
1. Water level measured at 7.9 m depth below ground surface (Elev.85.8 m) upon completion of drilling, prior to well installation.																					
2. Water level measured at 3.5 m depth below ground surface (Elev.90.2 m) after piezometer installation.																					
3. Water level measured at 2.2 m depth below ground surface (Elev. 91.5 m) in piezometer on March 19, 2019.																					

PROJECT 1662333		RECORD OF BOREHOLE No C5-2		SHEET 1 OF 1		METRIC															
G.W.P. 2002-13-00		LOCATION N 4824641.8; E 296221.4 MTM NAD ZONE 10 (LAT. 43.561664; LONG. -79.606192)		ORIGINATED BY AM																	
DIST Central HWY QEW		BOREHOLE TYPE CME 75, 70 mm I.D. Hollow Stem Augers		COMPILED BY MPL																	
DATUM Geodetic		DATE March 3, 2019		CHECKED BY SEMP/SMM																	
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		
95.0	GROUND SURFACE							20 40 60 80 100					10 20 30			kN/m³					
0.0	ASPHALT (100 mm)							20 40 60 80 100					10 20 30								
94.4	CONCRETE (510 mm)							20 40 60 80 100					10 20 30								
0.6	Silty sand (FILL) Very loose to compact Brown with oxidation staining Moist		1	SS	12		94														
			2	SS	4		93														
			3	SS	5		92														
			4	SS	3		91														
			5	SS	6		90														
	- Becoming wet at a depth of 4.3 m		6A	SS	15		89														
90.1	SILT and SAND, trace clay Compact Grey Wet		6B	SS	3		88														
89.7	Sandy CLAYEY SILT, trace to some gravel (TILL) Soft to stiff Grey Moist		7	SS	6		87														
5.3			8	SS	9		86														
			9	SS	2		85														
			10	SS	100/0.25		84														
86.8	CLAYEY SILT with SAND, some gravel, containing shale fragments (TILL) Hard Grey Moist		11	SS	100/0.25																
8.2			12	SS	100/0.25																
			13	SS	100/0.25																
83.9	END OF BOREHOLE																				
11.1	NOTE: 1. Open borehole dry upon completion of drilling.																				

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PROJECT 1662333		RECORD OF BOREHOLE No C5-3		SHEET 1 OF 1		METRIC											
G.W.P. 2002-13-00		LOCATION N 4824619.4; E 296238.7 MTM NAD ZONE 10 (LAT. 43.561463; LONG. -79.605978)		ORIGINATED BY KN													
DIST Central HWY QEW		BOREHOLE TYPE Portable Rig - 76 mm O.D. Casing and Wash boring		COMPILED BY ACM													
DATUM Geodetic		DATE March 7-8, 2019		CHECKED BY SEMP/SMM													
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	20 40 60 80 100	20 40 60 80 100	W <sub>p</sub> W W <sub>L</sub>	W <sub>p</sub> W W <sub>L</sub>	W <sub>p</sub> W W <sub>L</sub>	γ	GR SA SI CL			
89.8	GROUND SURFACE																
0.0	SILT and SAND, trace to some organics, trace clay Very loose to compact Brown Wet		1	SS	2												
89.0			2A	SS	12		89							0 49 48 3			
0.8	CLAYEY SILT to CLAYEY SILT with SAND to SILT and SAND, trace to some gravel, trace rootlets, cobbles and boulders present (TILL) Stiff to hard to very dense Brown to grey Moist to wet		3	SS	24		88							13 32 42 13			
			4	SS	55/0.23												
	- Limestone boulder (300 mm thick) cored from 2.2 m to 2.5 m - Sand pockets present below 2.6 m - Split-spoon bouncing at 3.2 m		5A	RC													
			5B	RC													
			6	SC			87							2 11 60 27			
			7	SC													
			8	SS	50/0.15												
			9	SS	27/0.06												
	- Limestone boulders (280 mm thick) cored 3.7 m to 4.0 m		10	RC			86										
			11	RC													
	- Limestone cobble (230 mm thick) cored between 4.0 m to 4.6 m - Limestone cobble (150 mm thick) cored between 4.9 m to 5.9 m		12	SC			85										
			13	SS	24/0.06												
			14	RC													
83.7			15	SC			84										
6.3	SAND, trace to some silt, trace gravel, trace clay, trace cobble fragments present Grey Wet END OF BOREHOLE		16	SS	7									5 87 7 1			
	NOTES:  1. Water level measured at ground surface within casing upon completion of drilling.  2. A third-weight hammer was used and the N values have been adjusted to reflect a full weight hammer for consistency.  * The SPT "N" value for Sample 16 may not be representative due to blowing sands prior sampling.  3. Water level measured at 2.7 m depth below ground surface (Elev. 87.1 m) in piezometer on March 13, 2019.																



PROJECT 1662333		RECORD OF BOREHOLE No NRW3-5				SHEET 1 OF 1		METRIC						
G.W.P. 2002-13-00		LOCATION N 4824661.4; E 296190.9 MTM NAD 83 ZONE 10 (LAT. 43.561832; LONG. -79.606567)				ORIGINATED BY ACM								
DIST Central HWY QEW		BOREHOLE TYPE CME 55, 50 mm I.D., Hollow Stem Augers				COMPILED BY CC								
DATUM Geodetic		DATE June 25, 2018				CHECKED BY SMM								
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						
93.7	GROUND SURFACE													
0.0	ASPHALT (150 mm)													
0.2	Silty sand to sand, some gravel (FILL) Loose to compact Brown Moist		1	SS	7									
			2A	SS	13									
92.2														
1.5	SILT and SAND, trace clay Compact Grey Moist to wet		3A	SS	19									
			3B											
			4	SS	30									
90.7														
3.0	CLAYEY SILT with SAND, some gravel to CLAYEY SILT with GRAVEL (TILL) Stiff to hard Grey Moist		5	SS	13									
			6	SS	18									
			7	SS	65									
	- Auger grinding from 5.2 m to 6.1 m and from 8.2 m to 9.1 m depth													
			8	SS	60/0.13									
			9	SS	46									
85.0														
8.7	Silty Gravelly SAND, trace clay (TILL) Very dense Grey Moist to wet below 10.7 m depth		10	SS	50/0.08									
			11	SS	50/0.13									
82.2														
11.5	END OF BOREHOLE		12	SS	50/0.08									
	NOTES:  1. Borehole caved to a depth of 1.5 m below ground surface upon removal of hollow-stem augers.  2. Water level measured at a depth of about 1.5 m below ground surface (Elev. 92.2 m) after removal of augers and borehole caved.													

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Start of Sample No. 5 (2.21 m)



End of Sample No. 5 (2.62 m)

Start of Sample No. 10 (3.66 m)

Start of Sample No. 11 (3.94 m)



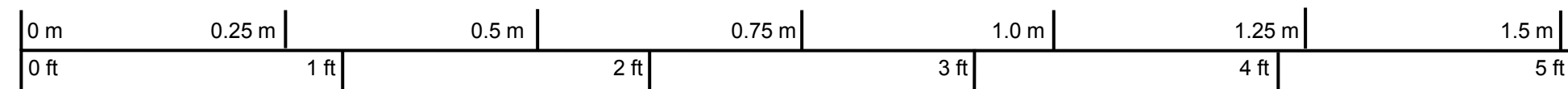
End of Sample No. 10 (3.94 m)

End of Sample No. 11 (4.57 m)


Start of Sample No. 14 (4.93 m)



End of Sample No. 14 (5.94 m)



Scale

PROJECT					
MTO Assignment 2015-E-0033 Sanitary Sewer Installation Station 17+460 Mississauga Road to Hurontario Street					
TITLE					
Limestone Cobbles and / or Boulders Core Photograph Borehole C5-3 (2.21 m to 5.94 m)					
 GOLDER			PROJECT No. 1662333		
			FILE No. ----		
			DRAFT	ACM	20190411
			CADD	--	
			CHECK	SMM	20190416
			REVIEW	JMAC	20190422
			SCALE	AS SHOWN	VER. 1.
			FIGURE A-1		

