



## Foundation Investigation and Design Report

*Trenchless Installation of Highway 403 & Aberdeen Ave.  
Underground Crossing for Alectra Utilities, City of Hamilton,  
Ontario*

Latitude: 43.257274; Longitude: -79.907396

MTO GEOCREs No. 30M05-363

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**Prepared For:**

NBM Engineering Inc  
1525 Cornwall Road, # 27  
Oakville, Ontario  
L6J 0B2  
Attn: Adel Michial, P.Eng.

**Prepared By:**

EXP Services Inc.  
1595 Clark Boulevard  
Brampton, ON L6T 4V1  
Canada

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## Geotechnical Foundation and Investigation Report

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### Issue and Revised Record

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## Part I: Foundation Investigation Report

*Trenchless Installation of Highway 403 & Aberdeen Ave. Underground Crossing for Alectra  
Utilities, City of Hamilton, Ontario*

## 1.0 Introduction

EXP Services Inc. (EXP) was retained by NBM Engineering Inc. (NBM) to provide detailed foundation engineering services for the trenchless installation of the Highway 403 (Alexander Graham Bell Parkway) and Aberdeen Avenue underground crossing for Alectra Utilities in Hamilton, Ontario. The scope of work for the foundation investigation is outlined in the drawings provided by NBM in an email dated March 7, 2023. The scope of this report is specifically limited to the proposed trenchless installation of the underground crossing below Highway 403 and Aberdeen Avenue in Hamilton, Ontario.

The preliminary drawings titled “HWY 403 Underground Crossing” for the proposed underground crossing were provided to EXP by NBM. The purpose of the investigation was to evaluate the subsurface conditions along the proposed alignment of the underground crossing, and based on this data, to permit detailed design for the trenchless installation of the underground crossing.

The site-specific geotechnical investigation consisted of borings, soil sampling, borehole logging, and field and laboratory testing. Based on collected geotechnical data, this report provides an assessment of the geotechnical issues, geotechnical design parameters, and geotechnical foundation design recommendations for the proposed underground crossing. Geotechnical-related construction recommendations are also provided.

This foundation investigation report has been prepared specifically and solely for the project described herein. It contains the factual results of the investigation and the laboratory testing completed for this project.

## 2.0 Proposed Underground Crossing Description

The preliminary drawing titled “HWY 403 Underground Crossing” prepared by Alectra Utilities and provided by NBM, shows the proposed alignment and installation of the Highway 403 and Aberdeen Avenue underground crossing (Appendix B). A summary of the proposed underground crossing is as follows:

- The underground crossing is proposed to consist of two 914.4 mm (36”) HDPE pipes, spaced at a minimum of 5 m and set at a minimum depth of 5 m below Highway 403 (Alexander Graham Bell Parkway) and 3 m below the on ramps as per MTO standards.
- The proposed installation method of the pipes is Horizontal Directional Drilling (HDD).
- The installation of these pipes will be executed within 6 sections resulting in 6 sending and receiving pits each that are 1.5 m wide, 1.5 m long, and 1.5 m deep.
- The existing profile grade of the Highway and on ramps is planned to remain unchanged.

The preliminary drawings were included as part of this report for initial context to address the nature and scope of the investigation. It is understood that some changes might occur as a result of normal refinement or the findings of the geotechnical report.

## 3.0 Site Description and Geological Setting

### 3.1 Site Description

The site is located on the Highway 403 and in the areas between the Highway 403 eastbound ramp from Main Street West and the Highway 403 eastbound ramp from Aberdeen Avenue in Hamilton, Ontario. The site is adjacent to residential and commercial areas on the north side at the Main Street West and Highway 403 eastbound ramp and commercial areas on the south side of the site at the Aberdeen Avenue and Highway 403 eastbound ramp. The east and west areas of the site consist mainly of green space.

The general site conditions were assessed during a site reconnaissance on May 18, 2023, and during the field investigation works that took place between August 21, 2023, to October 12, 2023. The general topography of the site is undulating, where the natural ground surface is higher at the north and south ends of the site near the Highway 403 ramps, with areas of lower ground surface in between at the location of the highway and the adjacent greenspaces. A box culvert running in the east-west direction located in the greenspace north of the 403 westbound lane channels water below the 403 East Ramp from Main Street West. Vegetation at the site consists of mature trees, wild bushes, and shrubs in the greenspaces adjacent to the highway and other various species of mature vegetation in the surrounding areas along the Highway.

Photographs 1 to 14 (taken by EXP between August 2023 and October 2023) in Appendix A show the existing site and the drilling of the boreholes during the investigation. Photographs 1 and 2 show the greenspaces on the west and east sides of the Highway 403 east ramp from Main Street West, respectively. The vegetation in these areas vary, with wild bushes and shrubs prominent on the west side, and grass with some wild bushes and shrubs on the east side. Photographs 3 to 6 show the drilling of boreholes EXP-BH1, EXP-BH2, EXP-BH6, and EXP-BH7 in the north areas of the site, respectively. Additionally, Photograph 3 shows the condition of the Highway 403 east ramp surface coming from Main Street West and Photograph 6 shows the existing culvert that passes under the ramp. Photograph 7 shows the drilling of borehole EXP-BH8 in the right shoulder of the eastbound lane of Highway 403. Photographs 8 and 9 show the drilling of boreholes EXP-BH9, and EXP-BH10 in the greenspace on the west side of the Highway 403 east ramp from Aberdeen Avenue, respectively. Additionally, these photographs show the vegetation in this area of the site, which consists mainly of wild bushes and shrubs. Photographs 10 and 11 show the drilling of boreholes EXP-BH12 and EXP-BH13 that are in the south area of the site on the Highway 403 east ramp coming from Aberdeen Avenue and in the adjacent greenspace on the west side of the ramp, respectively. Photograph 12 shows the drilling of borehole EXP-BH14 on the Highway 403 east ramp coming from Main Street West. Photographs 13 and 14 show the crane that was used to lift the drill rig over the guard rail of the eastbound ramp coming from Main Street West to access borehole EXP-BH15 in the adjacent greenspace, and the drilling of EXP-BH15, respectively.

### 3.2 Geological Setting

According to the Ministry of Northern Development and Mines, Map 2556 (Quaternary Geology of Ontario, Southern Sheet, 1991) the surface conditions in the vicinity of the project area consists of Pleistocene Glaciolacustrine deposits: sand, gravelly sand and gravel; nearshore and beach deposits. According to the Geological Survey of Canada, Department of Energy, Mines and Resources, Map 1263A (Geology, Toronto - Windsor Area, Ontario), the bedrock geology of the site is of Queenston Formation consisting of red shale and mudstone with minor interbeds of silty limestone and dolomite.

## 4.0 Previous Investigations

There is no previous investigation at this site. However, there are available reports of the previous investigations performed in the vicinity of the site in the MTO GEOCRE library:

1. Geocres No. 30M05-322 "Preliminary Foundation and Investigation Design Report, Longwood Channel Rehabilitation, Highway 403, Hamilton, Ontario" by Thurber Engineering Ltd., dated April 5, 2016.
2. Geocres No. 30M05-277 "Foundation Investigation and Design Report, High Fills for Temporary Detour at Highway 403 Aberdeen Avenue Interchange, Highway 403 Rapid Bridge Replacement, Highway 6 Westerly to Aberdeen Avenue, Hamilton, Ontario" by Golder Associates Ltd., dated August 2009.
3. Geocres No. 30M05-269 "Foundation Investigation and Design Report, Temporary Bridge Deck Supports Structures, Highway 403 Bridge Rehabilitations from Highway 6 Westerly to Aberdeen Avenue, City of Hamilton, Ontario" by Golder Associates Ltd., dated March 12, 2009.
4. Geocres No. 30M05-036 "Foundation Investigation for Proposed Aberdeen Avenue Interchange, Hwy. #403, Hamilton, Ont., District #4, W.P. 182-60 – Struct. for Ramps 'B' & 'C', W.P. 266-60 - Struct. for Ramp 'D', and W.P. 140-57-1 – Grading Work. W.J. 60-F-6." dated July 19, 1960.

## 5.0 Field Investigation and Laboratory Analyses

### 5.1 Site Investigation and Field Testing

A site-specific investigation was undertaken by EXP between May 18, 2023, and October 12, 2023, and it included the following:

1. A walkover site assessment was carried out by a Geotechnical personnel from EXP;
2. Subsequent to the borehole layouts in the field, existing utilities were cleared by public utility companies;
3. Traffic control was performed in accordance with the Ontario Traffic Control Manual Book 7 – Temporary Conditions by Barricade Traffic Services Inc. from Concord, Ontario;
4. Fifteen (15) geotechnical boreholes (EXP-BH1 to EXP-BH15) were completed as part of the field investigation. The locations of the boreholes drilled during this investigation are shown on Drawing 1 in Appendix C and summarized in Table 1.1 below;
5. Boreholes EXP-BH2 to EXP-BH14 were advanced using a Diedrich D50 Turbo track-mounted drill rig and boreholes EXP-BH1, and EXP-BH15 were advanced using a Geoprobe track-mounted drill rig. Both drill rigs were owned and operated by Direct Environmental Drilling of London, Ontario. The boreholes were advanced using 83 mm inside diameter hollow stem augers. When a hard stratum was reached (refusal of split spoon), sampling of hard material was performed by diamond core drilling, using a 1.5 m long NQ double tube wireline core barrel;
6. Soil samples were taken at 0.75 m and 1.5 m intervals of depth by the Standard Penetration Test method (SPT), in general accordance with ASTM D1586. The test consists of freely dropping a 63.5 kg hammer a vertical distance of 0.76 m to drive a 51 mm O.D. split barrel (SS-split-spoon) sampler into the ground. The number of blows of the hammer required to drive the sampler into the relatively undisturbed ground by a vertical distance of 0.30 m is recorded as the Standard Penetration Resistance, or the N-value, of the soil which is indicative of the compactness of granular (or cohesionless) soils (gravels, sands and silts) or the consistency of cohesive soils (clays and clayey soils);
7. Shear vane testing was completed in the cohesive soils encountered within the boreholes during drilling, using a MTO vane in accordance with ASTM-D2573. A stabilizing vane collar rigidly attached to the borehole casing to maintain the shear vane in a central position at a consistent elevation during the torquing process was used. In-situ shear vane results are shown on the borehole logs as an indication of shear strength, corrected for plasticity index using Bjerrum method;
8. The fieldwork was supervised by a member of EXP's technical staff who directed the drilling and sampling operation, logged borehole data in accordance with MTO and/or ASTM Standards for Soils Classification,

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and retrieved soil samples for subsequent laboratory testing and identification. A member of EXP's technical staff was also present on site during fieldwork to oversee drilling operations;

9. All spoon samples obtained in the Standard Penetration Tests (SPT, ASTM D-1586) were placed in moisture proof bags after field classification. Samples were allocated from the spoon samples for moisture content testing without delay. They were subsequently re-examined under controlled laboratory conditions prior to assigning other laboratory tests;
10. The borehole locations (referenced to the MTM NAD83 coordinate system) and their ground surface elevations were surveyed by EXP personnel using a Trimble DA2 GNSS receiver with Trimble Catalyst GNSS positioning, having an accuracy of  $\pm 0.02$  m in the horizontal directions and 0.02 m in the vertical direction. Elevations measured during the site investigations are geodetic. MTM NAD83 Zone 10 coordinates and the ground surface elevations of the boreholes are listed in Table 1.1. It can also be found on the Record of Borehole Sheet (Appendix D);
11. Upon completion of drilling and field testing, the boreholes were backfilled with a mixture of bentonite and auger cuttings or grouted with bentonite. Portland cement was used to grout borehole EXP-BH6 for artesian. Groundwater level measurements were carried out in boreholes in accordance with MTO guidelines. The recorded groundwater levels after completion of drilling boreholes were presented in the borehole log sheets in Appendix D.
12. The borehole decommissioning was in general accordance with the Ministry of the Environment Regulation 903, as amended by Regulation 128/03 (the well regulation under the Ontario Water Resources Act).

Table 1.1. Summary of boreholes completed during this investigation

Borehole No.	Location	Section <sup>4</sup>	Location (MTM NAD 83 Zone ON-10)		Latitude	Longitude	Ground Surface Elevation <sup>1</sup> (m)	Borehole Depth <sup>2</sup> (m)
			Northing	Easting				
EXP Geotechnical Investigation								
EXP-BH1	Highway 403 East Ramp (Main St. W.)	A-A B-B	4790903.3	271722.8	43.257274	-79.907396	99.2	12.7
EXP-BH2	Greenspace on east side of Highway 403 East Ramp (Main St. W)	A-A	4790868.0	271722.3	43.256957	-79.907400	97.7	15.7
EXP-BH3		A-A B-B	4790840.4	271716.5	43.256708	-79.907469	96.9	17.2
EXP-BH4		A-A B-B	4790801.1	271721.5	43.256354	-79.907406	90.2	15.7
EXP-BH5		A-A C1-C1 C2-C2	4790764.7	271738.1	43.256027	-79.907199	88.7	15.7

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Borehole No.	Location	Section <sup>4</sup>	Location (MTM NAD 83 Zone ON-10)		Latitude	Longitude	Ground Surface Elevation <sup>1</sup> (m)	Borehole Depth <sup>2</sup> (m)
			Northing	Easting				
EXP-BH6 <sup>3</sup>		C1-C1 C2-C2 D-D	4790760.4	271774.1	43.255990	-79.906755	85.1	14.2
EXP-BH7 <sup>3</sup>		D-D	4790751.7	271797.1	43.255913	-79.906471	85.8	12.7
EXP-BH8	Highway 403 Eastbound Right Lane Shoulder	D-D	4790719.5	271825.2	43.255624	-79.906124	87.2	11.1
EXP-BH9	Greenspace on west side of Highway 403 East Ramp (Aberdeen Ave.)	D-D	4790696.3	271863.8	43.255417	-79.905647	93.3	15.9
EXP-BH10		D-D	4790682.8	271877.0	43.255296	-79.905483	92.6	15.9
EXP-BH11	Highway 403 East Ramp (Aberdeen Ave.)	D-D	4790640.8	271897.6	43.254919	-79.905227	94.6	10.7
EXP-BH12		D-D	4790606.6	271918.8	43.254612	-79.904964	96.1	7.6
EXP-BH13	Greenspace on west side of Highway 403 East Ramp (Aberdeen Ave.)	D-D	4790611.9	271903.5	43.254659	-79.905153	95.7	7.3
EXP-BH14	Highway 403 East Ramp (Main St. W.)	A-A B-B	4790868.9	271713.1	43.256964	-79.907513	98.6	15.7
EXP-BH15	Greenspace on west side of Highway 403 East Ramp (Main St. W.)	B-B C1-C1	4790773.5	271686.2	43.256104	-79.907839	90.2	9.6
Previous Investigation								
BH15-06 <sup>5</sup>	Highway 403 Westbound Lane	-	4790761.2	271825.0	43.25600	-79.90613	84.9	9.8



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Borehole No.	Location	Section <sup>4</sup>	Location (MTM NAD 83 Zone ON-10)		Latitude	Longitude	Ground Surface Elevation <sup>1</sup> (m)	Borehole Depth <sup>2</sup> (m)
			Northing	Easting				
BH-101 <sup>6</sup>	Greenspace on east side of Highway 403 East Ramp (Main St. W)	-	4790786.0	271747.0	43.25622	-79.90709	86.7	19.7
BH-106 <sup>6</sup>	Greenspace on west side of Highway 403 East Ramp (Main St. W.)	-	4790762.0	271688.0	43.25600	-79.90782	87.7	13.0
BH-32 <sup>7</sup>	Greenspace on east side of Highway 403 East Ramp (Main St. W)	-	4790722.1	271759.1	43.25564	-79.90694	84.6	6.1
BH-10 <sup>8</sup>	Highway 403 East Ramp (Main St. W.)	-	4790695.4	271824.9	43.25541	-79.90613	97.2	22.3

**Notes:**

1. The referenced elevations are geodetic.
2. Depths are relative to ground surface.
3. Terminated at shallow depth due to encountering artesian or potential for encountering artesian.
4. See Drawing 1 in Appendix C.
5. Selected Borehole from previous investigation 1 (Gecores No. 30M05-322) listed in Section 4.0 shown to aid EXP investigation.
6. Selected Borehole from previous investigation 2 (Gecores No. 30M05-277) listed in Section 4.0 shown to aid EXP investigation.
7. Selected Borehole from previous investigation 3 (Gecores No. 30M05-269) listed in Section 4.0 shown to aid EXP investigation.  
Selected Borehole from previous investigation 4 (Gecores No. 30M05-036) listed in Section 4.0 shown to aid EXP investigation.

## 5.2 Laboratory Testing

All soil samples returned to the laboratory were subjected to visual examination and classification. The laboratory testing program included the determination of natural moisture content on all soil samples and particle size distribution for approximately 25% of the collected soil samples. Atterberg limits testing was done in conjunction with grain size distribution tests on select samples. Five (5) soil samples were selected for chemical analysis and tested at a CALA-certified and accredited laboratory. Two (2) uniaxial compression tests were carried out on selected rock core samples. All the laboratory tests were carried out in accordance with MTO and/or ASTM standards as appropriate.

The five (5) soil samples selected for chemical analysis were sent to Bureau Veritas, a CALA-certified and accredited laboratory in London, Ontario. The selected soil samples for the analytical testing were placed in laboratory prepared glass jars, labelled and stored in a secure cooler.

## 6.0 Subsurface Conditions

The detailed subsurface conditions encountered in the boreholes advanced during this investigation are presented on the borehole log sheets in Appendix D. Laboratory test results of grain size analyses, Atterberg Limit tests, uniaxial compression tests, and chemical tests are provided in Appendix E. The “Explanation of Terms Used in Report” preceding the borehole logs in Appendix D forms an integral part of and should be read in conjunction with this report.

A borehole location plan and cross section subsurface profiles are provided in Appendix C. It should be noted that the stratigraphic boundaries indicated on the borehole log and cross section stratigraphic profiles are inferred from semi-continuous sampling, observations of drilling progress and results of Standard Penetration Tests (SPT). These boundaries typically represent transitions from one soil type to another and should not be regarded as exact planes of geological change. Furthermore, subsurface conditions may vary between and beyond the borehole locations.

In general, the subsurface conditions along the alignment of the underground crossing consist of asphalt or topsoil underlain by cohesionless gravelly sand to sand and gravel fill, followed by cohesive clayey silt fill, underlain by native clayey silt till. The native clayey silt till was underlain by sandy silt to sand and gravel in boreholes EXP-BH1, EXP-BH6, EXP-BH8, and EXP-BH10 in the middle to north end of the site. The native clayey silt till was underlain by residual soil and bedrock in boreholes EXP-BH11 to EXP-BH13 at the south end of the site.

A detailed description of the subsurface conditions encountered is discussed further in subsequent sections.

### 6.1 Subsoils

#### 6.1.1 Asphalt

Asphalt, approximately 0.08 m to 0.33 m thick, was encountered at the surface of boreholes EXP-BH1, EXP-BH8, EXP-BH11, EXP-BH12, and EXP-BH14.

