



GOLDER
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REPORT

Foundation Investigation and Design Report

*Trenchless Installation of Municipal Services Under Highway 6
Proposed 150 mm Diameter Watermain and Sanitary Sewer
Township of Centre Wellington, Ontario*

Submitted to:

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SP 517F01 Temporary Flow Passage System

Part A

FOUNDATION INVESTIGATION REPORT TRENCHLESS INSTALLATION OF MUNICIPAL SERVICES UNDER HIGHWAY 6 PROPOSED 150 mm DIAMETER WATERMAIN AND SANITARY SEWER TOWNSHIP OF CENTRE WELLINGTON, ONTARIO

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by RE/MAX Real Estate Centre Inc. (RE/MAX) to carry out a geotechnical investigation for the proposed installation of a 150 mm inner diameter watermain and sanitary sewer (i.e., two separate crossings) under Highway 6, north of Fergus in the Township of Centre Wellington, Ontario. The investigation and geotechnical recommendations provided are in general accordance with the Ministry of Transportation, Ontario (MTO) Corridor Encroachment Permit Application titled, “*Guidelines for Foundation Engineering – Tunneling Specialty*” (January 2020) considering that the proposed municipal services will cross under MTO’s right-of-way. It is noted Golder is registered in the MTO’s Registry, Appraisal and Qualification System (RAQS) under Foundation Engineering Category, Tunnelling – High Complexity Specialty.

The purpose of the field investigation is to establish the subsurface conditions at the location of the proposed trenchless crossings by methods of borehole drilling, in-situ testing and laboratory testing on selected soil samples.

This report (Part A) summarizes the factual results of field and laboratory work (including field investigation procedures, borehole stratigraphy, and geotechnical and analytical laboratory test results) as well as a description of the interpreted soil and groundwater conditions at the trenchless crossing site. Design and construction-related comments including recommended instrumentation and monitoring, associated with the watermain and sanitary sewer that will cross under MTO’s right-of-way, are presented in Part B of this report.

The report should be read in conjunction with the *Important Information and Limitations of This Report* attached following the text of this report. The reader’s attention is specifically drawn to this information as it is essential for the proper use and interpretation of this document.

2.0 PROJECT AND SITE DESCRIPTION

2.1 Project Description

It is understood that the residential property at 961 St. David St. (between Side Road 18 and Side Road 19) is expected to be developed and will require servicing connections to the Township’s watermain and sanitary sewer. The existing (and proposed extension) of the municipal services run parallel to Highway 6 (and east of the highway) and consequently the connections will need to extend perpendicular to and under the highway to reach the property on the west side of Highway 6.

Based on the drawing provided by RE/MAX (*Drawing PP1.1 – Servicing Connections Plan and Profile, dated February 25, 2021*), the watermain and sanitary sewer crossings under Highway 6 are proposed to be about 30.3 m and 31.9 m in length, respectively, and be installed about 3.0 m apart (in plan location) using trenchless installation methods. The watermain and the sanitary sewer are expected to be comprised of 150 mm inner diameter (with a 230 mm outer diameter on the bell end of the pipe) TerraBrute® PVC pipe material. The watermain is proposed to be encased in a 300 mm diameter smooth-walled steel casing. The invert of the watermain casing is proposed to range between about Elevations 420.6 m and 419.9 m, while the invert of the sanitary sewer is proposed to range between about Elevations 417.6 m and 418.4 m from the east side to the west side of Highway 6, respectively.

Approximately 6.0 m by 6.0 m sending/receiving pits are proposed at the eastern and western limits of the trenchless installations (i.e., near the proposed sanitary Maintenance Holes Nos. 2A and 1A).

2.2 Site Description

The site of the proposed watermain and sanitary sewer is located near the northern limit of Fergus (about 18 km northwest of City of Guelph) which is the largest community in the Township of Centre Wellington, Wellington County, Ontario.

Highway 6 (also known as St. David Street) at the location of the trenchless crossings carries a total of two lanes of traffic – southbound lane and northbound lane. The taper of a turning lane (i.e., from Highway 6 northbound to Sideroad 18 westbound) starts near the proposed crossings. The travelled portion of the highway, including the shoulders, consists of an asphalt surface.

A roadway entrance to a residential property (961 St. David St.) is located on the west side of Highway 6, immediately south of the proposed trenchless crossings. Overhead electrical transmission lines run parallel to Highway 6 along both sides of the highway. The overhead lines also cross the highway about 100 m north of the proposed trenchless crossings. Existing buried gas, fibre optic and bell lines run parallel to the highway and east of the watermain and sewer alignments.

The proposed sanitary Maintenance Hole No. 1A is located on the residential property at 961 St. David St. and the proposed sanitary Maintenance Hole No. 2A is located within the Highway 6 right-of-way in the ditch running parallel to the east side of the road.

The topography of the area in the immediate vicinity of the proposed trenchless crossings is relatively flat. The land east of Highway 6 at this site is used predominantly for agricultural purposes, whereas the land west of Highway 6 has been developed into residential and commercial properties. The existing ground surface is at about Elevation 423.2 m and Elevation 423.4 m near the proposed sanitary maintenance holes on the west and east side of the highway, respectively, while the centreline of Highway 6 is at about Elevation 424.2 m.

3.0 PREVIOUS GEOTECHNICAL INVESTIGATION

A previous geotechnical investigation was carried out by others in 2013 (LVM, 2013) in the vicinity of the site. One relevant borehole from the previous investigation (Borehole BH-01-13) was advanced approximately 30 m south of the proposed crossings and has been incorporated into this report to supplement the subsurface information obtained from the current field investigation which involved the advancement of two boreholes. The previous borehole location is shown on Drawing 1 and a copy of the borehole record is provided in Appendix D.

4.0 FIELD INVESTIGATION PROCEDURES

The field work at the site was carried out on April 26, 2021, during which time two boreholes, designated as Boreholes 20-1 and 20-2, were advanced near the proposed sanitary Maintenance Holes Nos. 1A and 2A which represent the eastern and western limits of the proposed trenchless crossings. The approximate borehole locations as well as the borehole coordinates and ground surface elevations are described below.

Borehole Designation	Approximate Location	Coordinates (MTM NAD 83 Zone 10)		Ground Surface Elevation ¹
		Northing (Latitude)	Easting (Longitude)	
20-1	Proposed Sanitary Maintenance Hole No. 1A	4842177.7 m (43.716064°)	232751.3 m (-80.394132°)	423.1 m
20-2	Proposed Sanitary Maintenance Hole No. 2A	4842194.4 m (43.716216°)	232774.9 m (-80.393842°)	423.8 m

Note:

1. The ground surface elevation is reference relative to CGVD28 or HT2.0 Datum.

The subsurface soil conditions encountered in the boreholes are shown on the borehole records in Appendix A. A list of abbreviations and symbols is also provided in Appendix A to assist in the interpretation of the borehole records. The locations of the as-drilled boreholes are shown in plan on Drawing 1.

The boreholes were advanced by a CME-75 truck-mounted drill rig supplied and operated by Geo-Environmental Drilling Inc. of Milton, Ontario, using 200 mm outer diameter, continuous flight, hollow-stem augers. The soil samples were obtained at intervals of depth of about 0.75 m and 1.5 m. All soil samples were collected using a 50 mm outer diameter split-spoon sampler driven by an automatic hammer in accordance with Standard Penetration Test (SPT) procedures.

The boreholes were advanced to a depth of about 8.2 m and 9.8 m below existing ground surface and backfilled upon completion of drilling in general accordance with Ontario Regulation 903 (*Wells*) (as amended).

Prior to commencement of fieldwork, Golder arranged for the clearance of underground utilities/services. This included contacting Ontario One Call and retaining a private locator to scan the area in the vicinity of Borehole 20-1 near the proposed sanitary Maintenance Hole No. 1A located on private property (i.e., 961 St. David St.). The field work was observed on a full-time basis by a member of Golder's engineering staff who monitored drilling and sampling operations, and logged the boreholes in the field. The soil samples were transported to Golder's Mississauga geotechnical laboratory where the samples underwent further visual and tactile examination and geotechnical laboratory testing.

Geotechnical index testing (i.e., water content, Atterberg limits, and grain size distribution) was carried out on selected soil samples. All of the laboratory tests were carried out in accordance with MTO Laboratory and/or ASTM Standards, as appropriate.

Two soils samples were also collected and submitted, under chain-of-custody procedures, to Bureau Veritas Laboratories of Mississauga, Ontario (a Standards Council of Canada accredited laboratory) for analysis of a suite of corrosivity including pH, sulphate, sulphide, chloride and resistivity/conductivity.

5.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

5.1 Regional Geology

The site is located within a drumlinized till plain of the Guelph Drumlin Field physiographic region as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984). This area has been subjected to extensive glaciations during the last 200,000 years. At least two periods of continental glaciation are known to have occurred

within this period of time which were interrupted by warmer climate interglacial periods. The glaciers from the most recent glacial periods (Wisconsin Glaciation) withdrew from the area between approximately 8,000 years and 10,000 years ago.

The Guelph Drumlin Field physiographic region lies northwest of the Paris Moraine and consists of approximately 300 drumlins, or glacial hills, of various sizes. The lowland surrounding the drumlins consists of fluvially deposited soil. The till soil in the drumlins is mostly derived from the underlying dolostone. It is loamy, calcareous, pale brown in colour and contains red shale fragments. The till is relatively sandier and covered by a layer of fine sand and silt to the northeast of the physiographic region where the project site is located. Boulders can be found throughout the till deposit.

The overburden is generally greater than 15 m in thickness and is underlain at the site by dolostone of the Guelph Formation.

5.2 Overview of Local Subsurface Conditions

The subsurface soil and groundwater conditions encountered in the boreholes advanced at the site, together with the results of the in-situ and geotechnical/analytical laboratory testing, are presented on the borehole records (provided in Appendix A) and the laboratory figures/sheets (provided in Appendices B and C) The results of the in-situ field tests (i.e., SPT 'N'-values) as presented on the borehole records are uncorrected, and 'N'-values are based on SPT sampling procedures carried out with an automatic hammer.

The stratigraphic boundaries shown on the borehole records and on the soil strata profile (i.e., Drawing 1) are inferred from observations of drilling progress, non-continuous sampling and in-situ sampling, and therefore represent transitions between soil types rather than exact planes of geologic change. Further, subsurface conditions will vary between and beyond the borehole locations.

In general, the subsurface conditions encountered at the proposed trenchless crossings consist of sand and gravel and silty sand fill (associated with the Highway 6 embankment) underlain by a granular deposit comprised of moist to wet, sandy silt to silty sand to sand which in turn is underlain by a low plasticity cohesive deposit comprised of clayey silt-silt. The cohesive deposit is underlain by a predominantly clayey silt-silt to clayey silt till deposit, is interlayered with a sandy silt till deposit. The sandy silt till contains varying amounts of gravel and inferred cobbles and boulders. The till deposit is underlain in places by a wet, silty sand deposit. A more detailed description of the major soil strata is provided below.

5.2.1 Topsoil / Asphalt

An approximately 250 mm thick layer of topsoil was encountered at ground surface in Borehole 20-1 which was advanced through the grass covered property at 961 St. David St. The surface of the topsoil layer was encountered at approximately Elevation 423.1 m.

An approximately 130 mm thick layer of asphalt was encountered at ground surface in Borehole 20-2 which was advanced through the northbound shoulder of Highway 6. The surface of the asphalt layer was encountered at approximately Elev. 423.8 m.

Similarly, Borehole BH-01-13 encountered a 125 mm thick layer of asphalt at ground surface (Elevation 423.5 m).

5.2.2 SAND and GRAVEL (SP/GP) (Fill)

An approximately 0.6 m thick layer of fill comprised of brown sand and gravel was encountered below the asphalt in Borehole 20-2. The top of the fill layer was encountered at approximately Elevation 423.7 m.

An SPT 'N'-value of 37 blows per 0.3 m of penetration was measured within the sand and gravel fill layer, indicating a dense state of compactness.

A water content of about 3% was measured on a sample of the sand and gravel fill.

Similarly, BH-01-13 encountered an approximate 0.8 m thick layer of granular fill below the asphalt.

5.2.3 SILTY SAND (SM) (Fill)

An approximately 0.4 m and 0.8 m thick layer comprised of brown silty sand fill was encountered below the topsoil in Borehole 20-1 and below the sand and gravel fill in Borehole 20-2, respectively. The top of the layer was encountered at approximately Elevations 422.8 m and 423.1 m in Boreholes 20-1 and 20-2, respectively.

SPT 'N'-values of 4 blows and 14 blows per 0.3 m of penetration were measured within the silty sand fill layer, indicating a very loose to compact state of compactness.

The water content measured on two samples of the silty sand fill was about 15% and 12%.

Similarly, Borehole BH-01-03 encountered a 0.5 m thick layer of sand fill below the sand and gravel embankment fill. A 0.3 m thick layer of topsoil was present below the sand fill in BH-01-03.

5.2.4 Sandy SILT (ML) to SILTY SAND (SM) to SAND (SP-SM)

A 2.1 m and 2.2 m thick granular deposit comprised of moist to wet, brown sandy silt to silty sand to sand to gravelly sand was encountered below the fill layers in Boreholes 20-1 and 20-2. The top of the granular deposit was encountered at approximately Elevation 422.4 m. The sand layers are generally poorly graded and contain some fines.

The SPT 'N'-values measured within the granular deposit range from 11 blows to 20 blows per 0.3 m of penetration, indicating a compact state of compactness.

Water contents measured on eight samples of the sandy silt to silty sand to sand deposit range from about 9% to 22%.

The results of grain size distribution tests carried out on four samples of the granular deposit are shown on Figure 1 in Appendix B.

Similarly, Borehole BH-01-03 encountered an approximate 2.3 m thick deposit of wet, compact silt to sand below the fill and topsoil deposits.

5.2.5 CLAYEY SILT-SILT (CL-ML)

A 1.7 m and 0.4 m thick cohesive deposit of brown to grey clayey silt-silt was encountered below the granular deposit in Boreholes 20-1 and 20-2, respectively. The top of the cohesive deposit was encountered at approximately Elevation 420.4 m and Elevation 420.2 m in the respective boreholes.

The SPT 'N'-values measured within the cohesive deposit range between about 5 blows and 13 blows per 0.3 m of penetration, suggesting a firm to stiff consistency.

Water contents ranging from about 21% to 25% were measured on five samples of the clayey silt-silt deposit.

The result of grain size distribution testing carried out on two samples of the clayey silt-silt deposit is shown on Figure 2 in Appendix B.

Atterberg limits tests carried out on three samples of the cohesive deposit measured liquid limits ranging between about 21% to 22%, plastic limits between about 16% and 17%, and plasticity indices between about 4% and 6%. The results of the Atterberg limits tests are shown on the plasticity chart on Figure 3 in Appendix B, and indicate that the soil is classified as a clayey silt-silt of low plasticity.

5.2.6 CLAYEY SILT-SILT (CL-ML) to CLAYEY SILT (CL) (TILL)

A glacial till deposit comprised of grey clayey silt-silt to clayey silt was encountered below the clayey silt-silt deposit in Boreholes 20-1 and 20-2. Interlayers and variable amounts of silt, sand, and gravel were encountered within the deposit as noted on the borehole records. The top of the clayey silt-silt to clayey silt till deposit was encountered at approximately Elevations 418.6 m and 419.8 m in the respective boreholes. The glacial till deposit encountered in Borehole 20-1 was 2.7 m thick, and in Borehole 20-2 the glacial till deposit was penetrated for a thickness of 5.8 m before it was terminated within this deposit at a depth of about 9.8 m below existing ground surface, corresponding to Elevation 414.1 m. Auger grinding was noted during drilling operations throughout the till deposit inferring the presence of cobbles and/or boulders which are typically encountered in glacial till deposits in this area.

The SPT 'N'-values measured within the clayey silt-silt to clayey silt till deposit generally range from 11 blows to 40 blows per 0.3 m of penetration, with one value of 50 blows for 0.05 m of penetration, suggesting a stiff to hard consistency.

Water contents measured on seven samples of the clayey silt-silt to clayey silt till deposit range from about 8% to 12%.

The result of a grain size distribution test carried out on one sample of the clayey silt-silt to clayey silt till is shown on Figure 4 in Appendix B.

Atterberg limits tests were carried out on the fine-grained portion of three samples of the clayey silt-silt to clayey silt (till) deposit and measured liquid limits ranging from about 16% to 20%, plastic limits ranging from about 11% to 16%, and plasticity indices ranging from about 4% to 9%. The results of the Atterberg limits tests are shown on the plasticity chart on Figure 5 in Appendix B and indicate that the fine-grained portion of the till deposit can be classified as a clayey silt-silt to clayey silt of low plasticity.

A silty interlayer was encountered in Borehole 20-1 at a depth of about 6.2 m below ground surface, corresponding to Elevation 416.9 m. Atterberg limits testing carried out on a sample of the interlayer indicate it is non-plastic.

In the previous borehole (i.e., BH-01-13), a similar glacial till deposit was encountered at about Elevation 419.5 m and extended to the termination of the borehole. The till deposit generally consisted of clayey silt-silt, but transitioned to a saturated sandy silt till deposit from a depth of about 7.0 m to 8.8 m (between Elevations 416.5 m and 414.7 m). The presence of cobbles and boulders above and below the till deposit were described to be present in the borehole record.

5.2.7 SILTY SAND (SM)

A lower granular deposit comprised of brown silty sand was encountered below the till deposit in Borehole 20-1. The top of the lower granular deposit was encountered at a depth of about 7.2 m below ground surface, corresponding to approximately Elevation 415.9 m. Borehole 20-1 penetrated the deposit for a thickness of 1.0 m before being terminated within this deposit at a depth of about 8.2 m below existing ground surface, corresponding to approximately Elevation 414.9 m.

An SPT 'N'-value measured within the lower granular deposit is 31 blows per 0.3 m of penetration, indicating a dense state of compactness.

A water content measured on a sample of the silty sand deposit is about 15%.

The results of a grain size distribution test carried out on a sample of the lower granular deposit is shown on Figure 6 in Appendix B.

5.3 Groundwater Conditions

Groundwater was encountered within the open borehole at a depth of about 4.8 m below ground surface (Elevation 418.3 m) in Borehole 20-1. Borehole 20-2 was dry upon completion of drilling. However, these water level measurements do not represent the stabilized groundwater level. The recovered soil samples were generally moist, but wet samples were also recovered from the upper sandy silt to silty sand to sand deposit between depths of about 1.5 m and 2.8 m below existing ground surface (between Elevations 421.7 m and 420.4 m) in Borehole 20-1 and between depths of about 3.0 m and 3.6 m below existing ground surface (between Elevations 420.8 m and 420.2 m) in Borehole 20-2. Wet samples were also recovered from the lower silty sand deposit between depths of 7.2 m and 8.2 m below existing ground surface (between Elevations 415.9 m and 414.9 m) in Borehole 20-1.

The previous Borehole BH-01-13 (borehole record provided in Appendix D) included the installation of nested groundwater monitoring wells comprised of two standpipe piezometers screened at different depths. Details of the standpipe piezometer installations and a summary of piezometric water level measurements are provided below.