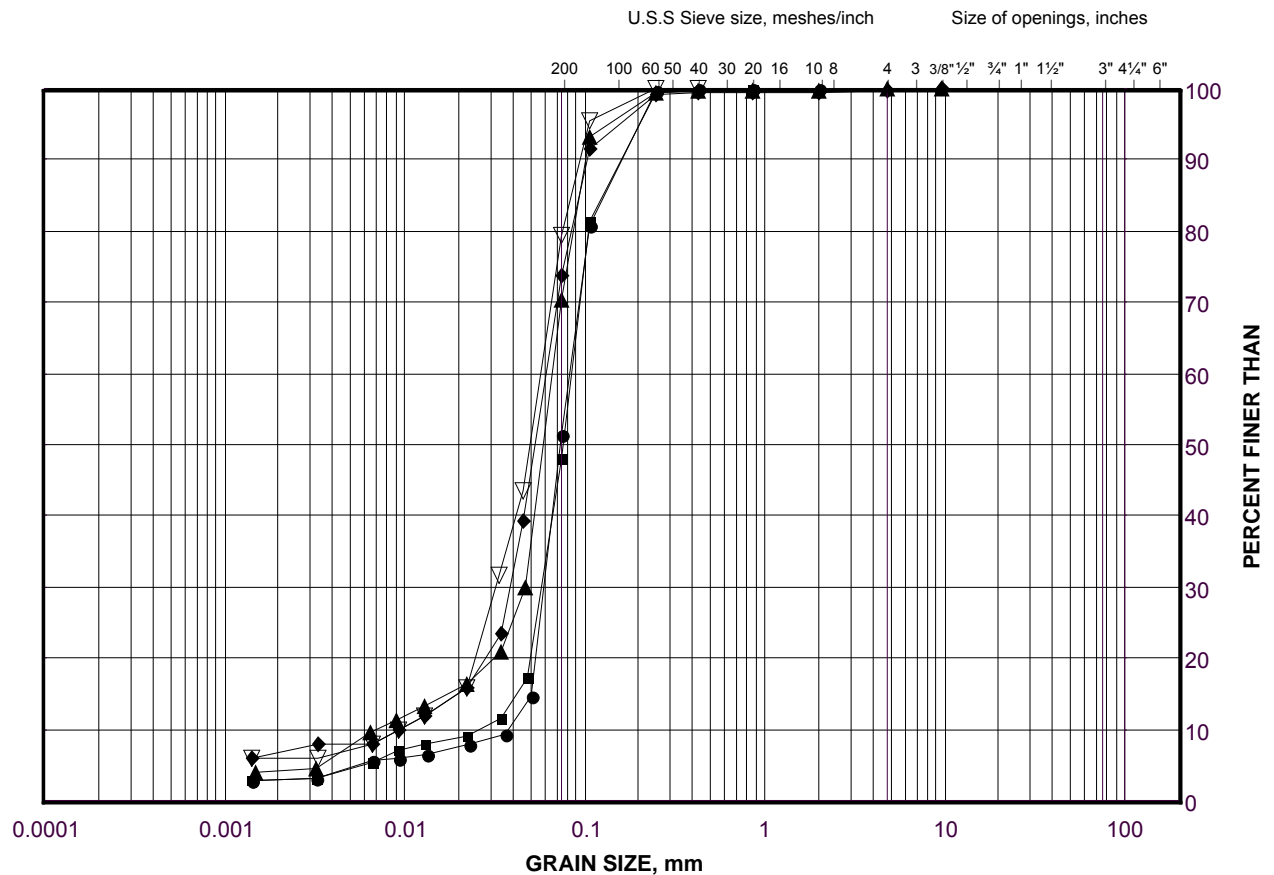
**APPENDIX B**

# Geotechnical Laboratory Test Results

# GRAIN SIZE DISTRIBUTION

Sandy Silt to Silt and Sand

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)
●	C5-3	2A	89.1
■	NRW3-5	4	91.1
◆	C5-1	6	90.3
▲	C5-2	6B	90.0
▽	C5-1	7	89.6

Project Number: 1662333

Checked By: SMM

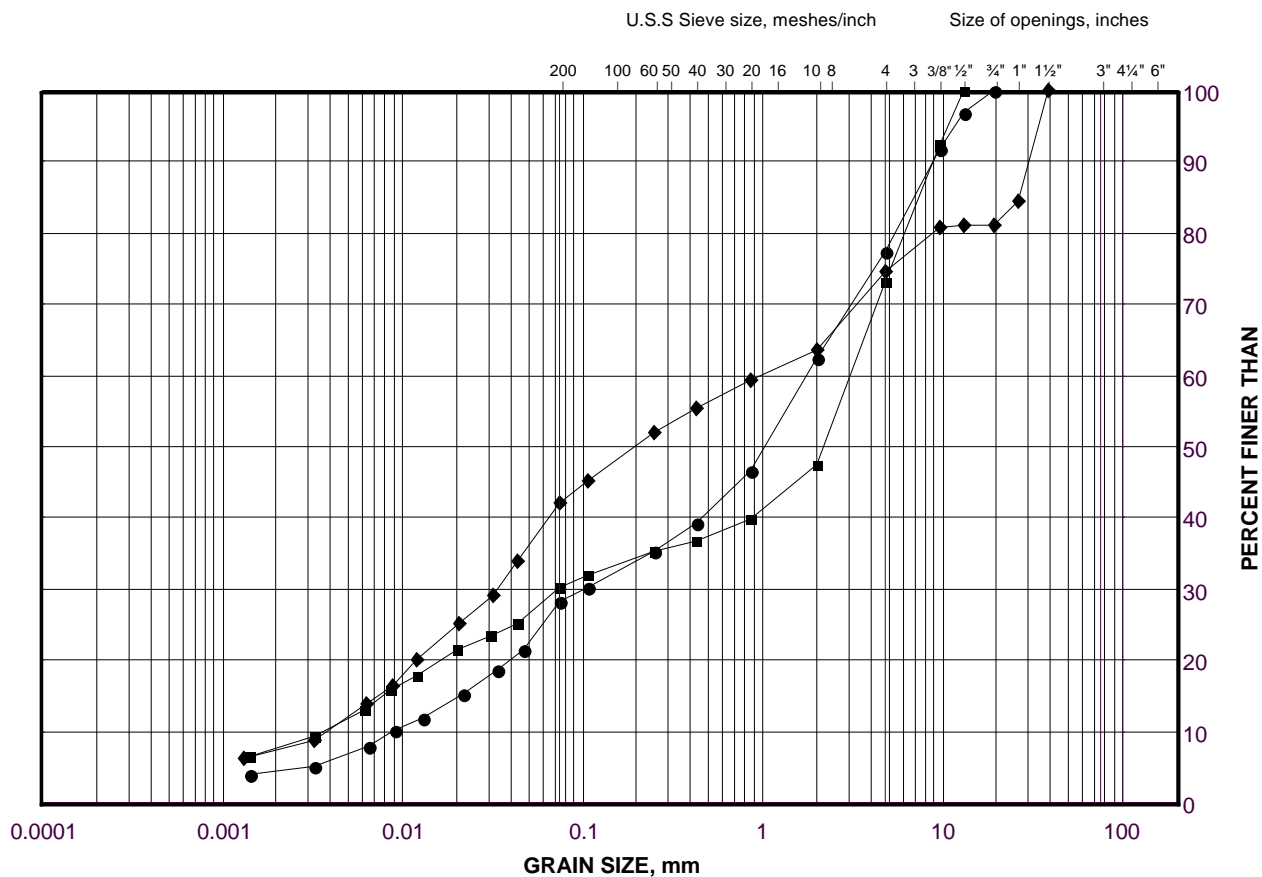
**Golder Associates**

Date: 05-Apr-19

# GRAIN SIZE DISTRIBUTION

Gravelly Silt and Sand to Silty Gravelly Sand (Till)