#### 6.1.2 Topsoil

Topsoil, approximately 0.13 m to 0.20 m thick, was encountered at the surface of boreholes EXP-BH4 to EXP-BH7, EXP-BH9, EXP-BH10, EXP-BH13, and EXP-BH15.

#### 6.1.3 Cohesionless Fill: Gravelly Sand / Sand and Gravel

Cohesionless fill consisting of gravelly sand / sand and gravel was encountered below the asphalt in boreholes EXP-BH1, EXP-BH8, EXP-BH11, EXP-BH12, and EXP-BH14, below the topsoil in boreholes EXP-BH4 to EXP-BH7, EXP-BH9, EXP-BH10, EXP-BH13, and EXP-BH15, and at the surface of borehole EXP-BH2, and EXP-BH3. The depths and elevations of the fill layer encountered at these borehole locations are listed in Table 1.2.

Table 1.2. Summary of cohesionless fill: gravelly sand / sand and gravel layer

Borehole No.	Elevation <sup>1</sup> (m)		Layer Surface Depth <sup>2</sup> (m)	Layer Thickness (m)
	Top	Bottom		
EXP Geotechnical Investigation				
EXP-BH1	99.0	98.5	0.2	0.5
EXP-BH2	97.7	96.9	0.0	0.8
EXP-BH3	96.9	96.8	0.0	0.1
EXP-BH4	90.0	89.4	0.2	0.6
EXP-BH5	88.5	87.9	0.2	0.6
EXP-BH6	84.9	84.4	0.2	0.5
EXP-BH7	85.6	85.0	0.2	0.6
EXP-BH8	86.8	86.1	0.2	0.7
EXP-BH9	93.2	92.3	0.1	0.9
EXP-BH11	94.5	93.8	0.1	0.7
EXP-BH12	95.9	95.2	0.2	0.7
EXP-BH13	95.5	95.4	0.2	0.1
EXP-BH14	98.4	97.8	0.2	0.6
EXP-BH15	90.0	89.4	0.2	0.6
Previous Investigation				
BH15-06	84.8	83.6	0.1	1.2
BH32	84.2	83.8	0.3	0.5

## Notes:

1. The referenced elevations are geodetic.
2. Depths are relative to ground surface.

The composition of this fill material generally consisted of gravelly sand to sand and gravel with trace to some silt, trace clay, and trace organics. The fill was generally dark brown to brown in colour, and damp to wet. The SPT “N” values obtained within this fill material ranged from 2 to 33 blows per 0.3 m penetration, suggesting that this fill layer was very loose to dense in compactness, but generally loose to compact.

Laboratory testing performed by EXP on selected samples consisted of thirteen (13) moisture content tests. The test results are as follows:

Moisture Content:

- 3% to 17%

The results of the moisture content tests are provided on the record of borehole sheets in Appendix D.

#### 6.1.4 Cohesionless Fill: Sand and Silt / Silt

Cohesionless fill consisting of sand and silt / silt was encountered below the cohesionless gravelly sand / sand and gravel fill layer in borehole EXP-BH1 and the cohesive clayey silt fill layer in borehole EXP-BH14. The depths and elevations of the fill layer encountered at these borehole locations are listed in Table 1.3.

Table 1.3. Summary of cohesionless fill: sand and silt / silt layer

Borehole No.	Elevation <sup>1</sup> (m)		Layer Surface Depth <sup>2</sup> (m)	Layer Thickness (m)
	Top	Bottom		
EXP Geotechnical Investigation				
EXP-BH1	98.5	92.7	0.7	5.8
EXP-BH14	94.0	93.2	4.6	0.8
Previous Investigation				
BH101	82.9	80.7	3.8	2.2

Notes:

1. The referenced elevations are geodetic.
2. Depths are relative to ground surface.

The composition of this fill material generally consisted of silt with some clay and trace sand to sand and silt with trace gravel and trace clay. The fill was generally mottled dark brown to brown in colour, and moist to wet. The SPT “N” values obtained within this fill material ranged from 6 to 15 blows per 0.3 m penetration, suggesting that this fill layer was loose to compact in compactness.

Laboratory testing performed by EXP on selected samples consisted of eight (8) moisture content tests, two (2) grain size distribution test, and two (2) Atterberg limits tests that were non-plastic. The test results are as follows:

Moisture Content:

- 21% to 29%

Grain Size Distribution:

- 0% to 3% gravel
- 3% to 37% sand
- 53% to 86% silt
- 7% to 11% clay

The results of the moisture content, grain size distribution, and Atterberg limits test are provided on the record of borehole sheets in Appendix D. The results of the grain size distribution test are also provided on Figure 1 in Appendix E.

### 6.1.5 Cohesive Fill: Clayey Silt

Cohesive fill consisting of clay and silt was encountered below the cohesionless fill layer in boreholes EXP-BH1 to EXP-BH12, and EXP-BH14 to EXP-BH15. The depths and elevations of this layer encountered at this borehole location is listed in Table 1.4.

Table 1.4. Summary of cohesive fill: clayey silt layer

Borehole No.	Elevation <sup>1</sup> (m)		Layer Surface Depth <sup>2</sup> (m)	Layer Thickness (m)
	Top	Bottom		
EXP Geotechnical Investigation				
EXP-BH1	92.7	87.0	6.5	5.7
EXP-BH2	96.9	87.0	0.8	9.9
EXP-BH3	96.8	87.8	0.1	9.0
EXP-BH4	89.4	83.7	0.8	5.7
EXP-BH5	87.9	82.6	0.8	5.3
EXP-BH6	84.4	81.3	0.8	3.1
EXP-BH7	85.0	81.9	0.8	3.1
EXP-BH8	86.1	85.7	1.0	0.4
EXP-BH9	92.3	90.1	0.9	2.2
EXP-BH10	92.4	90.3	0.2	2.1
EXP-BH11	93.8	93.0	0.8	0.8
EXP-BH12	95.2	94.6	0.9	0.6
EXP-BH14	97.8	94	0.8	3.8
	93.2	89.2	5.3	4.0
EXP-BH15	89.4	82.6	0.8	6.8
Previous Investigation				
BH10	97.2	91.1	0.0	6.1
BH15-06	83.6	82.7	1.3	0.9
BH32	84.4	84.2	0.2	0.2
	83.8	82.5	0.8	1.6

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Borehole No.	Elevation <sup>1</sup> (m)		Layer Surface Depth <sup>2</sup> (m)	Layer Thickness (m)
	Top	Bottom		
BH101	86.6	82.9	0.1	3.7
BH106	87.7	80.4	0.0	7.3

**Notes:**

1. The referenced elevations are geodetic.
2. Depths are relative to ground surface.

The composition of this fill material generally consisted of clayey silt with trace to some sand and trace gravel. Trace organics were present in boreholes EXP-BH1, EXP-BH6 to EXP-BH8, EXP-BH10, and EXP-BH14. The fill was generally brown, brownish grey, or mottled brown, grey, red, and black in colour, and moist to wet. The SPT “N” values obtained within this fill material ranged from 2 to 25 blows per 0.3 m penetration, suggesting that this fill layer very soft to very stiff in consistency, but generally firm to very stiff. In-situ field vane tests performed within the deposit measured shear strengths ranging between approximately 36 kPa to greater than 145 kPa with a sensitivity ranging between 3 to 6. The Atterberg limits test results suggest that this cohesive layer was of low plasticity.

Laboratory testing performed by EXP on selected samples consisted of sixty-nine (69) moisture content tests, seventeen (17) grain size distribution tests, and seventeen (17) Atterberg limits tests. The test results are as follows:

**Moisture Content:**

- 12 % to 28%

**Grain Size Distribution:**

- 0% to 8% gravel
- 1% to 30% sand
- 45% to 75% silt
- 1% to 45% clay

**Atterberg Limits:**

- Liquid Limit: 18% to 36%
- Plastic Limit: 14% to 22%
- Plasticity Index: 3% to 15%

The results of the moisture content, grain size distribution, and Atterberg limits test are provided on the record of borehole sheets in Appendix D. The results of the grain size distribution test and Atterberg limits test are also provided on Figures 2 to 4, and Figures 10 to 12, respectively, in Appendix E.

### 6.1.6 Clayey Silt Till

Native clayey silt till was encountered below the cohesive fill layer in boreholes EXP-BH2 to EXP-BH11, and EXP-BH13 to EXP-BH15. The depths and elevations of this layer encountered at these borehole locations are listed in Table 1.5.

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Table 1.5. Summary of clayey silt layer

Borehole No.	Elevation <sup>1</sup> (m)		Layer Surface Depth <sup>2</sup> (m)	Layer Thickness (m)
	Top	Bottom		
EXP Geotechnical Investigation				
EXP-BH2	87.0	82.0	10.7	5.0
EXP-BH3	87.8	79.7	9.1	8.1
EXP-BH4	83.7	74.5	6.5	9.2
EXP-BH5	82.6	73.0	6.1	9.6
EXP-BH6	81.3	71.3	3.8	10.0
EXP-BH7	81.9	73.1	3.8	8.8
EXP-BH8	85.7	76.0	1.5	9.7
EXP-BH9	90.1	77.4	3.2	12.7
EXP-BH10	90.3	77.3	2.3	13
EXP-BH11	93.0	89.2	1.5	3.8
EXP-BH13	95.4	94.9	0.3	0.5
EXP-BH14	89.2	82.9	9.4	6.3
EXP-BH15	82.6	80.6	7.6	2.0
Previous Investigation				
BH10	91.1	75.0	6.1	16.1
BH15-06	82.7	75.1	2.2	7.6
BH32	82.5	78.5	2.1	4.0
BH101	80.7	68.2	5.9	12.5
BH106	80.4	74.8	7.3	5.6

## Notes:

1. The referenced elevations are geodetic;
2. Depths are relative to ground surface.

The composition of this material generally consisted of clay and silt, with trace to some sand, and trace gravel. The material was generally grey in colour, and moist to wet. The SPT “N” values obtained within this material ranged from 0 to 49 blows per 0.3 m penetration suggesting that this layer was very soft to hard in consistency, but generally soft to very stiff. In-situ field vane tests performed within the deposit measured shear strengths ranging between approximately 29 kPa to greater than 145 kPa with a sensitivity ranging between 1 to 4. The Atterberg limits test results suggest that this cohesive layer was of low plasticity.

Laboratory testing performed by EXP on selected samples consisted of eighty-seven (87) moisture content tests, twenty-four (24) grain size distribution tests, and twenty-four (24) Atterberg limits tests. The test results are as follows:

**Moisture Content:**

- 10% to 34%

**Grain Size Distribution:**

- 0% to 8% gravel
- 1% to 24% sand
- 38% to 67% silt
- 30% to 59% clay

**Atterberg Limits:**

- Liquid Limit: 24% to 34%
- Plastic Limit: 14% to 18%
- Plasticity Index: 7% to 17%

The results of the moisture content, grain size distribution, and Atterberg limits test are provided on the record of borehole sheets in Appendix D. The results of the grain size distribution test and Atterberg limits test are also provided on Figures 5 to 7, and Figures 13 to 15, respectively, in Appendix E.

### 6.1.7 Sandy Silt / Sand and Gravel

Native sandy silt / sand and gravel was encountered below the native clayey silt till layer in boreholes EXP-BH1, EXP-BH6, EXP-BH8, and EXP-BH10. The depths and elevations of this layer encountered at these borehole locations are listed in Table 1.6

Table 1.6. Summary of sandy silt / sand and gravel layer

Borehole No.	Elevation <sup>1</sup> (m)		Layer Surface Depth <sup>2</sup> (m)	Layer Thickness (m)
	Top	Bottom		
EXP Geotechnical Investigation				
EXP-BH1	87.0	86.5	12.2	0.5
EXP-BH6	71.3	71.0	13.8	0.3
EXP-BH8	76.5	76.0	10.7	0.5
EXP-BH10	77.3	76.7	15.2	0.6
Previous Investigation				
BH10	75.0	74.9	22.3	0.1
BH101	68.2	67.8	18.4	0.4

Notes:



1. The referenced elevations are geodetic.
2. Depths are relative to ground surface.

The composition of this material generally consisted of sandy silt with some clay and trace to some gravel to sand and gravel with trace silt. The material was generally reddish brown to grey in colour, and moist to wet. The SPT “N” values obtained within this material ranged from 8 to 17 blows per 0.3 m penetration suggesting that this layer was loose to compact in compactness.

Laboratory testing performed by EXP on selected samples consisted of five (5) moisture content tests, two (2) grain size distribution test, and two (2) Atterberg limits test that were non-plastic. The test results are as follows:

Moisture Content:

- 10% to 20%

Grain Size Distribution:

- 0% to 17% gravel
- 21% to 34% sand
- 37% to 68% silt
- 11% to 12% clay

The results of the moisture content, grain size distribution, and Atterberg limits test are provided on the record of borehole sheets in Appendix D. The results of the grain size distribution tests are also provided on Figure 8 in Appendix E.

#### 6.1.8 Residual Soil

Residual soil was encountered below the native clayey silt till layer in borehole EXP-BH11, and below the cohesive fill layer in boreholes EXP-BH12, and EXP-BH13. The depths and elevations of this layer encountered at these borehole locations are listed in Table 1.7.

Table 1.7. Summary of residual soil

Borehole No.	Elevation <sup>1</sup> (m)		Layer Surface Depth <sup>2</sup> (m)	Layer Thickness (m)
	Top	Bottom		
EXP Geotechnical Investigation				
EXP-BH11	89.2	88.5	5.3	0.7
EXP-BH12	94.6	92.5	1.5	2.1
EXP-BH13	94.9	92.9	0.8	2.0
Previous Investigation				
BH101	67.8	67.0	18.9	0.8

Notes:

1. The referenced elevations are geodetic.
2. Depths are relative to ground surface.

This material deposit consists of a varying mixture of severe weathered bedrock and sedimentary materials. The composition of this material generally consisted clayey silt with some sand and some shale fragments. The material was generally red in colour, and damp to moist. The SPT “N” values obtained within this material ranged from 63 to 91 blows per 0.3 m penetration to 100 blows per 0.08 m penetration suggesting that this layer was hard in consistency. The Atterberg limits test results suggest that this layer was of low plasticity.

Laboratory testing performed by EXP on selected samples consisted of seven (7) moisture content tests, one (1) grain size distribution test, and one (1) Atterberg limits test. The test results are as follows:

**Moisture Content:**

- 5% to 7%

**Grain Size Distribution:**

- 0% gravel
- 12% sand
- 68% silt
- 20% clay

**Atterberg Limits:**

- Liquid Limit: 26%
- Plastic Limit: 18%
- Plasticity Index: 8%

The results of the moisture content, grain size distribution, and Atterberg limits test are provided on the record of borehole sheets in Appendix D. The results of the grain size distribution test and Atterberg limits test are also provided on Figure 9 and Figure 16, respectively, in Appendix E.

### 6.1.9 Bedrock

Bedrock was confirmed by coring in boreholes EXP-BH11, EXP-BH12, and EXP-BH13. Elevations of the top of bedrock were between Elev. 93.1 m to 88.5 m. Based on the three (3) drilled boreholes, the bedrock slopes downwards towards the north as inferred from available data. The bedrock in these boreholes was investigated by coring approximately 4.5 m to 4.6 m into the stratum. The bedrock surface depths and elevations encountered at these borehole locations are also listed in Table 1.8. Photographs of the rock cores are included in Appendix E.

Table 1.8. Summary of bedrock

Borehole No.	Elevation <sup>1</sup> (m)		Layer Surface Depth <sup>2</sup> (m)	Uniaxial Compressive Strength – UCS (MPa)
	Top	Bottom		
EXP-BH11	88.5	83.9	6.1	6.5
EXP-BH12	92.5	88.5	3.7	-
EXP-BH13	92.9	88.4	2.7	6.7

Notes:

1. The referenced elevations are geodetic.
2. Depths are relative to ground surface.

Based on the bedrock NQ cores (~ core diameter 47 mm) recovered, the bedrock core samples are described as Queenston shale (red) with grey interbeds and occasional clayey silt seam alterations. The Rock Quality Designation (RQD) measured on the core samples ranged from approximately 0% to 59%, indicating a rock mass of very poor to fair quality. The total core recovery (TCR) of the bedrock cores ranged from 67% to 100%.

The uniaxial compressive strength (UCS) was measured to be about 6.5 MPa to 6.7 MPa, indicating weak (R2) rock, according to the CFEM. The laboratory uniaxial compression tests results are presented on the borehole records in Appendix D, as well as in Appendix E.

## 6.2 Groundwater and Surface Water Conditions

Groundwater levels in all boreholes were observed during and upon completion of drilling. The groundwater levels measured in piezometers installed in boreholes EXP-BH3, EXP-BH5, EXP-BH7, and EXP-BH10 are shown on the borehole logs and are presented below in Table 1.9. Groundwater levels were observed in EXP-BH11 to EXP-BH13 in open hole prior to rock coring but not after due to the use of water for rock coring procedures. Artesian conditions were encountered in borehole EXP-BH6 at an elevation of approximately 71.4 m.

Table 1.9 Groundwater levels measured in piezometers encountered at the site

Borehole No.	Date Measured	Ground Surface Elevation (m)	Groundwater Depth <sup>1</sup> /Elevation (m)
EXP Geotechnical Investigation			
EXP-BH3	September 6, 2023 September 7, 2023	96.9	14.2/82.7 13.7/83.29
EXP-BH5	September 1, 2023 September 6, 2023	88.7	1.3/87.5 1.2/87.5
EXP-BH7	August 25, 2023 August 28, 2023 August 30, 2023 September 1, 2023 September 6, 2023	85.8	0.7/85.0 0.7/85.0 0.8/84.9 1.0/84.8 1.2/84.6
EXP-BH10	August 28, 2023 August 29, 2023	92.6	1.1/91.5 0.8/91.7
Previous Investigation			
BH15-06	October 4, 2015	84.9	2.8/82.1

Note:

1. Depths are relative to ground surface.

It should be noted that fluctuations in the level of the groundwater may occur due to seasonal variations, (precipitation, snowmelt, rainfall), local soil permeability, construction remediation activities, and other related factors.

### 6.3 Chemical Analysis

Five (5) soil samples were selected for chemical analysis during the field investigations performed by EXP. The soil samples collected by EXP were tested at a CALA-certified and accredited laboratory. The results of the analysis are included in Appendix E and summarized in Table 1.10.