Groundwater Monitoring Well Designation	Depth / Elevation of Piezometer / Sand Pack	Screened Deposit	Piezometric Water Level Measurements	
			May 27, 2013	June 14, 2013
			Depth / Elevation	Depth / Elevation
BH-01-13 (shallow standpipe)	1.5 m to 3.0 m / 422.0 m to 420.5 m	Compact Silt to Sand	1.4 m / 422.1 m	1.1 m / 422.5 m
BH-01-13 (deep standpipe)	7.0 m to 10.5 m / 416.5 m to 413.0 m	Very Dense Sandy Silt to Hard Clayey Silt (Till)	2.9 m / 420.6 m	2.7 m / 420.8 m

It is noted that the groundwater level is subject to seasonal fluctuations and precipitation events and is expected to be higher during wet seasons and periods of heavy and/or sustained precipitation.

5.4 Analytical Testing of Soil

Two composite soil samples were selected from the clayey silt-silt and the silt till deposits and submitted to Bureau Veritas Laboratories in Mississauga, Ontario for corrosivity testing. The analytical laboratory test results are provided on the Certificate of Analysis presented in Appendix C, and summarized below.

Borehole No.	Sample No. (BH) ¹	Average Approx. Sample Depth / Elevation (BH) (m)	Material Type	Resistivity (ohm-cm)	Conductivity (μohm/cm)	pH	Chloride (Cl) Content (μg/g)	Sulphate (SO ₄) Content (μg/g)
20-1 & 20-2	6 (20-1) & 6A (20-2)	4.1 / 419.0 (20-1) & 3.9 / 420.0 (20-2)	Clayey silt-silt	3100	324	8.0	120	75
20-1 & 20-2	7 (20-1) & 7 (20-2)	4.9 / 418.2 (20-1) & 4.9 / 419.0 (20-2)	Clayey silt-silt till	3300	301	8.1	80	97

Note:

1. Two soil samples from the respective deposits, each one from Boreholes 20-1 and 20-2, were combined and submitted as one analytical sample (i.e., analytical sample I.D.s 20-1 SS6 + 20-2 SS6A and 20-1 SS7 + 20-2 SS7).

6.0 CLOSURE

The field work for this investigation was supervised by Ms. Darcy Hansen, E.I.T., a geotechnical engineer-in-training at Golder. The Foundation Investigation Report was prepared by Ms. Darcy Hansen, E.I.T. and reviewed by Mr. Tomasz Zalucki, P.Eng., a geotechnical engineer at Golder.

Mr. Kevin Bentley, P.Eng., a senior geotechnical engineer and MTO Foundations Designated Contact for Golder, conducted an independent technical and quality control review of the report.

Signature Page

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Tomasz Zalucki, P.Eng
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DH/TZ/KJB/dh/ml

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Part B

FOUNDATION DESIGN REPORT TRENCHLESS INSTALLATION OF MUNICIPAL SERVICES UNDER HIGHWAY 6 PROPOSED 150 mm DIAMETER WATERMAIN AND SANITARY SEWER TOWNSHIP OF CENTRE WELLINGTON, ONTARIO

7.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

7.1 General

This section of the report provides a geotechnical discussion and recommendations for the design and installation of the proposed 150 mm inner diameter watermain and sanitary sewer under MTO's right-of-way (i.e., Highway 6) using trenchless methods. These recommendations are based on interpretation of the factual data obtained from two boreholes, Boreholes 20-1 and 20-2, advanced during Golder's subsurface investigation and existing information at the site of the proposed trenchless crossings.

The discussion and recommendations contained in this report are intended to provide the designers with sufficient information to complete the detail design of the proposed trenchless crossings. This Foundation Investigation and Design Report, with the interpretation and recommendations are intended for the use of the designer and the Ministry of Transportation, Ontario (MTO) during their review and permitting of the work where it passes beneath MTO right-of-way and should not be used or relied upon for any other purpose or by any other parties, including the construction or design-build Contractor(s). The Contractor(s) undertaking the work must make their own interpretation based on the factual data in Part A (Foundation Investigation) of this 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 aspects of construction must make their own interpretation of the factual information provided as it may affect equipment selection, construction methods, scheduling, and the like.

7.2 Proposed Alignment of Trenchless Crossings

It is understood that the Township of Centre Wellington has proposed to extend its existing municipal infrastructure (i.e., a watermain and a sanitary sewer) along Highway 6 in Fergus. The residential property at 961 St. David St. (between Side Road 18 and Side Road 19) is expected to be developed and will require servicing connections to the Township's watermain and sanitary sewer.

Based on the drawing provided by RE/MAX (*Drawing PP1.1 – Servicing Connections Plan and Profile, dated February 25, 2021*), the watermain and sanitary sewer crossings under Highway 6 are proposed to be about 30.3 m and 31.9 m in length, respectively, and be installed about 3.0 m apart (in plan location) using trenchless installation methods. The watermain and the sanitary sewer are expected to be comprised of 150 mm inner diameter (with a 230 mm outer diameter on the bell end of the pipe) TerraBrute® PVC pipe material. The watermain is proposed to be encased in a 300 mm diameter smooth-walled steel casing. The invert of the watermain casing is proposed to range between about Elevations 420.6 m and 419.9 m, while the invert of the sanitary sewer is proposed to range between about Elevations 417.6 m and 418.4 m from the east side to the west side of Highway 6, respectively.

An approximately 6.0 m by 6.0 m sending / receiving pit is proposed at the eastern and western limits of the trenchless installations (i.e., near proposed sanitary Maintenance Hole Nos. 2A and 1A).

The existing ground surface is at about Elevation 423.2 m and Elevation 423.4 m near the proposed sanitary maintenance holes on the west and east side of the highway, respectively, while the centreline of Highway 6 is at about Elevation 424.2 m.

A summary of the proposed carrier pipe/liner dimensions and invert depths/elevations are summarized below and shown on Drawing 1.

Type of New Municipal Infrastructure	Diameter / Type of Proposed Pipe	Length of Trenchless Crossing	Utility Invert Elevation / Depth	Approximate Soil Cover Thickness ^{1, 2}
Watermain	150 mm inner diameter PVC pipe encased in 300 mm diameter (D) steel casing	30.3 m	West Limit: 419.9 m / 3.3 m	3.0 m (> 10D)
			East Limit: 420.6 m / 2.8 m	2.5 m (> 8D)
Sanitary Sewer	150 mm inner diameter PVC pipe (possible casing up 300 mm (D) diameter assumed)	31.9 m	West Limit: 418.4 m / 4.7 m	4.5 m (> 15D)
			East Limit: 417.6 m / 5.8 m	5.5 m (> 18D)

Note:

1. Thickness of soil cover is measured from top of casing overbort to ground surface at Maintenance Hole No. 1A or 2A and D is casing diameter.

2. The minimum thickness of soil cover occurs where the bore/tunnel crosses the ditch on the west side of Highway 6; about 2.0 m (7D) and 4.0 m (13D) above the casing overborts of the watermain and sanitary sewer, respectively.

Based on the table above, this project is considered to have a low complexity level for tunnelling specialty services according to the MTO Corridor Encroachment Permit classification.

7.3 Trenchless Installation Methods

7.3.1 General Description

Based on the proposed alignment and diameter of the proposed crossings, the viable trenchless methods considered herein include horizontal directional drilling (HDD), horizontal auger boring (commonly referred to as jack-and-bore), pipe ramming, and micro-tunneling using a Microtunnel Boring Machine (MTBM). A brief description of these trenchless construction methods is provided below.

- **Horizontal Directional Drilling (HDD):** HDD involves drilling of a relatively small diameter pilot hole (generally on the order of 100 mm to 150 mm) using a remotely controlled and steerable drilling bit on a flexible string of drill rods, while the bore is supported using a bentonite slurry. Once the pilot hole is complete, the bore is typically reamed in one or more passes to a larger diameter, and then the final pipe is pulled through the bore (using the drill rods to pull the pipe into place). HDD equipment is available for drilling in both bedrock and overburden, but drilling is challenging in bouldery ground (e.g., glacial till containing cobbles and boulders). Deep sending and receiving (entrance and exit) pits are generally not required; however, larger laydown areas are required to install the final pipe/casing, and the crossing typically needs to be longer to accommodate the shallow entry and exit angles for the drilling equipment and allowable bending radius of the pipe/casing (on the order of 10 degrees to 30 degrees from horizontal). Bores are typically limited to less than 1 m in diameter.
- **Horizontal Auger Boring (Jack-and-Bore):** In Ontario, a traditional jack-and-bore operation typically involves pushing a steel pipe/casing horizontally into the ground by jacking while simultaneously cutting the ground with an auger head operating near the leading end of the steel pipe. The spoil is generally removed from within the casing using an auger boring machine. The cutting head is driven by, and is positioned at, the leading end of an auger string that is established within the casing pipe. Jacking (sending) and receiving pits are required. Typically, there is limited ability to steer the casing during jacking unless more advanced techniques are used such as the pilot-tube method. Jack-and-bore may be challenging in bouldery soils (e.g., glacial till containing

cobbles and boulders). In some cases, contractors will attempt to run the auger cutting head in front of the lead end of the casing to advance the pipe in difficult ground; however, this approach can lead to high risks for ground losses leading to settlement and/or sinkholes at the ground / road surface. This method is also considered to be a higher risk option in running or flowing ground (dry or saturated sand and silt) where uncontrolled loss of soil may occur at the tunnel face and flow into the casing.

In some cases, traditional jack-and-bore equipment is supplemented with a specialized rotating cutting head, sometimes referred to as a Small Boring Unit (SBU). These cutting heads are welded to the lead end of steel casings, can sometimes include limited alignment adjustment capabilities, and can be fitted with rock disc cutters in bouldery ground. In the ideal ground conditions (e.g., hard glacial till and/or weathered rock), the small boring heads can be advantageous. However, these systems are not well suited to and should not be used in saturated and potentially flowing or running ground conditions. Further, these systems should not be confused with microtunnelling systems that operate using very different principles of ground support.

- **Pipe Ramming:** Pipe ramming uses a pneumatic tool to hammer a steel pipe or casing into the ground. The pipe is almost always driven “open” to thereby direct the soil into the pipe interior instead of compacting it outside the pipe. The leading edge of the pipe typically has a cutting shoe (small overcut) to reduce friction between the casing and soil and to improve the load conditions on the pipe. Soil/pipe friction reduction can also be achieved with lubrication, and different types of bentonite and/or polymers can be used for this purpose. Depending on the length of the installation, the soils inside the pipe can be removed either periodically during or after the installation by augering (using an auger boring machine), scrapers, “pipe shovels”, compressed air or water jetting. The spoil removal equipment depends on the diameter of the casing, soil types being removed, and accessibility. 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 cobbles and boulders depending on their size, number, and their positions relative to the pipe leading edge and diameter. Partial or full removal of materials from within the pipe, to facilitate driving, should not be carried out if the ground through which the pipe is being driven consists of saturated granular soils (i.e., silt, sand, gravel). As with traditional jack-and-bore methods, flowing ground conditions and/or operating the cleanout augers beyond, at or near the leading edge of the casing can result in significant ground losses, excessive surface settlement and, in some cases, sinkholes that could propagate to the surface.
- **Micro-tunnelling using MTBM:** Micro-tunneling using a MTBM is a method of installing pipes in bores/tunnels typically ranging from about 0.6 m to 3.0 m in diameter behind a steerable remote-controlled shield that is pressurized with a bentonitic slurry at the cutting face to balance earth pressures and minimize ground losses. The process is essentially remote-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. Micro-tunnelling equipment is generally more suited to tunnelling through overburden. Availability of this equipment for the anticipated small diameter in the project area is likely limited. Some MTBM's are promoted as being able to “crush” cobbles with internal cone crushing systems and others have been promoted as capable of passing cobbles/boulders of as much as one-third of the bore diameter, however, both approaches to managing larger stones can be highly problematic and incapable of completing construction in bouldery ground. Large numbers of cobbles can also “choke” these machines and result in failure of the bore. In bouldery ground, where the boulders can be firmly held in place by the surrounding soil matrix, equipping MTBMs with rock-disc cutters can be successful. In all cases, detailed review of the conditions and equipment configuration are needed prior to construction to achieve a reasonable probability of success.

7.3.2 Subsurface Conditions and Tunnelman's Ground Classification

The subsurface conditions encountered at the boreholes advanced along/adjacent to the proposed trenchless crossings are shown on Drawing 1 and generally consist of sand and gravel fill (associated with the Highway 6 embankment) underlain by an approximately 2 m thick granular deposit of sandy silt to silty sand to sand which in turn is underlain by an approximately up to 1 m thick cohesive deposit of clayey silt-silt. The cohesive deposit is underlain by a clayey silt-silt to clayey silt till deposit which in turn is underlain by a lower wet silty sand deposit. The glacial till deposit contains layers / zones of saturated sandy silt with variable amounts gravel. Cobbles/boulders were inferred to be present by grinding of the augers during drilling and were identified at various depths in the previous borehole (BH-01-01) advanced by others near the site.

Based on the design drawings provided by RE/MAX, the anticipated soil conditions within the proposed bore/tunnel horizon (i.e., proposed tunnel path) for the trenchless crossings are summarized below.

■ Watermain

- Bore/tunnel horizon (for 300 mm diameter casing): Between approximately Elevations 420.2 m and 419.9 m at the western limit of the crossing and between approximately Elevations 420.9 m and 420.6 m at the eastern limit of the crossing.
- Anticipated Soil Conditions: Firm clayey silt-silt to wet compact sand to sandy silt at the western limit and wet compact silty sand to gravelly sand at the eastern limit of the crossing.

■ Sanitary Sewer

- Bore/tunnel horizon (for 150 mm inner diameter carrier pipe and assuming up to 300 mm diameter casing may be required for installation): Between approximately Elevations 418.7 m and 418.4 m at the western limit of the crossing and between approximately Elevations 417.9 m and 417.6 m at the eastern limit of the crossing.
- Anticipated Soil Conditions: Firm clayey silt-silt to very stiff clayey silt-silt (till) at the western limit and very stiff to hard clayey silt-silt to clayey silt (till) at the eastern limit of the crossing.

The groundwater level in Borehole 20-1 was measured at about Elevation 418.3 m during drilling, and Borehole 20-2 was dry upon completion of drilling, however, these water levels are not considered to represent the stabilized groundwater level at the project site. The groundwater level measured in the shallow and deep standpipe piezometers in Borehole BH-01-13 (previously installed and measured by others in June 2013), located about 30 m south of the proposed trenchless crossings, varies between approximately 1.1 m and 2.7 m below ground surface (Elevation 422.5 m and 420.8 m) respectively. Therefore, the groundwater level (i.e., piezometer head) is expected to be at about Elevation 422.5 m at the site, resulting in the water level ranging from about 1.9 m to 2.6 m above the invert of the bore/tunnel for the watermain and about 4.1 m to 4.9 m above the invert of the bore/tunnel for the sanitary sewer.

The anticipated soils that the trenchless installations would extend through may be classified based on the Tunnelman Ground Classification System developed by Terzaghi (1950) and modified by Heuer (1974). The System is commonly used to describe the potential behaviour of various soil types at an unsupported tunnel face during excavation. This System uses qualitative "stand-up time" criteria to classify the ground into six principal categories as follows: firm, slow ravelling/fast ravelling, squeezing, running/cohesive-running, flowing and swelling. This System also differentiates the ground behaviour of various soil types above and below the groundwater table. Therefore, this Ground Classification System has been adopted to provide an objective evaluation of the anticipated ground behaviour during trenchless installations. Correlating the soil classification with Terzaghi's modified

Tunnelman Ground Classification System, the soils encountered along the proposed trenchless installation horizons (i.e., tunnel paths) can be described as follows:

■ **Watermain**

- The firm clayey silt-silt deposit anticipated at the western portion of the proposed tunnel/bore may be classified as “firm” to “slow ravelling” during initial excavation, but will degrade with time and likely exhibit “slow ravelling” to “fast ravelling” behaviour below the groundwater level.
- The saturated compact sandy silt to sand, and silty sand to gravelly sand deposit anticipated along the majority of the tunnel/bore may be classified as “flowing” below the groundwater level, and “running” above the groundwater level.

■ **Sanitary Sewer**

- The firm to stiff clayey silt-silt deposit anticipated at the western portion of the proposed tunnel/bore may be classified as “firm” to “slow ravelling” during initial excavation, but will degrade with time and likely exhibit “slow ravelling” to “fast ravelling” behaviour above and below the groundwater level.
- The very stiff to hard clayey silt-silt to clayey silt (till) anticipated along the majority of the proposed tunnel/bore may be classified as “slow ravelling” to “fast ravelling” above and below the groundwater level. Any cohesionless layers / zones (e.g., sandy silt layers) may exhibit “flowing” behaviour below the groundwater level.

7.3.3 Assessment of Trenchless Methods

It is noted that the contractor should be responsible for selecting the trenchless method and equipment for the installation, unless specific methods are otherwise prohibited. This report provides guidance on the influence of ground behaviour on some possible trenchless installation methods, however, 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 from the current subsurface investigation and their experience in similar soil conditions.

A comparison of trenchless installation methods considered at this site is provided in Table 1 based on the ground conditions encountered in the boreholes, proposed bore/tunnel run lengths of about 30 m, and anticipated excavation diameters of about 300 mm for the watermain casing and 300 mm for the sanitary sewer (if a casing is required).

Assuming the tunnel diameter would not exceed about 300 mm, the use of a MTBM is not considered practical given this small tunnel diameter is near the lower bound limit of this trenchless technology, especially in the Ontario region. Even if a bigger MTBM is utilized to install a larger diameter casing (e.g., 600 mm diameter casing), this technology is not considered economically viable given the short tunnel drives associated with the proposed crossings. The horizontal auger boring (i.e., jack-and-bore) method of construction is also not considered a practical alternative considering the very high risk of ground loss due to overmining in saturated granular soils, especially the poorly-graded sands below the groundwater level, as encountered at the project site. Even with a depressed groundwater level along the entire alignment, the risk of overmining is not entirely eliminated. The risk of ground loss decreases for the sanitary sewer crossing which is shown to be deeper and within the cohesive deposits, although the potential presence of sandy / silty interlayers within the till deposit could lead to overexcavation and associated ground loss.

Consequently, the feasible trenchless methods of installation at this site are considered to be pipe ramming and HDD. Pipe ramming also poses a risk of overmining if the soil plug inside the pipe casing has to be periodically “cleaned-out” using water pressure (i.e., water jetting), air pressure, or augers via an auger boring machine. However, considering the small diameter and short length of the proposed crossings, the “cleaning-out” of the steel casing can likely be carried out once the entire casing has been hammered from the entry pit/shaft to exit pit/shaft. The HDD method is also feasible; however, it is noted that the send and receive pits (especially for the deeper sanitary sewer) will likely need to extend well beyond the limits of the proposed crossing to accommodate shallow entry and exit angles for the drilling equipment. Consequently, additional private property entry/land use agreements may be required to construct the pits and prepare the laydown areas. Furthermore, detailed drilling fluid and pressure design/analysis will be required to prevent hydrofracture (i.e., inadvertent fluid return to the surface – more details provided below), especially for the relatively shallow watermain crossing in granular deposits.