FIGURE B-2A



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

## LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	NRW3-5	10	84.3
■	C5-1	8B	88.7
◆	C5-1	9	88.1

Project Number: 1662333

Checked By: SMM

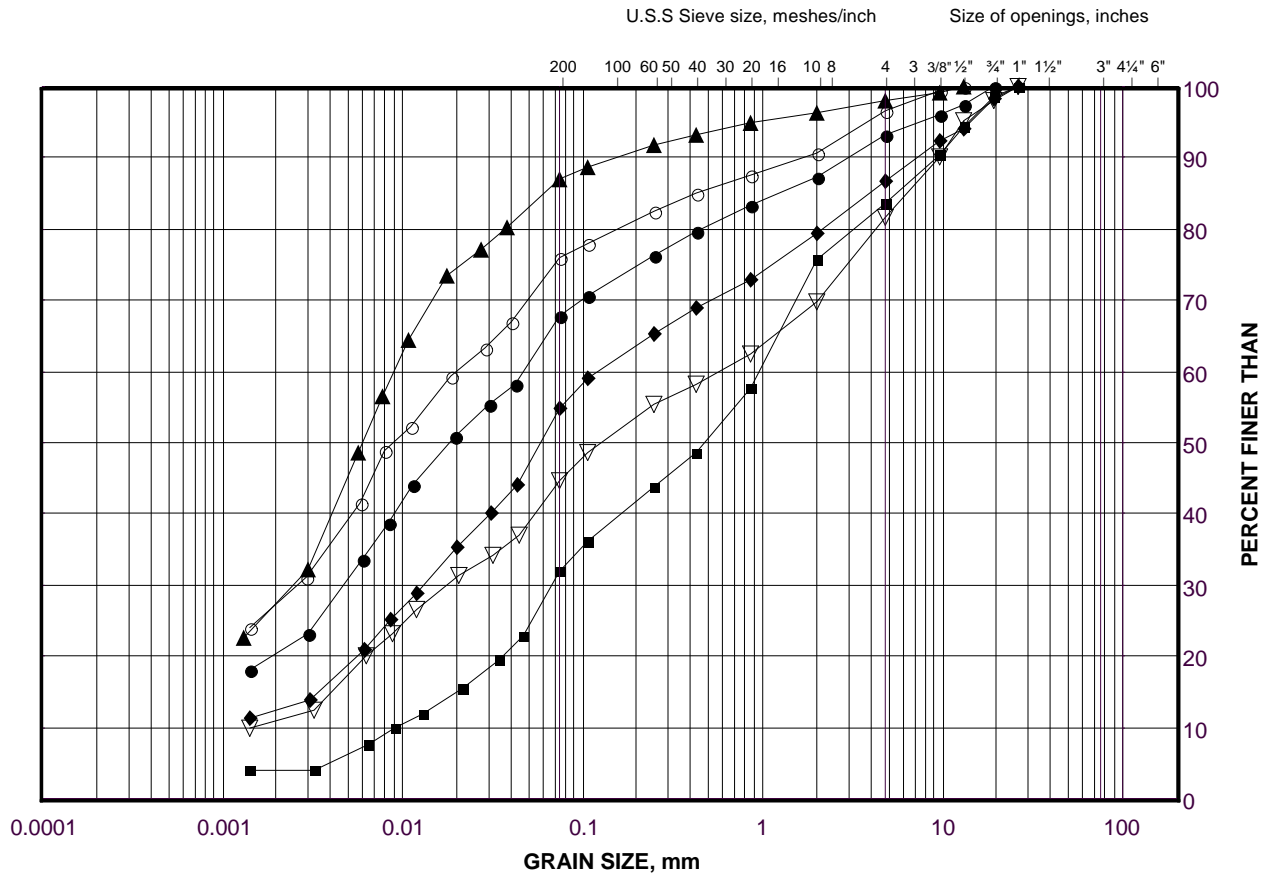
Golder Associates

Date: 01-May-19

# GRAIN SIZE DISTRIBUTION

Clayey Silt with Sand to Clayey Silt (Till)

FIGURE B-2B



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

## LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	C5-2	10	87.1
■	C5-2	11	85.7
◆	C5-3	3	88.3
▲	C5-3	6	87.1
▽	NRW3-5	6	89.6
○	C5-2	8	88.6

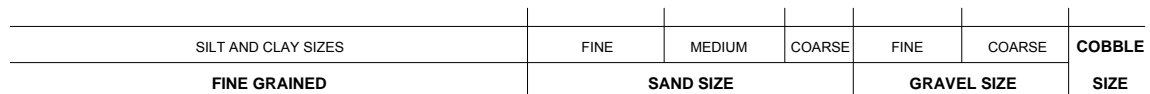
Project Number: 1662333

Checked By: SMM

**Golder Associates**

Date: 01-May-19

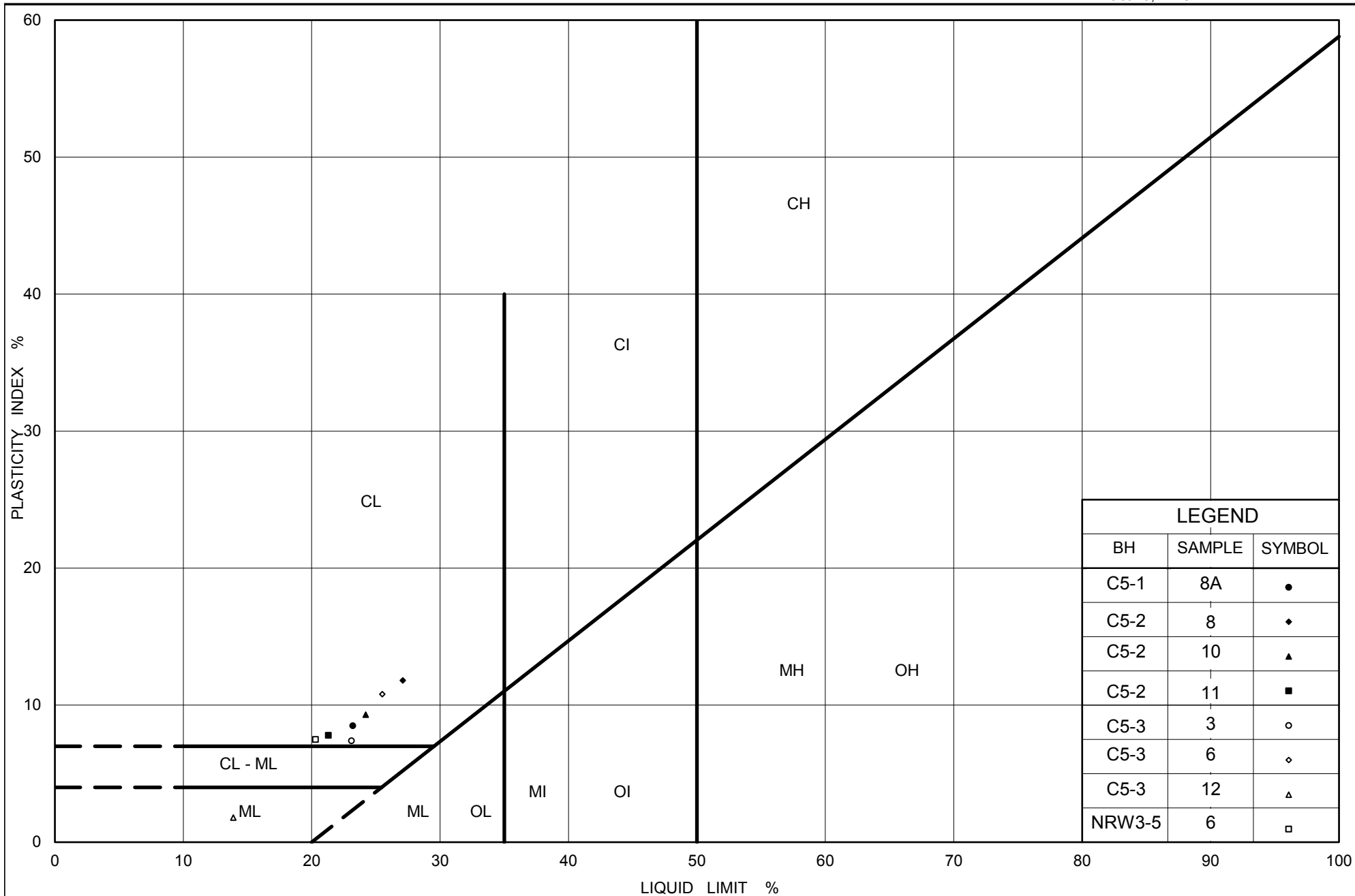
## FIGURE B-3



SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	C5-1	11	85.8
■	C5-3	16	83.5

Date: 05-Apr-19





Ministry of Transportation

Ontario

## PLASTICITY CHART

Silt and Sand (with slight plasticity) / Sandy Clayey Silt / Clayey  
Silt with Sand / Clayey Silt (Till)

Figure No. Figure B-4

Project No. 1662333

Checked By: SMM

**APPENDIX C**

# Analytical Laboratory Test Results

Your Project #: 1662333  
Site Location: QEW/CREDIT RIVER  
Your C.O.C. #: 674645-01-01

**Attention: Sandra McGaghran**

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

**Report Date: 2018/07/25**  
Report #: R5317501  
Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**MAXXAM JOB #: B8I3581**

**Received: 2018/07/20, 16:17**

Sample Matrix: Soil  
# Samples Received: 7

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Chloride (20:1 extract)	7	N/A	2018/07/25	CAM SOP-00463	EPA 325.2 m
Conductivity	7	N/A	2018/07/24	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl <sub>2</sub> EXTRACT	7	2018/07/24	2018/07/24	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	7	2018/07/20	2018/07/24	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	7	N/A	2018/07/25	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 #: 1662333  
Site Location: QEW/CREDIT RIVER  
Your C.O.C. #: 674645-01-01

**Attention: Sandra McGaghran**

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

**Report Date: 2018/07/25**  
Report #: R5317501  
Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**MAXXAM JOB #: B8I3581**  
**Received: 2018/07/20, 16:17**

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.  
Ema Gitej, Senior Project Manager  
Email: EGitej@maxxam.ca  
Phone# (905)817-5829

=====

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

Maxxam Job #: B8I3581  
Report Date: 2018/07/25

Golder Associates Ltd  
Client Project #: 1662333  
Site Location: QEW/CREDIT RIVER  
Sampler Initials: CC