Table 1.10. Summary of chemical analysis results

Borehole ID	Sample	Depth (m)	Chloride (ppm)	Sulphate (ppm)	pH	Conductivity (mS-cm)	Resistivity (ohm-cm)	Redox Potential (mV)
EXP-BH3	SS6	3.8 – 4.3	130	75	7.84	468	2100	450
EXP-BH5	SS6	3.8 – 4.3	340	66	7.58	727	1400	370
EXP-BH8	SS9	6.1 – 6.6	21	130	8.07	295	3400	110
EXP-BH10	SS9	6.1 – 6.6	250	500	7.99	940	1100	430
EXP-BH15	SS6	3.8 – 4.3	<20	89	7.08	290	3400	340

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## Part II: Foundation Design Report

Trenchless Installation of Highway 403 & Aberdeen Ave. Underground Crossing for Alectra  
Utilities, City of Hamilton, Ontario

## 7.0 ENGINEERING DISCUSSION & RECOMMENDATIONS

### 7.1 General

This section of the report provides geotechnical design recommendations for the installation of two 914.4 mm (36") HDPE pipes using trenchless technology for crossing under Hwy 403 and Aberdeen Avenue in the City of Hamilton, Ontario. The recommendations are based on interpretation of the factual data obtained from the borehole advanced during the current investigation at the site performed by EXP between August 21 and October 12, 2023. The compiled factual data is presented in **Part I-Foundation Investigation Report** of this report. The interpretation and recommendations provided are intended solely to permit designers to assess trenchless installation method alternatives. Comments on construction are only provided to highlight issues that could affect the design. Contractors bidding on the works should make their own assessments of the factual data and how it might affect construction means and methods, scheduling and the like.

The preliminary drawing titled "HWY 403 Underground Crossing" prepared by Alectra Utilities and provided by NBM, shows the proposed alignment and installation of the Highway 403 and Aberdeen Avenue underground crossing (Appendix B). Based on this information, the underground crossing is proposed to consist of two 36' HDPE pipes, spaced at a minimum of 5 m, with a minimum depth of 5 m below Highway 403 (Alexander Graham Bell Parkway) and 3 m below the on ramps as per MTO standards.

It is understood that the proposed installation method of the pipes at this crossing is Horizontal Directional Drilling (HDD). The installation of these pipes will be executed within 6 sections resulting in 6 sending and receiving pits each that are 1.5 m wide, 1.5 m long, and 1.5 m deep. The existing profile grade of the highway and on ramps is planned to remain unchanged.

This part of the report provides comments and recommendations for the geotechnical design and planned construction of the HDPE pipes. These comments and recommendations are provided in accordance with the latest editions of the Canadian Highway Bridge Design Code (CHBDC) (CAN/CSA-S6-19), Guideline for MTO Foundation Engineering Services Version 03 (April 2022), Guidelines for Foundation Engineering – Tunneling Speciality for Corridor Encroachment Permit Application (January 2020), MTO NSSP for Pipe Installation by Trenchless Method (June 2021), the Canadian Foundation Engineering Manual (CFEM) (2006), MTO Gravity Pipe Design Guidelines (May 2007), and generally accepted good practice. Pertinent construction issues from a geotechnical standpoint are examined in general accordance with the Request for Proposal provided in an email dated March 7, 2023. Lateral earth pressure parameters are also provided for the design of temporary protection systems (if required).

### 7.2 Tunneling Details and Expected Ground Conditions

A summary of the subsurface conditions expected to be encountered at each of the trenchless installation sections is provided in Table 2.1 below. It is understood that HDD has been chosen as the preferred tunneling method by the Owner.

Seasonal variations in the water table should be expected, with higher levels occurring during wetter periods of the year (such as spring thaw and late fall) and lower levels during drier periods.

Table 2.1. Tunneling Details and Expected Ground Conditions

Section <sup>1</sup>	Approx. Length of Section (m) <sup>2</sup>	Bottom of Sending Pit Elevation (m)	Bottom of Receiving Pit Elevation (m)	Expected Ground Conditions	Groundwater Elevation (m) <sup>2</sup>
A-A	158.8	96.1	86.0	Loose to compact silt, compact silt and sand fill, soft to very stiff clayey silt fill	82.7 to 87.5
B-B	138.9	96.0	87.1	Loose to compact silt, compact silt and sand fill, firm to very stiff clayey silt fill	82.7 to 87.5
C1-C1	85.4	88.4	84.4	Very loose to compact gravelly sand fill, soft to very stiff clayey silt fill	84.6 to 87.5
C2-C2	40.2	87.3	84.4	Very loose to compact gravelly sand fill, soft to very stiff clayey silt fill	84.6 to 87.5
D-D	219.0	82.2	96.6	Stiff clayey silt fill, very soft to stiff clayey silt till, residual soil/weathered shale bedrock (~Sta. 0+170 to 0+220)	84.6 to 91.7

Note:

1. Sections as defined in drawings in Appendix B and Appendix C.
2. Based on stabilized monitoring well data

### 7.3 Trenchless Installation Methods

It is understood that the proposed installation method of the pipes in all sections is Horizontal Directional Drilling (HDD) for crossing under Highway 403 and Aberdeen Avenue. However, for completeness, the following trenchless methods are discussed in this report:

- (i) Horizontal Directional Drilling
- (ii) Microtunneling
- (iii) Jack and Bore

The installation of the proposed HDPE pipes should be in accordance with the MTO NSSP for Pipe Installation by Trenchless Method (June 2021) and Guidelines for Foundation Engineering – Tunneling Speciality for Corridor Encroachment Permit Application (February 2021).

During the field investigation, residual soil/shallow weak weathered shale bedrock was encountered between Station 0+170 and Station 0+220 along Section D-D (See Appendix B and Appendix C). Conventional tunneling methods are capable of drilling through this material, however mixed-face drilling conditions between soil and rock pose additional difficulty and risks during tunneling. Open cut excavation supported with temporary protection systems may be considered as an alternative means to installing the HDPE pipes along this segment.

#### 7.3.1 Tunnelman's Ground Classification

Drawing 1 in Appendix B shows that the location of tunneling horizon in relation to the existing ground surface while the drawings in Appendix C shows the proposed tunneling horizon with respect to the encountered soil stratigraphy. Based on these drawings, it is expected that the proposed tunneling excavation will be performed through fill comprised of loose to dense sand and gravel/gravelly sand, loose to compact silt to sand and silt, and generally firm

to very stiff clayey silt, native clayey silt till, residual soil and highly to moderately weathered weak shale bedrock. In addition, the tunneling operation is expected to be within the groundwater fluctuation levels which can range from being approximately 9.3 m below the pipe up (EXP-BH03) to 3.4 m above the pipe (EXP-BH07). In general, it is expected that the tunnel will be located within moist to wet silt/clayey silt fill. However, at the far east end of the tunnels (i.e. below Hwy 403 Ramp Eastbound), it appears that the tunnel will be located within mixed face conditions with clayey silt till and weathered shale bedrock. It is recommended that a NSSP be included in the Contract Documents to warn the Contractor of the interface between the mixed faced soil conditions and sloping residual soil/weathered shale bedrock that will be encountered approximately at Station 0+170 along Section D-D (i.e. between EXP-BH11 and EXP-BH13, approximately 30 m long). An example of this NSSP is provided in Appendix F. Additionally, it is recommended to the Designer to consider raising the vertical alignment to avoid this mixed face condition, if it is possible.

In general, the fill and native material behavior along the tunnel horizon should be anticipated to vary. However, based on Terzaghi's Tunnelman's Ground Classification System, it is expected that the cohesionless fills above the groundwater table will likely behave as will behave as "running" material, whereas these soils below water table will likely behave as "flowing". The clayey silt fill and native clayey silt will likely behave as "ravelling" above the groundwater table and "squeezing" below the groundwater table. Therefore, tunnel face instability caused by these cohesionless soils would be generally expected, so excavation within unsupported tunnel face should be done in a manner to control potential groundwater seepage and to prevent possible ground loss.

### 7.3.2 Trenchless Installation Alternatives

Table 2.2 summarizes advantages disadvantages for some of the possible alternatives for the proposed HDPE installation using trenchless technology. Additionally, Table 2.3 provides a general comparison of technical issues associated with these trenchless methods. The following sections provide a discussion for some of the options for the proposed trenchless installation.



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Table 2.2. Trenchless installation alternatives for HDPE pipe installation

Installation Method	Advantages	Disadvantages	Relative Cost	Ranking
Horizontal Directional Drilling (HDD)	<ul style="list-style-type: none"> <li>Handles wide variety of ground conditions.</li> <li>Steerable both horizontally and vertically to maintain and adjust alignment.</li> <li>Suitable for tunnelling under groundwater table</li> <li>Alignment can be adjusted to avoid obstructions.</li> <li>Local contractors are available in the area.</li> <li>Short mobilization time</li> <li>Rapid drilling</li> <li>Minor settlement if fluid well controlled</li> <li>Choice of equipment, cutterheads, and operational parameters can be tailored to the shale's properties and any associated challenges</li> </ul>	<ul style="list-style-type: none"> <li>Potential for inadvertent drilling returns</li> <li>Requires drilling fluid to maintain the bore which could allow subsidence.</li> <li>Obstructions problematic, but alignment can be adjusted to avoid obstructions.</li> <li>Annular space filling (i.e. fluid or grouting)</li> <li>Drilling through mixed-face conditions (soil and weathered shale bedrock) at the east end</li> </ul>	<ul style="list-style-type: none"> <li>Less expensive than micro-tunnelling</li> </ul>	1
Microtunneling	<ul style="list-style-type: none"> <li>In general, handles wide variety of ground conditions.</li> <li>Ability to control excavation face stability.</li> <li>Steerable horizontally to maintain and adjust alignment.</li> <li>Suitable for tunnelling under groundwater table.</li> <li>Alignment can be adjusted to avoid obstructions.</li> <li>Minimum surface disruption</li> <li>Accurate</li> <li>Local contractors available</li> <li>Choice of equipment, cutterheads, and operational parameters can be tailored to the shale's properties and any associated challenges</li> </ul>	<ul style="list-style-type: none"> <li>High construction cost</li> <li>Obstructions could be problematic.</li> <li>No access during tunnelling.</li> <li>Excavation and shoring for sending and receiving pits required to achieve starting grade.</li> <li>Requires large area for jacking shaft and support equipment.</li> <li>Dewatering possibly required at sending and receiving pits.</li> <li>Requires sophisticated equipment.</li> <li>Drilling through mixed-face conditions (soil and weathered shale bedrock) at the east end</li> </ul>	<ul style="list-style-type: none"> <li>More expensive than other trenchless methods</li> </ul>	2

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Installation Method	Advantages	Disadvantages	Relative Cost	Ranking
Jack and Bore	<ul style="list-style-type: none"> <li>Handles wide variety of ground conditions.</li> <li>It can be used with any conventional auger boring machine.</li> <li>Auger can be manually removed to permit removal of obstructions.</li> <li>Steerable system</li> <li>Commonly used in Ontario</li> <li>Short mobilization time</li> <li>Relatively simple operation</li> <li>Choice of equipment and operational parameters can be tailored to the shale's properties and any associated challenges</li> </ul>	<ul style="list-style-type: none"> <li>Dewatering required since GWL could be encountered within tunnelling horizon as well as at sending/receiving pits</li> <li>Cobbles and boulders can stop advancement of casing requiring retrieval of auger and hand mining which may not be feasible if the size of the pipe is not big enough</li> <li>Difficult to control excavation face stability.</li> <li>Requires large area for jacking shaft and support equipment.</li> <li>Pipe can be difficult to steer.</li> <li>Short and long-term settlement possible</li> <li>Fluid to support annular space required</li> </ul>	<ul style="list-style-type: none"> <li>Less expensive than micro-tunnelling but more expensive than HDD</li> </ul>	3

Table 2.3. General comparison of technical issues associated with trenchless methods

Typical Limitations	Tunneling Method		
	Jack & Bore	Horizontal Directional Drilling (HDD)	Microtunneling
Length of drive and diameter	<ul style="list-style-type: none"> <li>Drive lengths to 150 m</li> <li>Diameters up to 1500 mm are feasible</li> </ul>	<ul style="list-style-type: none"> <li>Drive pullback lengths of several hundred meters are feasible</li> <li>HDD can drill up to about 1,500 m in length</li> <li>In Southern Ontario, HDD diameters less than 750 mm are commonplace but larger bores (such as 900 mm proposed) add risk, complexity, and considerable cost</li> </ul>	<ul style="list-style-type: none"> <li>Drive lengths of 300 m are typical, provided that Intermediate Jacking Stations (IJS) are launched every 75 m</li> <li>Microtunnels up to 1500 mm dia. can be readily constructed in Ontario; 3000 mm dia. may be feasible by specialists</li> </ul>
Ability to control line and grade	<ul style="list-style-type: none"> <li>Average control of line and grade</li> <li>Limited ability to steer and to correct grade</li> </ul>	<ul style="list-style-type: none"> <li>Specialized tracker system is needed to control line and grade</li> <li>Fair to good</li> </ul>	<ul style="list-style-type: none"> <li>Good</li> <li>Line and grade control to within <math>\pm 40</math> mm is feasible over 300 m drive</li> </ul>

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Highway 403 & Aberdeen Avenue, Hamilton, Ontario  
Final Report  
Date: Dec. 20, 2023

Typical Limitations	Tunneling Method		
	Jack & Bore	Horizontal Directional Drilling (HDD)	Microtunneling
<b>Ability to control ground surface displacement</b>	<ul style="list-style-type: none"> <li>Poor</li> <li>No ability to retain running ground</li> </ul>	<ul style="list-style-type: none"> <li>Fair</li> <li>Ground heave and hydro fracturing may result from excessive rates of pullback</li> <li>Bore stability relies on good quality control and circulation of drilling mud</li> </ul>	<ul style="list-style-type: none"> <li>Good</li> <li>Slurry shield MTBM can balance earth pressures in the shield to a variety of soil and groundwater conditions</li> <li>Full and immediate ground support by means of jacking pipe</li> </ul>
<b>Ability to deal with mixed face ground conditions</b>	<ul style="list-style-type: none"> <li>Mixed face conditions will likely cause line and grade deviations to occur</li> <li>Overmining may result when augering is labored due to hard ground</li> <li>Augers may jam on rock slabs</li> </ul>	<ul style="list-style-type: none"> <li>Mixed ground may interfere with line and grade control</li> </ul>	<ul style="list-style-type: none"> <li>Good</li> <li>High pressure water jets are necessary to breakdown cohesive clays</li> </ul>
<b>Ability to deal with flowing or unstable face conditions</b>	<ul style="list-style-type: none"> <li>No ability to deal with flowing or unstable face conditions</li> <li>Flowing soils may result in total collapse or excessive ground loss</li> <li>Method is unsuitable in cohesionless soils below the water table</li> </ul>	<ul style="list-style-type: none"> <li>Bore wall stability can be maintained with suitably viscous drilling fluid and filter cake buildup on bore wall</li> <li>Risk of pipe jamming during pullback if stones or cobbles become dislodged from crown of bore</li> </ul>	<ul style="list-style-type: none"> <li>Slurry shield MTBMs are better suited to flowing ground conditions than any other trenchless method</li> </ul>
<b>Ability to deal with cobbles, boulders, and other obstructions</b>	<ul style="list-style-type: none"> <li>For bores &gt;900 mm, auger removal and personnel entry are needed to break up boulders, however the tunnel face must be cohesive for this to be safely conducted</li> </ul>	<ul style="list-style-type: none"> <li>Cobbles and rock slabs may jam pipe in bore during pullback</li> <li>Boulders will result in a failed bore</li> </ul>	<ul style="list-style-type: none"> <li>Combination of disk and pick cutters is needed</li> <li>Person entry not practical</li> <li>Wood troublesome</li> </ul>

Among the considered tunneling options, HDD is assessed as the most feasible and economical option at this site. The following sections in this report provide general recommendations for trenchless installation of the HDPE pipes.

### 7.3.2.1 Horizontal Directional Drilling

Horizontal Directional Drilling (HDD) is considered feasible for the installation of the proposed conduit into the fill comprised of silt, clayey silt, and sand and gravel/gravelly sand, native clayey silt and residual soil/highly to moderately weak weathered shale bedrock. HDD can drill up to about 1,500 m in length with steering capacity for typical pipe diameters ranging between 100 mm and 1,200 mm. The diameter of the proposed tunnel constructed by HDD for the proposed HDPE pipes is expected to be around 36 inches (~914 mm). Primary support is not required, as a drilling fluid is used for temporary support and transportation of the cuttings. The risk of loss of drilling fluid is minimal since the tunnel is at least 5 m below Highway 403 (Alexander Graham Bell Parkway) and 3 m below the on ramps as per MTO standards. High density polyethylene or steel pipes can be utilized at this site.

Directional drilling is a two-step process. First, a small diameter pilot hole is drilled the entire length of the proposed pipeline. Behind the bit, the motor is powered by bentonite slurry, which is pumped through the drill string from

the bore entrance. The slurry acts as a lubricant and helps force the soil back to the surface. After the pilot hole is complete, pulling back reaming tools, from the pipe insertion point to the rig side, enlarges the pilot hole. To achieve the appropriate bore size it may be necessary to perform several reaming operations. Generally, all reaming procedures prior to the actual product installation are referred to as pre-reams, and the final ream to which the product pipe is attached is referred to as the back-ream. After the pre-reams, the pulling head and connecting product pipe are attached to the reamer using a swivel, a device that isolates the product pipe from the rotation of the drill pipe. The product pipe is then pulled behind the final reamer back through the directional drill path to the exit pit on the rig side. The NSSP for Pipe Installation by Trenchless Method and OPSS.MUNI 450, Construction Specifications for Pipeline and Utility Installation by HDD should be applied during construction.

According to the NSSP and OPSS.MUNI 450 the work site for pipeline installation in soil by HDD should be graded or filled to provide a level working area for the drilling rig. However, if the space for the entry and exit points is restricted so bore entry and exit angles exceed the recommended values in ASTM F1962-20 (bore entry angles should be in the range of 8° to 20° from the ground surface, while bore exit angles should be relatively shallow; preferably 10°) the bore would be initiated from bore pits.

One of the risks associated with directional drilling is the escape of drilling mud into the environment as a result of a spill, tunnel collapse or the rupture of mud to the surface, commonly referred to as “frac-out”. Frac-outs are caused when excessive drilling pressure results in drilling mud propagating vertically toward the surface. The risk of frac-outs can be reduced through proper mix design and careful monitoring. Additionally, a minimum cover depth of 5 meters between the pipe's upper surface and any pavement should be provided. For pipe segments near the entry and exit pits that have less than 5 meters of cover, casing will be required.

As noted before, tunneling through residual soil/weathered shale bedrock should be expected from Station 0+170 to 0+220 along Section D-D (see Appendix B and Appendix C). HDD is capable of tunnelling through the shale, but it requires careful planning, the right equipment, and expertise to address the specific challenges posed by shale. Appropriate means and methods for tunnelling through the weak weathered shale should be utilized, including an appropriate drill bit capable of efficiently drilling should be selected, which could break and disintegrate the layers, resulting in fragments that can be easily floated out of the hole. For back-reaming operations, rock bits with hardened carbide cutter teeth are recommended which will generate an initial force to break the shale. As the bit rotates, it will induce the fractures to spread, ensuring continuous fracturing and cutting throughout the drilling process. The contractor should be aware of the interface between native clayey silt and sloping weathered shale bedrock/residual soil at Station 0+170 along Section D-D.