The main geotechnical issues and risks associated with trenchless installations at this site include:

- **Flowing / Running Soil Leading to Ground or Highway Settlement** – Given that the tunnel horizon along the proposed watermain alignment consists predominantly of compact granular soils (i.e., generally silty sand to sand deposits) below the groundwater level, there is the potential for such granular soils to “flow” or “run” at the bore/tunnel face and into the casing and towards the send/receive pit/shaft. Such “flow” could cause significant loss of ground at and above the face of bore/tunnel excavation that could propagate to the ground surface in the form of sinkholes or settlement. Also, considering the two crossings are proposed to be located in close proximity to each other, ground disturbance will be compounded in the same general area unless the two crossings are spaced further apart. Although dewatering along the alignments is not necessarily required if HDD or pipe ramming is selected, careful control of trenchless operations is critical to ensure a sufficient soil plug is maintained behind the lead casing to prevent uncontrolled loss of ground during the pipe ramming operation, and that proper drilling fluid viscosity and pressure is utilized during the HDD operation to reduce the risk of collapse of the bore.
- **Hydrofracture/Inadvertent Fluid Returns** – Drilling fluid pressures must be carefully designed and monitored to avoid exceeding the maximum allowable fluid pressure, above which hydraulic fracturing, or “frac-out”, is anticipated. Hydraulically fracturing the overburden soils is a potential risk during an HDD installation or use of a slurry MTBM, especially for the watermain, with generally about 3 m of cover soil to highway surface, but where the ditch on the west side of Highway 6 crosses the bore/tunnel with less than approximately 2 m of soil cover. Removal of excessive soil cuttings and/or lost circulation from hydraulic fracturing can potentially cause ground disturbance and/or collapse of the drillhole which in turn could lead to settlement/sinkholes at the ground or highway surface. The potential for frac-out is dependent on the type of drilling equipment, drilling and reaming methodology, down hole drilling fluid properties (e.g., density, viscosity, etc.), groundwater levels, drill path geometry (particularly the elevation of entry and exit pits in relation to the HDD hole profile elevation and depth of overburden cover (i.e., overburden stress levels)), which all impact the drilling fluid pressure.
- **Dynamic Impact Loads Leading to Ground or Highway Settlement** - Dynamic impact loads applied to the steel casing during the pipe ramming operation generate vibrations that are transferred from the casing to the surrounding soils. As such, any loose granular soils surrounding the casing, may experience densification and settlement and should be taken into consideration when developing the pipe ramming work plan. Ground vibrations induced by the ramming operation become more prominent as the casing diameter increases (i.e., larger hammers which generate more power/energy transfer are required to advance the casing). However, the casing diameter at the site is considered relatively small (i.e., up to about 300 mm). The effect of ground

vibrations on adjacent settlement-sensitive structures and underground utilities, if present, should also be assessed.

- **Steering / Profile Control** – It is noted that there is a risk of not achieving the desired alignment and profile during the trenchless operation, especially for the pipe ramming operation where steering control is limited after the initial alignment from the ramming pit and the short length of the crossing limits steering capabilities for HDD. This is of particular concern for the installation of the sanitary sewer which is a gravity-flow pipe where profile/grade is critical to maintain functionality of the sewer system. Stringent grade tolerances are critical in ensuring proper flow of effluent. Therefore, to reduce the risk of not achieving the minimum design grade, consideration should be given to either increasing the slope for the crossing or installing a larger diameter casing (such as a 600 mm diameter casing). A larger casing diameter will provide the flexibility to adjust the grade of the sanitary sewer pipe below Highway 6 and provide sufficient strength (steel) for pipe ramming operations. In particular, the current profile of the sewer near the west limit is near the interface of the firm clayey silt and very stiff to hard clayey silt-silt till (i.e., mixed face), as a result, challenges maintaining profile control along this firm / very stiff interface can be expected.
- **Obstructions** – Glacial till deposits are known to contain cobbles and boulders that can deflect or impede trenchless construction equipment. The presence of cobbles/boulders was inferred during the recent investigation and documented on the previous borehole record from the past investigation near the site. The sanitary sewer crossing will encounter the till soils, and as such, potentially cobbles and boulders. Difficulties in maintaining grade/alignment should be expected if cobbles/boulders are encountered and there is a risk that the crossing may need to be abandoned if the obstruction cannot be effectively removed/penetrated without compromising the integrity of the highway.

7.3.4 Trenchless Considerations

All trenchless work should be carried out in general accordance with MTO's Corridor Encroachment Permit Application titled, "*Guidelines for Foundation Engineering – Tunneling Specialty*" (January 2020). The Contract Documents must include a specification outlining the Contractor's experience, procedures and equipment to be used for the trenchless crossing, similar to MTO's Special Provision (SP) titled "*Pipe Installation by Trenchless Methods*", dated January 2019, a copy of which is included in Appendix E. Prior to construction, the Contractor should be required to submit the proposed construction work plan, dewatering plans, machine specifications, slurry management plans and equipment, obstruction contingency plans and the monitoring program for review and approval from the MTO, and other relevant stakeholders as may be required. It is further recommended that the geotechnical aspects of the Contractor's work plan for the trenchless crossing be reviewed by a qualified geotechnical engineer prior to construction. These plans should identify all hazards and the methods proposed to mitigate interference to the highway, existing utilities/services, and any nearby infrastructure, such as heave, settlement, obstructions, and changes of alignment or profile. The Contractor's work plan should also include a provision for compensation grouting and for grouting around the outside of any temporary or permanent ground support systems should the need arise.

Performance of the completed trenchless crossing will largely depend on the Contractor's construction procedures and techniques. As such, all trenchless works should be carried out by an experienced specialist Contractor employing only qualified workers skilled in their trade, under the direction of an experienced foreman. In general, when crossing beneath highways, trenchless operations should be carried out continuously (i.e., 24 hours per day) from the start of casing/pipe advancement until the installation is complete. Continuous operations assist with minimizing risks of equipment becoming bound in the tunnel/bore by time-dependent increases in friction and/or

adhesion, uncontrolled ground losses, and other adverse problems that may occur while the work area and equipment are unattended. If forward motion of the casing/pipe is halted at any time other than for pre-planned reasons (e.g., addition of casing/pipe sections, etc.), and prevention of voids or uncontrolled loss of ground under the highway cannot be assured, consideration should be given to abandoning the casing/pipe by filling by pressure-grouting the pipe/casing as soon as possible.

Provided the trenchless installation is carried out in general accordance with the above, settlements of less than 25 mm can be expected to occur at the highway surface, with the potential for additional settlements (up to about 50 mm) to occur at the ditches or in any areas where the soil cover above the top of the tunnel/bore is less than 2.0 m.

Considering that the sanitary sewer is proposed to be founded at a greater depth compared to the watermain, it is assumed (and recommended) that the sanitary sewer be installed first. This trenchless installation sequence will allow the Contractor to modify the selected installation method, if required, and monitor ground deformations prior to installation of the watermain which has considerably less soil cover. This strategy will also reduce the risk of the watermain casing experiencing settlements induced by the installation of the sanitary sewer.

It is noted that the watermain is proposed to be offset 3.0 m (centreline-to-centreline in plan) away from the sanitary sewer and run parallel to the sewer alignment; this offset will ensure that the watermain will be situated outside of the zone of influence typically associated with tunnelling activities if ground loss/disturbance occurs (i.e., a line projected at about 1H:1V from the invert of the sewer bore/tunnel).

Furthermore, if pipe ramming is selected as the preferred method of trenchless installation, consideration should be given to driving the steel casing downhill (i.e., from a higher elevation to lower elevation) to reduce the risk of soils “flowing” into the casing from above the bore.

7.3.5 Grouting/Sealing

Depending on the trenchless method of installation selected and overcut (diameter of tunnel/bore excavation relative to the outside diameter of the casing/pipe), there may be a requirement to grout the annulus during and/or after installation of the casing/pipe in order to reduce the risk and/or limit settlements to tolerable levels (typically less than 25 mm is considered acceptable).

For installations where 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 or inferred, a provision should also be made for a program of compensation grouting above the casing pipe and/or to maintain the pavement structure.

7.4 Settlement Monitoring

Settlements associated with trenchless installation methods are typically of two types:

- Large settlements: These settlements are the result of loss of ground due to over-excavation caused by the inability to control adverse ground conditions or due to the tunnelling/boring operator's inexperience and/or errors. Large settlements can lead to the creation of voids and/or sinkholes above the installed pipe/casing.
- Systematic settlements: These settlements are primarily caused by the collapse of the annular space between the pipe/casing and the tunnel/bore annulus or by deformation of the soils ahead of the advanced tunnel/bore.

The magnitude of such settlement is highly dependent on the construction procedures utilized (i.e., tunnel/bore size, cutting shoes, final reamer size, depth of installation, drilling fluid design – including, but not limited to, viscosity and pressure, etc.).

A provision for a settlement monitoring program must be made in the Contract Documents to:

- Document the effects of the trenchless installations on the overlying highway;
- Obtain prior warning of ground movements that could occur due to the construction methods and equipment or unforeseen ground conditions;
- Verify the contractor's compliance with the ground movement limits imposed in the Contract; and,
- Allow adjustments to be made to the tunnelling/boring methods such that the ground movement limits established are not exceeded.

The proposed monitoring program should be consistent with the minimum requirements in MTO's Corridor Encroachment Permit Application titled, "*Guidelines for Foundation Engineering – Tunneling Specialty*" (January 2020), as summarized below. A more stringent settlement monitoring program is provided in the example SP titled, "*Pipe Installation by Trenchless Methods*" in Appendix E which may be recommended by MTO, but may not be required given the low complexity level of these crossings.

7.4.1 Instrumentation

A series of five surface monitoring points and two in-ground monitoring points should be installed along each trenchless alignment, at the approximate locations shown on Drawing 2. The exact locations of the monitoring points will depend on the actual site conditions and final alignment of the crossings. The monitoring points should be installed as follows:

- Surface monitoring points (i.e., reflectors and/or identifiable markings) directly over the alignment along the centreline of the proposed watermain and sanitary sewer where these services cross Highway 6, on the paved surface of the highway. The surface monitoring points should be spaced at 5 m (maximum). Alternatively, precision reflectorless survey monitoring may be used provided repeatable accuracy and precision as specified in the Contract is achieved.
- In-ground monitoring points consisting of a sleeved iron bar set to a minimum depth of 1.6 m below ground/pavement surface, or extending to no deeper than 1.0 m above the tunnel/bore invert elevation. The elevation of the top of the bars may be read remotely using reflectors at the top of the iron bars. Alternatively, precision reflectorless survey monitoring may be used. The in-ground monitoring points provide the best measure of the ground settlement effects of trenchless methods, as they are unaffected by frost heave, thaw settlement or the bridging action of the pavement structure.

7.4.2 Monitoring

A qualified surveying firm should be retained to confirm the set-up and to carry out the settlement monitoring during construction; their equipment and procedures must be capable of surveying the settlement point elevation to within ± 2 mm of the actual elevation with repeatable accuracy and precision. It is noted that at this site, traffic control will likely be required in order to carry out monitoring of the instrumentation unless adequate reflector locations and/or reflectorless technology are used at all locations.

Prior to the start of construction, all monitoring points should be read a minimum of three times, on three separate days, to provide a baseline against which all subsequent monitoring results will be compared. The monitoring points should be surveyed a minimum of three times (sets) per day during trenchless installation of the casing pipe, including during shut-down periods and weekends. An allowance should be made for more frequent monitoring (up to every four hours) should observations dictate. Once installation of the casing pipe is complete, monitoring should continue for a minimum of two weeks, provided further settlement has stopped, after which monitoring may be reduced to weekly readings for a period of three months.

Based on the monitoring results, the following represents trigger levels that define magnitude of movement and corresponding actions:

- If the Review Level (maximum of 10 mm of displacement relative to baseline readings) is reached, the Contractor will need to review or modify the trenchless method, rate of sequence of construction or ground stabilization measures to mitigate further ground displacement. The Contractor should provide a formal plan that states actions that will be implemented to ensure that the Alert Level is not reached.
- If the Alert Level (maximum of 15 mm of displacement relative to the baseline readings) is reached, the Contractor will need to stop all work/construction, and execute pre-planned methods to secure the site, and mitigate further movements to assure safety of public and to maintain vehicular traffic. No construction is to take place until the conditions specified in the Contractors mitigation plan are satisfied.

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.

7.5 Construction Considerations

7.5.1 Temporary Excavations for Pits / Shafts

Excavations for the proposed 6.0 m by 6.0 m send/receive pits/shafts are anticipated to be located near the boreholes and extend through the following soil deposits (from top to bottom):

- **Eastern Pit/Shaft (down to about 6.2 m below ground surface, to Elevation 417.2 m) – Borehole 20-2:**
 - Compact silty sand to gravelly sand
 - Stiff clayey silt-silt
 - Very stiff clayey silt-silt (till) to clayey-silt (till)
- **Western Pit/Shaft (down to about 5.1 m below ground surface, to Elevation 418.1 m) – Borehole 20-1:**
 - Very loose to loose silty sand fill
 - Compact sandy silt to silty sand to sand
 - Firm clayey silt-silt
 - Very stiff clayey silt-silt (till) to clayey silt (till)

The piezometric groundwater level in the vicinity of the project site is anticipated to be at about Elevation 422.5 m.

Conventional mechanized excavation equipment with appropriate cutting tools should be suitable for excavation through the existing fill and native soils. The selection of the excavation equipment should consider the presence of cobbles and boulders within the glacial till deposit encountered at the project site.

All excavations must be carried out in accordance with Ontario Regulation 213 (*Occupational Health and Safety Act for Construction Projects*), as amended. The existing granular embankment fill, the firm clayey silt as well as the compact sandy silt to silty sand to sand above the groundwater table can be classified as Type 3 soils according to OHSA. The granular soils below the groundwater table would be classified as Type 4 soils; however, if dewatered, these soils can be classified as Type 3 soils, except for the very stiff glacial till deposit, which can be classified as a Type 2 soil. Temporary excavations (i.e., those which are open for a relatively short time period) within Type 3 soils should be made with side slopes no steeper than 1H:1V, while temporary excavations within Type 4 soils should be made with side slopes no steeper than 3H:1V.

To maintain temporary excavation stability, excavated materials should be placed away from the edge of the excavation at a distance equal to the depth of the excavation or greater. In addition, stockpiling of the excavated soil, construction material, and construction equipment should be prohibited adjacent to the excavations to minimize surcharge loading near the crest of the excavations.

Proper pit/shaft construction is essential for the success of any trenchless operation. For this reason, it is preferable that construction of pits/shafts be carried out by (or in close collaboration with) the specialist trenchless subcontractor. If the pits/shafts are to be constructed by the general contractor on behalf of the trenchless contractor, the pit/shaft design and construction must be compatible with the trenchless equipment and methods.

Given that the footprint of any open cut construction for the pits/shafts will likely encroach within the highway embankment or ditch, a global stability analysis for the temporary condition will need to be performed by the contractor for acceptance by the Owner (i.e., MTO). Currently, the proposed pit/shaft near the eastern limit of the crossings is shown to daylight near the east paved shoulder of Highway 6. As such, temporary slope protection and/or temporary protection systems will be required at this location to allow for uninterrupted traffic and reduce the risk associated with compromising the highway embankment. Construction staging may also be considered to keep vehicular traffic further away from the proposed pit/shaft.

7.5.2 Temporary Protection Systems

Based on the close proximity of Highway 6 to the proposed pit/shaft at the eastern limit of the proposed crossings and private property /ditchline at the west limit, as well as presence of underground utilities and hydro poles on the east side of Highway 6, temporary protection systems will be required.

It is anticipated that a driven interlocking steel sheet pile system is suitable at this site. Alternatively, the contractor may use a soldier pile and lagging system; however, the eastern and western limits of the crossing would need to be adequately dewatered prior to installation of the lagging boards as the granular soils will not have adequate stand-up time to permit installation of the lagging boards.

The sheet piles or soldier piles will need to extend to a sufficient depth to provide the necessary passive resistance for the retained soil height, plus any surcharge loads behind the protection system. Difficulties and/or inability of driven piles to penetrate through the glacial till deposit may be encountered as a result of the potential presence of cobbles/boulders, reducing the potential for a cantilever design. Lateral support of the sheet pile wall or soldier pile wall could be provided in the form of struts, rakers, or temporary anchors, if and as required. Drilling through/into the cobbles/boulders may also be necessary to permit construction of the pits/shafts, depending on the detail design of the pits/shafts. The temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*), as amended by SP 105S09. The lateral movement of the protection systems should meet Performance Level 2 as a minimum and as specified in OPSS.PROV 539, provided

that any utilities, if present within the zone of influence, can tolerate this magnitude of deformation. If not, a more stringent Performance Level may be required by the affected utility owners.

The selection, design, construction, maintenance, and monitoring of the temporary protection system(s) is the responsibility of the Contractor.

The temporary protection systems may be designed using the following soil parameters:

Fill / Soil Type	Bulk Unit Weight, γ ¹	Internal Angle of Friction, ϕ'	Undrained Shear Strength, s_u	Lateral Earth Pressure Coefficients ²		
				K_a (Active)	K_o (At-Rest)	K_p (Passive ³)
Compact to Dense Silty Sand to Sand and Gravel (Fill)	20 kN/m ³	30°	-	0.33	0.50	3.00
Very Loose to Loose Silty Sand (Fill)	19 kN/m ³	28°	-	0.36	0.53	2.77
Compact Sandy Silt to Silty Sand to Sand to Gravelly Sand	19 kN/m ³	29°	-	0.35	0.52	2.88
Firm to Stiff Clayey Silt-Silt	18 kN/m ³	30°	50 kPa ⁴	0.33	0.50	3.00
Very Stiff to Hard Clayey Silt-Silt to Clayey Silt Till	20 kN/m ³	32°	150 kPa ⁴	0.31	0.47	3.25

Notes:

1. The design groundwater level may be assumed to be at Elevation 422.5 m based on the piezometric groundwater levels measurements taken in the vicinity of the project site (LVM, 2013). The effective unit weight (i.e., unit weight of water subtracted from the bulk unit weight) should be used for soils/fills below the groundwater table.
2. The lateral earth pressure coefficients presented above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are expected, the coefficients should be corrected accordingly.
3. The total passive resistance below the base of the excavation (i.e., within the temporary protection system enclosure) may be calculated based on the values of K_p indicated above, but reduced by an appropriate factor that considers the allowable wall movement in accordance with Figure C6.27 of the Canadian Highway Bridge Design Code (CHBDC, 2019) to account for the fact that large strains would be required for mobilization of the full passive resistance.
4. For the cohesive deposits, an assessment of both the drained (i.e., based on ϕ') and undrained (i.e., based on s_u) cases should be made to establish the more conservative earth pressure condition for design).

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

Consideration could be given to either partial or full removal of the temporary protection system upon completion of construction or each stage of construction, as required. At this site, full removal of the protection system should be required to mitigate potential impediments to future reconstruction work.

7.5.3 Surface Water and Groundwater Control

Based on the available piezometric groundwater levels in the vicinity of the project site (measured at about Elevation 422.5 m based on a shallow standpipe piezometer installed in Borehole BH-01-13 advanced by LVM) and saturated granular soils observed during borehole advancement (measured as high as Elevation 421.8 m), excavations for the proposed pits/shafts will extend below the groundwater level, unless only shallow pits are required if HDD is selected as the preferred method of trenchless installation.

For pits/shafts extending down to/below the invert of the proposed watermain and sanitary sewer, groundwater lowering/dewatering will be required to facilitate excavation of the pits/shafts and operation of the trenchless activities/installation of the watermain and sewer in the dry. It is assumed that construction of the maintenance holes will also be required within the pits/shafts. Depending on the method of trenchless installation and associated risks, lowering the groundwater level below the invert of the tunnel/bore across the alignment may also be required.