### RESULTS OF ANALYSES OF SOIL

<b>Maxxam ID</b>		HGV911	HGV912	HGV913	HGV914	HGV915	HGV916		
<b>Sampling Date</b>		2018/06/28	2018/07/05	2018/06/25	2018/07/15	2018/07/12	2018/06/25		
<b>COC Number</b>		674645-01-01	674645-01-01	674645-01-01	674645-01-01	674645-01-01	674645-01-01		
	<b>UNITS</b>	<b>NRW3-1-SA4</b>	<b>NRW3-9-SA4</b>	<b>NRW3-3-SA4</b>	<b>NRW7-3-SA4</b>	<b>NRW7-1-SA3</b>	<b>NRW3-5-SA4</b>	<b>RDL</b>	<b>QC Batch</b>

<b>Calculated Parameters</b>									
Resistivity	ohm-cm	1400	2600	5500	1800	1200	3000		5640959

<b>Inorganics</b>									
Soluble (20:1) Chloride (Cl-)	ug/g	330	180	36	170	390	<20	20	5644648
Conductivity	umho/cm	721	386	180	564	805	337	2	5644382
Available (CaCl2) pH	pH	7.94	8.05	7.94	7.71	7.86	8.04		5642903
Soluble (20:1) Sulphate (SO4)	ug/g	88	21	32	<20	31	240	20	5644672

RDL = Reportable Detection Limit

QC Batch = Quality Control Batch

<b>Maxxam ID</b>		HGV917		
<b>Sampling Date</b>		2018/06/22		
<b>COC Number</b>		674645-01-01		
	<b>UNITS</b>	<b>NRW3-7-SA3A</b>	<b>RDL</b>	<b>QC Batch</b>

<b>Calculated Parameters</b>				
Resistivity	ohm-cm	350		5640959

<b>Inorganics</b>				
Soluble (20:1) Chloride (Cl-)	ug/g	1300	40	5644648
Conductivity	umho/cm	2870	2	5644382
Available (CaCl2) pH	pH	8.01		5642903
Soluble (20:1) Sulphate (SO4)	ug/g	55	20	5644672

RDL = Reportable Detection Limit

QC Batch = Quality Control Batch

Maxxam Job #: B8I3581  
Report Date: 2018/07/25

Golder Associates Ltd  
Client Project #: 1662333  
Site Location: QEW/CREDIT RIVER  
Sampler Initials: CC

## TEST SUMMARY

**Maxxam ID:** HGV911  
**Sample ID:** NRW3-1-SA4  
**Matrix:** Soil

**Collected:** 2018/06/28  
**Shipped:**  
**Received:** 2018/07/20

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5644648	N/A	2018/07/25	Deonarine Ramnarine
Conductivity	AT	5644382	N/A	2018/07/24	Tahir Anwar
pH CaCl2 EXTRACT	AT	5642903	2018/07/24	2018/07/24	Gnana Thomas
Resistivity of Soil		5640959	2018/07/24	2018/07/24	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5644672	N/A	2018/07/25	Deonarine Ramnarine

**Maxxam ID:** HGV912  
**Sample ID:** NRW3-9-SA4  
**Matrix:** Soil

**Collected:** 2018/07/05  
**Shipped:**  
**Received:** 2018/07/20

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5644648	N/A	2018/07/25	Deonarine Ramnarine
Conductivity	AT	5644382	N/A	2018/07/24	Tahir Anwar
pH CaCl2 EXTRACT	AT	5642903	2018/07/24	2018/07/24	Gnana Thomas
Resistivity of Soil		5640959	2018/07/24	2018/07/24	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5644672	N/A	2018/07/25	Deonarine Ramnarine

**Maxxam ID:** HGV913  
**Sample ID:** NRW3-3-SA4  
**Matrix:** Soil

**Collected:** 2018/06/25  
**Shipped:**  
**Received:** 2018/07/20

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5644648	N/A	2018/07/25	Deonarine Ramnarine
Conductivity	AT	5644382	N/A	2018/07/24	Tahir Anwar
pH CaCl2 EXTRACT	AT	5642903	2018/07/24	2018/07/24	Gnana Thomas
Resistivity of Soil		5640959	2018/07/24	2018/07/24	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5644672	N/A	2018/07/25	Deonarine Ramnarine

**Maxxam ID:** HGV914  
**Sample ID:** NRW7-3-SA4  
**Matrix:** Soil

**Collected:** 2018/07/15  
**Shipped:**  
**Received:** 2018/07/20

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5644648	N/A	2018/07/25	Deonarine Ramnarine
Conductivity	AT	5644382	N/A	2018/07/24	Tahir Anwar
pH CaCl2 EXTRACT	AT	5642903	2018/07/24	2018/07/24	Gnana Thomas
Resistivity of Soil		5640959	2018/07/24	2018/07/24	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5644672	N/A	2018/07/25	Deonarine Ramnarine

**Maxxam ID:** HGV915  
**Sample ID:** NRW7-1-SA3  
**Matrix:** Soil

**Collected:** 2018/07/12  
**Shipped:**  
**Received:** 2018/07/20

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5644648	N/A	2018/07/25	Deonarine Ramnarine

Maxxam Job #: B8I3581  
Report Date: 2018/07/25

Golder Associates Ltd  
Client Project #: 1662333  
Site Location: QEW/CREDIT RIVER  
Sampler Initials: CC

## TEST SUMMARY

**Maxxam ID:** HGV915  
**Sample ID:** NRW7-1-SA3  
**Matrix:** Soil

**Collected:** 2018/07/12  
**Shipped:**  
**Received:** 2018/07/20

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Conductivity	AT	5644382	N/A	2018/07/24	Tahir Anwar
pH CaCl2 EXTRACT	AT	5642903	2018/07/24	2018/07/24	Gnana Thomas
Resistivity of Soil		5640959	2018/07/24	2018/07/24	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5644672	N/A	2018/07/25	Deonarine Ramnarine

**Maxxam ID:** HGV916  
**Sample ID:** NRW3-5-SA4  
**Matrix:** Soil

**Collected:** 2018/06/25  
**Shipped:**  
**Received:** 2018/07/20

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5644648	N/A	2018/07/25	Deonarine Ramnarine
Conductivity	AT	5644382	N/A	2018/07/24	Tahir Anwar
pH CaCl2 EXTRACT	AT	5642903	2018/07/24	2018/07/24	Gnana Thomas
Resistivity of Soil		5640959	2018/07/24	2018/07/24	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5644672	N/A	2018/07/25	Deonarine Ramnarine

**Maxxam ID:** HGV917  
**Sample ID:** NRW3-7-SA3A  
**Matrix:** Soil

**Collected:** 2018/06/22  
**Shipped:**  
**Received:** 2018/07/20

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5644648	N/A	2018/07/25	Deonarine Ramnarine
Conductivity	AT	5644382	N/A	2018/07/24	Tahir Anwar
pH CaCl2 EXTRACT	AT	5642903	2018/07/24	2018/07/24	Gnana Thomas
Resistivity of Soil		5640959	2018/07/24	2018/07/24	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5644672	N/A	2018/07/25	Deonarine Ramnarine



### GENERAL COMMENTS

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

Package 1	5.0°C
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**Results relate only to the items tested.**

## QUALITY ASSURANCE REPORT

Golder Associates Ltd  
Client Project #: 1662333  
Site Location: QEW/CREDIT RIVER  
Sampler Initials: CC

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
5642903	Available (CaCl <sub>2</sub> ) pH	2018/07/24			100	97 - 103			1.9	N/A
5644382	Conductivity	2018/07/24			99	90 - 110	<2	umho/cm	4.7	10
5644648	Soluble (20:1) Chloride (Cl <sup>-</sup> )	2018/07/25	NC	70 - 130	99	70 - 130	<20	ug/g	4.0	35
5644672	Soluble (20:1) Sulphate (SO <sub>4</sub> )	2018/07/25	NC	70 - 130	107	70 - 130	<20	ug/g	8.7	35

N/A = Not Applicable

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

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

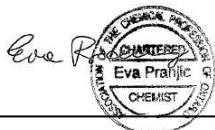
Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

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

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

### VALIDATION SIGNATURE PAGE

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



Ewa Pranjić, M.Sc., C.Chem, Scientific Specialist

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## CHAIN OF CUSTODY RECORD

Page of

INVOICE TO:		REPORT TO:		PROJECT INFORMATION:		Laboratory Use Only:	
Company Name	#1326 Golder Associates Ltd .	Company Name	GOLDER ASSOCIATES	Quotation #	B80683	Maxxam Job #:	Bottle Order #:
Attention:	Accounts Payable	Attention:	Sandra McGaghran	P.O. #:			
Address:	6925 Century Ave Suite 100	Address:	6925 Century Ave. SUITE 100	Project:	1662333		
	Mississauga ON L5N 7K2		MISSISSAUGA, ON.	Project Name:		COC #:	Project Manager:
Tel	(905) 567-4444	Tel:		Site #			
Email:	AP_CustomerService@golder.com	Email:	smcgaghran@golder.com	Sampled By	CC/AM		

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

Regulation 153 (2011)			Other Regulations		Special Instructions
<input type="checkbox"/> Table 1	<input type="checkbox"/> Res/Park	<input type="checkbox"/> Medium/Fine	<input type="checkbox"/> CCME	<input type="checkbox"/> Sanitary Sewer Bylaw	
<input type="checkbox"/> Table 2	<input type="checkbox"/> Ind/Comm	<input type="checkbox"/> Coarse	<input type="checkbox"/> Reg 558	<input type="checkbox"/> Storm Sewer Bylaw	
<input type="checkbox"/> Table 3	<input type="checkbox"/> Agri/Other	<input type="checkbox"/> For RSC	<input type="checkbox"/> MISA	Municipality _____	
<input type="checkbox"/> Table _____			<input type="checkbox"/> PWQO		
			<input type="checkbox"/> Other _____		

Include Criteria on Certificate of Analysis (Y/N)?

	Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix
1	NRW3-1-SA4	QEW/CREDIT RIVER	2018/06/28	AM	SOIL
2	NRW3-9-SA4	"	2018/07/05	AM	SOIL
3	NRW3-3-SA4	"	2018/06/25	AM	SOIL
4	NRW7-3-SA4	"	2018/07/15	AM	SOIL
5	NRW7-1-SA3	"	2018/07/12	AM	SOIL
6	NRW3-5-SA4	"	2018/06/25	AM	SOIL
7	NRW3-7-SA3A	"	2018/06/22	AM	SOIL
8					
9					
10					

## ANALYSIS REQUESTED (PLEASE BE SPECIFIC)

[illegible]

## Turnaround Time (TAT) Required

Please provide advance notice for rush projects

Regular (Standard) TAT: 10-15 minutes

(will be applied if Rush TAT is not specified):

Standard TAT = 5-7 Working days for most tests

Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.

## Job Specific Rush TAT (if applies to entire submission)

Date Required: \_\_\_\_\_ Time Required: \_\_\_\_\_

Rush Confirmation Number: \_\_\_\_\_

(call lab for #)

# of Bottles	Comments
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20-Jul-18 16:17

Ema Gitei



B8I3581

- KVG ENV-1180

* RELINQUISHED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	RECEIVED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	# jars used and not submitted	Laboratory Use Only				
SHANIANU KAR / <i>[Signature]</i>	12/07/20	4:00 PM.	<i>[Signature]</i>	2018/07/20	16:17		Time Sensitive	Temperature (°C) on Receipt	Custody Seal	. Yes	No
								16/3 148	Intact		

\* UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO MAXXAM'S STANDARD TERMS AND CONDITIONS. SIGNING OF THIS CHAIN OF CUSTODY DOCUMENT IS ACKNOWLEDGMENT AND ACCEPTANCE OF OUR TERMS WHICH ARE AVAILABLE FOR VIEWING AT [WWW.MAXXAM.CA/TERMS](http://WWW.MAXXAM.CA/TERMS).

\* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

\*\* SAMPLE CONTAINER, PRESERVATION, HOLD TIME AND PACKAGE INFORMATION CAN BE VIEWED AT [HTTP://MAXXAM.CA/WP-CONTENT/UPLOADS/ONTARIO-COC.PDF](http://MAXXAM.CA/WP-CONTENT/UPLOADS/ONTARIO-COC.PDF)

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

White: Maxxa      Yellow: Client

Your Project #: 1662333  
Your C.O.C. #: 709061-01-01

**Attention: David Marmor**

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

**Report Date: 2019/03/26**  
Report #: R5644475  
Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**MAXXAM JOB #: B974455**

**Received: 2019/03/21, 16:07**

Sample Matrix: Rock  
# Samples Received: 10

Analyses	Quantity	Date	Date	Laboratory Method	Reference
		Extracted	Analyzed		
Chloride (20:1 extract)	10	2019/03/25	2019/03/26	CAM SOP-00463	EPA 325.2 m
Conductivity	10	2019/03/25	2019/03/25	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl2 EXTRACT	10	2019/03/25	2019/03/25	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	10	2019/03/22	2019/03/26	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	10	2019/03/25	2019/03/26	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. Where applicable, unless otherwise noted, Measurement Uncertainty has not been accounted for when stating conformity to the referenced standard.

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. Maxxam is not responsible for the accuracy or any data impacts, that result from the information provided by the customer or their agent.

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. When sampling is not conducted by Maxxam, results relate to the supplied 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 #: 1662333  
Your C.O.C. #: 709061-01-01

**Attention: David Marmor**

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

**Report Date: 2019/03/26**  
Report #: R5644475  
Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**MAXXAM JOB #: B974455**  
**Received: 2019/03/21, 16:07**

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.  
Ema Gitej, Senior Project Manager  
Email: EGitej@maxxam.ca  
Phone# (905)817-5829

=====

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

### RESULTS OF ANALYSES OF ROCK

Maxxam ID		JGK384	JGK385	JGK386	JGK387	JGK388	JGK389		
Sampling Date		2019/03/21 01:30	2019/03/21 01:30	2019/03/21 01:30	2019/03/21 01:30	2019/03/21 01:30	2019/03/21 01:30		
COC Number		709061-01-01	709061-01-01	709061-01-01	709061-01-01	709061-01-01	709061-01-01		
	UNITS	1662333 C1-2	1662333 C1-1	1662333 C2-2	1662333 C2-3	1662333 C3-3	1662333 C3-1	RDL	QC Batch

#### Calculated Parameters

Resistivity	ohm-cm	2100	1700	2500	2600	3800	3700		6032288
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#### Inorganics

Soluble (20:1) Chloride (Cl-)	ug/g	32	37	<20	71	<20	<20	20	6035188
Conductivity	umho/cm	469	583	407	391	266	274	2	6035037
Available (CaCl2) pH	pH	8.19	8.02	8.08	8.14	8.19	8.19		6035215
Soluble (20:1) Sulphate (SO4)	ug/g	160	350	190	72	51	35	20	6035189

RDL = Reportable Detection Limit

QC Batch = Quality Control Batch

Maxxam ID		JGK390	JGK391	JGK392	JGK393		
Sampling Date		2019/03/20 04:30	2019/03/20 04:30	2019/03/20 04:30	2019/03/20 04:30		
COC Number		709061-01-01	709061-01-01	709061-01-01	709061-01-01		
	UNITS	1662333 C4-2	1662333 C4-3	1662333 C5-2	1662333 C5-1	RDL	QC Batch

#### Calculated Parameters

Resistivity	ohm-cm	1500	1000	1700	3100		6032288
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#### Inorganics

Soluble (20:1) Chloride (Cl-)	ug/g	250	410	240	<20	20	6035188
Conductivity	umho/cm	670	991	578	323	2	6035037
Available (CaCl2) pH	pH	7.77	7.77	7.85	7.78		6035215
Soluble (20:1) Sulphate (SO4)	ug/g	130	190	130	220	20	6035189

RDL = Reportable Detection Limit

QC Batch = Quality Control Batch



## TEST SUMMARY

**Maxxam ID:** JGK384  
**Sample ID:** 1662333 C1-2  
**Matrix:** Rock

**Collected:** 2019/03/21  
**Shipped:**  
**Received:** 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6035188	2019/03/25	2019/03/26	Deonarine Ramnarine
Conductivity	AT	6035037	2019/03/25	2019/03/25	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	6035215	2019/03/25	2019/03/25	Gnana Thomas
Resistivity of Soil		6032288	2019/03/26	2019/03/26	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6035189	2019/03/25	2019/03/26	Alina Dobreanu

**Maxxam ID:** JGK385  
**Sample ID:** 1662333 C1-1  
**Matrix:** Rock

**Collected:** 2019/03/21  
**Shipped:**  
**Received:** 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6035188	2019/03/25	2019/03/26	Deonarine Ramnarine
Conductivity	AT	6035037	2019/03/25	2019/03/25	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	6035215	2019/03/25	2019/03/25	Gnana Thomas
Resistivity of Soil		6032288	2019/03/26	2019/03/26	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6035189	2019/03/25	2019/03/26	Alina Dobreanu

**Maxxam ID:** JGK386  
**Sample ID:** 1662333 C2-2  
**Matrix:** Rock

**Collected:** 2019/03/21  
**Shipped:**  
**Received:** 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6035188	2019/03/25	2019/03/26	Deonarine Ramnarine
Conductivity	AT	6035037	2019/03/25	2019/03/25	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	6035215	2019/03/25	2019/03/25	Gnana Thomas
Resistivity of Soil		6032288	2019/03/26	2019/03/26	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6035189	2019/03/25	2019/03/26	Alina Dobreanu