The drilling fluid used for the HDD operation should be selected by the HDD contractor taking into account that the drilling fluid should be able to:

- transport all drill cuttings to the surface;
- cleaning off build-up on drill bits and reamer cutters;
- cooling the downhole tools;
- lubricating to reduce the friction between the product pipe and the bore wall; and,
- stabilize the bore path against squeezing by exerting a positive hydraulic pressure against the bore wall.

Proper control of the gel strength is important to minimize the possibility of hydrofracture caused by excessive downhole pressures.

The possible presence of cobbles and boulders within the native till deposit along the tunnel alignment might create problems for directional drilling construction as well. A high torque capacity boring machine will help in breaking down cobbles and boulders.

Contractors bidding on this project should be required to submit their bore plan and methodology, including specifications for drilling fluid, maximum and minimum pressures utilized for excavation during the HDD process,

prevention of hydrofracturing, locations of relief pits, drilling fluid recycling and disposal plan, emergency measures and materials to be used in case of hydrofracture etc., for review by the geotechnical engineer. All components of the drilling fluid must meet the requirements of ANSI (American National Standard Institute) Certified 60.

### **7.3.2.2 Microtunneling**

Microtunnelling should be feasible to install the proposed conduit. The microtunneling method is a non-entry, remotely controlled, guided 2-stage process, which provides continuous support to the excavation face. In this method a Micro Tunneling Boring Machine (MTBM) is used for soil cutting, while a pipe is jacked into place behind the cutting head with hydraulics. The MTBM is equipped with a slurry spoil removal system to control the groundwater inflow and counterbalance the earth and hydrostatic pressure while tunneling through the mixed face conditions. The cutting tool and the drilling fluid must be able to handle the different materials and the “mixed face” condition. In order to minimize the resistance along the pipe exterior, a bentonite grout lubricant can be injected behind the cutting face. Steel, concrete or fibreglass pipes can be installed with this method.

The contractor should be aware of the interface between native clayey silt and sloping weathered shale bedrock which starts approximately at Station 0+170 along Section D-D and ends at Station 0+120. The choice of equipment, cutterheads, and operational parameters should be tailored to the shale's properties and any associated challenges.

The major advantage of the microtunneling method is that its performance is not affected by high groundwater levels, so the dewatering is not required. The major disadvantages of microtunneling for this project is considered to be the relatively high costs of mobilization and installation.

### **7.3.2.3 Jack and Bore**

The jack and bore method involves drilling a borehole from a jacking pit (sending pit) with a rotary cutter head within the confines of a steel casing or liner which is jacked ahead for support. The casing is pushed through the soil with a hydraulic ram, and soil is removed with an auger. The auger transports spoils from the cutting head back to the jacking pit. The procedures must conform to all relevant OPSS standards and industrial standards.

Based on the proposed tunnel diameters, pipe jacking using mechanical means is generally feasible for the proposed installations, however, the elevation and gradient of the pipe must be closely controlled during the course of the jack and bore. Lubricant selected based on the characteristics of the surrounding soil may be provided to reduce the friction between the casing and the borehole walls. In addition, very weathered weak shale bedrock and potential obstacles such as boulders and cobbles which might be encountered in the till could make the pipe jacking difficult (i.e. high jacking forces). However, one of the advantages of using the jack and bore method for the pipe installation is that the auger can be manually removed to permit clearing of these obstructions or equipped with rock-cutting teeth.

Considering the high groundwater level at the site, advanced dewatering/depressurization below the proposed tunneling horizon will be required.

To reduce loss of ground and groundwater ingress, consideration may be given to jacking the casing across the alignment as far as possible, prior to auguring. EXP recommends the lead auger be kept at least one casing diameter behind the lead end of the casing to minimize the potential for ground losses. Furthermore, any significant voids between the casing and the surrounding soil should be filled with pressurized cementitious grout to prevent / minimize ground loss. The jacking and boring operations should be continued without stoppage until completion. In addition, the installation of the proposed pipe must not interfere with existing utilities. Therefore, driving of the pipe has to be fairly accurate noting that there is only limited steering ability, where minor adjustments can be made should it be necessary or to address obstructions. Generally, utility tunneling using the pipe jacking method is a relatively slow and labor-intensive process. The actual tunnel advance rate is a function of soil conditions encountered, method of soil excavation, spoil removal, pipe liners materials, and field conditions.

The contractor should be aware of the interface between native clayey silt and sloping weathered shale bedrock which starts approximately at Station 0+170 along Section D-D and ends at Station 0+120. The choice of equipment and operational parameters should be tailored to the shale's properties and any associated challenges.

Given the length and layout of the proposed HDPE pipes, and the limited ability to steer and to correct grade, the Jack and Bore tunneling method is considered as the least applicable tunnel installation method for this site.

### 7.3.3 Sending and Receiving Pits

#### 7.3.3.1 Excavation

The installation of these pipes will be executed within 6 sections resulting in 6 sending and receiving pits each that are 1.5 m wide, 1.5 m long, and 1.5 m deep. Excavation for the sending/receiving pits is expected to be conducted through the following materials:

- Sending pits near EXP-BH01: loose to compact silt fill and/or firm to very stiff clayey silt fill
- Sending/receiving pit near EXP-BH15: compact gravelly sand followed by stiff to very stiff clayey silt fill
- Sending/receiving pit near EXP-BH05: compact gravelly sand followed by soft to very stiff clayey silt fill
- Sending/receiving pit near EXP-BH06: very loose sand and silt fill followed by stiff clayey silt fill
- Receiving pit near EXP-BH12: compact to dense sand and gravel fill followed by stiff clayey silt fill

The Contractor should be aware that the slope height, slope inclination, or excavation depths must in no case exceed those specified in local, provincial, or federal safety regulations.

Excavation for the sending/receiving pits shall be performed according to OPSS.PROV 401 and the Occupational Health and Safety Act (OHSA) and Regulations for Construction (O. Reg. 213/91). The existing fills may be classified as Type 3 soil above the groundwater table, and Type 4 soil below the groundwater table in conformance with the OHSA. In accordance with OHSA regulations, if the excavation contains more than one type of soil, the excavation shall be constructed according to the type with the highest number. Any excavation deeper than 1.2 m should be sloped back to a safe angle of 45 degrees or flatter, according to the Act. Sloughing may be encountered where loose fill or where water bearing zones are present. Locally, where loose/soft materials are encountered, or within zones of persistent seepage at depth, it may be necessary to flatten the slopes.

In order to provide the required excavation geometry for the drilling (e.g., vertical front face for tunnel entry and a vertical rear face with a ballast system to act as a reaction force) and to minimize possible negative impact on the stability of the existing embankment slope due to excavations required for the bore/jacking pits, the sides of the excavation will have to be shored if the jack and bore or microtunneling method is used.

Ingress of groundwater and surface water has to be controlled. Technical specifications must ensure that the Contractor submits a groundwater and surface water control plan describing the proposed method for control.

Based on the current proposed dimensions for the send/receiving pits for HDD installation, shoring will likely not be required for excavation of the pits.

#### 7.3.3.2 Backfilling

It is anticipated that backfilling work will be required at the launching and receiving pits to return site condition to pre-construction grades. These excavations should be backfilled with inorganic on-site soils placed in maximum 300 mm thick lifts and compacted according to OPSS.PROV 501. Any organic, excessively wet, compressible or otherwise deleterious materials should not be used for backfilling purposes. Any shortfall of suitable on-site excavated materials can be made up with imported and approved materials such as OPSS.PROV 1010 Granular A, Granular B Type II, or Select Subgrade Materials.

All backfill and compaction operations should be monitored by qualified geotechnical personnel to approve materials, to evaluate placement operations, and to verify that the specified degree of compaction is being achieved throughout the fill.

### 7.3.4 Temporary Shoring

Temporary protection systems are not anticipated for the construction of the sending and receiving pits for this project due to their shallow depth (1.5 m). However, if required, a shoring system such as steel sheet piles or soldier pile and lagging system can be employed for temporary excavations at this site at most locations, depending on where the shoring will be required. Where shallow weak weather shale bedrock is present (between Station 0+170 and 0+220 along Section D-D, see Appendix B and Appendix C), a soldier piles and lagging system is most likely to be used.

It will be the Contractor's responsibility to design a suitable temporary support system. OPSS.PROV 539 regarding temporary protection systems should be followed. The shoring system should be designed using the parameters recommended in Table 2.4 of this report.

The Contractor should be responsible for the complete design, construction, monitoring and removal of the installed protection system. The protection system shall be designed to provide protection for excavations as required by the OHSA, at locations specified in the contract, and at any locations where the stability, safety or function of an existing structure and/or utility may be impaired by construction work. Decommissioning of temporary shoring must be consistent with good practice to avoid interference with highway systems and utilities, if any. The protection system shall be designed for the Performance Level 2 (for small, less important sections). The minimum requirements for monitoring should include the survey measurements of 6 m apart scaled targets attached to the shoring wall at the specified elevations. If movement approaches the allowable limit of 25 mm (Performance Level 2), suitable measures should be taken to ensure stability of the protection system and to ensure that the movement does not exceed the performance level specified.

#### 7.3.4.1 Lateral Earth Pressure

Temporary shoring for the excavation of the sending and receiving pits (if any) should be designed to resist lateral earth pressure. The expression for calculating lateral earth pressure is given by:

$P = K(\gamma h + q)$  for non-braced cut, or  $K(0.65\gamma h + q)$  for braced cut  
 where,

$P$  = earth pressure intensity at depth  $h$ , kPa

$K$  = earth pressure coefficient

$\gamma$  = unit weight of retained soil, kN/m<sup>3</sup>

$q$  = surcharge near wall, kPa

$h$  = depth to point of interest, m

The above expression does not take into account hydrostatic pressure, which must be included for the groundwater levels measured on the site. Table 2.4 lists earth pressure parameters for given materials. These recommendations assume level backfill and ground surface behind the walls.



Table 2.4. Material types and earth pressure properties

Material	Unfactored Friction Angle $\phi'$ ( $^{\circ}$ )	Coefficient of Active Earth Pressure ( $K_a$ )	Coefficient of Passive Earth Pressure ( $K_p$ )	Coefficient of Earth Pressure At-Rest ( $K_o$ )	Unit Weight $\gamma$ (kN/m <sup>3</sup> )
Granular A	35	0.27	3.69	0.43	22.8
Granular B Type II	35	0.27	3.69	0.43	22
Existing Sand and Gravel to Gravelly Sand Fill (generally loose to dense)	32	0.31	3.25	0.47	21
Existing Silt/Sand and Silt Fill (very loose to compact)	28	0.36	2.77	0.53	20
Existing Clayey Silt Fill (generally firm to very stiff) <sup>1</sup>	30	0.33	3.00	0.5	19
Clayey Silt Till (generally firm to very stiff) <sup>1</sup>	30	0.33	3.00	0.5	19
Sandy Silt/Sand and Gravel (loose to compact)	30	0.33	3.00	0.5	20

Note:

1. Assumes long term conditions. In short term conditions  $K_a = K_p = 1$

The mobilization of full active or passive resistance requires a measurable and perhaps significant wall movement or rotation. Therefore, unless the structural element can tolerate these deflections, the at rest earth pressure should be used in design.

The effect of compaction surcharge should be taken into account in the calculations of active and at rest earth pressures. The lateral pressure due to compaction should be taken as at least 12 kPa at the surface, and its magnitude should be assumed to diminish linearly with depth to zero at the depth where the active (or at rest) pressure is equal to 12 kPa. This pressure distribution should be added to the calculated active (or at rest) pressure.

It is likely that bracing for the temporary support system (if any) will be required at a maximum interval of 5 m. For multiple support systems refer to Canadian Foundation Engineering Manual (CFEM) for apparent earth pressure distributions (CFEM, Section 26.10.3, Figure 26.8).

### 7.3.5 Ground Movements

Settlement around the tunnel would be due ground loss or “immediate” settlement caused by tunneling. In general, the immediate settlement is a direct result of the overcut and movement of ground at the heading during tunneling. The factors that influence the immediate settlement include the soil strength and the method of tunneling. Technical specifications should ensure that:

- The use of over-cutters (excavating to a diameter greater than the pipe diameter) is kept under required limits; and
- The program of instrumentation is carried out as per the monitoring plan.



To reduce the risk of ground settlement/subsidence, trenchless installations require a minimum depth of overburden cover over the tunnel crown. As the depth of overburden cover decreases, the risk of concentrated subsidence increases, as does the risk of extreme events such as sinkholes forming at the ground surface. In Ontario, the general practice is to maintain a depth of cover equivalent to 2 to 3 tunnel diameters, at least for open-faced tunneling methods. At this site, the proposed conduit alignment has a minimum cover of 3 m under the ramps and 5 m under Highway 403, resulting in a cover-to-diameter ratio of 3.3 and 5.5 for ramps and Highway 403, respectively, which is greater than is required.

The potential settlement also depends on the construction practices. To avoid excess settlements:

- Auguring ahead of the carrier pipe should not be permitted.
- Pause/delays in the tunneling operation should be minimized.

Considering the depth of the conduit and construction method recommended, it is expected that the bore construction using the HDD method will result in less than 10 mm of vertical movement (i.e. estimated based on Pack's equation (Peck, R.B. 1969. Deep excavations and tunneling in soft ground. Proceeding of 7th international conference on soil mechanics and foundation engineering. Mexico City: State of the Art Report)) assuming that good construction practice will be followed including the application of proper drilling fluid and drilling pressure to prevent hydrofracturing.

### **7.3.6 Ground Movement Monitoring**

Ground movement monitoring is recommended for all tunnel crossings for this project and will be required at all MTO crossings. Condition surveys should be carried out before the construction takes place and after the completion of the proposed tunneling. The survey should document the pavement surface conditions (i.e. cracks, distortion and deviations, heaves, and depressions) and surrounding infrastructure (bridges, culverts, etc.). The preliminary methodology of the settlement monitoring program is outlined in the following sections. A finalized monitoring plan can be developed and implemented by EXP once the alignments and contractor's proposed construction methods are finalized.

#### **7.3.6.1 Monitoring Points**

The monitoring should consist of surface and deep settlement points along the center line of the proposed tunnels while crossing roads. The deep settlement points should be installed above the crown of the tunnel and below the frost penetration depth of 1.2 m. The spacing of the surface and deep settlement points should not exceed 5.0 m. Locations of the settlement points are subject to the land owner approval where traffic disruption might occur. Structure monitoring points should also be installed to monitor any movements of the existing overpass structures and each of the culverts.

#### **7.3.6.2 Reading Frequency**

An average of at least two readings should be taken to establish the initial conditions. A minimum of three (3) sets of readings should be taken daily during construction and work stoppages. The monitoring should be extended after the construction completion for at least 2 weeks provided all settlements have stopped.

### 7.3.6.3 Data Collection and Transfer

A procedure should be established in consultation with the Region and land owners to ensure that the monitoring data will reach all parties as soon as possible. The consultant and the contractor should interpret monitoring data as needed. The Geotechnical Engineer should be contacted for technical support in the interpretation of the ground movements and review of the contractor response when review and alert levels are reached.

### 7.3.6.4 Criteria for Assessment – Review and Alert Levels

An average of two initial readings shall be recorded as baseline readings, all the subsequent readings should be compared to the baseline reading. A maximum value of 10 mm relative to the baseline reading shall be considered as a review level, at which, the method, rate and sequence of construction, or ground stabilization measures should be reviewed or modified to mitigate further ground movement before construction proceeds.

A maximum value of 15 mm relative to the baseline readings shall be considered as an Alert Level, at which, the contractor shall cease construction operations, secure the site to mitigate further movements and to assure safety of public and maintain traffic.

## 7.4 Dewatering

Both surface and ground water should be directed away from the excavation area(s) at all times. Dewatering shall be carried out in accordance with OPSS.PROV 517 and SP 517F01 (Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation). It is the responsibility of the Contractor to propose a suitable dewatering system based on the time of construction and groundwater levels. The method used should not undermine the existing roadway.

Based on the monitoring well readings taken at the site (which are considered stabilized and therefore represent the established long-term average groundwater table), groundwater at the site is interpreted to range between Elev. 82.7 m to Elev. 91.7 m. Based on the proposed location of the HDPE pipes, groundwater level can range from being approximately 9.3 m below the pipe up (EXP-BH03) to 3.4 m above the pipe (EXP-BH07).

The HDD installation does not require the dewatering at the site, therefore the settlement due to dewatering should not be issue in this project.

For installation of the sending/receiving pits, it is anticipated that control of seepage can be accomplished by conventional pumping from sumps in oversized excavations. This dewatering can likely be achieved by gravity drainage and pumping from strategically placed sumps with side ditches. Confirmation of control should be verified before general excavation to final levels.

All collected water should be discharged away from the MTO right-of-way/highway at a sufficient distance from the excavated area to prevent the water from re-entering the excavation. Sediment control measures such as silt fences should be provided at the discharge point of the dewatering system. Caution should also be taken to avoid any adverse impact to the environment.

## 7.5 Corrosion Potential and Cement Type

Five (5) soil samples were selected for chemical analyses during the previous investigation by Golder (July 2020). The testing was completed to determine the potential degradation of the concrete in the presence of soluble sulphates

and the potential of corrosion of exposed steel of the utility components, if any. The analyses results are summarized in Table 1.10 of this report.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The soil pH value measured at the site ranged from 7.08 to 7.99 which is within the normal range of soil pH of 5.5 to 8.5 and therefore is not considered to be detrimental to durability of the utility components (AASHTO, 2000/MTO Gravity Pipe Design Guidelines, April 2014). The chemical data indicates resistivity values ranging from 1100 ohm-cm to 3400 ohm-cm indicating moderate ( $4500 > R > 2000$  ohm-cm) to low ( $R < 2000$  ohm-cm) resistivity of the tested soil which suggests moderate to high potential for corrosion of buried metallic elements as per Table 3.2 of the MTO Gravity Pipe Design Guideline. The measured chloride content ranged from under 20 to 340 ppm ( $\mu\text{g/g}$ ) which also indicates a very low potential for additional corrosion (Molinas and Mommandi, 2009).

These chemical test results may be used to aid in the selection of coatings and corrosion protection systems for buried steel components, if any. For buried concrete components, consideration should be given by the designer to designing for a « C » type of exposure class of concrete as defined by CSA A23.1:19 Table 1, since the conduits may be exposed to de-icing salt.

The maximum water-soluble sulphate content of the soils tested is 500 ppm ( $\mu\text{g/g}$ ), i.e. 0.05%, and being less than 0.10% (as per CSA A23.1:19, Table 3) does not require sulphate resistant cement, if any. The data supports our local experience.

## **7.6 Obstructions during Tunnelling and Installation of Temporary Protection Systems**

Cobbles and/or boulders were not noted to be contained within the fill and native soil deposits at the site during site investigation. However, given the nature of the native soils (till) and that cobbles and boulders were encountered in the native soils in nearby sites in the region, their presence should be anticipated. Therefore, care must be taken since the presence of these obstructions may affect the tunnelling and installation of protection system elements. It is recommended that a NSSP be included in the Contract Documents to warn the Contractor of the presence of cobbles and/or boulders within the overburden soils. An example of NSSP for obstructions is provided in Appendix F.