The groundwater level should be lowered to at least 1 m below the base of the proposed excavation level (including bore/tunnel invert) to maintain basal stability and allow for construction in dry conditions at the pits/shafts. Depending on the actual groundwater level at the time of construction, dewatering of the pits/shafts may be sufficient to lower the groundwater level across a portion of the trenchless alignment, especially for the watermain alignment. Groundwater may be lowered at the pits/shafts and along the tunnel alignment by providing an active dewatering system consisting of an adequate number of deep wells or well points, likely screened into the sand to silty sand. A specialist dewatering Contractor will be required and will need to work in collaboration with the General Contractor and specialist trenchless Contractor in order to design an effective dewatering system during the temporary works.

Depending on the design and installation of the temporary protection system, it may be possible to excavate within the system (e.g., sheet pile box) and dewater the pits/shafts using an adequate number of sumps and pumps installed and operated in advance/during the excavation. If a watertight sending / receiving pit is being considered, it will need to be designed against buoyancy and hydrostatic forces.

If pipe ramming is the chosen trenchless option, some form of dewatering along the trenchless alignments may be required to reduce the potential for flowing soil conditions and inadvertent soil loss through the casing during trenchless operations. Although dewatering from the pits/shafts may be adequate, additional dewatering measures such as installation of wells or horizontal drains from within pits/shafts may be necessary to lower the groundwater level near the eastern and western limits of the trenchless crossings.

Dewatering operations must be in accordance with OPSS.PROV 517 (*Dewatering*) and the requirements outlined in the SP for "*Pipe Installation by Trenchless Method*". At the east pit/shaft location, there is an existing drainage ditch that may be impeded by the construction operations. Depending on the surface water flow and final location of the pit/shaft relative to the drainage ditch, temporary diversion or control of surface water may be required. The hydrotechnical engineers and designers should determine if MTO's SP 517F01 (*Temporary Flow Passage System*) is required in the Contract Documents at this location. A copy of this specification is provided in Appendix E for reference.

The Contractor is responsible for the design, operation, monitoring and impacts of dewatering requirements, which depends on their chosen method of open-cut excavation / temporary protection system to construct the pits/shafts and selected trenchless method of installation. The Contractor is also responsible for confirming that the radius of groundwater drawdown does not impact the existing highway and any surrounding settlement-sensitive infrastructure or water wells. Given the relatively compact nature of the native sands and silty sands above the firm clayey silt-silt and till soils, it is not anticipated that the temporary dewatering activities will have a major impact on the highway. Details pertaining to dewatering activities are provided in a separate report prepared by Golder (May 2021).

For construction dewatering takings greater than 400 m³/day, a Permit to Take Water (PTTW) will be required from the Ministry of the Environment Conservation and Parks (MECP). As part of the ongoing municipal works along St. David Street North and Sideroad 18, Golder prepared a PTTW application and supporting documents on behalf of the Township of Centre Wellington that included dewatering for both the municipal works and the 961 St. David Street watermain and sanitary sewer crossings. The MECP has issued PTTW Number 5274-C37MBL which allows

for a dewatering rate of 5,100 m³/day for the municipal works plus an increase up to 6,300 m³/day for a 20 day period for the dewatering required for the crossings.

Surface water should be directed away from open excavation areas/pits/shafts to prevent ponding of water that could result in disturbance and weakening of the subgrade and/or affect construction or open cut/temporary support system operations, as applicable. Depending on the water flow through the drainage ditch at the time of construction and staging/diversion requirements/limitations, temporary cofferdams (e.g., sandbags or more extensive systems) may also be required.

7.5.4 Vibration Monitoring

The need/requirement for carrying out vibration monitoring should be considered for construction operations during trenchless installation and/or during installation of temporary protection systems for pit/shaft construction, to ensure that the vibration levels at nearby settlement-sensitive structures and underground utilities are maintained below tolerable levels. Based on previous experience, the suggested maximum peak particle velocities (PPV) for various types of infrastructure are as follows:

- The PPV on commercial/industrial buildings shall not exceed 50 mm/s;
- The PPV on private structures, wells, etc. shall not exceed 25 mm/s; and,
- The PPV on utilities shall not exceed 10 mm/s, although this should be confirmed by the affected utility owners.

It is considered good practice to conduct pre-construction and post-construction condition surveys and vibration monitoring at existing structures within an approximately 100 m radius of any trenchless installation or protection system installation, and in some cases agencies may choose to expand the radius beyond this limit for attenuation of construction-induced vibrations, to mitigate potential claims from property owners. For this site, given the presence of various underground utilities (e.g., fiber optic cables immediately east of the proposed trenchless crossings) and the existing structures located within 100 m of the proposed undercrossing, pre-construction and post-construction condition surveys are recommended.

7.5.5 Recommendations for Construction Materials Based on Analytical Testing

One composite soil sample was selected from both the clayey silt-silt and till deposits and submitted to Bureau Veritas in Mississauga, Ontario for testing a suite of parameters associated with potential corrosion to steel and deterioration of concrete. The analytical results are summarized in Section 5.4 and presented in Appendix C. The potential for sulphate attack and corrosion are discussed in the following paragraphs. However, it is ultimately up to the civil designer to determine the appropriate construction materials, including the exposure class and ensuring that all aspects of CSA A23.2-24 Section 4.1.1 (*Durability Requirement*) are followed when designing concrete elements.

In order to assess the potential severity of sulphate attack on concrete (e.g. the maintenance holes) during its service life, the analytical test results were compared to CSA A23.1-14 Table 3 (*Additional Requirements for Concrete Subjected to Sulphate Attack*). The water-soluble sulphate concentration measured on select samples of the clayey silt-silt and clayey silt-silt till deposits was below 0.1%, which is below the moderate degree of exposure class (i.e., below the class exposure limits). Therefore, based on the two test results when the designer is selecting the exposure class for concrete structures in contact with the clayey silt-silt and clayey silt-silt till soils, the effects of the sulphates may not need to be considered. However, given the location of the maintenance holes next to Highway 6, they may be exposed to de-icing salts/chemicals and selection of the exposure class should consider this.

The clayey silt-silt sample measured a pH of 8.0 and a resistivity of 3,100 ohm-cm. The till soil sample measured a pH of 8.1 and a resistivity of 3,300 ohm-cm. According to the MTO Gravity Pipe Design Guidelines (2014), the pH measured on both soil samples is not considered detrimental to structure durability as it is less than a pH of 8.5. As per Table 3.2 (*Soil Corrosiveness and Resistivity*) of the MTO Gravity Pipe Design Guidelines (2014), the resistivity measured on both soil samples is greater than 2,000 ohm-cm and less than 4,500 ohm-cm, which suggests that the soil corrosiveness is moderate ($2,000 \text{ ohm-cm} < R < 4,500 \text{ ohm-cm}$).

7.5.6 Backfilling

The excavated soils from the proposed pits/shafts are anticipated to be comprised of sand and gravel fill, sandy silt to silty sand to sand, clayey silt-silt and till soils. These soils may be considered for reuse as backfill material, however, these deposits will likely require drying in order to achieve adequate compaction levels and are generally considered frost susceptible so should not be used within the frost depth adjacent to the new watermain / sewer maintenance structures or highway embankment. Furthermore, the silty deposits, particularly the sandy silt, clayey silt-silt and sandy silt interlayer in the till comprised of a significant amount of silt content (i.e., about 35% to 80% of silt-sized particles), and are susceptible to over-wetting, inclement weather (i.e., rainfall), and freezing temperatures. Therefore, it is recommended that these materials be used in landscape areas and outside of the highway right-of-way or thoroughly mixed with granular soils prior to being used for backfill. These materials should also be placed and compacted in accordance with OPSS.PROV 501 (*Compacting*), as amended by SP 105S22.

Granular materials which meet the requirements of OPSS.PROV 1010 (*Aggregates*), as amended by SP 110S06, Select Subgrade Material (SSM) or Granular 'B' Type I may be imported and is preferred for use as backfill directly against the new sanitary maintenance holes, within the highway embankment, or surrounding the casing / pipe in open cut or within the frost depth (i.e., upper 1.6 m at this site) of the embankment fill. These materials should also be placed and compacted in accordance with OPSS.PROV 501 (*Compacting*), as amended by SP 105S22.

7.5.7 Soil Reuse / Excess Soil Disposal

Appropriate analytical/environmental testing of fill and native deposits encountered at the project site will be required to assess the suitability of the materials for re-use and off-site disposal. Suitability of the soils for reuse on the site can be determined by comparing the test results to the Ontario Ministry of the Environment, Conservation and Parks (MECP) Table 2 Standards.

Any excess material generated during construction activities that is of appropriate environmental quality as per the Ontario MECP Table 2 Standards, may be used as backfill provided the soil satisfies the following criteria:

- The soil is obtained from a location that is not within an area of potential environmental concern, as determined by a Phase I environmental site assessment prepared by a Qualified Person in general accordance with Ontario Reg. 153/04 (*Records of Site Condition*);
- The soil shows no evidence of potential environmental impact, including staining, discoloration or odours that are potentially associated with petroleum hydrocarbons or other contaminants;
- The soil is free of other wastes, which are prohibited in any amount, including: putrescible material (e.g., organic materials, wood, etc.), concrete, cement fines, rebar, plastic, scrap metal, asphalt pavement, shingles, rubbish, glass, and garbage; and,
- The soil is geotechnically suitable and approved for use by a qualified geotechnical engineer.

Alternatively, any excess material may be removed off-site to a receiving site, such as a property appropriately permitted in accordance with the applicable bylaw of the local municipality or a waste management facility permitted in accordance with Part V of the Environmental Protection Act. It is advisable to review a potential receiving site's acceptable fill protocol to determine what documentation must be submitted to facilitate acceptance by the receiving site.

Furthermore, movement of soil to a site that has a Record of Site Condition on file with the Ontario MECP may require that specific testing protocols are followed and that the materials must satisfy the applicable standards. Additionally, Ontario Regulation 406/19 (*On-Site and Excess Soil Management*), was recently passed in Ontario to address reuse of soil, excess soil planning actions, landfilling of excess soils, and brownfields redevelopment. These regulatory changes should be reviewed in terms of the specifics of the proposed works, including soil quality, excavation volumes, and timing of construction activities.

8.0 CLOSURE

The Foundation Design Report was prepared by Ms. Darcy Hansen, E.I.T. and reviewed by Mr. Tomasz Zalucki, P.Eng., a geotechnical engineer at Golder.

Mr. Kevin J. Bentley, P.Eng., a Senior Geotechnical Engineer, who is MTO RAQS certified for high complexity tunnelling assignments, and is the MTO Foundations Designated Contact for Golder, conducted an independent technical and quality control review of the report.

Signature Page

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Ontario Provincial Standard Specifications (OPSS):

OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 517	Construction Specification for Dewatering of Pipeline, Utility and Associated Structure Excavation
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material

Ontario Regulations:

- Ontario Regulation 213/91 Construction Projects, under Occupational Health and safety Act, R.S.O. 1990, c.O.1
- Ontario Regulation 903 Wells, under Ontario Water Resources Act, R.S.O. 1990, c. O.40
- Ontario Regulation 153/04 Records of Site Condition, under Environmental Protection Act, R.S.O. 1990, c.E. 19
- Ontario Regulation 406/19 On-Site and excess Soil Management, under Environmental Protection Act, R.S.O. 1990, c.E.19

Ontario Special Provisions (SP):

SP	Pipe Installation by Trenchless Methods
SP 105S09	Amendment to OPSS 539, November 2014 (March 2018)
SP 105S22	Amendment to OPSS 501, November 2014 (June 2016)
SP 110S06	Amendment to OPSS 1010, April 2013 (May 2019)
SP 517F01	Temporary Flow Passage System

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder cannot be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, Golder may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client can not rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Ground Water Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report. The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

Tables

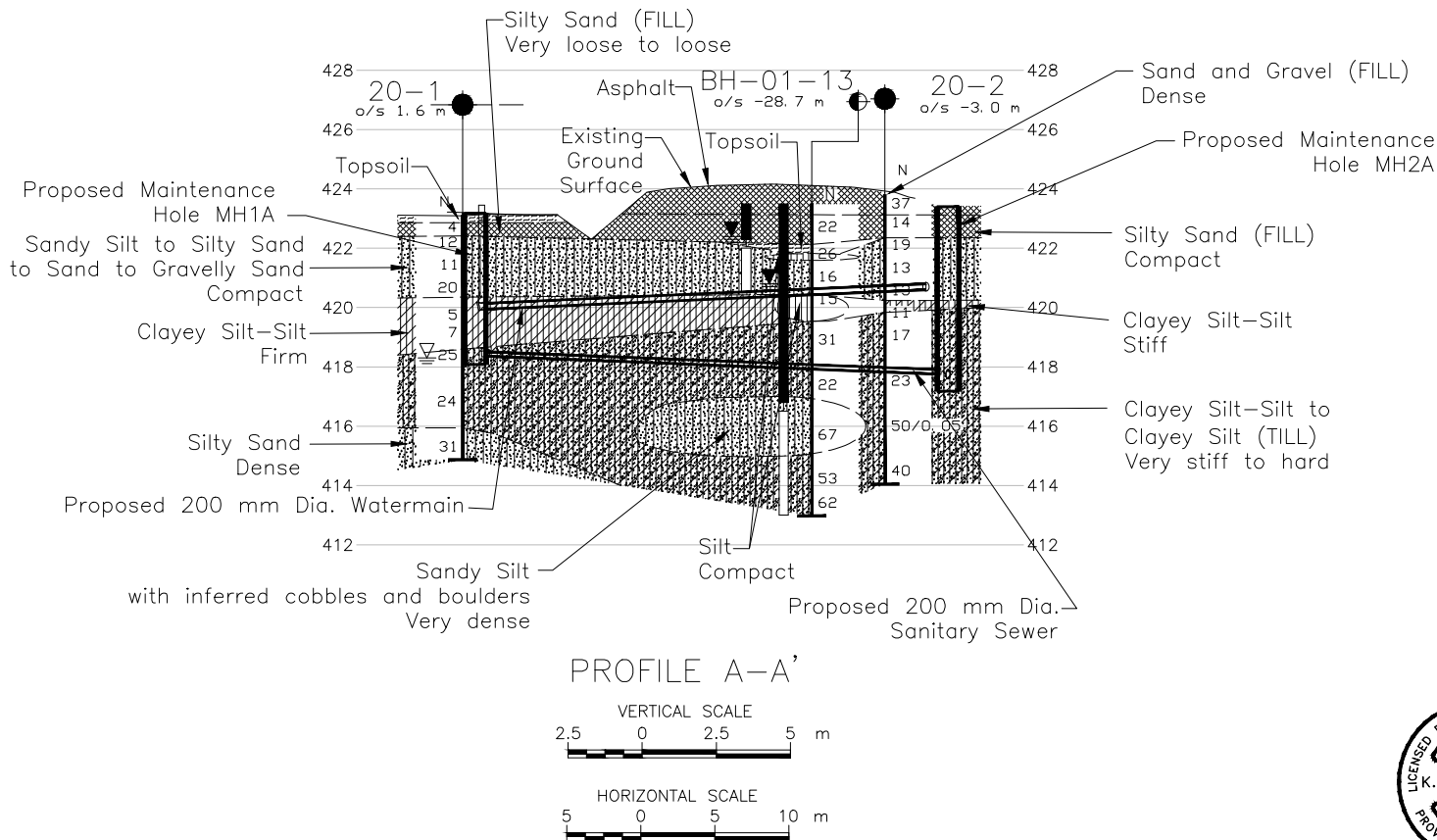
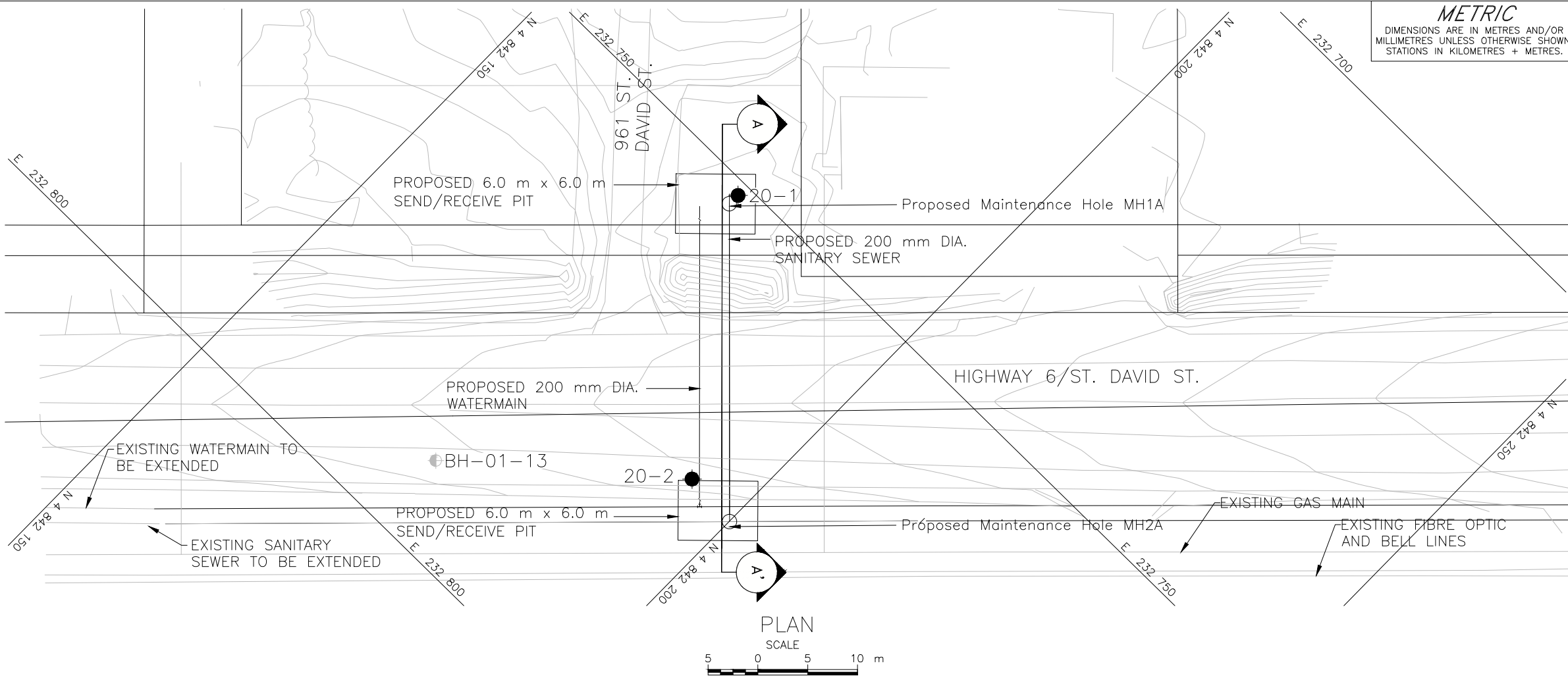
Table 1: Evaluation of Trenchless Pipe Installation Methods

Installation Method	Feasibility of Trenchless Method	Advantages	Disadvantages	Relative Costs	Risk/Consequences
Pipe Ramming	Feasible	<ul style="list-style-type: none">■ No thrust block/jacking frame required.■ Ideal for relatively short drives and installation of small diameter pipes, as required at the project site.■ Better suited for penetrating through potential obstructions such as cobbles and boulders compared to jack-and-bore.■ Accuracy (alignment and grade) of over-sized rammed casing provides flexibility when inserting carrier pipe, especially for a gravity pipe sewer.	<ul style="list-style-type: none">■ Longer work area may be required for ramming pit/shaft compared to jack and bore.■ Potential for obstructions (e.g., cobbles and boulders) to deflect casing and/or halt operations, although more compatible compared to jack-and-bore.■ Higher noise levels generated during ramming operation compared to other trenchless methods (potential issues with noise bylaws).■ Vibrations may cause settlement in very loose to loose soils and adjacent settlement-sensitive structures/underground utilities, if present.■ Groundwater lowering required to reduce risk of flowing soils from entering the casing■ Accuracy (alignment and grade) relies on initial set-up and limited steerability once ramming begins■ Over-sized steel casing required for both crossings to accommodate installation loads and limited steerability	<ul style="list-style-type: none">■ Least expensive method (comparable cost to jack-and -bore method, especially if soils need to be periodically removed within the casing as it is being advanced).	<ul style="list-style-type: none">■ Vibrations may impact traffic or nearby residences (low risk of damage, but risk of complaints).■ Relatively low risk of vibrations causing settlement of foundation soils, except in very loose soils.■ Relatively low risk for ground heave at highway surface given small diameter of casing and soil cover.■ Risk of ground surface subsidence increases with decreasing cover near drainage ditches (i.e., about 2 m soil cover), however, low risk of settlement at highway where soil cover is typically greater than 3 m.■ Risk of soil ingress at face (lead end of casing) and through casing into entry pit if groundwater is not lowered (flowing soils) and/or if sufficient soil plug is not maintained in casing throughout crossing.■ Low risk of cobbles/boulders for watermain but moderate risk for sewer in till where cobbles/boulders could impede/halt installation operations.