**Maxxam ID:** JGK387  
**Sample ID:** 1662333 C2-3  
**Matrix:** Rock

**Collected:** 2019/03/21  
**Shipped:**  
**Received:** 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6035188	2019/03/25	2019/03/26	Deonarine Ramnarine
Conductivity	AT	6035037	2019/03/25	2019/03/25	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	6035215	2019/03/25	2019/03/25	Gnana Thomas
Resistivity of Soil		6032288	2019/03/26	2019/03/26	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6035189	2019/03/25	2019/03/26	Alina Dobreanu

**Maxxam ID:** JGK388  
**Sample ID:** 1662333 C3-3  
**Matrix:** Rock

**Collected:** 2019/03/21  
**Shipped:**  
**Received:** 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6035188	2019/03/25	2019/03/26	Deonarine Ramnarine
Conductivity	AT	6035037	2019/03/25	2019/03/25	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	6035215	2019/03/25	2019/03/25	Gnana Thomas

## TEST SUMMARY

**Maxxam ID:** JGK388  
**Sample ID:** 1662333 C3-3  
**Matrix:** Rock

**Collected:** 2019/03/21  
**Shipped:**  
**Received:** 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Resistivity of Soil		6032288	2019/03/26	2019/03/26	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6035189	2019/03/25	2019/03/26	Alina Dobreanu

**Maxxam ID:** JGK389  
**Sample ID:** 1662333 C3-1  
**Matrix:** Rock

**Collected:** 2019/03/21  
**Shipped:**  
**Received:** 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6035188	2019/03/25	2019/03/26	Deonarine Ramnarine
Conductivity	AT	6035037	2019/03/25	2019/03/25	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	6035215	2019/03/25	2019/03/25	Gnana Thomas
Resistivity of Soil		6032288	2019/03/26	2019/03/26	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6035189	2019/03/25	2019/03/26	Alina Dobreanu

**Maxxam ID:** JGK390  
**Sample ID:** 1662333 C4-2  
**Matrix:** Rock

**Collected:** 2019/03/20  
**Shipped:**  
**Received:** 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6035188	2019/03/25	2019/03/26	Deonarine Ramnarine
Conductivity	AT	6035037	2019/03/25	2019/03/25	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	6035215	2019/03/25	2019/03/25	Gnana Thomas
Resistivity of Soil		6032288	2019/03/26	2019/03/26	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6035189	2019/03/25	2019/03/26	Alina Dobreanu

**Maxxam ID:** JGK391  
**Sample ID:** 1662333 C4-3  
**Matrix:** Rock

**Collected:** 2019/03/20  
**Shipped:**  
**Received:** 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6035188	2019/03/25	2019/03/26	Deonarine Ramnarine
Conductivity	AT	6035037	2019/03/25	2019/03/25	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	6035215	2019/03/25	2019/03/25	Gnana Thomas
Resistivity of Soil		6032288	2019/03/26	2019/03/26	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6035189	2019/03/25	2019/03/26	Alina Dobreanu

**Maxxam ID:** JGK392  
**Sample ID:** 1662333 C5-2  
**Matrix:** Rock

**Collected:** 2019/03/20  
**Shipped:**  
**Received:** 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6035188	2019/03/25	2019/03/26	Deonarine Ramnarine
Conductivity	AT	6035037	2019/03/25	2019/03/25	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	6035215	2019/03/25	2019/03/25	Gnana Thomas
Resistivity of Soil		6032288	2019/03/26	2019/03/26	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6035189	2019/03/25	2019/03/26	Alina Dobreanu

## TEST SUMMARY

**Maxxam ID:** JGK393  
**Sample ID:** 1662333 C5-1  
**Matrix:** Rock

**Collected:** 2019/03/20  
**Shipped:**  
**Received:** 2019/03/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6035188	2019/03/25	2019/03/26	Deonarine Ramnarine
Conductivity	AT	6035037	2019/03/25	2019/03/25	Kazzandra Adeva
pH CaCl2 EXTRACT	AT	6035215	2019/03/25	2019/03/25	Gnana Thomas
Resistivity of Soil		6032288	2019/03/26	2019/03/26	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6035189	2019/03/25	2019/03/26	Alina Dobreanu

### GENERAL COMMENTS

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

Package 1	-2.0°C
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**Results relate only to the items tested.**

## QUALITY ASSURANCE REPORT

Golder Associates Ltd  
Client Project #: 1662333  
Sampler Initials: JP

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
6035037	Conductivity	2019/03/25			102	90 - 110	<2	umho/cm	0.40	10
6035188	Soluble (20:1) Chloride (Cl <sup>-</sup> )	2019/03/26	108	70 - 130	103	70 - 130	<20	ug/g	NC	35
6035189	Soluble (20:1) Sulphate (SO <sub>4</sub> )	2019/03/26	115	70 - 130	109	70 - 130	<20	ug/g	3.8	35
6035215	Available (CaCl <sub>2</sub> ) pH	2019/03/25			100	97 - 103			0.39	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 (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).



\_\_\_\_\_  
Anastassia Hamanov, Scientific Specialist

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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.

<b>INVOICE TO:</b>		<b>REPORT TO:</b>		<b>PROJECT INFORMATION:</b>		<b>Laboratory Use Only:</b>	
Company Name: #1326 Golder Associates Ltd		Company Name: David Marmor		Quotation #: B80683		Maxxam Job #:	
Attention: Accounts Payable		Attention: David Marmor		P.O. #:		Bottle Order #:	
Address: 6925 Century Ave Suite 100		Address:		Project: 1662332		709061	
Mississauga ON L5N 7K2				Project Name:		COC #:	
Tel: (905) 567-4444 Fax: (905) 567-6561		Tel: Fax:		Site #:		Project Manager:	
Email: AP_CustomerService@golder.com		Email: David_Marmor@golder.com		Sampled By:		C#709061-01-01	

MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY						ANALYSIS REQUESTED (PLEASE BE SPECIFIC)										Turnaround Time (TAT) Required:				
<b>Regulation 153 (2011)</b> <input type="checkbox"/> Table 1 <input type="checkbox"/> Res/Park <input type="checkbox"/> Medium/Fine <input type="checkbox"/> Table 2 <input type="checkbox"/> Ind/Comm <input type="checkbox"/> Coarse <input type="checkbox"/> Table 3 <input type="checkbox"/> Agri/Other <input type="checkbox"/> For RSC <input type="checkbox"/> Table			<b>Other Regulations</b> <input type="checkbox"/> CCME <input type="checkbox"/> Sanitary Sewer Bylaw <input type="checkbox"/> Reg 558 <input type="checkbox"/> Storm Sewer Bylaw <input type="checkbox"/> MISA Municipality <input type="checkbox"/> PWQO <input type="checkbox"/> Other			<b>Special Instructions</b>			Field Filtered (please circle): Metals / Hg / Cr VI Corrosivity pig (Cl, SO4, pH, EC/Resistivity)										Please provide advance notice for rush projects <b>Regular (Standard) TAT:</b> (will be applied if Rush TAT is not specified) Standard TAT = 5-7 Working days for most tests. Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details. <b>Job Specific Rush TAT (if applies to entire submission)</b> Date Required: Time Required: Rush Confirmation Number: (call lab for #)	
Include Criteria on Certificate of Analysis (Y/N)?																				
Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix																
1	1662333 C1-2	21/3/2019	1:30	Rock																
2	1662333 C1-1	21/3/2019	1:30	Rock																
3	1662333 C2-2	21/3/2019	1:30	Rock																
4	1662333 C2-3	21/3/2019	1:30	Rock																
5	1662333 C3-3	21/3/2019	1:30	Rock																
6	1662333 C3-1	21/3/2019	1:30	Rock																
7	1662333 C4-2	20/3/2019	4:30	Soil																
8	1662333 C4-3	20/3/2019	4:30	Soil																
9	1662333 C5-2	20/3/2019	4:30	Soil																
10	1662333 C5-1	20/3/2019	4:30	Soil																

21-Mar-19 16:07  
 Ema Gitej  
  
**B974455**  
 URE ENV-1222

* RELINQUISHED BY: (Signature/Print)		Date: (YY/MM/DD)		Time		RECEIVED BY: (Signature/Print)		Date: (YY/MM/DD)		Time		# jars used and not submitted		Laboratory Use Only	
JANE PETER (Jane)		2019/03/21		3:00pm		[Signature]		2019/03/21		16:07				Time Sensitive Temperature (C) on Recei: -3/-2/-1 Custody Seal Present Intact Yes No White: Maxxa Yellow: Client	

\* UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO MAXXAM'S STANDARD TERMS AND CONDITIONS. SIGNING OF THIS CHAIN OF CUSTODY DOCUMENT IS ACKNOWLEDGMENT AND ACCEPTANCE OF OUR TERMS WHICH ARE AVAILABLE FOR VIEWING AT WWW.MAXXAM.CA/TERMS.

\* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

\*\* SAMPLE CONTAINER, PRESERVATION, HOLD TIME AND PACKAGE INFORMATION CAN BE VIEWED AT HTTP://MAXXAM.CA/WWP-CONTENT/UPLOADS/ONTARIO-COC.PDF.

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

**APPENDIX D**

**Non-Standard Special Provisions  
and Notice to Contractor**



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

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Special Provision

November 2018

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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>
<b>1.0</b>	<b>SCOPE</b>

This specification covers the requirements for the installation of watermain at Station 15+825 and Station 17+035 and sanitary sewer at Station 15+825, Station 16+560 and Station 17+460 crossing the Queen Elizabeth Way (QEW) between west of Mississauga Road and west of Hurontario Street by a selected trenchless method.

**2.0 REFERENCES**

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

**Ontario Provincial Standard Specifications, General**

OPSS 180 Management of Disposal of Excess Material

**Ontario Provincial Standard Specifications, Construction**

OPSS 401 Trenching, Backfilling, and Compacting

OPSS 402 Excavating, Backfilling, and Compacting for Maintenance Holes, Catch Basins, Ditch Inlets and Valve Chambers

OPSS 403	Rock Excavation for Pipelines, Utilities, and Associated Structures in Open Cut
OPSS 404	Support Systems
OPSS 409	Closed-Circuit Television (CCTV) Inspection of Pipelines
OPSS 491	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 517	Dewatering
OPSS 539	Temporary Protection Systems

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

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

### **CSA Standards**

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

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

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

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

17025	General Requirements for the Competence of the Testing and Calibration Laboratories
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## **3.0 DEFINITIONS**

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

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

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

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

**Design Engineer** means the Engineer retained by the Contractor who produces the design and working

drawings and other engineering documents required of the Contractor. The Design Engineer shall be licensed to practice in the Province of Ontario.

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

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

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

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

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

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

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

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

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

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

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

**Inadvertent Returns** means the unexpected flow of fluids, saturated materials (or flowing soil) towards the

drilling rig that typically originated from an artesian aquifer encountered during the drilling process.

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

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

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

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

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

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

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

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

**Reaming** means a process for enlarging the bore path

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

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

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

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

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

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

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

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

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

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

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

#### **4.0 DESIGN AND SUBMISSION REQUIREMENTS**

##### **4.01 Design**

###### **4.01.01 General**

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

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

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

Pipe ramming, horizontal directional drilling and Auger Jack and Bore methods are prohibited for use on these trenchless crossings.

##### **4.02 Submission Requirements**

###### **4.02.01 Qualifications**

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

###### **4.02.01.01 Project Superintendent**

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

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

#### **4.02.01.02 Trenchless Contractor**

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

#### **4.02.01.03 Design Engineer**

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

#### **4.02.01.04 Design Checking Engineer**

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

#### **4.02.02 Working Drawings**

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

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

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

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

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

a) Plans and Details:

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

xi. Locations of protection systems.

b) Designs

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

c) Materials:

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

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

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

d) Upstream/Downstream Portal Installation Procedure:

- The access shaft or entry/exit pit details, as applicable.
- 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.
- Details of tunnelling equipment/methods to be used for the works.

f) Excavation and Dewatering:

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

g) Monitoring Method:

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

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



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

#### **4.02.03                      Quality Control Certificate**

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

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

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

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

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

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

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

### **5.0                                      MATERIALS**

#### **5.01                                      Pipe**

##### **5.01.01                                  General**

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

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

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

All fittings shall be designed to be watertight.

### **5.01.02 Steel Pipe**

Steel pipe shall be according to ASTM A252.

All steel casing pipe shall be square cut.

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

### **5.01.03 HDPE Pipe**

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

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

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

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

### **5.01.04 Concrete Pipe**

Concrete pipe shall be according to OPSS 1820.

### **5.02 Concrete**

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

### **5.03 Steel Reinforcement**

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

### **5.04 Wood**

Wood shall be according to OPSS 1601.

### **5.05 Drilling Fluids**

Drilling fluid shall be mixed according to the working drawings.

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

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

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

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

## **5.06 Grout**

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

## **6.0 EQUIPMENT**

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

Auger Jack and Bore methods are prohibited for use on these crossings.

### **6.02 Pipe Ramming**

Pipe ramming methods are prohibited for use on these crossings

### **6.03 Horizontal Directional Drilling**

#### **6.03.01 General**

Horizontal Directional Drilling methods are prohibited for use on these crossings.

## **6.04 Tunnelling**

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

- a) rock or boulder breaking and removal;
- b) equipment used within shields for spilling, fore-poling, face drainage, breasting boards/plates and for otherwise maintaining support of the tunnel crown and face under all anticipated conditions;
- c) jacking systems;
- d) alignment control systems;

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

## **6.05**

### **Microtunnelling Equipment**

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

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

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

- a) Remote Control System – The Contractor shall provide a MTBM that includes a remote control system with the following features:
- i. Allows for operation of the system without the need for personnel to enter the microtunnel. Has a display available to the operator, at a remote operation console, showing the position of the shield in relation to a design reference together with other information such as face pressure, roll, pitch, steering attitude, valve positions, thrust force cutter head torque, rate of advance and installed length.
  - ii. Integrates the system of excavation and removal of spoil and its simultaneous replacement by Product Pipe. As each pipe section is jacked forward, the control system shall synchronize all of the operational functions of the system.
  - iii. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.
  - iv. The system shall monitor and continuously balance the soil/bedrock and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.
  - v. The pressure at the excavation face shall be managed by controlling the volume of spoil removal with respect to the advance rate.
  - vi. The system shall include a separation process designed to provide adequate separation of the spoil from the slurry so that slurry with a sediment content within the limits required for successful microtunnelling, can be returned to the cutting face for reuse. Appropriately contain spoil at the site prior to disposal.
  - vii. The type of separation process shall be suited to the size of microtunnel being constructed, the soil type being excavated, and the work space available at each work area.
  - viii. The system shall allow the composition of the slurry to be monitored to maintain the slurry weight and viscosity limits required.
- b) Active Direction Control - Provide an MTBM that includes an active direction control system with the following features:
- i. Controls line and grade by a guidance system that relates the actual position of the MTBM to a design reference Provides active steering information that shall be monitored and transmitted to the operating console and recorded.
  - ii. Provides positioning and operation information to the operator on the control console.

## **6.05.01**

### **Pipe Jacking Equipment**

Provide a pipe jacking system with the following features:

- a) Has the main jacks mounted in a jacking frame located in the launch shaft.
- b) Has a jacking frame that successively pushes towards a receiving shaft, a string of Product Pipe that follows the microtunnelling excavation equipment.
- c) Has sufficient jacking capacity to push the microtunnelling excavation equipment and the string of pipe through the ground.

- d) The main jack station may be complemented with the use of intermediate jacking stations as required.
- e) Has a capacity at least 20 percent greater than the calculated maximum jacking load.
- f) Develops a uniform distribution of jacking forces on the end of the casing pipe.
- g) Provides and maintains a pipe lubrication system at all times to lower the friction developed on the surface of the pipe during jacking.
- h) Jack Thrust Blocking shall adequately support the jacking pressure developed by the main jacking system.
- i) Special care shall be taken when setting the pipe guide rails in the jacking shaft to ensure correctness of the alignment, grade, and stability.

#### **6.05.02 Spoil Separation System**

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

#### **6.05.03 Electrical Equipment, Fixtures and Systems**

Electrical equipment shall be suitably insulated for noise reduction. Noise produced by electrical equipment must comply with local municipal noise by-laws.

Electrical systems shall conform to requirements of the Canadian Electrical Code – CSA C22.1.

### **7. CONSTRUCTION**

#### **7.01 General**

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

The Project Superintendent shall supervise the work at all times.

##### **7.01.01 Layout, Alignment and Depth Control**

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

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

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

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

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

##### **7.01.02 Construction Shafts**

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

Shafts shall be maintained in a drained condition.

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

#### **7.01.03 Protection Systems**

The construction of all protection systems shall be according to 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, procedures, and materials employed shall prevent the migration of soil and/or rock material into the excavation from adjacent ground.

#### **7.01.06 Preservation and Protection of Existing Facilities**

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

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

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

#### **7.01.07 Transporting, Unloading, Storing and Handling Materials**

Manufacturer's handling and storage recommendations shall be followed.

#### **7.01.08 Trenching, Backfilling and Compacting**

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

#### **7.01.09 Support Systems**

Support systems shall be according to OPSS 404.

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

The Contractor is alerted that cobbles and boulders are expected in the soil deposits at the site. The Contractor shall address the removal of cobbles and boulders in the proposed method of construction. Removal of cobbles shall be expected to be routine and will not be considered cause for obstruction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered and shall set aside materials claimed as boulders for quantification in the presence of the Contract Administrator. Quantities of boulders expected at this site for the basis of bidding and adjustments to the price, if any, are provided within the Contract Documents.