## 8.0 CLOSURE

The recommendations made in this report are in accordance with our present understanding of the project and are provided solely for the team responsible for the design of the works described herein.

A subsurface investigation is a limited sampling of a site; the subsurface conditions have been established only at the test hole locations. Should conditions at the site be encountered which differ from those reported at the test locations, we require that we be notified immediately in order to assess this additional information and our recommendations, as appropriate. It may then be necessary to perform additional investigation and analysis.

This Foundation Investigation and Design Report has been prepared by Ciarra Alexander, M.Eng., and Daniel Mroz, M.E.Sc., E.I.T. It was reviewed by Silvana Micic, Ph.D., P.Eng., TaeChul Kim, M.E.Sc., P.Eng. and by Stan E. Gonsalves, M.Eng., P.Eng., Designated MTO Foundation Contact.

### EXP Services Inc.



Ciarra Alexander, M.Eng.  
Technical Specialist



Daniel Mroz, M.E.Sc., E.I.T.  
Technical Specialist



Silvana Micic, Ph.D., P.Eng.  
Senior Geotechnical Engineer  
Project Manager



Stan E. Gonsalves, M.Eng., P.Eng.  
Principal Engineer  
Designated MTO Foundation Contact



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Canadian Standards Association (CSA), 2019. Canadian Highway Bridge Design Code and Commentary on CAN/CSA-S6-19. CSA Special Publication.

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Ministry of Northern Development and Mines, Map 2556. Quaternary Geology of Ontario, Southern Sheet, 1991

Ministry of Transportation, April 2014. MTO Gravity Pipe Design Guidelines. Circular Culverts and Storm Sewers.

Ministry of Transportation, April 2022. Guideline for MTO Foundation Engineering Services, Version 03

Molinas, A., and Mommandi, A., 2009. Development of New Corrosion/Abrasion Guidelines for Selection of Culvert Pipe Materials, Report No. CDOT-2009-11. Colorado Department of Transportation, DTD Applied Research and Innovation Branch.

### **ASTM International:**

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

### **Ontario Provincial Standard Specifications (OPSS):**

OPSS.PROV 401 Construction Specification for Trenching, Backfilling and Compacting

OPSS.MUNI 450 Construction Specification for Pipeline and Utility Installation in Soil b Horizontal Directional Drilling

OPSS.PROV 501 Construction Specification for Compacting

OPSS.PROV 517 Construction Specification for Dewatering

OPSS.PROV 539 Construction Specification for Temporary Protection Systems

OPSS.PROV 1010 Material Specification for Aggregates - Base, Subbase, Select Subgrade, And Backfill Material

### **Ontario Provincial Standard Drawings (OPSD):**

OPSD 3090.101 Foundation Frost Penetration Depths for Southern Ontario

### **Special Provisions (SP):**

SP 51701 Amendment to OPSS 517

MTO NSSP for Pipe Installation by Trenchless Method (June 2021);

Guidelines for Foundation Engineering – Tunneling Speciality for Corridor Encroachment Permit Application  
(February 2021)

**Ontario Water Resources Act:**

R.R.O 1990, Regulation 903 Wells, under Ontario Water Resources Act, R.S.O. 1990, c. O.40

**Ontario Occupational Health and Safety Act (OHSA):**

Ontario Regulation 213/91 Construction Projects

## 10.0 LIMITATIONS AND USE OF REPORT

### **BASIS OF REPORT**

This report ("Report") is based on site conditions known or inferred by the geotechnical investigation undertaken as of the date of the Report. Should changes occur which potentially impact the geotechnical condition of the site, or if construction is implemented more than one year following the date of the Report, the recommendations of EXP may require re-evaluation.

The Report is provided solely for the guidance of design engineers and on the assumption that the design will be in accordance with applicable codes and standards. Any changes in the design features which potentially impact the geotechnical analyses or issues concerning the geotechnical aspects of applicable codes and standards will necessitate a review of the design by EXP. Additional field work and reporting may also be required.

Where applicable, recommended field services are the minimum necessary to ascertain that construction is being carried out in general conformity with building code guidelines, generally accepted practices and EXP's recommendations. Any reduction in the level of services recommended will result in EXP providing qualified opinions regarding the adequacy of the work. EXP can assist design professionals or contractors retained by the Client to review applicable plans, drawings, and specifications as they relate to the Report or to conduct field reviews during construction.

Contractors contemplating work on the site are responsible for conducting an independent investigation and interpretation of the borehole results contained in the Report. The number of boreholes necessary to determine the localized underground conditions as they impact construction costs, techniques, sequencing, equipment and scheduling may be greater than those carried out for the purpose of the Report.

Classification and identification of soils, rocks, geological units, contaminant materials, building envelopment assessments, and engineering estimates are based on investigations performed in accordance with the standard of care set out below and require the exercise of judgment. As a result, even comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations or building envelope descriptions involve an inherent risk that some conditions will not be detected. All documents or records summarizing investigations are based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated. Some conditions are subject to change over time. The Report presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, these should be disclosed to EXP to allow for additional or special investigations to be undertaken not otherwise within the scope of investigation conducted for the purpose of the Report.

### **RELIANCE ON INFORMATION PROVIDED**

The evaluation and conclusions contained in the Report are based on conditions in evidence at the time of site inspections and information provided to EXP by the Client and others. The Report has been prepared for the specific site, development, building, design or building assessment objectives and purpose as communicated by the Client. EXP has relied in good faith upon such representations, information and instructions and accepts no responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of any misstatements, omissions, misrepresentation or fraudulent acts of persons providing information. Unless specifically stated otherwise, the

applicability and reliability of the findings, recommendations, suggestions or opinions expressed in the Report are only valid to the extent that there has been no material alteration to or variation from any of the information provided to EXP.

## **STANDARD OF CARE**

The Report has been prepared in a manner consistent with the degree of care and skill exercised by engineering consultants currently practicing under similar circumstances and locale. No other warranty, expressed or implied, is made. Unless specifically stated otherwise, the Report does not contain environmental consulting advice.

## **COMPLETE REPORT**

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment form part of the Report. This material includes, but is not limited to, the terms of reference given to EXP by its client ("Client"), communications between EXP and the Client, other reports, proposals or documents prepared by EXP for the Client in connection with the site described in the Report. In order to properly understand the suggestions, recommendations and opinions expressed in the Report, reference must be made to the Report in its entirety. EXP is not responsible for use by any party of portions of the Report.

## **USE OF REPORT**

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. No other party may use or rely upon the Report in whole or in part without the written consent of EXP. Any use of the Report, or any portion of the Report, by a third party are the sole responsibility of such third party. EXP is not responsible for damages suffered by any third party resulting from unauthorised use of the Report.

## **REPORT FORMAT**

Where EXP has submitted both electronic file and a hard copy of the Report, or any document forming part of the Report, only the signed and sealed hard copy shall be the original documents for record and working purposes. In the event of a dispute or discrepancy, the hard copy shall govern. Electronic files transmitted by EXP have utilized specific software and hardware systems. EXP makes no representation about the compatibility of these files with the Client's current or future software and hardware systems. Regardless of format, the documents described herein are EXP's instruments of professional service and shall not be altered without the written consent of EXP.



## Appendix A – Site Photographs



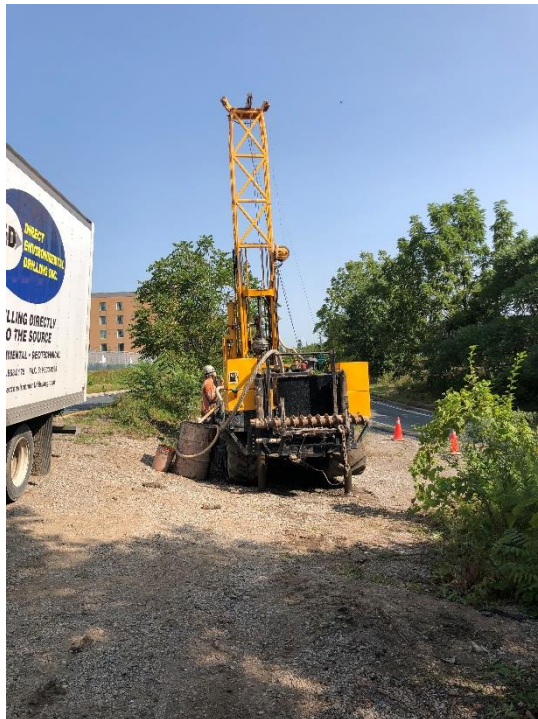
Photograph 1. Greenspace on west side of Highway 403 East Ramp from Main St. W (looking southwest), September 6, 2023



Photograph 2. Greenspace on east side of Highway 403 East Ramp from Main St. W (looking north), August 24, 2023



Photograph 3. Drilling EXP-BH1 (looking northeast), September 6, 2023



Photograph 4. Drilling EXP-BH2 (looking north), September 1, 2023





Photograph 5. Drilling EXP-BH6 (looking north), August 22, 2023



Photograph 6. Drilling EXP-BH7 (looking west), August 24, 2023



Photograph 7. Drilling EXP-BH8 (looking northeast), October 12, 2023



Photograph 8. Drilling EXP-BH9 (looking southeast), August 22, 2023





Photograph 9. Drilling EXP-BH10 (looking east), August 22, 2023



Photograph 10. Coring EXP-BH11 (looking southeast), August 28, 2023



Photograph 11. Drilling EXP-BH13 (looking southeast), August 21, 2023



Photograph 12. Drilling EXP-BH14 (looking northwest), September 7, 2023



Photograph 13. Crane lifting Geoprobe for EXP-BH15 (looking northwest), September 5, 2023



Photograph 14. Drilling EXP-BH15 (looking east), September 5, 2023



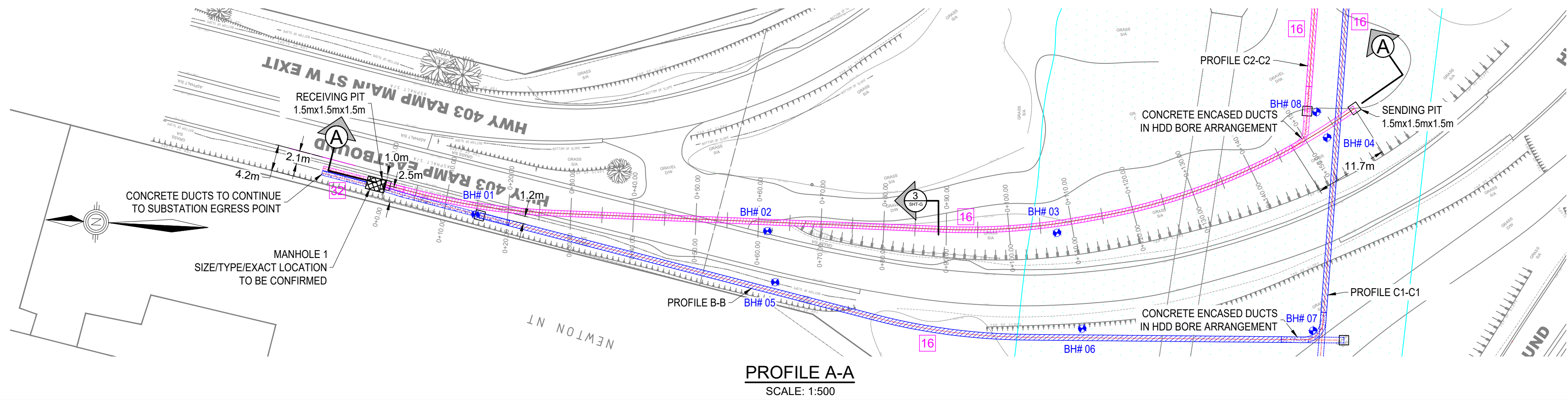
Appendix B –  
Alectra Drawings of Proposed HDPE Pipe Installation



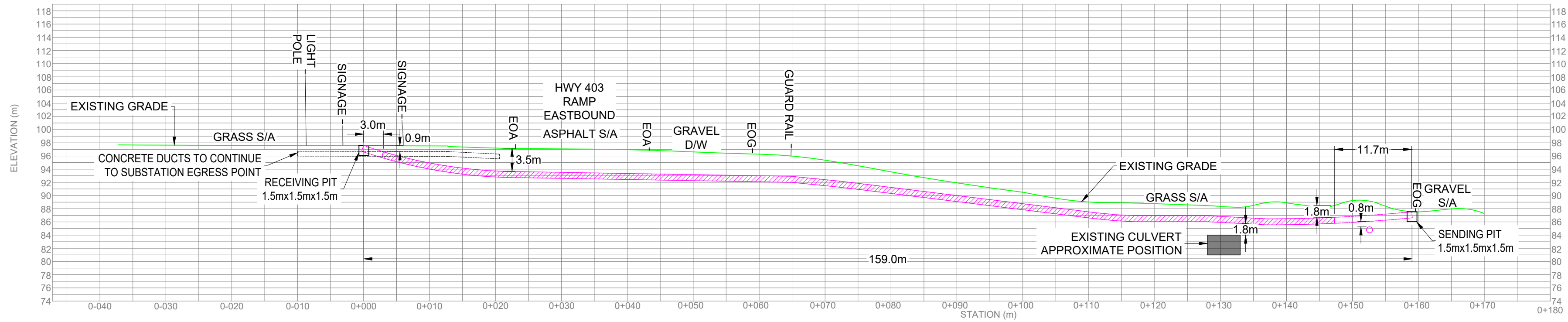


Age Group	No	Small	Medium	Big	Very big
1	~45%	~35%	~10%	~5%	~5%
5	~35%	~40%	~15%	~5%	~5%
10	~25%	~45%	~20%	~10%	~10%
15	~15%	~40%	~25%	~15%	~5%
20	~10%	~35%	~25%	~20%	~10%

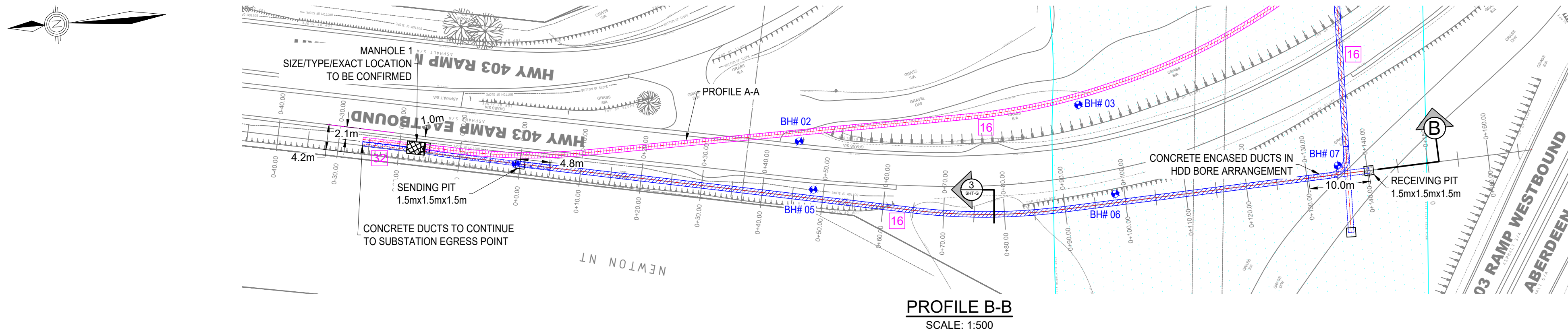




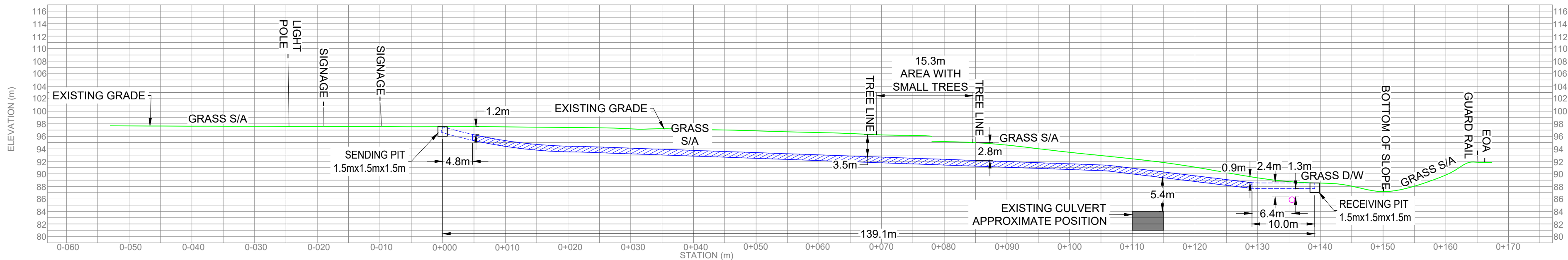
PROFILE A-A  
SCALE: 1:500



PROPOSED HDD BORE CROSS SECTION A-A  
SCALE: 1:500



PROFILE B-B  
SCALE: 1:500



PROPOSED HDD BORE CROSS SECTION B-B  
SCALE: 1:500

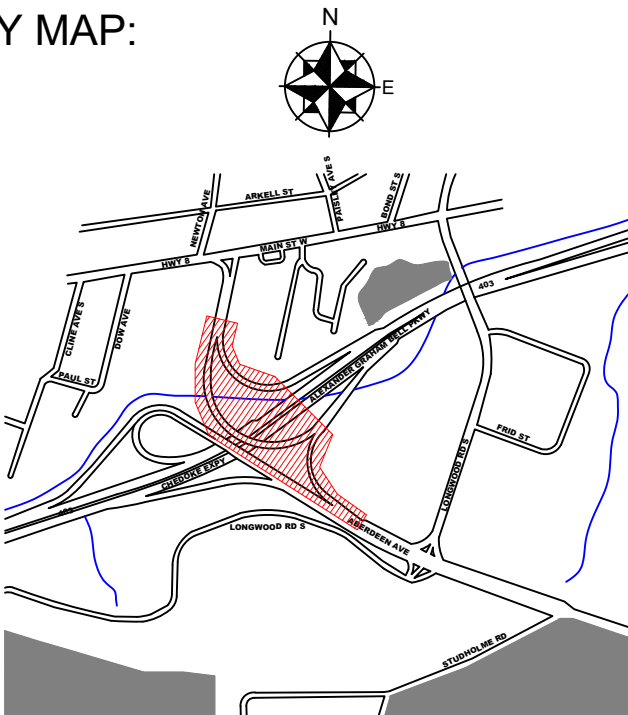
LEGEND:

SYMBOL

DESCRIPTION

- ROUTE 1: PROPOSED U/G HDD BORE PIPE
- ROUTE 1: HDD BORE PIPE TO BE REMOVED
- ROUTE 1: PROPOSED CONCRETE ENCASED DUCTBANK
- ROUTE 2: PROPOSED U/G HDD BORE PIPE
- ROUTE 2: HDD BORE PIPE TO BE REMOVED
- ROUTE 2: PROPOSED CONCRETE ENCASED DUCTBANK
- INDICATES QUANTITY OF HDPE CARRIER DUCTS
- GEOTECHNICAL TEST BOREHOLES
- MANHOLE: SIZE/TY/PE/EXACT LOCATION TO BE CONFIRMED

KEY MAP:



NO.	ISSUED/REVISED	DES. TECH.	APPD.	MM/DD/YYYY

PROJECT NAME:

HWY 403 Underground Crossing

DRAWN BY:

M.Day

DESIGNED BY:

A.Michial

SCALE:

1:500

DATE:

DECEMBER 22, 2022

WORK ORDER NUMBER:

634412

DRAWING NUMBER:

WORK INSTRUCTION CERTIFICATE OF APPROVAL

The work instruction has been assembled by utilizing only certified construction standards, certified specifications, approved equipment and it meets the safety requirements of Section 4 of Ontario Regulation 220/04.