Installation Method	Feasibility of Trenchless Method	Advantages	Disadvantages	Relative Costs	Risk/Consequences
HDD	Feasible	<ul style="list-style-type: none">■ Launching and receiving pits are significantly shallower compared to other trenchless methods, thereby limiting or eliminating the need for temporary protection systems for trenchless installation; however, may still be needed for maintenance holes and connections with open cut sections.■ Directional drilling often requires less support equipment compared to other trenchless methods.■ Dewatering not required along bore path but will be required for connections / maintenance holes.■ Accuracy (alignment and grade) of over-sized bored casing provides flexibility when inserting carrier pipe, especially for gravity pipe sewer	<ul style="list-style-type: none">■ Large/long laydown areas required to accommodate shallow entry and exit angles for the drilling equipment and accommodate allowable bending radius of casing pipe for pullback operations, resulting in need for private property entry/land use agreements.■ Soil cover of about 5 m typically preferred to reduce potential for hydrofracture in areas of very loose to loose granular soils and pavement structure; however, only 3 m of cover for watermain and less than 2 m of soil cover in ditch areas.■ Deep pits/shafts still needed for maintenance holes and connections.■ Dewatering still required for pits/shafts for maintenance holes and to accommodate construction in dry conditions for connections.	<ul style="list-style-type: none">■ Comparable to pipe ramming methods considering dewatering along alignment not required, but less costly than tunneling with a MTBM.	<ul style="list-style-type: none">■ Low risk of drilling bit getting stuck/binding in silty/fine sand deposits provided drilling fluid is designed properly.■ Careful design and control of drilling fluid viscosity and pressure is required due to high risk of hydrofracture and/or inadvertent returns where soil cover above the proposed watermain is less than 2 m, and about 3 m below highway for watermain.■ Risk of ground surface subsidence increases with decreasing cover.■ Low risk of cobbles/boulders for watermain but moderate risk expected within the till (proper tooling / cutting bits required).■ Risk of losing drilling fluid during construction of maintenance holes and connections with open cut sections at depth which could lead to ground settlements following installation.
Horizontal Auger Boring (also know as Jack-and-Bore)	<p>Marginally feasible for watermain with dewatering along alignment, but not recommended due to high risk of ground loss.</p> <p>Feasible for sewer profile.</p>	<ul style="list-style-type: none">■ Accuracy (alignment and grade) of over-sized bored casing provides flexibility when inserting carrier pipe, especially for gravity pipe■ This method of trenchless installation can be supplemented with guided auger boring techniques (i.e., pilot tube) to improve alignment control; however, risk of pilot tube encountering refusal within very stiff to hard till with cobbles / boulders.	<ul style="list-style-type: none">■ Large and more robust entry pit/shaft required for jacking/thrust block.■ Obstructions (e.g., cobbles and boulders) if encountered may deflect and/or halt bore.■ Groundwater lowering (i.e., dewatering) required along the proposed alignments to prevent flowing soils from entering the casing, as maintaining a sufficient soil plug inside the casing is difficult in silty/sandy soils and till soils such as those encountered at the site.■ Running of silty and sandy soils may still occur if careful control of jacking/augering procedure to maintain sufficient soil plug is not maintained■ Over-sized steel casing required for both crossings to accommodate installation loads and limited steerability (unless pilot-tube methods are adopted and successful).	<ul style="list-style-type: none">■ Comparable cost to pipe ramming method.	<ul style="list-style-type: none">■ Risk of augers getting stuck/binding in silty/fine sand deposits.■ High risk of soil ingress at face (i.e., leading edge of casing) if groundwater is not lowered below tunnel invert along full length of the proposed alignments. Even with a depressed groundwater level along the entire alignment, the risk of overmining is considered high due to running sands/silts along watermain profile and mixed face along sewer profile encountered at the project site.■ Risk of ground surface / highway subsidence increases with decreasing soil cover, particularly for watermain where soil cover is about 3 m and near the ditches where soil cover is less than 2 m.■ Increased risk of cobbles / boulders impeding / halting operations along sewer alignment compared to other methods due to inability of augers to penetrate.

Installation Method	Feasibility of Trenchless Method	Advantages	Disadvantages	Relative Costs	Risk/Consequences
Tunnelling using a Microtunnel Boring Machine (MTBM)	Feasible, but may not be cost effective (i.e. economically not viable at the project site).	<ul style="list-style-type: none">■ Slurry machines are able to counterbalance earth and water pressures in a controlled manner, thereby providing continuous face support and reducing the risk of ground losses during tunneling.■ Machines can be steered continuously, providing precise control over line and grade.■ Potential effects on structures and underground utilities next to the tunnel alignment can be better controlled than other trenchless methods.■ MTBM can also be specified to have the capability to cut and crush cobbles and boulders.■ Dewatering not required along bore path.	<ul style="list-style-type: none">■ Expensive, especially for short drives.■ Small MTBMs (600 mm or less in diameter) are not common in the Ontario region.■ Large laydown area required as slurry processing systems/separation plants required together with additional working area at shaft/pit locations for some systems.■ MTBMs may not allow cutter changes during drive since there is no access to the head for small diameter MTBMs.■ Susceptible to hydrofracture depending on slurry viscosity and pressure.■ Special design and a highly experienced operator is required where there is relatively low soil cover along the proposed tunnel drive.	<ul style="list-style-type: none">■ Most expensive method of installation.	<ul style="list-style-type: none">■ High risk of hydrofracture and/or inadvertent returns along the proposed watermain alignment where the soil cover is as small as 2 m near the ditches.■ Risk of ground surface subsidence/settlement increases with decreasing cover.■ MTBMs need to be typically greater than 600 mm to be efficient and effective.■ If obstructions (cobbles/boulders) are encountered along the tunnel drive, there is a risk of a small diameter MTMB not being equipped to penetrate through such obstructions and the tunnel would need to be abandoned.

Drawings

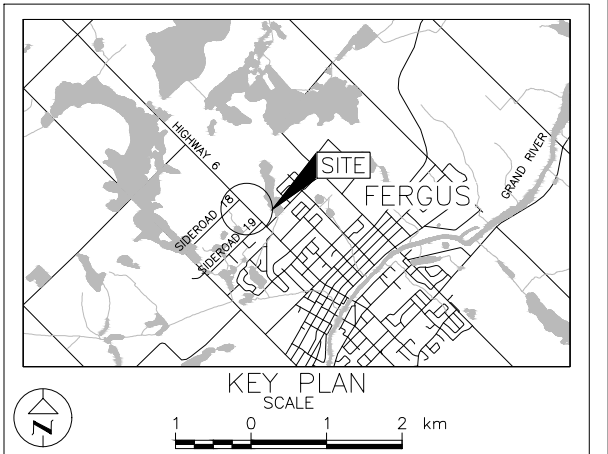


METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No.

HIGHWAY 6 TRENCHLESS CROSSINGS
SANITARY SEWER AND WATERMAIN
BOREHOLE LOCATIONS AND SOIL
STRATA

SHEET



LEGEND

- Borehole - Current Investigation
- Approximate Borehole - Previous Investigation (LVM, 2013)
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL in piezometer, measured on June 14, 2013
- WL upon completion of drilling

BOREHOLE CO-ORDINATES (MTM NAD83 ZONE 10)			
No.	ELEVATION	NORTHING	EASTING
BH-01-13	423.5	4842174.7	232791.6
20-2	423.8	4842194.4	232774.9
20-1	423.1	4842177.7	232751.3

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.

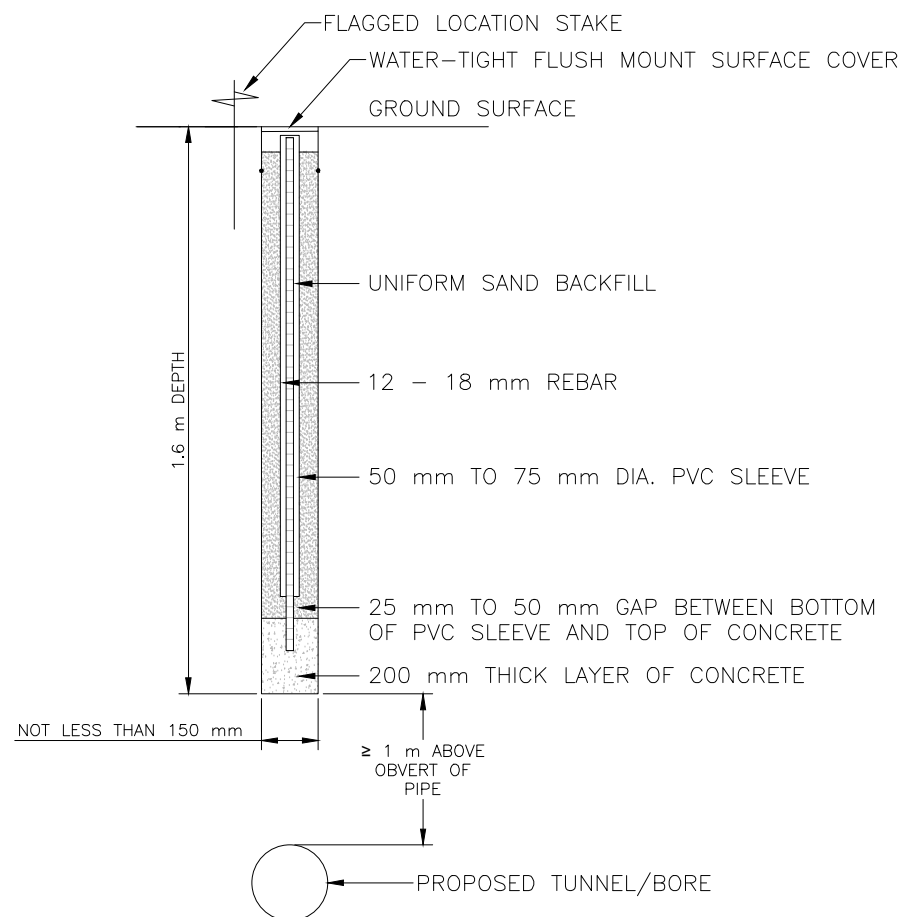
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

REFERENCE

Base plans provided in digital format by MTE Consultants Inc., drawing file no. ACAD-48650-100-PP1.dwg, received July 14, 2021.



NO.	DATE	BY	REVISION
Geocres No. 40P9-65			
HWY. HWY 6	PROJECT NO. 21460183		DIST.
SUBM'D. DH	CHKD. DH	DATE: 10/25/2021	SITE:
DRAWN: SA	CHKD. TZ	APPD. KJB	DWG. 1



12 mm (MIN.) DIAMETER x 25.4mm LONG
HEX HEAD BOLT (COUNTERSINK IN ASPHALT)

12.7 mm x 34.9 mm FLAT WASHER

GROUND SURFACE

34.9 mm

25.4 mm

12.7 mm

19 mm

7.7 mm

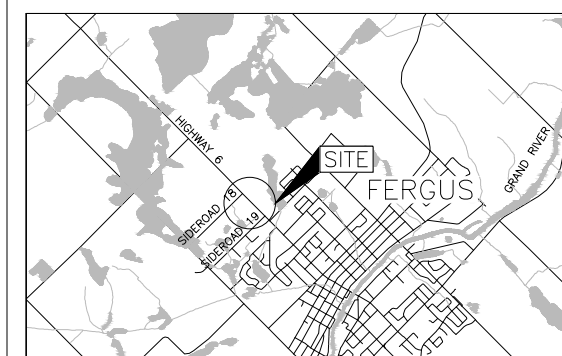
12.7 mm DIA. PRE-DRILLED PILOT HOLE
FILLED WITH NON-EXPANSIVE EPOXY

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

CONT No.
GWP No.



HIGHWAY 6 TRENCHLESS CROSSINGS SANITARY SEWER AND WATERMAIN SETTLEMENT MONITORING PLAN LOCATIONS AND DETAILS







KEY PLAN
SCALE



1 0 1 2 km

LEGEND

-  Borehole – Current Investigation
 Approximate Borehole – Previous Investigation (LVM, 2013)
 Surface Monitoring Point
 In-Ground Monitoring Point

BOREHOLE CO-ORDINATES (MTM NAD83 ZONE 10)			
No.	ELEVATION	NORTHING	EASTING
BH-01-13	423.5	4842174.7	232791.6
20-2	423.8	4842194.4	232774.9
20-1	423.1	4842177.7	232751.3



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 MTE Consultants Inc., drawing file no. ACAD-48650-100-PP1.dwg, received July 14, 2021.

NO.	DATE	BY	REVISION		
Geocres No. 40P9-65					
HWY. HWY 6		PROJECT NO. 21460183		DIST. .	
SUBM'D.		CHKD. DH	DATE: 10/25/2021		SITE:
DRAWN: SA		CHKD. TZ	APPD. KJB		DWG. 2

APPENDIX A

Record of Borehole Sheets

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

MINISTRY OF TRANSPORTATION, ONTARIO

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>200	>8
COBBLES	Not Applicable	75 to 200	3 to 8
GRAVEL	Coarse	19 to 75	0.75 to 3
	Fine	4.75 to 19	(4) to 0.75
SAND	Coarse	2.00 to 4.75	(10) to (4)
	Medium	0.425 to 2.00	(40) to (10)
	Fine	0.075 to 0.425	(200) to (40)
FINES	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY COMPONENTS^{1,2}

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

1. Only applicable to components not described by Primary Group Name.

2. Classification of Primary Group Name based on Unified Soil Classification System (ASTM D2487) for coarse-grained soils; fine-grained soils described per current MTO Soil Classification System.

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Cone Penetration Test (CPT)

An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and sleeve friction (f_s) are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); N_d :

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

SAMPLES

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

SOIL TESTS

w	water content
PL, w_p	plastic limit
LL, w_L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D _R	relative density (specific gravity, G _s)
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
Y	unit weight

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

COARSE-GRAINED SOILS

Compactness¹

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

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

2. SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.

FINE-GRAINED SOILS

Consistency

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

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.

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

Field Moisture Condition

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

LIST OF SYMBOLS

MINISTRY OF TRANSPORTATION, ONTARIO

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

I. GENERAL

π	3.1416
$\ln x$	natural logarithm of x
\log_{10}	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)

σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
c'	effective cohesion
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction $= \tan \delta$
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 or 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 ρ . Unit weight symbol is γ .
where $\gamma = \rho \cdot g$ (i.e., mass density multiplied by
acceleration due to gravity)

Notes: 1
2

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

PROJECT		21460183		RECORD OF BOREHOLE No 20-1				SHEET 1 OF 1		METRIC							
G.W.P.				LOCATION				N 4842177.7; E 232751.3 MTM NAD 83 ZONE 10 (LAT. 43.716064; LONG. -80.394132)		ORIGINATED BY							
DIST		HWY 6		BOREHOLE TYPE				Power Augers, 200 mm O.D. Continuous Flight Hollow Stem Augers		COMPILED BY							
DATUM		Geodetic		DATE				April 26, 2021		CHECKED BY							
										TZ							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		SHEAR STRENGTH kPa										WATER CONTENT (%)
423.1	GROUND SURFACE						20	40	60	80	100						
0.0	TOPSOIL (250 mm)																
0.3	SILTY SAND (SM), with rootlets (FILL)		1	SS	4												
422.4	Very loose to loose Brown Moist																
0.7			2	SS	12												
421.7	SILTY SAND (SM) Compact Brown Moist																
1.5			3	SS	11												
420.7	SAND (SP-SM), trace fines Compact Brown Wet		4A	SS	20												
420.4	Sandy SILT (ML) Compact Brown Wet		4B	SS													
2.8			4C	SS													
418.6	CLAYEY SILT-SILT (CL-ML), trace sand Firm Grey Moist		5	SS	5												
			6	SS	7												
418.6																	
4.5	CLAYEY SILT-SILT (CL-ML), some sand to sandy, some gravel (TILL) Very stiff Grey Moist		7	SS	25												
	- Periodic grinding of augers from 4.8 m to 7.2 m																
	- Silty interlayer encountered at a depth of about 6.2 m below ground surface (Elev. 416.9 m)		8	SS	24												
415.9																	
7.2	SILTY SAND (SM), trace gravel Dense Brown Wet		9	SS	31												
414.9																	
8.2	END OF BOREHOLE																
NOTES: 1. Groundwater level measured in open borehole at a depth of about 4.8 m below ground surface (Elev. 418.3 m) upon completion of drilling. 2. Borehole backfilled with bentonite/cement grout upon completion of drilling.																	