#### **7.01.14 Management of Excess Material**

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

#### **7.01.15 Site Restoration**

Site restoration shall be according to OPSS 492.

### **7.02 Auger Jack & Bore Installation**

#### **7.02.01 Method of Installation Procedure**

Auger Jack and Bore methods are prohibited for these crossings,

#### **7.02.02 Pipe Installation**

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

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

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

#### **7.03 Pipe Ramming Installation**

Pipe ramming methods are prohibited for these crossings.

#### **7.04 Horizontal Directional Drilling Installation**

##### **7.04.01 General**

Horizontal Direction Drilling methods are prohibited for these crossings.

#### **7.05 Tunnelling Installation**

##### **7.05.01 General**

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

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

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

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

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

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

If excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease



excavation and make the excavation face secure. The Contractor shall then evaluate methods of construction and revise as necessary to ensure the safe continuation of the work.

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

#### **7.05.01 Tunnelling Method**

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

#### **7.05.02 Primary Liner (Support System)**

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

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

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

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

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

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

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

#### **7.05.03 Secondary Liner**

##### **7.05.03.01 Placing of Grout**

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

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

## **7.06            Microtunnelling**

### **7.06.01        General**

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

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

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

The Contractor shall maintain clean working conditions at all times.

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

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

### **7.06.02        Method of Installation**

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

- The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
- Selection of the excavation method and jacking equipment shall take into consideration the subsurface conditions within the tunnel alignment.
- Perform microtunnelling operations in a manner that will minimize the movement of the ground in front of and surrounding the tunnel in conformance with the limits listed in the Contract Documents.
- Prevent damage to structures and utilities above and in the vicinity of the microtunnelling operations.
- Excavated diameter should be the minimum size required to permit pipe installation by jacking.
- Whenever there is a condition encountered which could endanger the microtunnel excavation or adjacent structures if tunnelling operations cease, continue to operate without intermission including 24-hour working days, weekends and holidays, until the condition no longer exists.
- Maintain an envelope of lubricant around the exterior of the pipe during the jacking and excavation operation to reduce the exterior soil/pipe friction and possibility of the pipe seizing in place.
- In the event a section of pipe is damaged during the jacking operation or a joint failure occurs, as evidenced by inspection, visible ground water inflow or other observations, the Contractor shall submit for approval his methods for repair or replacement of the pipe.

### **7.06.03        Casing Installation**

Casing must withstand the jacking forces determined by the Contractor.

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

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

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

## **7.07 Instrumentation and Monitoring**

The work specified in this Section includes furnishing and installing instruments for monitoring of settlement (and heave) and ground stability.

### **7.07.01 Surface Monitoring Points**

Surface settlement points for monitoring ground stability shall be installed at the pavement/ground surface level on the shoulder, side slope and pavement at intervals of 5 m or less along the tunnel alignment centreline. For trenchless crossings at Station 17+035 and Station 17+460 surface settlement points shall be installed as arrays of three points at intervals of 5 m or less along the tunnel alignment centreline of the highway crossing and centred on the tunnel alignment. Arrays are not required for trenchless crossings at Station 15+825, Station 15+850 and Station 16+650. The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within a repeatability (combined accuracy and precision of equipment and methods)  $\pm 2$  mm of the actual elevation.

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

### **7.07.02 In-Ground Monitoring Points**

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

### **7.07.03 Installation, Replacement and Abandonment**

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

### **7.07.03 Monitoring and Reporting Frequency**

The Contractor shall survey and otherwise obtain elevations of all settlement monitoring points at the

following time intervals:

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

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

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

### **7.07.03            Benchmarks**

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

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

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

- a) Review Level: If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate or sequence of construction or ground stabilization measures to mitigate further ground displacement. If this Review Level is exceeded, the Contractor shall immediately notify the CA and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.
- b) Alert Level: If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic. No construction shall take place until all of the following conditions are satisfied:
  - i. The cause of the settlement has been identified.
  - ii. The Contractor submits a corrective/preventive plan.
  - iii. Any corrective and/or preventive measure deemed necessary by the Contractor is implemented.
  - iv. The CA deems it is safe to proceed.

## **9.                    MEASUREMENT FOR PAYMENT**

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

## **10. BASIS OF PAYMENT**

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

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

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

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

- (a) Where such drains and service connections are shown on the contract drawings the cost of connections shall be included in the contract price for pipe installation.
- (b) Where such drains and service connections are not shown on the contract drawings, the cost of connections will be considered an allowable extra to the contract.

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

### **Notes to Designer**

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

### **Designer Fill Ins**

#### **Design and Submission Requirements**

##### **\*4.01 Design Requirements**

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

##### **4.02 Qualifications**

##### **\*\*4.02.01.01 Project Superintendent**

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

\*\*\*4.02.01.02 Tunnelling/Trenchless Contractor

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

\*\*\*\*4.02.01.03 Design Engineer

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

\*\*\*\*\*4.02.01.04 Design Checking Engineer

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

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

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

\*\*\*\*\*7.07 Instrumentation and Monitoring

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

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

Criteria selection shall be project specific as recommended in the FIDR

WARRANT: Always with this specification

**PROTECTION SYSTEM – Item No.**

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Special Provision

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**Amendment to OPSS 539, November 2014**

**593.07.02          Removal of Protection Systems**

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

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

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

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

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

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

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Special Provision No. 517F01

July 2017

**Amendment to OPSS 517, November 2016**

**Design Storm Return Period and Preconstruction Survey Distance**

**517.01 SCOPE**

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

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

**517.04 DESIGN AND SUBMISSION REQUIREMENTS**

**517.04.01 Design Requirements**

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

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

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

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

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



**Table A**

IDF Curve Location	Latitude: 43.554167			Longitude: -79.612500		
Temporary Flow Passage Systems						
Site Name / Station Reference	Minimum Return Period (Years)	Return Period Flow Estimates (m³/s)				Design Engineer Requirements (Note 1)
		2 Year	5 Year	10 Year	25 Year	
Credit River Bridge	2	120.0	223.0	291.0	369.0	Yes
Stavebank Creek	2	0.7	1.1	1.6	2.0	No
Kenollie Creek	2	3.1	4.7	5.4	10.0	No
Dewatering Systems						
Site Name / Station Reference	Preconstruction Survey Distance (Note 2) (m)					Design Engineer Requirements (Note 1)
Credit River Bridge	50					Yes
Note:						
1. “Yes” means the design Engineer and design-checking Engineer shall have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work. “No” means a minimum experience level is not required for the design Engineer and design-checking Engineer.						
2. “N/A” indicates a preconstruction survey is not required.						

## **NOTICE TO CONTRACTOR – Subsurface Obstructions**

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### Special Provision

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The Contractor shall be alerted to the potential presence of cobbles, boulders and limestone and shale fragments in the fill and native soils, glacially derived soils and residual soils, as encountered in various boreholes advance at the various structure locations associated with the QEW widening from Mississauga Road to Hurontario Street. Consideration of the presence of these obstructions must be made in the selection of appropriate equipment and procedures for advancing caissons, excavations for shallow foundations, stormwater management pond, overhead sign supports, high mast light pole foundations, noise barrier walls, culverts, and installation of any temporary protection systems that may be required.

The Contractor is hereby notified that in some areas of the site, and in particular in the general vicinity of the east pier for the QEW Credit River Bridge WB, rip-rap and other cobble and boulder size obstructions are present at and below ground surface. These obstructions may impede or prevent excavation, grading, construction of access roads and/or crane pads and lay-down areas, and the installation of some types of protection systems/cofferdams.

The Contractor is hereby notified that in some areas of the site, and in particular in the general vicinity of the front and side slopes adjacent to the west abutment for the QEW Credit River Bridge WB, soil/rock anchor obstructions are present at and below the ground surface. These obstructions may impede or prevent excavation, grading, and construction of the abutment and/or the Multi-Use Trail and are to be removed where encountered above the elevation of the existing upper access road only. No soil/rock anchors are to be removed below the elevation of the existing upper access road.

The Contractor is hereby notified that between the west abutment of the existing QEW Credit River Bridge and the west abutment of the existing multi-use path (beneath the existing QEW Credit River Bridge) soil/rock anchor obstructions are present at and below the ground surface. These obstructions may impede or prevent the advancement of the drilled shafts for the west abutment of the East-West Active Transportation bridge. If they are encountered the Contract Administrator is to be notified immediately and this may require adjustments to the drilled shaft layout.

The presence of the above-noted near surface conditions shall be considered by the Contractor in the selection of appropriate equipment and procedures for various activities, including but not limited to excavation, grading, installation of the foundations and installation of cofferdams/protection systems.



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