Name	Date
Signature	Position

FINAL CIVIL CONSTRUCTION CERTIFICATE

The construction as recorded in this drawing is consistent with the approved plan, certified construction standards and/or work instruction and that approved equipment has been used.

Name	Date
Signature	Position

RECORD OF INSPECTION

(APPLIES TO COMPLETED DRAWING)

☐ PROGRESSIVE RECORD OF INSPECTION (APPLIES TO HIGHLIGHTED AREA ONLY)

☐ NON-CONFORMANCE HAS BEEN IDENTIFIED REPORT ATTACHED

INITIALS	DATE
----------	------

CERTIFICATE

THIS IS TO CERTIFY THAT THE CONSTRUCTION AS RECORDED IN THIS DRAWING IS CONSISTENT WITH THE APPROVED PLAN, STANDARD DESIGNS OR WORK INSTRUCTION AND THAT ONLY APPROVED EQUIPMENT HAS BEEN USED. ALL NON-CONFORMANCE ISSUES HAVE BEEN RECTIFIED.

NAME	POSITION
SIGNATURE	DATE

LINES CONSTRUCTION CERTIFICATE

The construction as recorded in this drawing is consistent with the approved plan, certified construction standards and/or work instruction and that approved equipment has been used.

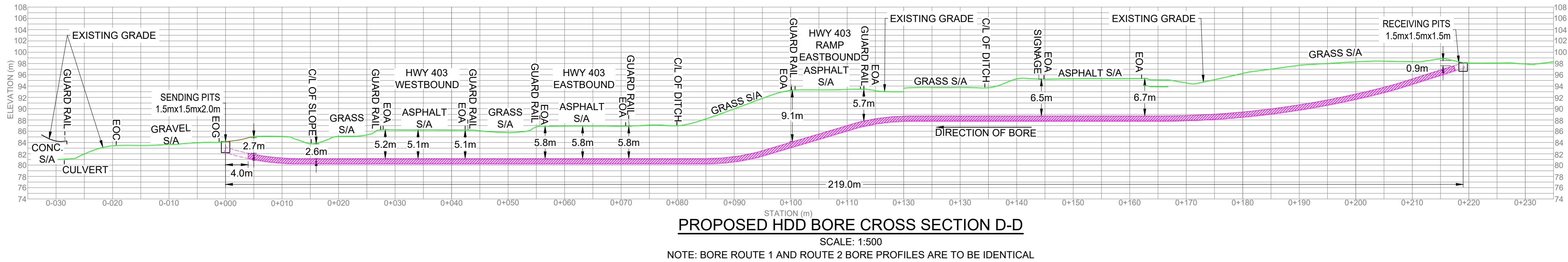
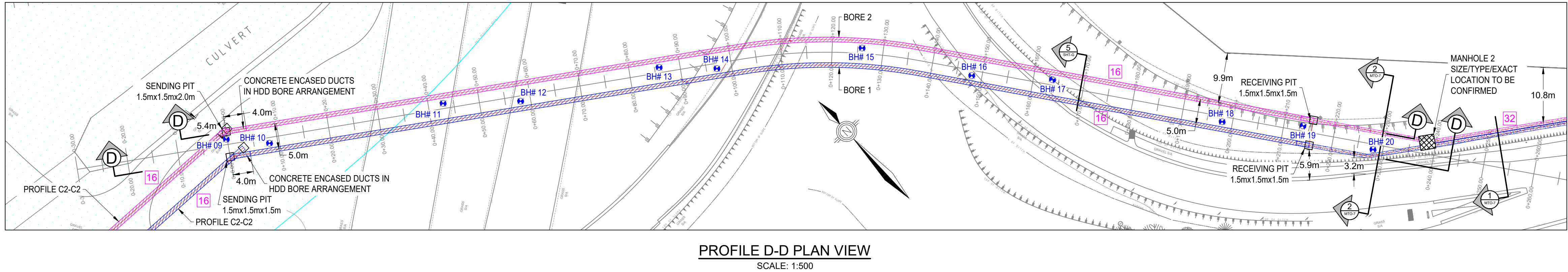
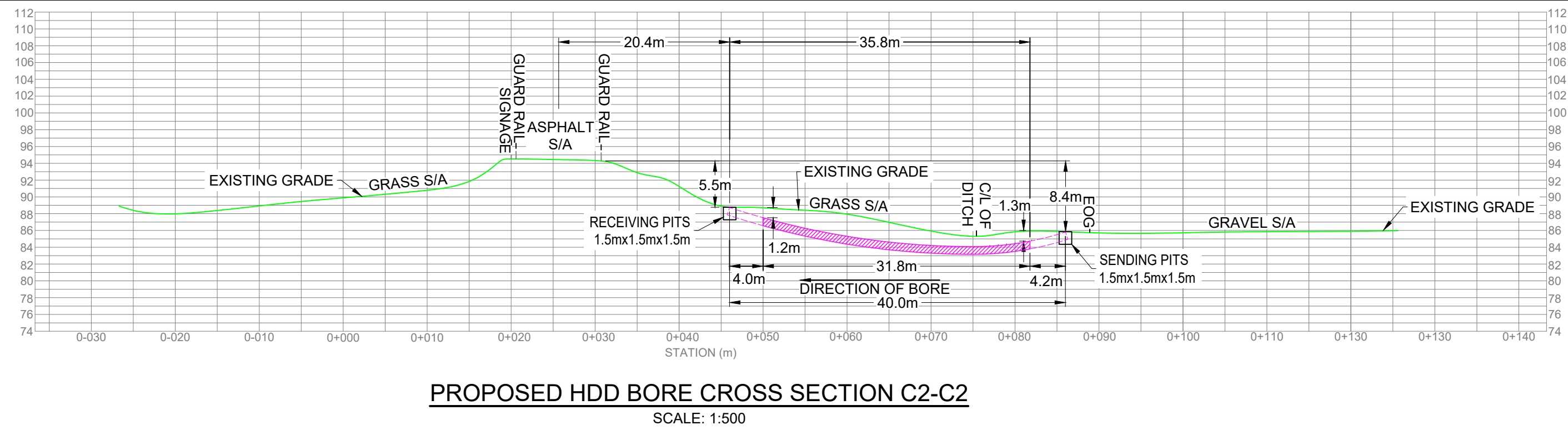
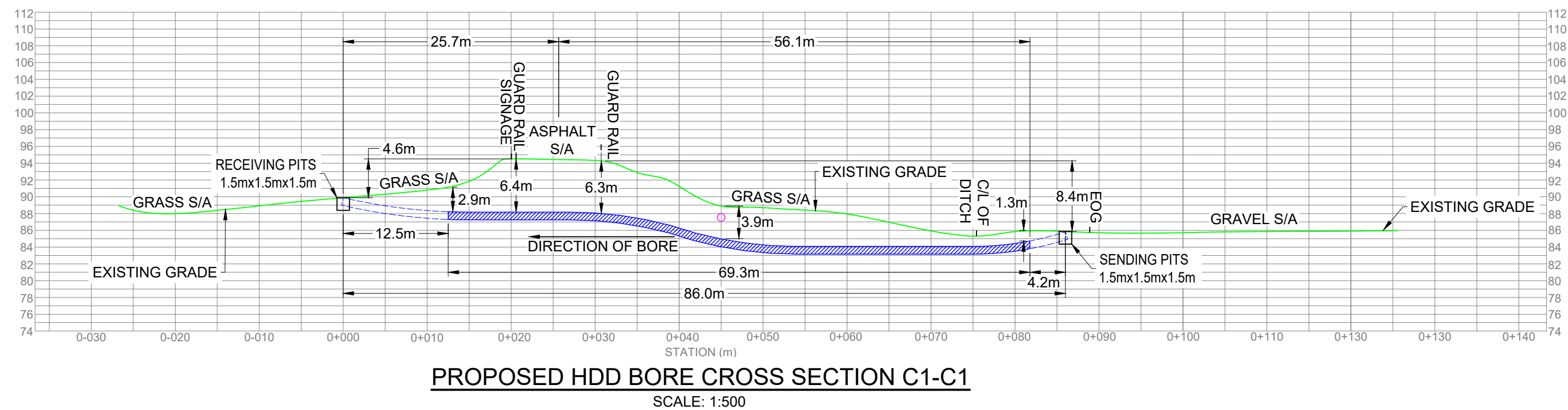
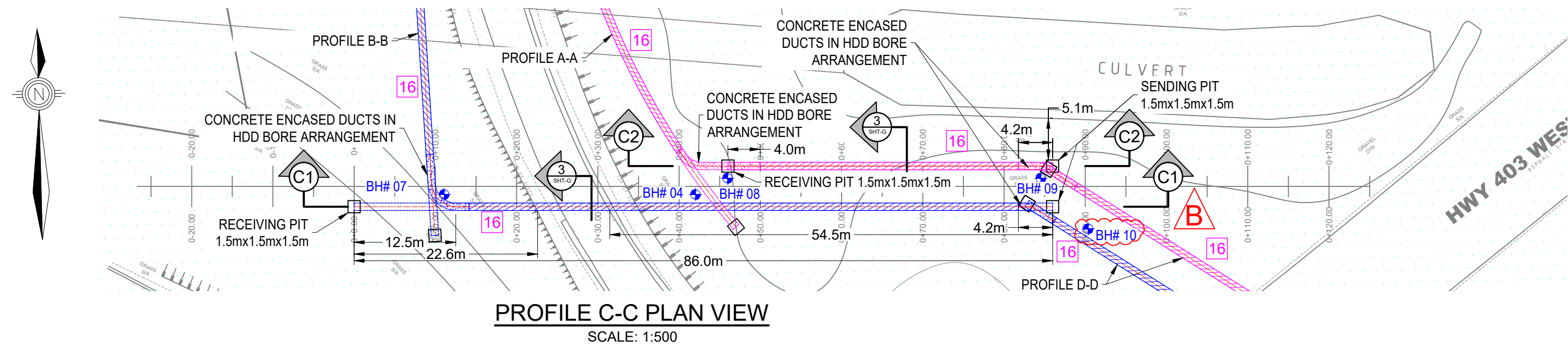
[PARTIAL ENERGIZATION (Applies to Highlighted Area Only)]

Name/Signature	Date	Partial 1
Name/Signature	Date	Partial 2
Name/Signature	Date	Partial 3
Name/Signature	Date	Partial 4
Name/Signature	Date	Partial 5

[FINAL ENERGIZATION (Applies to Complete Drawing)]

Name	Date
Signature	Position





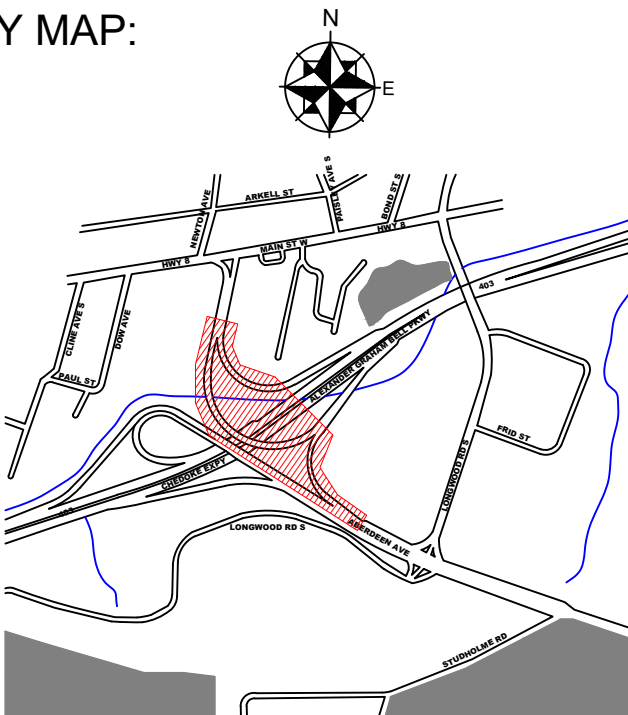
LEGEND:

SYMBOL

DESCRIPTION

- ROUTE 1: PROPOSED U/G HDD BORE PIPE
- ROUTE 1: HDD BORE PIPE TO BE REMOVED
- ROUTE 1: PROPOSED CONCRETE ENCASED DUCTBANK
- ROUTE 2: PROPOSED U/G HDD BORE PIPE
- ROUTE 2: HDD BORE PIPE TO BE REMOVED
- ROUTE 2: PROPOSED CONCRETE ENCASED DUCTBANK
- INDICATES QUANTITY OF HDPE CARRIER DUCTS
- GEOTECHNICAL TEST BOREHOLES
- MANHOLE: SIZE/TYPE/EXACT LOCATION TO BE CONFIRMED

KEY MAP:



NO.	ISSUED/REVISED	DES. TECH.	APPD.	MM/DD/YYYY



PROJECT NAME: HWY 403 Undergroud Crossing	
DRAWN BY: M.Day	DESIGNED BY: A.Michial
SCALE: 1:500	DATE: DECEMBER 22, 2022
WORK ORDER NUMBER: 634412	DRAWING NUMBER:

WORK INSTRUCTION CERTIFICATE OF APPROVAL

This work instruction has been assembled by utilizing only certified construction standards, certified specifications, approved equipment and it meets the safety requirements of Section 4 of Ontario Regulation 220/04.

Name \_\_\_\_\_ Date \_\_\_\_\_

Signature \_\_\_\_\_ Position \_\_\_\_\_

FINAL CIVIL CONSTRUCTION CERTIFICATE

The construction as recorded in this drawing is consistent with the approved plan, certified construction standards and/or work instruction and that approved equipment has been used.

Name \_\_\_\_\_ Date \_\_\_\_\_

Signature \_\_\_\_\_ Position \_\_\_\_\_

LINES CONSTRUCTION CERTIFICATE

The construction as recorded in this drawing is consistent with the approved plan, certified construction standards and/or work instruction and that approved equipment has been used.

[PARTIAL ENERGIZATION (Applies to Highlighted Area Only)]

Name/Signature \_\_\_\_\_ Date \_\_\_\_\_ Partial 1

Name/Signature \_\_\_\_\_ Date \_\_\_\_\_ Partial 2

Name/Signature \_\_\_\_\_ Date \_\_\_\_\_ Partial 3

Name/Signature \_\_\_\_\_ Date \_\_\_\_\_ Partial 4

Name/Signature \_\_\_\_\_ Date \_\_\_\_\_ Partial 5

[FINAL ENERGIZATION (Applies to Complete Drawing)]

Name \_\_\_\_\_ Date \_\_\_\_\_

Signature \_\_\_\_\_ Position \_\_\_\_\_

RECORD OF INSPECTION

☐ RECORD OF INSPECTION (APPLIES TO COMPLETED DRAWING)

☐ PROGRESSIVE RECORD OF INSPECTION (APPLIES TO HIGHLIGHTED AREA ONLY)

☐ NON-CONFORMANCE HAS BEEN IDENTIFIED REPORT ATTACHED

INITIALS \_\_\_\_\_ DATE \_\_\_\_\_

CERTIFICATE

THIS IS TO CERTIFY THAT THE CONSTRUCTION AS RECORDED IN THIS DRAWING IS CONSISTENT WITH THE APPROVED PLAN, STANDARD DESIGNS OR WORK INSTRUCTION AND THAT ONLY APPROVED EQUIPMENT HAS BEEN USED. ALL NON-CONFORMANCE ISSUES HAVE BEEN RECTIFIED.