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

PROJECT _____		RECORD OF BOREHOLE No BH-01-13		SHEET 1 OF 1		METRIC	
G.W.P. _____		LOCATION N 4842174.7; E 232791.6 MTM NAD ZONE (LAT. ; LONG.) _____		ORIGINATED BY _____			
DIST _____ HWY 6		BOREHOLE TYPE _____		COMPILED BY _____			
DATUM Geodetic		DATE May 23, 2013		CHECKED BY _____			

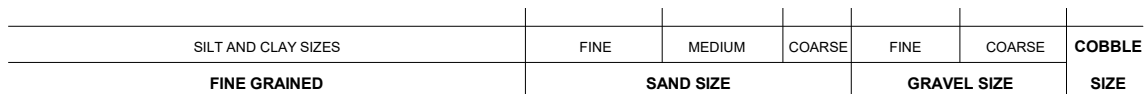
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
								20 40 60 80 100		20 40 60 80 100		15 30 45					
423.5	GROUND SURFACE																
0.0	ASPHALT (125 mm)																
0.1	FILL - SAND																
422.1	TOPSOIL		1	SS	22												
421.8	SILT		2	SS	26												
1.9	SAND		3	SS	16												
420.5	SILT		4	SS	15												
3.1	SILT TILL		5	SS	31												
419.5			6	SS	22												
4.0			7	SS	67												
			8	SS	53												
			9	SS	62												
413.0	END OF BOREHOLE																
10.5																	

GTA-MTO 001 S:\CLIENTS\MTOWHIGHWAY_602_DATA\GINT\HIGHWAY_6.GPJ GAL-GTA.GDT 10/25/21

APPENDIX B

Geotechnical Laboratory Test Results

FIGURE 1A

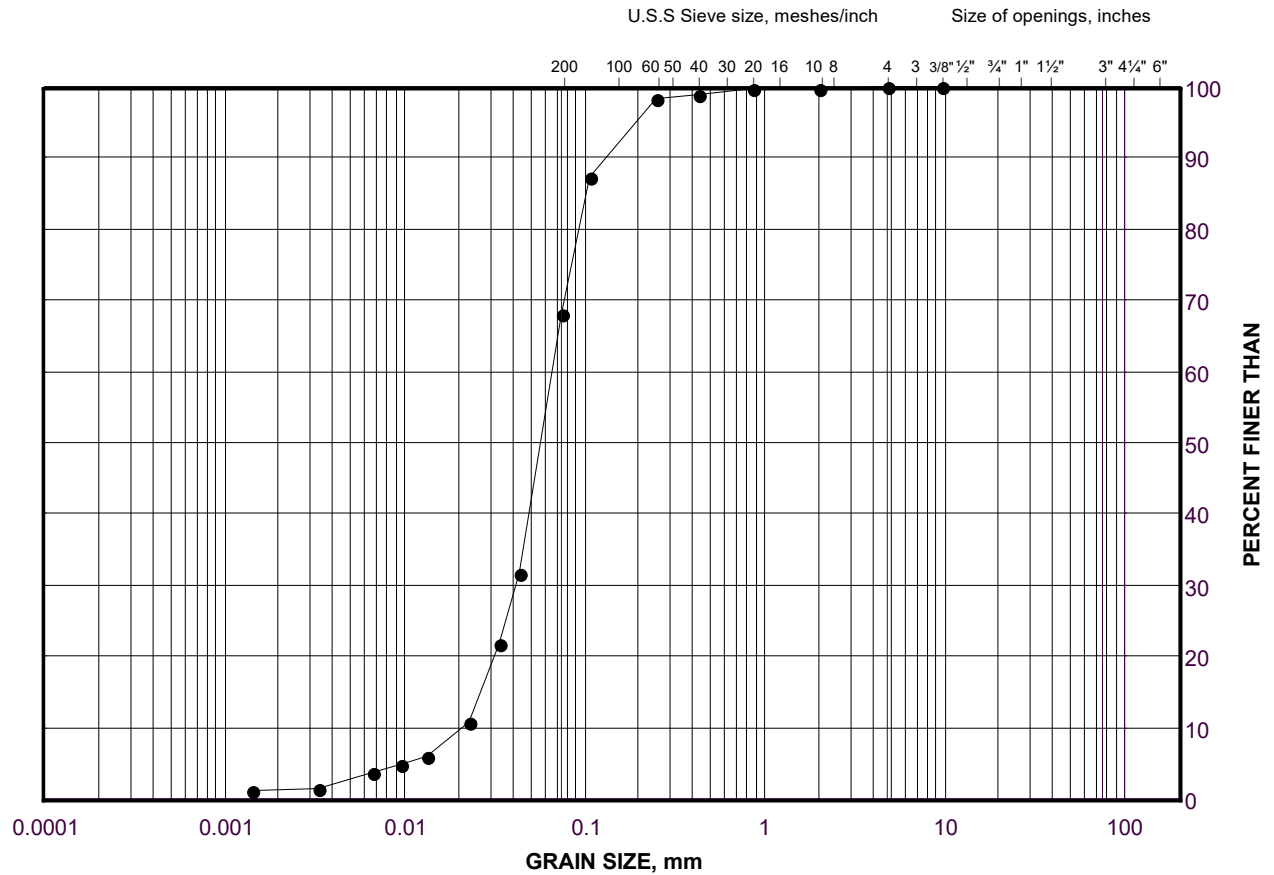


SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	20-1	3	421.2
■	20-2	3	422.0
◆	20-2	5A	420.5

GRAIN SIZE DISTRIBUTION

Sandy SILT (ML)

FIGURE 1B



LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	20-1	4B	420.4

Project Number: 21460183

Checked By: TZ

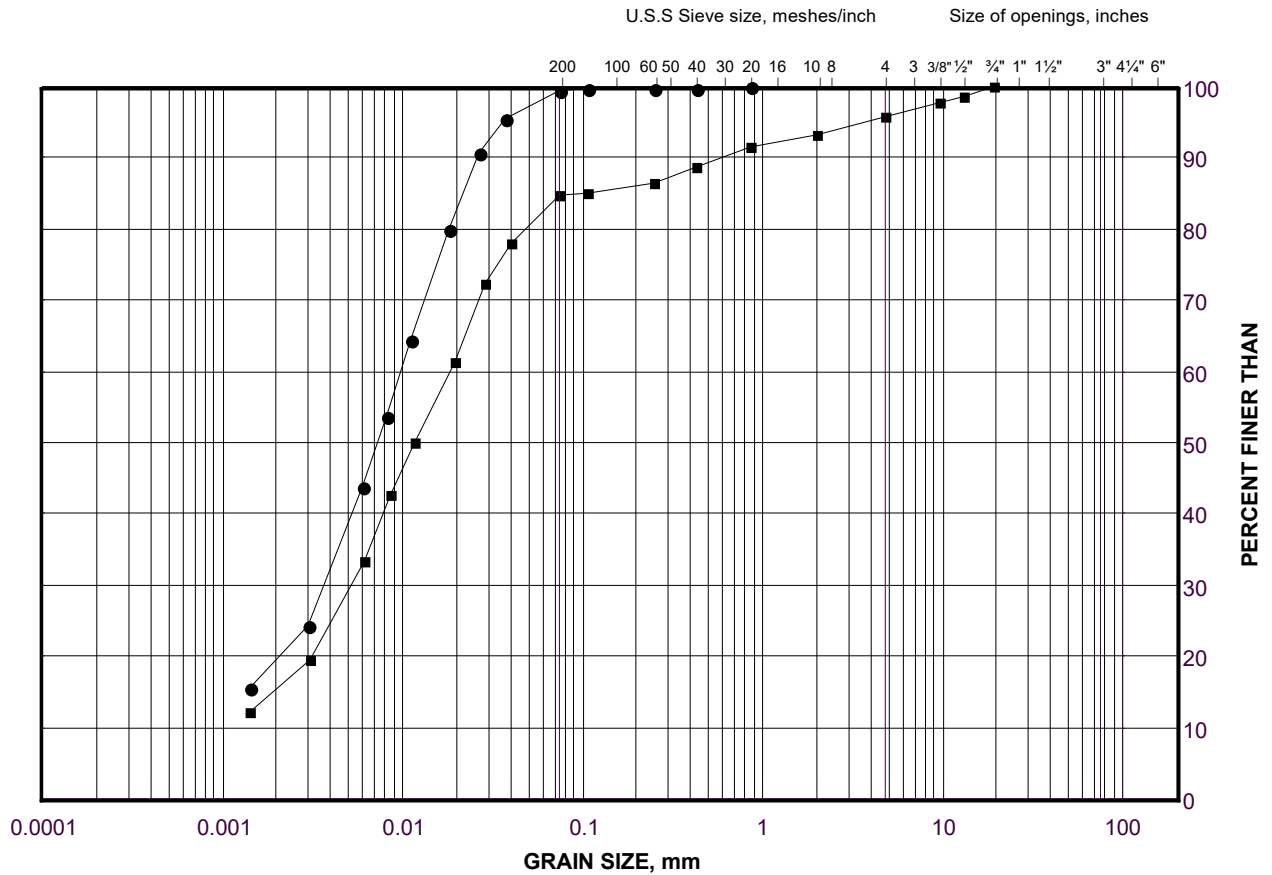
Golder Associates

Date: 20-May-21

GRAIN SIZE DISTRIBUTION

CLAYEY SILT-SILT (CL-ML)

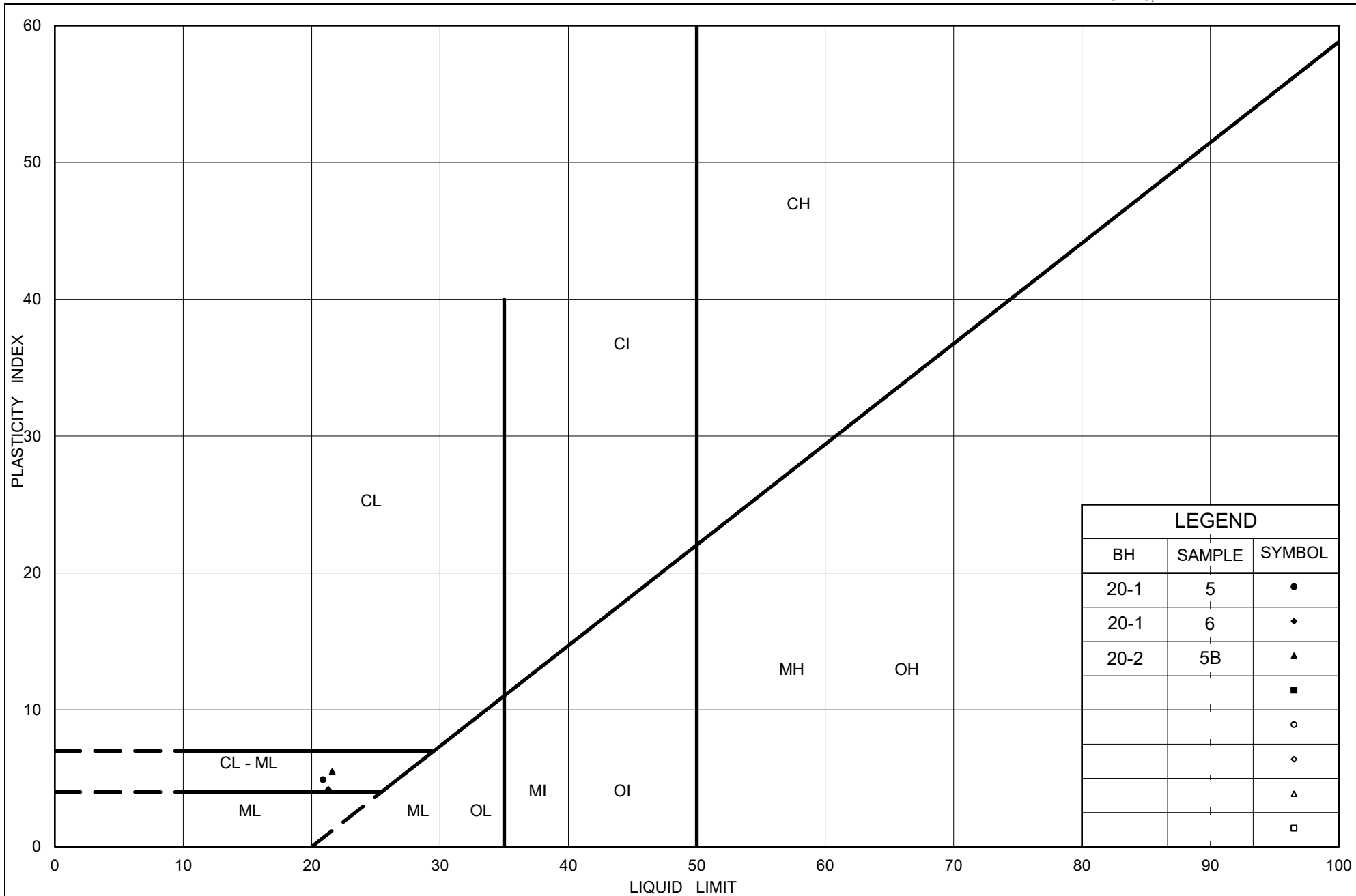
FIGURE 2



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	20-1	5	419.7
■	20-2	5B	420.2



Ministry of Transportation

Ontario

PLASTICITY CHART CLAYEY SILT-SILT (CL-ML)

Figure No. 3

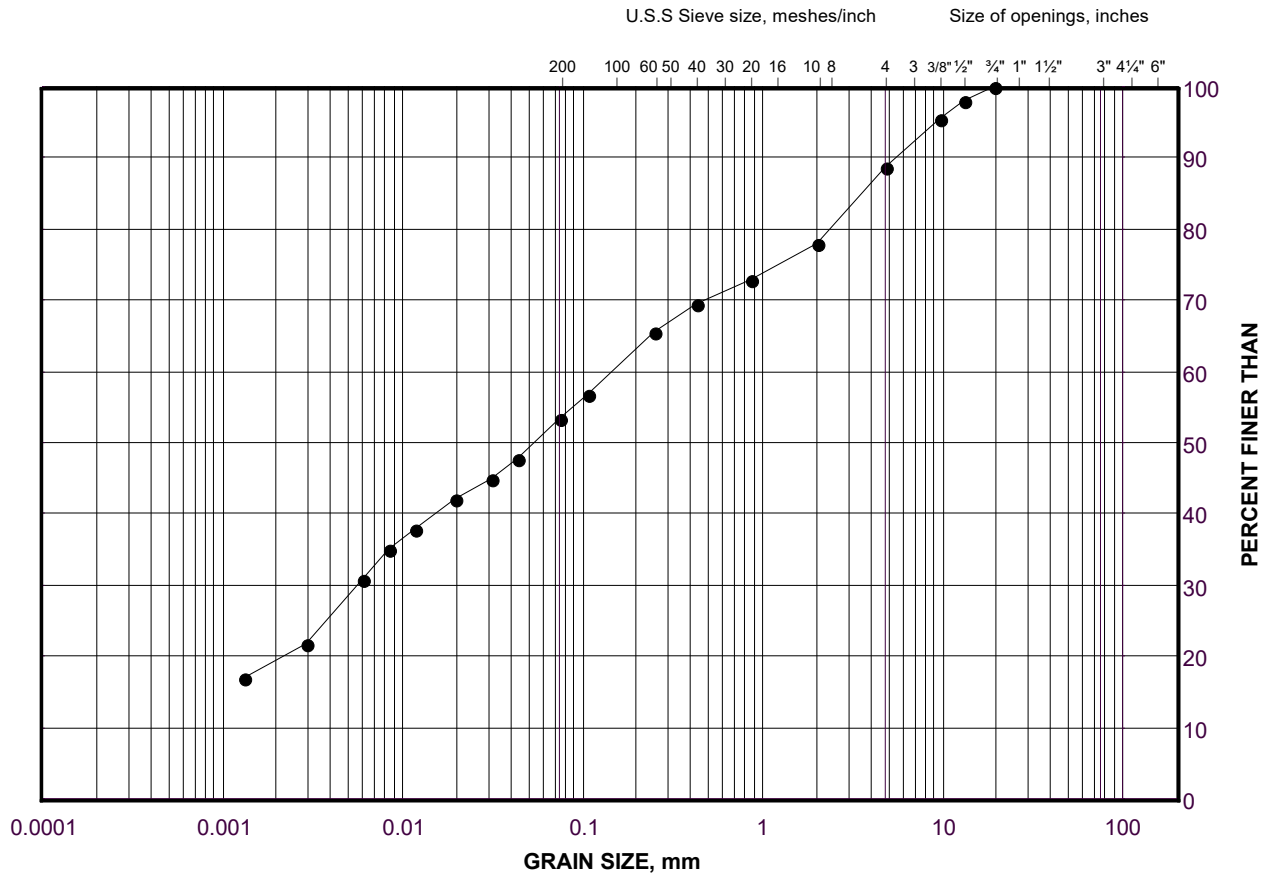
Project No. 21460183

Checked By: TZ

GRAIN SIZE DISTRIBUTION

Sandy CLAYEY SILT (CL) (TILL)

FIGURE 4



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

LEGEND

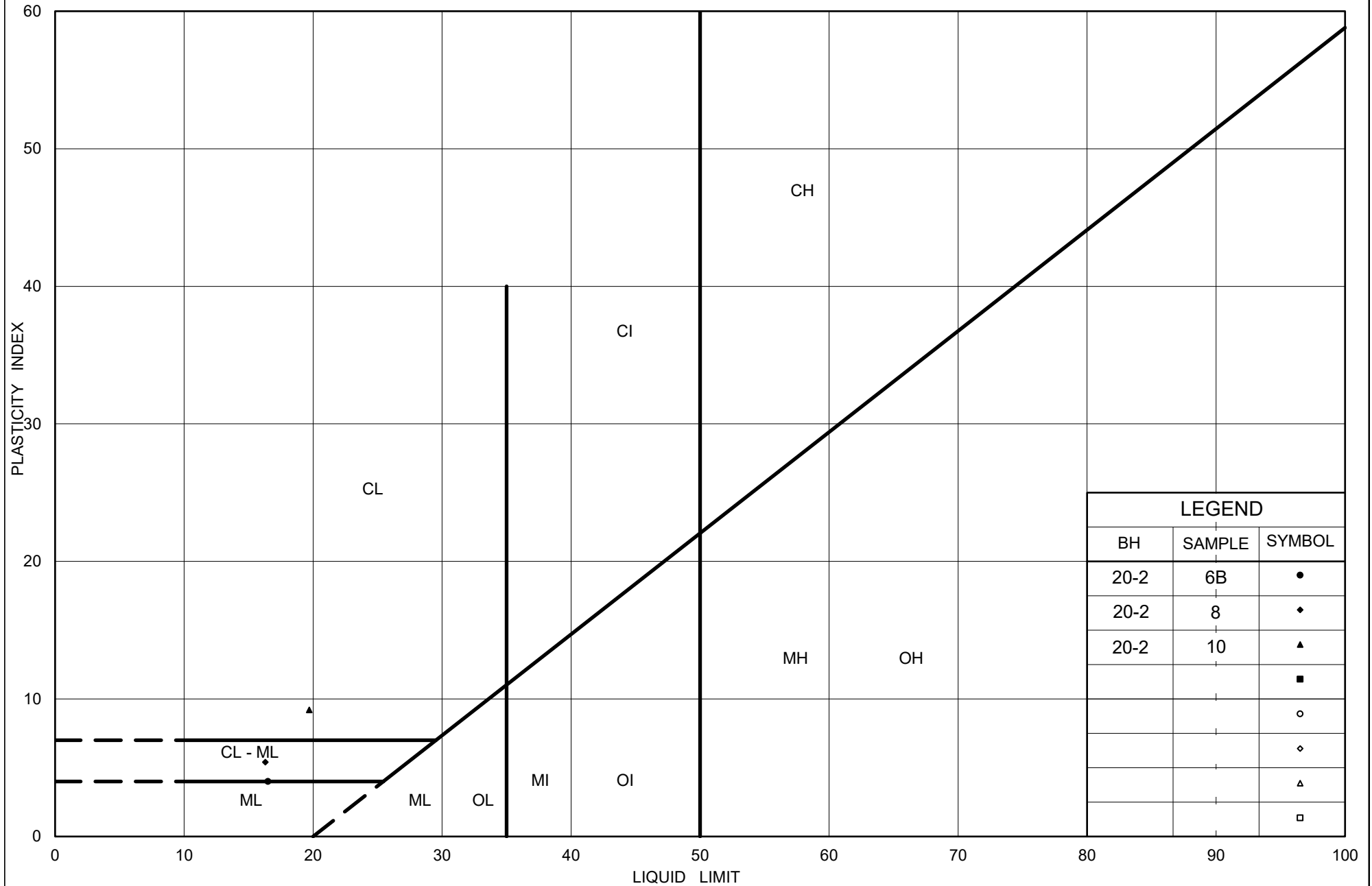
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	20-2	10	414.4