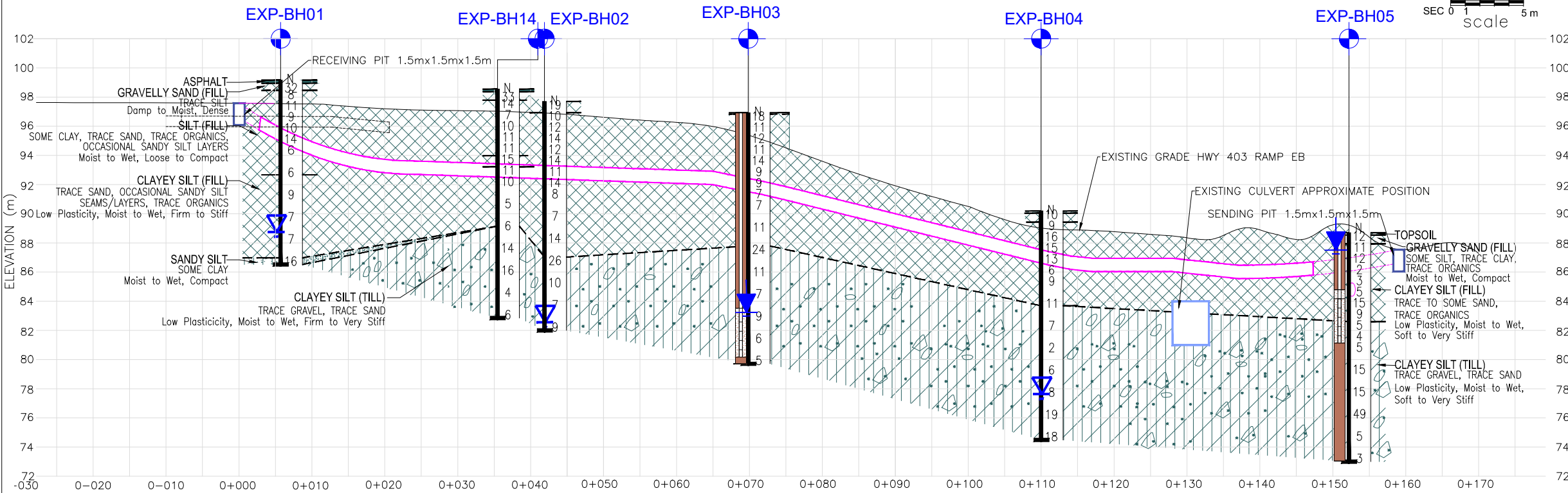
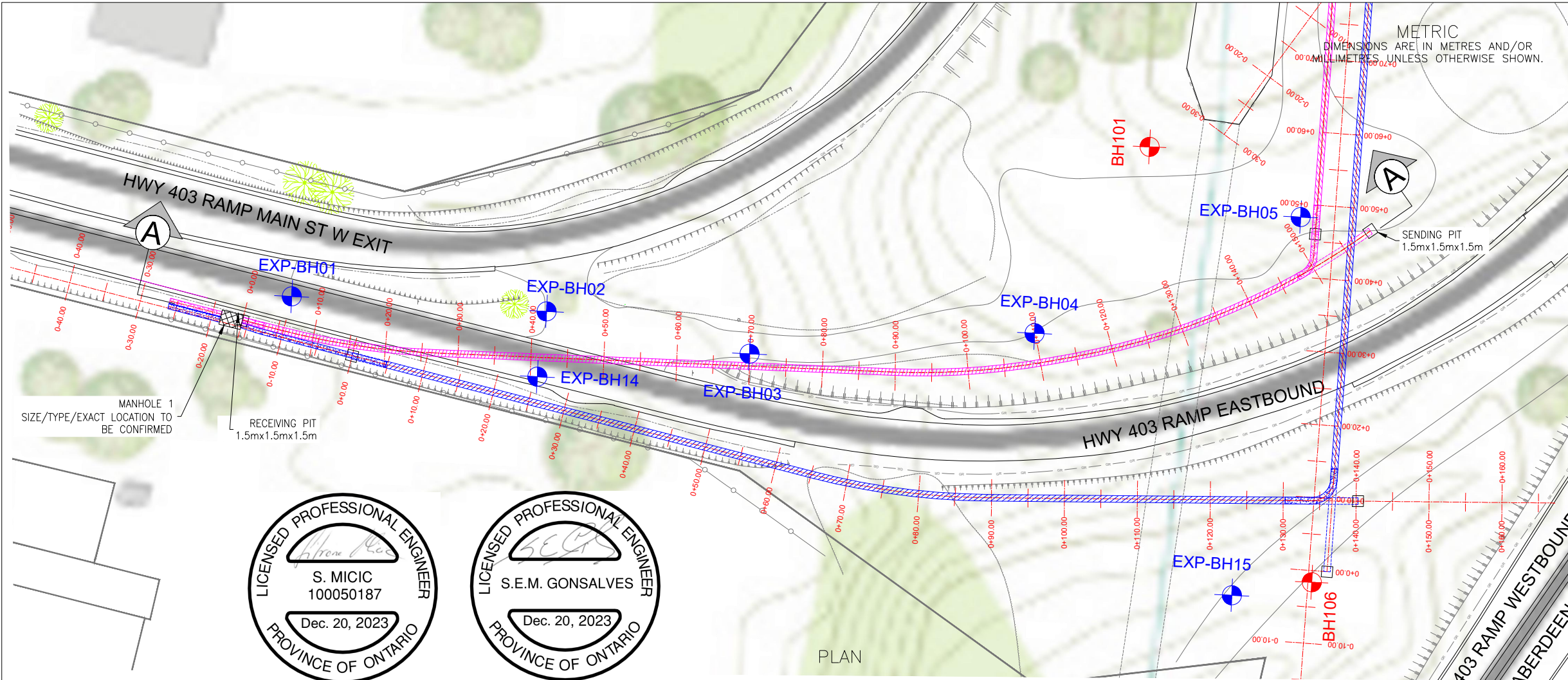
NAME \_\_\_\_\_ POSITION \_\_\_\_\_

SIGNATURE \_\_\_\_\_ DATE \_\_\_\_\_

## Appendix C – Borehole Location Plan and Stratigraphic Profile



FILE NAME: I:\2003-Brampton\Proposals\Projects\International\NBM\_Engineering - Proposals\Hamilton-H403 HDD Tunnel\Working drawing\Hamilton-H403 HDD Tunnel- borehole location plan & profile.dwg  
MODIFIED: 2023-10-31 12:56



CONT No. —  
ASSIG No.  
GWP No.

Trenchless Installation of Hwy 403 & Aberdeen Ave.  
Underground Crossing for Alectra Utilities, Hamilton, ON  
Latitude: 43.257274°; Longitude: -79.907396

SHEET  
1

EXP SERVICES INC.

KEY PLAN  
N.T.S.

LEGEND

Borehole Location

Previous Borehole Location

Water Level Upon Completion of Drilling  
( W. L. NOT STABILIZED)

Blows/0.3m (Std. Pen. Test, 475 J/blow)

Water Level in Piezometer (most recent)  
(W. L. STABILIZED)

Piezometer

Artesian

SOIL STRATA SYMBOLS

TOPSOIL

ASPHALT

FILL

SANDY SILT

CLAYEY SILT (TILL)

SAND AND GRAVEL

CLAYEY SILT (RESIDUAL SOIL)

BEDROCK

BOREHOLE COORDINATES/ NAD 83/ MTM ON-10

BH No.	ELEV.	NORTHING	EASTING
EXP-BH01	99.2	4790903	271723
EXP-BH02	97.7	4790868	271722
EXP-BH03	96.3	4790840	271717
EXP-BH04	90.2	4790801	271721
EXP-BH05	88.7	4790765	271738
EXP-BH14	98.6	4790869	271713

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.

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in the report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen. Cond.

REVISIONS

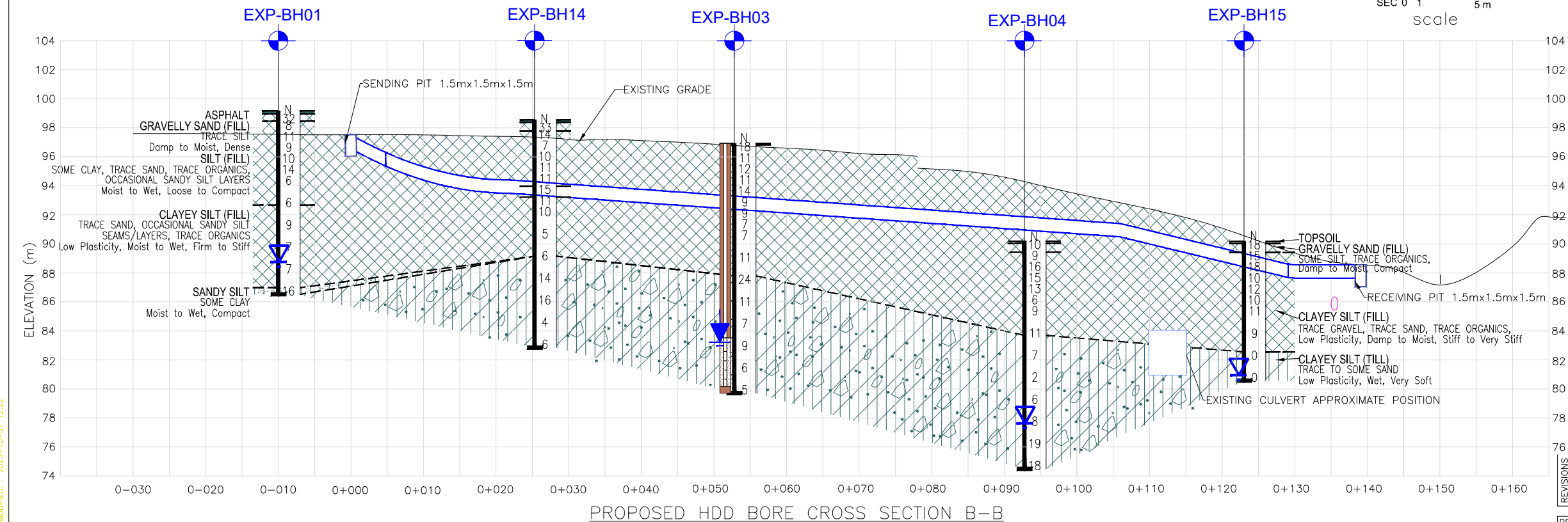
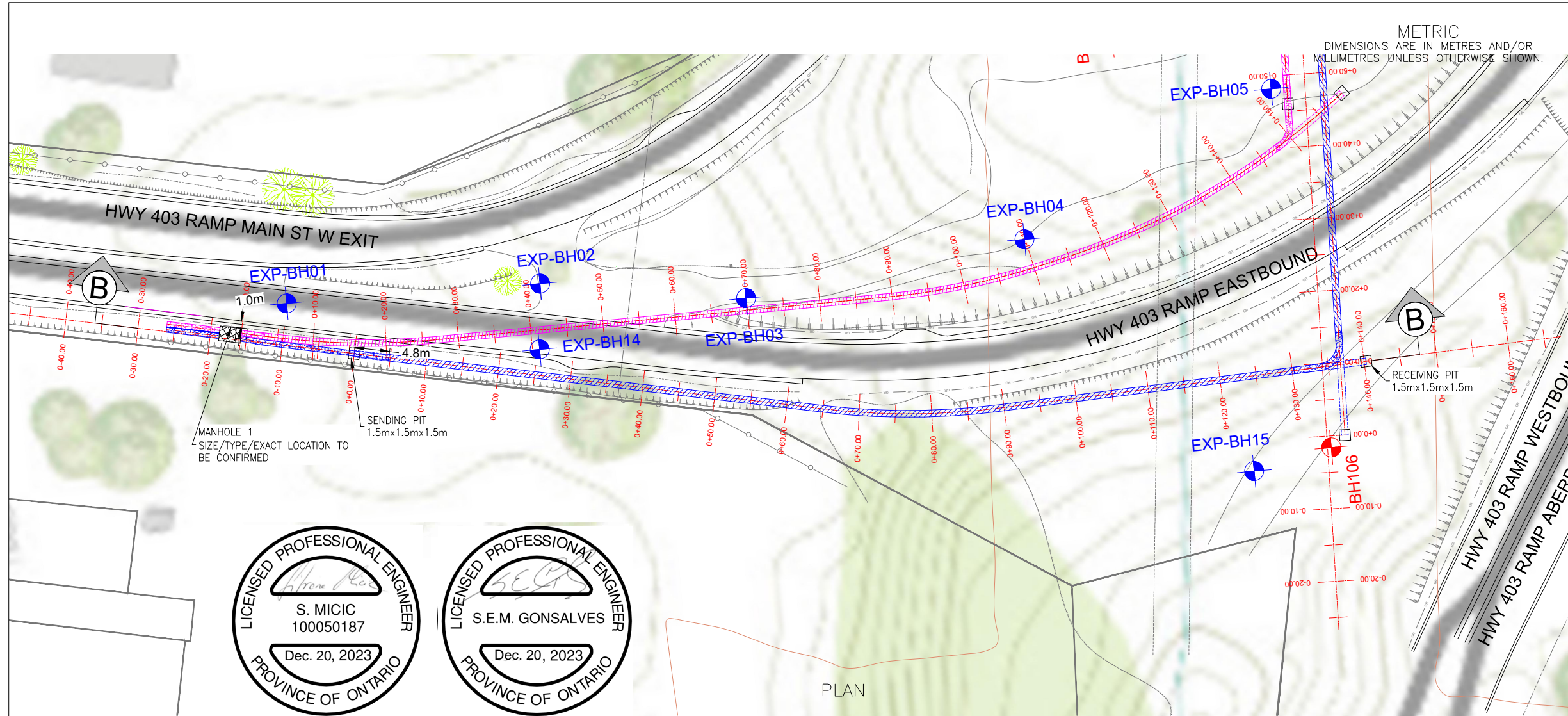
NO	DATE	BY	DESCRIPTION

SUBMISSION FOR MTO REVIEW

PROJECT No.	ADM-23006096-A0	GEOCRES No.	30M05-363
SUBM'D SH	CHKD. SM	DATE	Dec 20, 2023 SITE.
DRAWN SH	CHKD. TC	APPRD SG	DWG 01



FILE NAME: I:\2003-Brampton\Proposals\Projects\International\NBM\_Engineering - Proposals\Hamilton-H403 HDD Tunnel- borehole location plan & profile.dwg  
MODIFIED: 2023-10-31 12:22



CONT No. —  
ASSIG No. —  
GWP No. —

Trenchless Installation of Hwy 403 & Aberdeen Ave.  
Underground Crossing for Alectra Utilities, Hamilton, ON  
Latitude: 43.257274°; Longitude: -79.907396

SHEET  
2

**EXP SERVICES INC.**

KEY PLAN  
N.T.S.

LEGEND

Borehole Location

Previous Borehole Location

Water Level Upon Completion of Drilling  
( W. L. NOT STABILIZED )

N  
Blows/0.3m (Std. Pen. Test, 475 J/blow)

Water Level in Piezometer (most recent)  
(W. L. STABILIZED)

Piezometer

Artesian

SOIL STRATA SYMBOLS

TOPSOIL

CLAYEY SILT (TILL)

ASPHALT

SAND AND GRAVEL

FILL

CLAYEY SILT (RESIDUAL SOIL)

SANDY SILT

BEDROCK

BOREHOLE COORDINATES/ NAD 83/ MTM ON-10

BH No.	ELEV.	NORTHING	EASTING
EXP-BH01	99.2	4790903	271723
EXP-BH03	96.3	4790840	271717
EXP-BH04	90.2	4790801	271721
EXP-BH14	98.6	4790869	271713
EXP-BH15	90.2	4790773	271686

NOTES

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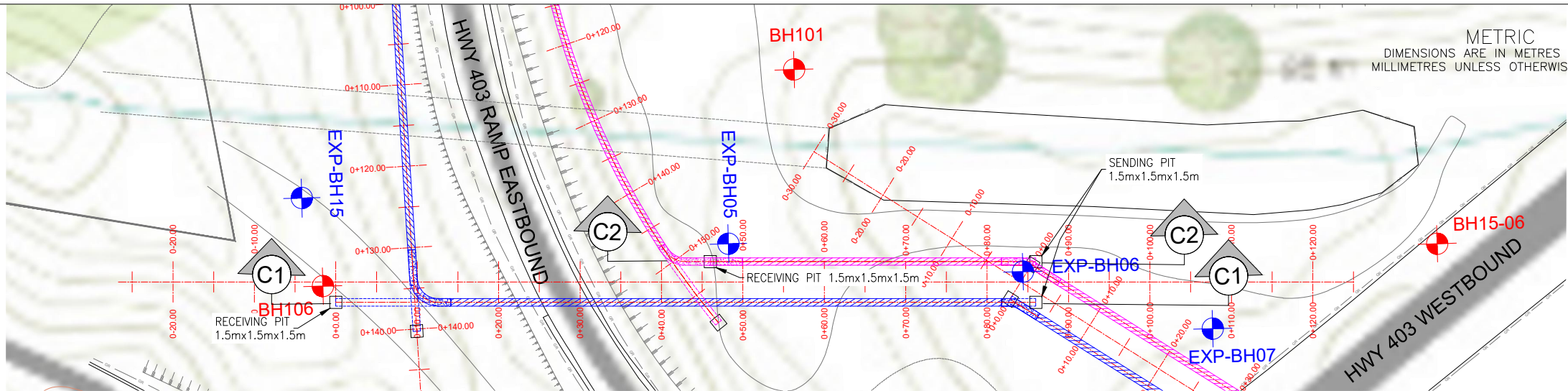
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REVISIONS

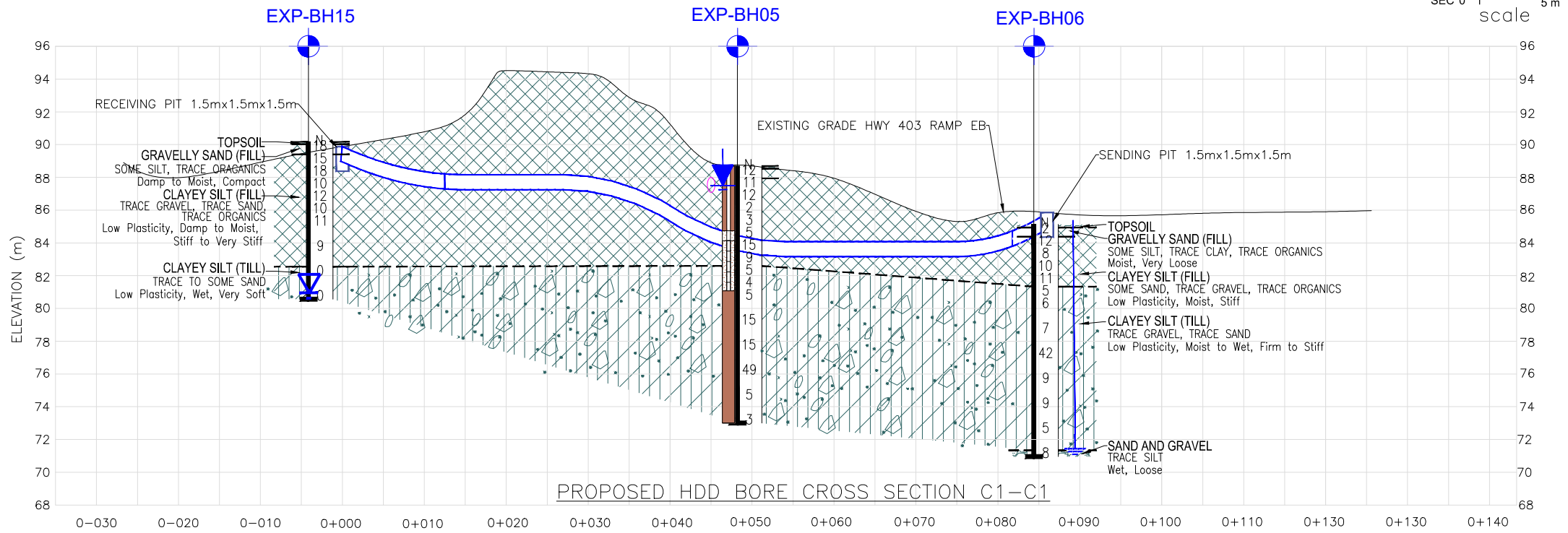
NO	DATE	BY	DESCRIPTION

PROJECT No.	ADM-23006096-A0	GEOCRES No.	30M05-363
SUBM'D SH	CHKD. SM	DATE	Dec 20, 2023
DRAWN SH	CHKD. TC	APPRD SG	SITE- DWG 02

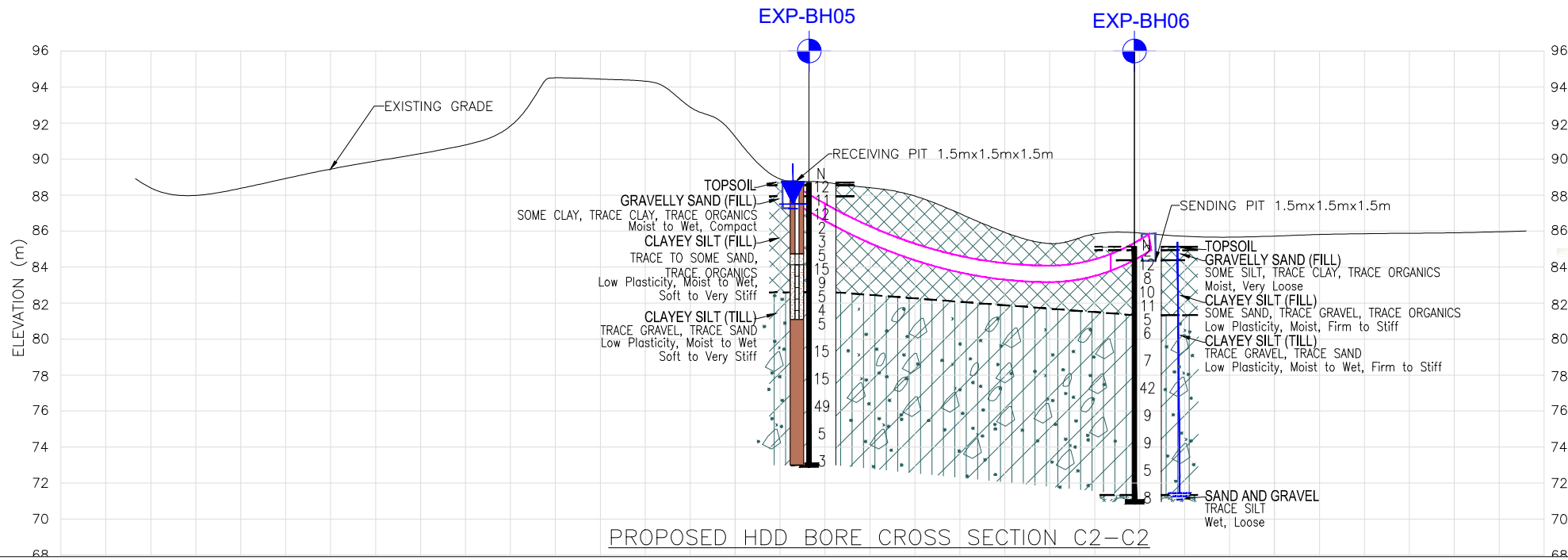




PLAN



PROPOSED HDD BORE CROSS SECTION C1-C1



PROPOSED HDD BORE CROSS SECTION C2-C2



CONT No.	—
ASSIG No.	
GWP No.	
Trenchless Installation of Hwy 403 & Aberdeen Ave. Underground Crossing for Alectra Utilities, Hamilton, ON Latitude: 43.257274°; Longitude: -79.907396	
BOREHOLE LOCATION PLAN & SOIL STRATA	
SHEET 3	



KEY PLAN  
N.T.S.