Project Number: 21460183

Checked By: TZ

Golder Associates

Date: 20-May-21



Ministry of Transportation

Ontario

PLASTICITY CHART CLAYEY SILT-SILT (CL-ML) to Sandy CLAYEY SILT (CL) (TILL)

Figure No. 5

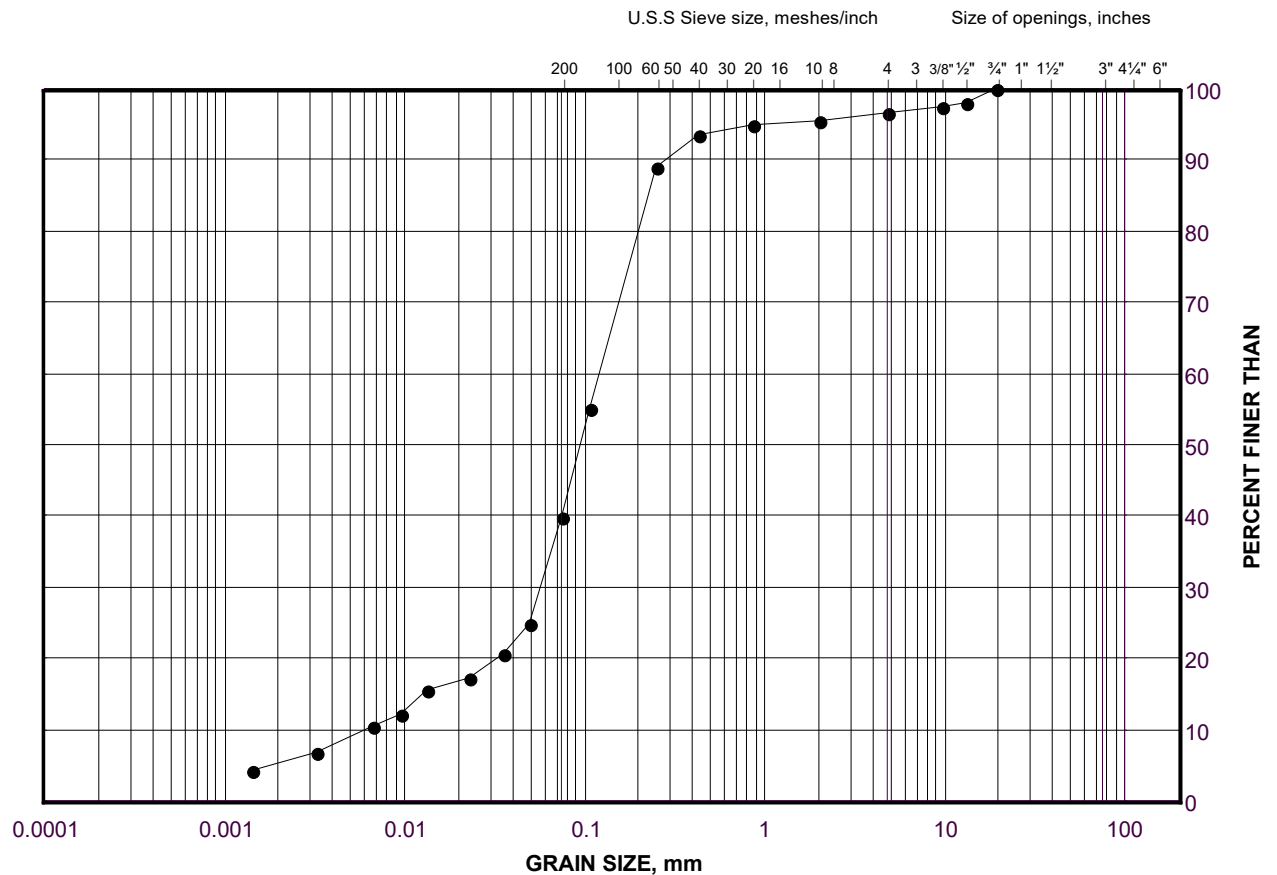
Project No. 21460183

Checked By: TZ

GRAIN SIZE DISTRIBUTION

~~Silty~~ SAND (SM)
SILTY

FIGURE 6



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	20-1	9	415.1

Project Number: 21460183

Checked By: TZ

Golder Associates

Date: 20-May-21

APPENDIX C

Analytical Laboratory Test Results



Your Project #: 21460183
Your C.O.C. #: 159124

Attention: Darcy Hansen

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

Report Date: 2021/05/20
Report #: R6642367
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BV LABS JOB #: C1D3498

Received: 2021/05/18, 12:46

Sample Matrix: Soil
Samples Received: 2

Analyses	Quantity	Date	Date	Laboratory Method	Analytical Method
		Extracted	Analyzed		
Chloride (20:1 extract)	2	2021/05/19	2021/05/20	CAM SOP-00463	SM 23 4500-Cl E m
Conductivity	2	2021/05/19	2021/05/19	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl2 EXTRACT	2	2021/05/20	2021/05/20	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	2	2021/05/18	2021/05/19	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	2	2021/05/19	2021/05/20	CAM SOP-00464	EPA 375.4 m

Remarks:

Bureau Veritas is accredited to ISO/IEC 17025 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Bureau Veritas are based upon recognized Provincial, Federal or US method compendia such as CCME, MELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Bureau Veritas' profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Bureau Veritas 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.

Bureau Veritas liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Bureau Veritas 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 Bureau Veritas, unless otherwise agreed in writing. Bureau Veritas 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 Bureau Veritas, 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 #: 21460183
Your C.O.C. #: 159124

Attention: Darcy Hansen

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

Report Date: 2021/05/20
Report #: R6642367
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BV LABS JOB #: C1D3498

Received: 2021/05/18, 12:46

Encryption Key

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

Ema Gitej, Senior Project Manager

Email: emese.gitej@bureauveritas.com

Phone# (905)817-5829

=====

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BUREAU
VERITAS

BV Labs Job #: C1D3498
Report Date: 2021/05/20

Golder Associates Ltd
Client Project #: 21460183
Sampler Initials: PM

SOIL CORROSIVITY PACKAGE (SOIL)

BV Labs ID		PPD182	PPD183			PPD183		
Sampling Date		2021/04/26	2021/04/26			2021/04/26		
COC Number		159124	159124			159124		
	UNITS	20-1 SS6+ 20-2 SS6A	20-1 SS7+ 20-2 SS7	RDL	QC Batch	20-1 SS7+ 20-2 SS7 Lab-Dup	RDL	QC Batch
Calculated Parameters								
Resistivity	ohm-cm	3100	3300		7358006			
Inorganics								
Soluble (20:1) Chloride (Cl-)	ug/g	120	80	20	7360481			
Conductivity	umho/cm	324	301	2	7360308			
Available (CaCl2) pH	pH	8.00	8.14		7362684			
Soluble (20:1) Sulphate (SO4)	ug/g	75	97	20	7360555	97	20	7360555
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate								



BUREAU
VERITAS

BV Labs Job #: C1D3498
Report Date: 2021/05/20

Golder Associates Ltd
Client Project #: 21460183
Sampler Initials: PM

TEST SUMMARY

BV Labs ID: PPD182
Sample ID: 20-1 SS6+ 20-2 SS6A
Matrix: Soil

Collected: 2021/04/26
Shipped:
Received: 2021/05/18

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	7360481	2021/05/19	2021/05/20	Alina Dobreanu
Conductivity	AT	7360308	2021/05/19	2021/05/19	Khushbu Vijay kumar Patel
pH CaCl2 EXTRACT	AT	7362684	2021/05/20	2021/05/20	Neil Dassanayake
Resistivity of Soil		7358006	2021/05/19	2021/05/19	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	7360555	2021/05/19	2021/05/20	Alina Dobreanu

BV Labs ID: PPD183
Sample ID: 20-1 SS7+ 20-2 SS7
Matrix: Soil

Collected: 2021/04/26
Shipped:
Received: 2021/05/18

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	7360481	2021/05/19	2021/05/20	Alina Dobreanu
Conductivity	AT	7360308	2021/05/19	2021/05/19	Khushbu Vijay kumar Patel
pH CaCl2 EXTRACT	AT	7362684	2021/05/20	2021/05/20	Neil Dassanayake
Resistivity of Soil		7358006	2021/05/19	2021/05/19	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	7360555	2021/05/19	2021/05/20	Alina Dobreanu

BV Labs ID: PPD183 Dup
Sample ID: 20-1 SS7+ 20-2 SS7
Matrix: Soil

Collected: 2021/04/26
Shipped:
Received: 2021/05/18

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Sulphate (20:1 Extract)	KONE/EC	7360555	2021/05/19	2021/05/20	Alina Dobreanu



GENERAL COMMENTS

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

Package 1	2.3°C
-----------	-------

Results relate only to the items tested.



BUREAU
VERITAS

BV Labs Job #: C1D3498

Report Date: 2021/05/20

QUALITY ASSURANCE REPORT

Golder Associates Ltd

Client Project #: 21460183

Sampler Initials: PM

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
7360308	Conductivity	2021/05/19			101	90 - 110	<2	umho/cm	1.8	10
7360481	Soluble (20:1) Chloride (Cl-)	2021/05/20	NC	70 - 130	104	70 - 130	<20	ug/g	25	35
7360555	Soluble (20:1) Sulphate (SO4)	2021/05/20	NC	70 - 130	105	70 - 130	<20	ug/g	0.026	35
7362684	Available (CaCl2) pH	2021/05/20			100	97 - 103			1.5	N/A

N/A = Not Applicable

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

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

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

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

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



BUREAU
VERITAS

BV Labs Job #: C1D3498

Report Date: 2021/05/20

Golder Associates Ltd

Client Project #: 21460183

Sampler Initials: PM

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by:

Anastassia Hamanov, Scientific Specialist

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**RUSH!**

6740 Campobello Road, Mississauga, Ontario L5N 2L8
Phone: 905-817-5700 Fax: 905-817-5779 Toll Free: 800-563-6266
CAM FCD-01191/6

CHAIN OF CUSTODY RECORD 159124 Page 1 of 1

Invoice Information		Report Information (if differs from invoice)		Project Information (where applicable)		Turnaround Time (TAT) Required				
Company Name: <u>Golder Associates Ltd.</u>	Company Name: <u>Golder Associates Ltd.</u>	Quotation #: _____	<input type="checkbox"/> Regular TAT (5-7 days) Most analyses							
Contact Name: <u>Accounts Payable</u>	Contact Name: <u>Darcy Hansen</u>	P.O. #/ AFER: _____	PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS							
Address: <u>6925 Century Ave. Suite 100</u>	Address: <u>6925 Century Ave. Suite 100</u>	Project #: <u>21460183</u>	Rush TAT (Surcharges will be applied)							
Phone: <u>905-517-4944</u> Fax: <u>905-567-1561</u>	Phone: <u>647-237-1256</u> Fax: _____	Site Location: _____	<input type="checkbox"/> 1 Day <input checked="" type="checkbox"/> 2 Days <input type="checkbox"/> 3-4 Days							
Email: <u>CanadaAccountsPayableInvoices@golder.com</u>	Email: <u>Darcy.Hansen@golder.com</u>	Site #: _____	Date Required: _____							
MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE BUREAU VERITAS LABORATORIES' DRINKING WATER CHAIN OF CUSTODY		Site Location Province: _____	Rush Confirmation #: _____							
Regulation 153		Analysis Requested		LABORATORY USE ONLY						
<input type="checkbox"/> Table 1 <input type="checkbox"/> Res/Park <input type="checkbox"/> Med/ Fine	<input type="checkbox"/> CCME <input type="checkbox"/> Sanitary Sewer Bylaw	<div>FIELD FILTERED (CIRCLE) Metals / Hg / CVI</div> <div>REG 153 METALS & INORGANICS</div> <div>REG 153 (CPMS) METALS</div> <div>REG 153 METALS (Hg, Cr VI, ICPMAS Metals, INMS - B)</div> <div>Standard Corrosivity Package (Chloride, Sulfate, Conductivity, Resistivity and pH)</div>		CUSTODY SEAL Y / N						
<input type="checkbox"/> Table 2 <input type="checkbox"/> Ind/Comm <input type="checkbox"/> Coarse	<input type="checkbox"/> MISA <input type="checkbox"/> Storm Sewer Bylaw			Present Intact						
<input type="checkbox"/> Table 3 <input type="checkbox"/> Agri/ Other	<input type="checkbox"/> PWQD <input type="checkbox"/> Region			N N 3/3/1						
<input type="checkbox"/> Table _____	<input type="checkbox"/> Other (Specify)			COOLING MEDIA PRESENT: <input checked="" type="checkbox"/> Y <input type="checkbox"/> N						
FOR RSC (PLEASE CIRCLE) Y / N				COMMENTS						
Include Criteria on Certificate of Analysis: Y / N		SAMPLER MUST BE KEPT COOL (< 10 °C) FROM TIME OF SAMPLING UNTIL DELIVERY TO BUREAU VERITAS								
SAMPLE IDENTIFICATION	DATE SAMPLED (YYYY/MM/DD)	TIME SAMPLED (HH:MM)	MATRIX	# OF CONTAINERS SUBMITTED	FIELD FILTERED (CIRCLE) Metals / Hg / CVI	REG 153 METALS & INORGANICS	REG 153 (CPMS) METALS	REG 153 METALS (Hg, Cr VI, ICPMAS Metals, INMS - B)	Standard Corrosivity Package (Chloride, Sulfate, Conductivity, Resistivity and pH)	WORLD DO NOT ANALYZE
1 20-1 SS6 + 20-2 SS6A	2021/04/26	PM	Soil	1					✓	
2 20-1 SS7 + 20-2 SS7	2021/04/26	PM	Soil	1					✓	
3										
4										
5										
6										
7										
8										
9										
10										
RELINQUISHED BY: (Signature/Print)	DATE: (YYYY/MM/DD)	TIME: (HH:MM)	RECEIVED BY: (Signature/Print)	DATE: (YYYY/MM/DD)	TIME: (HH:MM)	BV JOB #				
Priscilla Moore Rhoads	2021/05/18	12:45 PM	MEETHA SANYANTHAN	2021/05/18	12:46					

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COC-1004 (06/19)

White: BV Labs - Yellow: Client

APPENDIX D

Existing Borehole Records (LVM, 2013)

LIST OF ABBREVIATIONS

The abbreviations commonly employed on the borehole logs, on the figures, and in the text of the report, are as follows:

Sample Types		Soil Tests and Properties	
AS	Auger Sample	SPT	Standard Penetration Test
CS	Core Sample	UC	Unconfined Compression
RC	Rock Core	FV	Field Vane Test
SS	Split Spoon	ϕ	Angle of internal friction
TW	Thinwall, Open	γ	Unit weight
WS	Wash Sample	w_p	Plastic limit
BS	Bulk Sample	w	Water content
GS	Grab Sample	w_L	Liquid limit
WC	Water Content Sample	I_L	Liquidity index
TP	Thinwall, Piston	I_p	Plasticity index
		PP	Pocket penetrometer

Penetration Resistances	
Dynamic Penetration Resistance	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.) diameter 60° cone a distance 300 mm (12 in.). The cone is attached to 'A' size drill rods and casing is not used.
Standard Penetration Resistance, N (ASTM D1586)	The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) required to drive a standard split spoon sampler 300 mm (12 in.)
WH	sampler advanced by static weight of hammer
PH	sampler advanced by hydraulic pressure
PM	sampler advanced by manual pressure

Soil Description		
Cohesionless Soils	SPT N-Value	Relative Density (D_r)
Compactness Condition	(blows per 0.3 m)	(%)
Very Loose	0 to 4	0 to 20
Loose	4 to 10	20 to 40
Compact	10 to 30	40 to 60
Dense	30 to 50	60 to 80
Very Dense	over 50	80 to 100
Cohesive Soils	Undrained Shear Strength (C_u)	
Consistency	kPa	psf
Very Soft	less than 12	less than 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1000
Stiff	50 to 100	1000 to 2000
Very Stiff	100 to 200	2000 to 4000
Hard	over 200	over 4000
DTPL	Drier than plastic limit	Low Plasticity, $W_L < 30$
APL	About plastic limit	Medium Plasticity, $30 < W_L < 50$
WTPL	Wetter than plastic limit	High Plasticity, $W_L > 50$



Ground Elevation: 423.50 m

Borehole Number: BH-01-13

Job N°: P-0002195-0-01-100

Drill Date: 2013-05-23

Field Tech: R. McMillan

Drill Method: Hollow Stem Auger

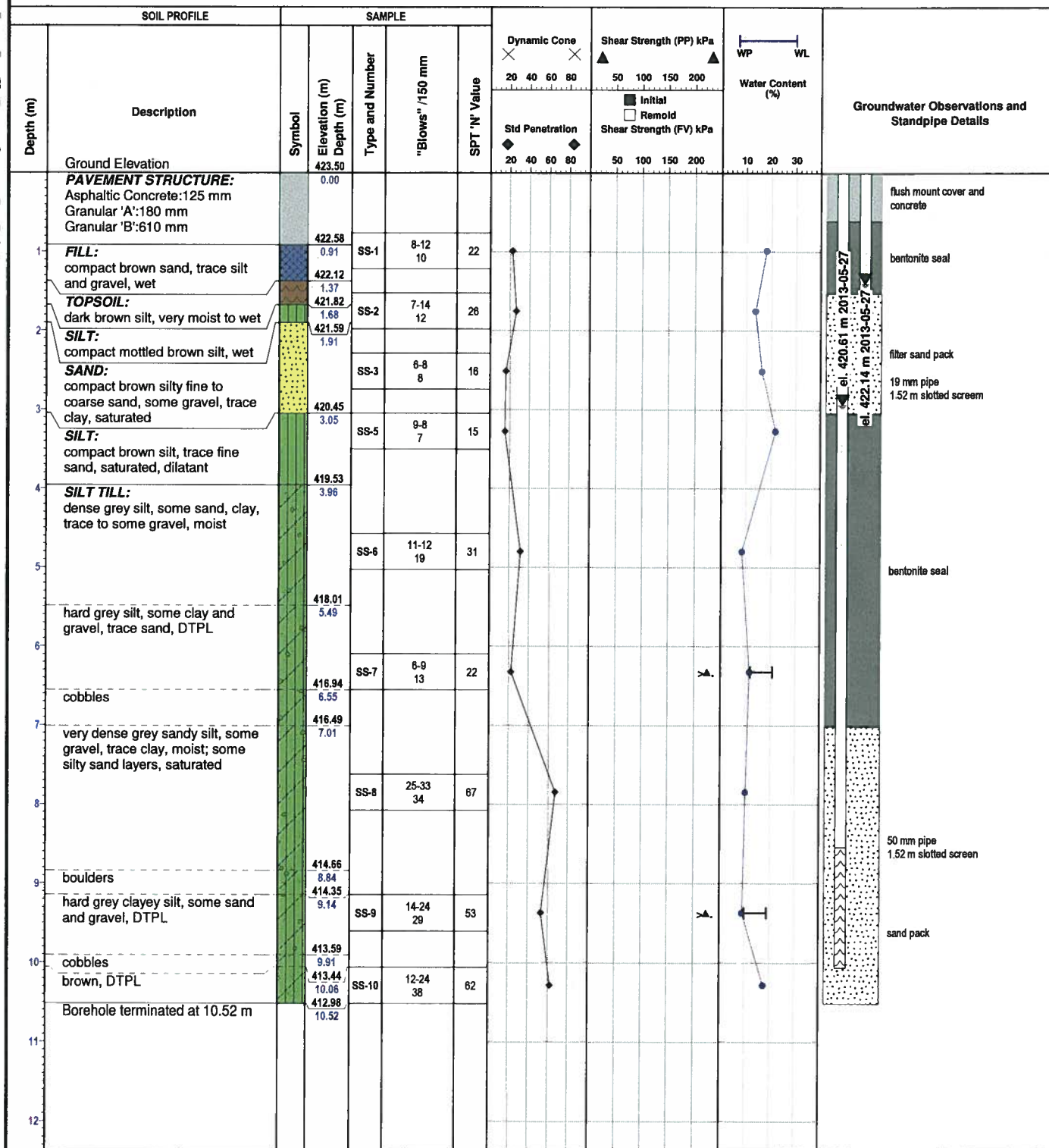
Project: Bonaire Highlands Subdivision - Highway 6 Services

Location: Sideroad 18 to Sideroad 19, Fergus, Ontario

V:\Style_LVM_Ontario\LogBorehole_Log_LVM_Ontario_NEW.sty - Printed: 2013-07-08 08h

Vertical Scale = 1 : 70.0

EQ-09-Ge-72 R.1 18.02.2011



Reviewed by: K.Thrams

Drafted by: E.Ciochon

Sheet: 1 of 1

Notes: Bulk sample BS-4 taken from 1.83 - 2.74 m (moisture content 18.9%), BS-11 taken from 5.49 - 6.71 m and BS-12 taken from 9.14 - 10.06 m.

APPENDIX E

MTO Special Provisions

**CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY
TRENCHLESS METHOD**

1.0 SCOPE

This Special Provision covers the requirements for the installation of pipes by a selected trenchless method.

2.0 REFERENCES

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

Ontario Provincial Standard Specifications, General

OPSS 180 General Specification for the Management of Excess Materials

Ontario Provincial Standard Specifications, Construction

OPSS 182 Environmental Protection for Construction in Waterbodies and On Waterbody Banks
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 Construction Specification for Support Systems
OPSS 409 Closed-Circuit Television (CCTV) Inspection of Pipelines
OPSS 490 Site Preparation for Pipelines, Utilities, and Associated Structures
OPSS 491 Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492 Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 510 Construction Specification for Removal
OPSS 517 Construction Specification for Dewatering
OPSS 539 Construction Specification for Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

OPSS 1004 Material Specification for Aggregates - Miscellaneous
OPSS 1350 Material Specification for Concrete - Materials and Production
OPSS 1440 Steel Reinforcement for Concrete
OPSS 1802 Material Specification for Smooth Walled Steel Pipe
OPSS 1820 Material Specification for Circular and Elliptical Concrete Pipe
OPSS 1840 Material Specification for Non-Pressure Polyethylene (PE) Plastic Pipe Products
OPSS 1841 Material Specification for Non-Pressure Polyvinyl Chloride (PVC) Plastic Pipe Products

CSA Standards

A3000 Cementitious Materials Compendium
B182.6 Profile polyethylene (PE) sewer pipe and fittings for leak-proof sewer applications

B182.8	Profile Polyethylene (PE) Storm Sewer and Drainage Pipe and Fittings
B182.13	Profile Polypropylene (PP) Sewer Pipe and Fittings for Leak-proof Sewer Applications
C22.1	Canadian Electrical Code
W59	Welded Steel Construction

American Society for Testing and Materials (ASTM) International Standards

A 252M-19	Standard Specification for Welded and Seamless Steel Pipe Piles
C-33	Standard Specification for Concrete Aggregates.
C-39	Standard Test method for Compressive Strength of Cylindrical Concrete
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 Special Provision, the following definitions apply:

Annular Space means the space between the inside edge of the opening and the outside edge of the penetrating item or inserted pipe.

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.

Boulder Number Ratio (BNR) means the number of individual boulders per m³ of cumulative boulder volume.

Boulder Volume Ratio (BVR) means the ratio between the cumulative volume of boulders and the volume of the material excavated.

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.

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.

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.

Horizontal Directional Drilling (HDD) means a surface-launched trenchless technology for the installation of pipes, conduits, and cables. HDD creates a pilot bore along the design pathway and reams the pilot bore in one or more passes to a diameter suitable for the product, which is pulled into the prepared bore in the final steps of the process.

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 microtunnelling boring machine (MTBM) or hand mining using a shield to support the opening.

MTBM means a microtunnelling boring machine.

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

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

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 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 m³ 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 tunnel boring machine (TBM) or microtunnelling boring machine (MTBM), through which spoil can pass only by manner of controlled-pressure and controlled flow slurry pumping systems.

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.

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.

TBM means a tunnel boring machine.

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

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.

Tunnelling means an underground method of constructing a passage using a tunnel boring machine (TBM) operated by personnel within the tunnel, a microtunnelling 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 trenchless installation for each pipe crossing for each location within the terms of this specification.

The trenchless installation method selected for each pipe crossing shall be designed for the subsurface conditions in accordance with 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.

* Designer Fill-in, See Notes to Designer

4.02 Submission Requirements

4.02.01 Qualifications

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

4.02.01.01 Project Superintendent

The Project Superintendent shall have a minimum of five (5) years experience on projects with similar scope and complexity.

During construction, the Project Superintendent shall not be changed without written permission from the Contract Administrator. A proposal to change the Project Superintendent shall be submitted at least one week prior to the actual change in Project Superintendent.

** Designer Fill-in, See Notes to Designer

4.02.01.02 Trenchless Contractor

The Trenchless Contractor shall have a minimum of five (5) years experience on projects with similar scope and complexity.

*** Designer Fill-in, See Notes to Designer

4.02.02 Working Drawings

Three (3) sets of Working Drawings for the selected trenchless installation method, and a Request to Proceed shall be submitted to the Contract Administrator two weeks (2) prior to the commencement of the Work or as per the Contract Documents.

The trenchless installation operation shall not proceed until a Notice to Proceed has been received from the Contract Administrator.

All Working Drawings shall bear the seal and signature of the Design Engineer and Design Checking Engineer.

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

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 traffic control plan.
- v. A safety plan including the company safety manual and emergency procedures.
- vi. The Working Area layout.
- vii. An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail.
- viii. 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.
- ix. 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.
- x. Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations.
- xi. Excavated materials disposal plan.
- xii. Locations of protection systems.
- xiii. Contingency plans for the following potential conditions:
 - Unforeseen obstructions causing stoppage.

- Deviation from required alignment and grade.
- Extended service disruption.
- Damage to the existing Utilities and methods of repair.
- Soil heaving or settlement.
- Contaminated soil or water.
- Alignment passing through buried structures.

b) Designs:

- i. Primary Liner/Secondary Liner design (e.g. steel liner plates, steel ribs and wood lagging, and steel casing 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.
- iv. Minimum depth of cover for trenchless installation appropriate for the highway type and pipe diameter, maximum excavation diameter, maximum annulus, alignment and grade tolerance etc.
- v. Detailed subsurface conditions along the proposed path or within the footprint of the trenchless technology equipment or pits/shafts.

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 (EPB), Slurry Pressure Balance (SPB).
- 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 Earth Pressure Balance (EPB) tunnel boring machine (TBM) and microtunnelling boring machine (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. Slurry, drilling fluids, and tunnelling fluids:

- Type, source, and physical and chemical properties of bentonite, polymer or other additives;
- Source of water;
- Method of mixing;
- 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 tunneling fluids or EPB spoils; and
- Method of disposal of the slurry, drilling fluids and associated spoil.

d) Upstream/Downstream Portal Installation Procedure:

- 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, Slurry Pressure Balance (SPB) and Earth Pressure Balance (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;

- viii. Basis for selection of excavation tools (e.g., bits, TBM face tools, MTBM face tools, excavator fittings, etc.) as related to expected ground conditions;
- ix. Jacking forces for installation of pipe, for driving of trenchless equipment forward and, in the case of Auger Jack & Bore, for advancing the lead end of the casing ahead of the lead end of the auger cutting tools.

g) Monitoring Method:

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

- i. Maintaining the alignment of the installation;
- ii. EPB, SPB and drilling fluid pressures at the leading edge of excavation (face), flow rates and volume or weights of spoil;
- iii. Jacking forces on pipes, linings and cutting tools;
- iv. Torque, total revolutions and revolution rates on rotating equipment such as TBM or MTBM heads, auger flights, drill bits, etc.
- v. Grout injection pressures and volumes;
- vi. Longitudinal position of all casings and excavation cutting tools (auger flight heads, TBM face, drill bit position, etc.); and
- vii. Ground displacements (heave and settlement); and noise and ground vibrations induced by trenchless construction.

4.02.03 As-Built Drawings

As-built drawings shall be submitted to the Contract Administrator in a reproducible format prior to the Contract completion.

The as-built drawings shall be dated and bear the seal and signature of the Design Engineer and Design Checking Engineer.

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 High Density Polyethylene Pipe

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

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

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

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

5.01.04 Concrete Pipe

Concrete pipe shall be according to OPSS 1820.

5.02 Concrete

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

5.03 Steel Reinforcement

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

5.04 Wood

Wood shall be according to OPSS 1601.

5.05 Drilling Fluids

Drilling fluid shall be mixed according to the Working Drawings.

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

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

Slurry shall be mixed according to the submitted slurry design and be appropriate for the anticipated

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

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

5.06 Grout

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

6.0 EQUIPMENT

6.01 Auger Jack & Bore

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

Pipe Auger Jack & Bore equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

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

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

6.02 Pipe Ramming

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

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

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

6.03 Horizontal Directional Drilling

6.03.01 General

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

6.03.02 Drilling Rig

The horizontal directional drilling rig shall:

- a) Consist of a leak free hydraulically powered boring system to rotate, push, and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head.
- b) Have drill rod that is suitable for both the drill and the product pipe installation.
- c) Contain a drill head that is steerable, equipped with the necessary cutting surfaces and fluid jets, and be suitable for the anticipated ground conditions.
- d) Have adequate reamers and down-bore tooling equipped with the necessary cutting surfaces and fluid jets to facilitate the product installation and be suitable for the anticipated ground conditions.
- e) Contain a guidance system to accurately guide boring operations.
- f) Be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation.
- g) Be grounded during all operations unless otherwise specified by the drilling rig manufacturer.

6.03.03 Drill Head

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

6.03.04 Guidance System

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

6.03.05 Drilling Fluid Mixing System

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

6.03.06 Drilling Fluid Delivery System

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

6.04

Tunnelling

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

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

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

6.05

Microtunnelling Equipment

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

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

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

- a) Remote Control System – The Contractor shall provide a MTBM that includes a remote control system with the following features:
 - i. Allows for operation of the system without the need for personnel to enter the microtunnel.
 - ii. 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.
 - iii. 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.
 - iv. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.
 - v. The system shall monitor and continuously balance the soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.
 - vi. The pressure at the excavation face shall be managed by controlling the volume of spoil removal with respect to the advance rate.
 - vii. 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.

- viii. 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.
 - ix. 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 – The Contractor shall provide a 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.
 - ii. Provides active steering information that shall be monitored and transmitted to the operating console and recorded.
 - iii. 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 % 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.

7.0 CONSTRUCTION

7.01 General

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting the 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 Contractor's Engineer shall supervise the work at all times.

A Request to Proceed shall be submitted to the Contract Administrator upon completion of each of the following operations and prior to commencement of each subsequent operation and no less than 2 weeks prior to the commencement of the trenchless installation.

- a) Site Surveying (see Clause 4.02)
- b) Excavation for pits including dewatering of excavations
- c) Jacking / Ramming / Directional Drilling of Casing / Liner
- d) Installation of the Product
- e) Grouting Operations

Operations a) to e) shall not proceed until the Contract Administrator has issued a Notice to Proceed for each proceeding operation.

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 Working 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 539.

Where the stability, safety, or function of an existing roadway, railway, watercourse, other works, ESA's, or proposed works 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 recommendations for transporting, unloading, storing, and handling of materials shall be followed.

7.01.08 Trenching, Backfilling and Compacting

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

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

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

7.01.10 Dewatering

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

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

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

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

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

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Cobbles and Boulders

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

**** Designer Fill-in, See Notes to Designer

7.01.12 Removal of Obstructions

The Contractor is alerted that obstructions such as, but not limited to wood debris, roots, and construction debris consisting of (broken asphalt, concrete etc.) are expected within the trenchless alignment as identified in the Contract Documents. Accordingly, the Contractor shall address methods for the removal of obstructions in the proposed method of construction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered and the Contractor's expected method of and schedule for removal.

***** Designer Fill-in, See Notes to Designer

7.01.13 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.

7.01.14 Site Restoration

Site restoration shall be according to OPSS 492.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

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

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

7.02.02 Pipe Installation

Concrete pipe joints shall be watertight 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 watertight, expandable, and stable grout.

7.03 Pipe Ramming Installation

For Pipe Ramming installation the following requirements apply:

- Only smooth walled steel pipe shall be used. Butt welding of pipe joints shall conform to CSA W59.
- Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement between the shafts/pits without overstressing of the pipe. Delays shall be avoided between ramming operations.
- A Ramming head shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- Two or more lubricated guide rails or sills shall be provided of sufficient length to fully support the pipe at the specified line and grade in the ramming pit. Pipe shall be installed to the line and grade specified.
- Removal of materials from within the pipe shall not be undertaken until the lead end of the pipe has

passed fully through and beyond the zone of influence of any overlying infrastructure.

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

7.04 Horizontal Directional Drilling Installation

7.04.01 General

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

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

7.04.02 Site Preparation

Site preparation shall be according to OPSS 490 and as specified herein.

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

7.04.03 Pilot Bore

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

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

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

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

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

7.04.04 Drilling Fluid Losses to Surface (“Frac-Out”)

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

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

7.04.05 Reaming

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

7.04.06 Product Installation

7.04.06.01 General

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

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

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

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

7.04.06.02 Pullback and Grouting

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

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

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

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

The space between the pipe and the walls of the excavated volume shall be filled with grout or slurry with gel

strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground.

7.05 Tunnelling Installation

7.05.01 General

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

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

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

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

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

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

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

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

7.05.02 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.

7.05.03 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.

7.05.04 Secondary Liner

7.05.04.01 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

***** Designer Fill-in, See Notes to Designer

7.07.01 General

The Contractor shall furnish, install and monitor Surface Monitoring Points (SMP) and In-Ground Monitoring Points at the locations shown on the Contract Drawings.

The equipment and procedures used for settlement monitoring during construction must be capable of

surveying the settlement point elevations to within a repeatability (combined accuracy and precision of equipment and methods) ± 2 mm of the actual elevation.

7.07.02 Surface Settlement Monitoring Points

Surface settlement monitoring points shall be installed on the traffic lanes and shoulders to monitor settlement and stability. The surface settlement monitoring points shall be installed centred on the tunnel alignment as arrays of three points at intervals of 5 m or less and off-set a lateral distance of 1.5 m on either side of the tunnel centerline.

Surface settlement monitoring points 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.

7.07.03 In-Ground Settlement Monitoring Points

In-ground settlement monitoring points shall be installed beyond the traffic lanes and shoulders to monitor settlement and stability of the ground surface between the surface settlement monitoring points and the entry and exit portals. In-ground settlement monitoring points shall be located at intervals of 5 m or less along the tunnel alignment.

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.

7.07.04 Installation, Replacement and Abandonment

The Contractor shall install all settlement monitoring points a minimum of two (2) 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.

7.07.05 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.

7.07.06 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

***** Designer Fill-in, See Notes to Designer

Based on the monitoring of the 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 Contract Administrator 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 complete with a Request to Proceed.
 - iii. Any approved corrective and/or preventive measure deemed necessary by the Contractor is implemented.
 - iv. Operations shall not proceed until the Contract Administrator has issued a Notice to Proceed for each corrective/preventive plan.

7.09 Certificate of Conformance

A Certificate of Conformance shall be submitted to the Contract Administrator upon completion of the installation of the pipe at each location. 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 Engineer and the Design Checking Engineer. The Certificate shall state that the pipe has been installed in general conformance with the Contractor's Submission and Design Requirements, sealed Working Drawings and Contract Documents.

8.0 QUALITY ASSURANCE – Not Used

9.0 MEASUREMENT FOR PAYMENT

Measurement shall be by Plan Quantity Payment as may be revised by Adjusted Plan Quantity Payment in metres, following along the centreline 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.

10.0 BASIS OF PAYMENT

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

If a pipe is installed inside the pipe liner, payment for the pipe 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.

***** Designer Fill-in, See Notes to Designer

NOTES TO DESIGNER:

* Insert the following fill-in: Any method that is not suitable shall be specified.

** Insert the following fill-in: Specify minimum requirements commensurate with complexity.

*** Insert the following fill-in: Specify minimum requirements commensurate with complexity.

**** Insert the following fill-in: 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.

***** Insert the following fill-in: Any known obstructions shall be specified.

***** Insert the following fill-in: The Instrumentation and Monitoring program shall be project specific. The work specified in this section includes furnishing and installing instruments for monitoring of settlement (and heave) and ground stability.

***** Insert the following fill-in: Project specific Review and Alert Levels shall be provided if required.

***** Insert the following fill-in: Payment for removal of boulders exceeding Boulder Volume Ratio (BVR) and Boulder Number Ratio (BNR) shall be by Time and Material.

WARRANT: Always with this specification.

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

Special Provision No. 517F01

July 2017

Amendment to OPSS 517, November 2016

Design Storm Return Period and Preconstruction Survey Distance

517.01 SCOPE

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

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

517.04 DESIGN AND SUBMISSION REQUIREMENTS

517.04.01 Design Requirements

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

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

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

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

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

Table A

IDF Curve Location	Latitude: *		Longitude: *			
Temporary Flow Passage Systems						
Site Name / Station Reference	Minimum Return Period (Years)	Return Period Flow Estimates (m ³ /s)				Design Engineer Requirements (Note 1)
		2 Year	5 Year	10 Year	25 Year	
**	***	****	****	****	****	Yes
Dewatering Systems						
Site Name / Station Reference	Preconstruction Survey Distance (Note 2) (m)					Design Engineer Requirements (Note 1)
**	150					Yes
<p>Note:</p> <p>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.</p> <p>2. "N/A" indicates a preconstruction survey is not required.</p>						

NOTES TO DESIGNER:**Designer Fill-in for Table A:**

- * Enter the latitude and longitude co-ordinates of the IDF Curve as obtained using the MTO IDF Curve Look up Tool. Create additional tables, as necessary, if more than one (1) IDF curve was used on the contract (i.e. on a very long contract there may be two IDF curves used to better represent rainfall events for two (2) different sections of the contract).
- ** Fill-in site name, work, and station reference as appropriate for the dewatering system and/or temporary flow passage system item locations.
- *** For temporary flow passage system item locations, fill-in the minimum design storm return period for the site based on MTO Drainage Design Standard TW-1.
- **** For temporary flow passage system item locations, fill-in the design flow rate estimates for the various return periods.
- ***** Insert "Yes" when recommended by the Foundation Engineer. Insert "No" otherwise.
- ***** Fill-in the required distance for preconstruction survey if recommended by the Foundation Engineer. Fill-in "N/A" if not recommended.

WARRANT: Always with these tender items.



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