LEGEND

- Borehole Location
- Previous Borehole Location
- Water Level Upon Completion of Drilling ( W. L. NOT STABILIZED)
- N Blows/0.3m (Std. Pen. Test, 475 J/blow)
- Water Level in Piezometer (most recent) (W. L. STABILIZED)
- Piezometer
- Artesian

SOIL STRATA SYMBOLS

TOPSOIL	CLAYEY SILT (TILL)
ASPHALT	SAND AND GRAVEL
FILL	CLAYEY SILT (RESIDUAL SOIL)
SANDY SILT	BEDROCK

BOREHOLE COORDINATES/ NAD 83/ MTM ON-10

BH No.	ELEV.	NORTHING	EASTING
EXP-BH05	88.7	4790765	271738
EXP-BH06	81.1	4790760	271774
EXP-BH15	90.2	4790773	271686

NOTES

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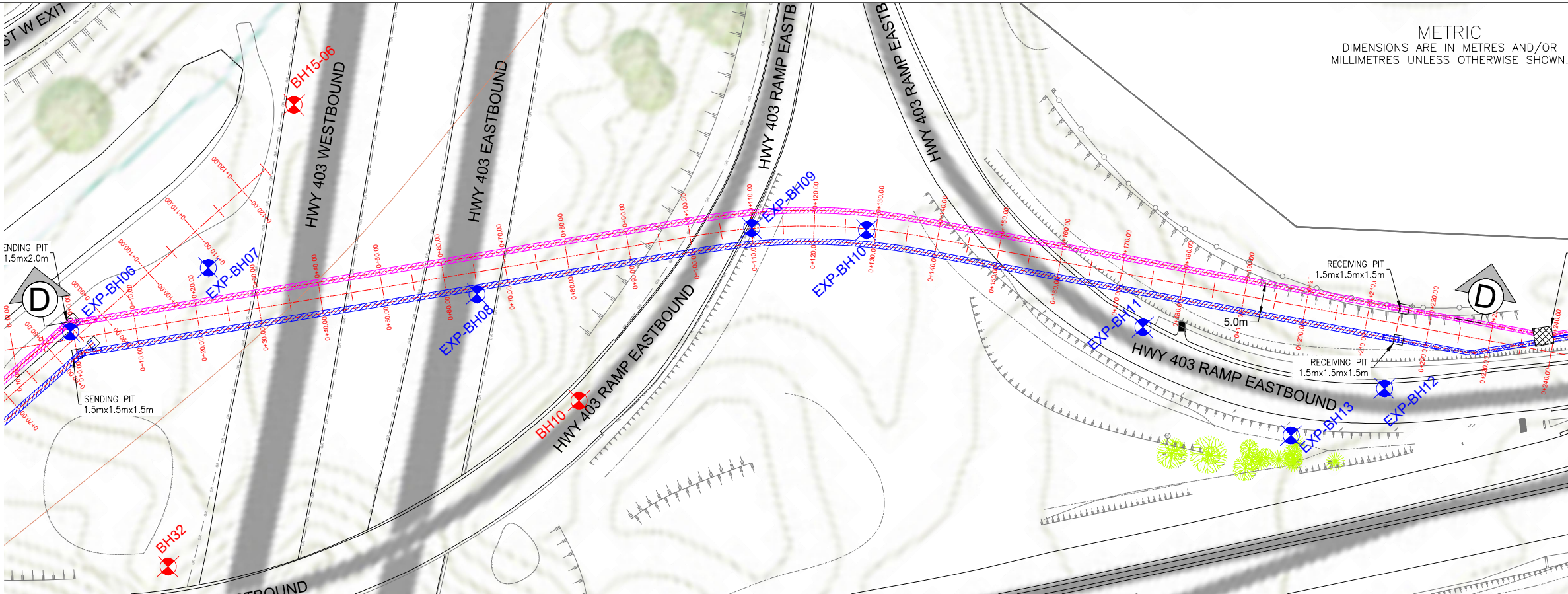
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

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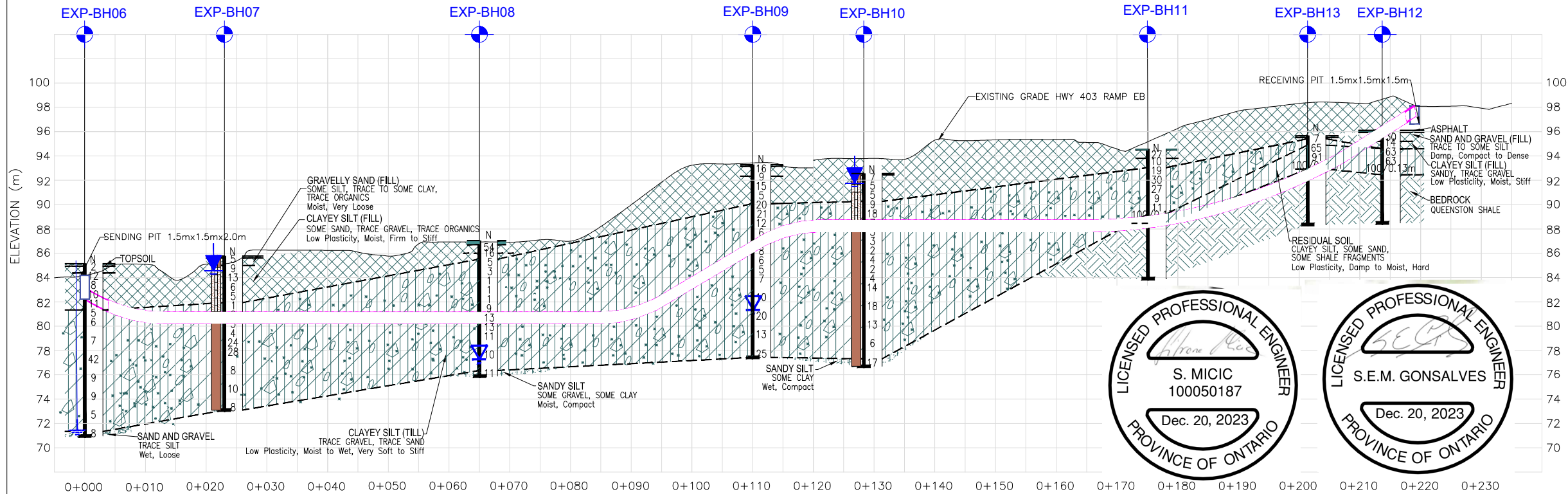
SUBMISSION FOR MTO REVIEW			
NO	DATE	BY	DESCRIPTION
PROJECT No.	ADM-23006096-A0	GEOCREs No. 30M05-363	
SUBM'D SH	CHKD. SM	DATE Dec 20, 2023	SITE-
DRAWN SH	CHKD. TC	APPRD SG	DWG 03



FILE NAME: I:\2003-Brampton\Proposals\Projects\International\NBM\_Engineering - Proposals\Hamilton-H403 HDD Tunnel\Working drawing\Hamilton-H403 HDD Tunnel- borehole location plan & profile.dwg  
MODIFIED: 2023-10-31 12:22




PLAN



PROPOSED HDD BORE CROSS SECTION D-D

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

CONT No.	—	
ASSIG No.		
GWP No.		
Trenchless Installation of Hwy 403 & Aberdeen Ave. Underground Crossing for Alectra Utilities, Hamilton, ON Latitude: 43.257274°; Longitude: -79.907396		SHEET
BOREHOLE LOCATION PLAN & SOIL STRATA		4










EXP SERVICES INC.



KEY PLAN  
N.T.S.

LEGEND

-  Borehole Location
-  Previous Borehole Location
-  Water Level Upon Completion of Drilling  
( W. L. NOT STABILIZED )
-  Blows/0.3m (Std. Pen. Test, 475 J/blow)
-  Water Level in Piezometer (most recent)  
(W. L. STABILIZED)
-  Piezometer
-  Artesian

SOIL STRATA SYMBOLS

-  TOPSOIL
-  SAND AND GRAVEL (FILL)
-  CLAYEY SILT (TILL)
-  SAND AND GRAVEL
-  CLAYEY SILT (RESIDUAL SOIL)
-  SANDY SILT
-  BEDROCK

BOREHOLE COORDINATES/ NAD 83/ MTM ON-10

BH No.	ELEV.	NORTHING	EASTING
EXP-BH06	81.1	4790760	271774
EXP-BH07	85.8	4790752	271797
EXP-BH08	87.2	4790719	271825
EXP-BH09	93.3	4790696	271864
EXP-BH10	92.6	4790683	271877
EXP-BH11	94.6	4790641	271898
EXP-BH12	96.1	4790607	271919
EXP-BH13	95.7	4790612	271903

NOTES

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SUBMISSION FOR MTO REVIEW			
NO	DATE	BY	DESCRIPTION
PROJECT No.	ADM-23006096-A0	GEOCREs No. 30M05-363	
SUBM'D SH	CHKD. SM	DATE Dec 20, 2023	SITE-
DRAWN SH	CHKD. TC	APPRD SG	DWG 04

Appendix D –  
EXP Borehole Logs (2023)

# Explanation of Terms Used on Borehole Records

## SOIL DESCRIPTION

Terminology describing common soil genesis:

*Topsoil:* mixture of soil and humus capable of supporting good vegetative growth.

*Peat:* fibrous fragments of visible and invisible decayed organic matter.

*Fill:* where fill is designated on the borehole log it is defined as indicated by the sample recovered during the boring process. The reader is cautioned that fills are heterogeneous in nature and variable in density or degree of compaction. The borehole description may therefore not be applicable as a general description of site fill materials. All fills should be expected to contain obstruction such as wood, large concrete pieces or subsurface basements, floors, tanks, etc.; none of these may have been encountered in the boreholes. Since boreholes cannot accurately define the contents of the fill, test pits are recommended to provide supplementary information. Despite the use of test pits, the heterogeneous nature of fill will leave some ambiguity as to the exact composition of the fill. Most fills contain pockets, seams, or layers of organically contaminated soil. This organic material can result in the generation of methane gas and/or significant ongoing and future settlements. Fill at this site may have been monitored for the presence of methane gas and, if so, the results are given on the borehole logs. The monitoring process does not indicate the volume of gas that can be potentially generated nor does it pinpoint the source of the gas. These readings are to advise of the presence of gas only, and a detailed study is recommended for sites where any explosive gas/methane is detected. Some fill material may be contaminated by toxic/hazardous waste that renders it unacceptable for deposition in any but designated land fill sites; unless specifically stated the fill on this site has not been tested for contaminants that may be considered toxic or hazardous. This testing and a potential hazard study can be undertaken if requested. In most residential/commercial areas undergoing reconstruction, buried oil tanks are common and are generally not detected in a conventional geotechnical site investigation.

*Till:* the term till on the borehole logs indicates that the material originates from a geological process associated with glaciation. Because of this geological process the till must be considered heterogeneous in composition and as such may contain pockets and/or seams of material such as sand, gravel, silt or clay. Till often contains cobbles (60 to 200 mm) or boulders (over 200 mm). Contractors may therefore encounter cobbles and boulders during excavation, even if they are not indicated by the borings. It should be appreciated that normal sampling equipment cannot differentiate the size or type of any obstruction. Because of the horizontal and vertical variability of till, the sample description may be applicable to a very limited zone; caution is therefore essential when dealing with sensitive excavations or dewatering programs in till materials.

Terminology describing soil structure:

*Desiccated:* having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.

*Stratified:* alternating layers of varying material or color with the layers greater than 6 mm thick.

*Laminated:* alternating layers of varying material or color with the layers less than 6 mm thick.

*Fissured:* material breaks along plane of fracture.

*Varved:* composed of regular alternating layers of silt and clay.

*Slickensided:* fracture planes appear polished or glossy, sometimes striated.

*Blocky:* cohesive soil that can be broken down into small angular lumps which resist further breakdown.



*Lensed:* inclusion of small pockets of different soil, such as small lenses of sand scattered through a mass of clay; not thickness.

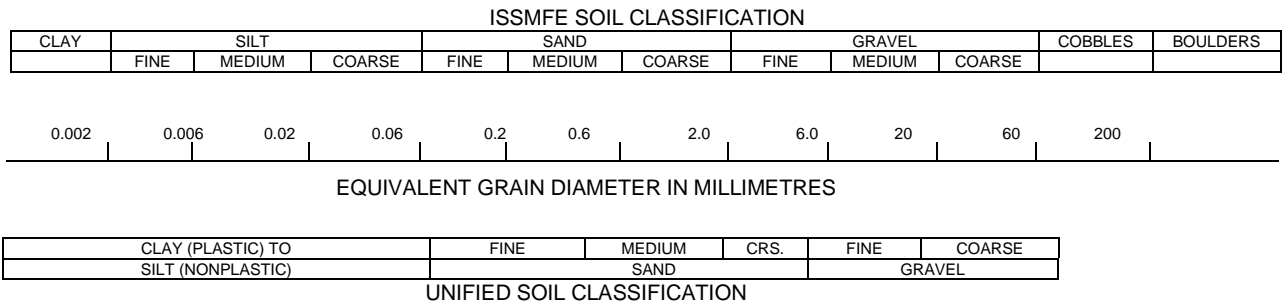
*Seam:* a thin, confined layer of soil having different particle size, texture, or color from materials above and below.

*Homogeneous:* same color and appearance throughout.

*Well Graded:* having wide range in grain sized and substantial amounts of all predominantly on grain size.

*Uniformly Graded:* predominantly on grain size.

All soil sample descriptions included in this report follow generally the ASTM D2487-11 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) with some modification to reflect current MTO practices. The system divides soils into three major categories: (1) coarse grained, (2) fine-grained, and (3) highly organic. The soil is then subdivided based on either gradation or plasticity characteristics. The system provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification. The classification excludes particles larger than 76 mm. Please note that, with the exception of those samples where a grain size analysis has been made, all samples are classified visually in accordance with ASTM D2488-09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). Visual classification is not sufficiently accurate to provide exact grain sizing or precise differentiation between size classification systems. Others may use different classification systems; one such system is the ISSMFE Soil Classification.



Terminology describing materials outside the USCS, (e.g. particles larger than 76 mm, visible organic matter, construction debris) is based upon the proportion of these materials present and as described below in accordance with Canadian Foundation Engineering Manual (CFEM):

Table a: Percent or Proportion of Soil

Term	Description	Criteria
"trace"	trace gravel, trace sand, etc.	1% - 10%
"some"	some gravel, some sand, etc.	10% - 20%
Adjective	gravelly, sandy, silty and clayey	20% - 35%
"and"	and gravel, and sand, etc.	>35%
Noun	gravel, sand, silt, clay	>35% and main fraction

The standard terminology to describe cohesionless soils includes the compactness as determined by the Standard Penetration Test 'N' value:

Table b: Apparent Density of Cohesionless Soil

	'N' Value (blows/0.3 m)
Very Loose	N<5
Loose	5≤N<10
Compact	10≤N<30
Dense	30≤N<50
Very Dense	50≤N

The standard terminology to describe cohesive soils includes consistency, which is based on undrained shear strength as measured by insitu vane tests, penetrometer tests, unconfined compression tests or similar field and laboratory analysis, Standard Penetration Test 'N' values can also be used to provide an approximate indication of the consistency and shear strength of fine grained, cohesive soils:

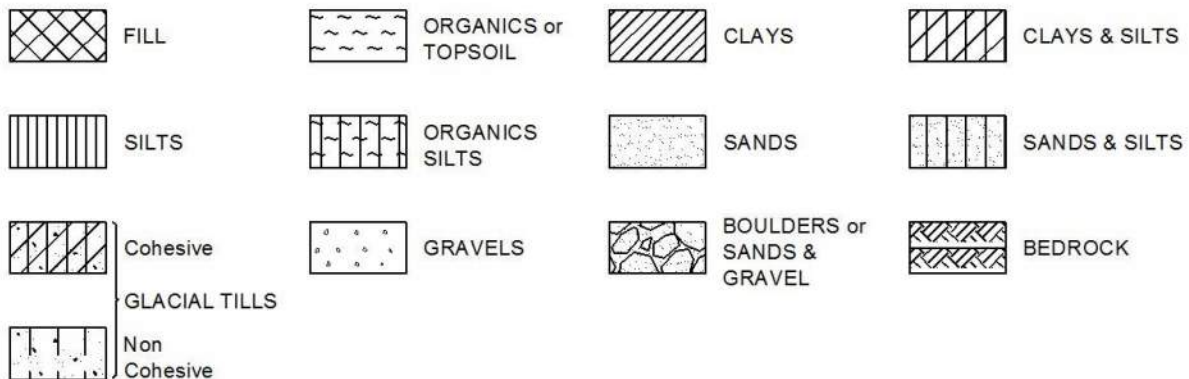
Table c: Consistency of Cohesive Soil

Consistency	Vane Shear Measurement (kPa)	'N' Value
Very Soft	<12.5	<2
Soft	12.5-25	2-4
Firm	25-50	4-8
Stiff	50-100	8-15
Very Stiff	100-200	15-30
Hard	>200	>30

Note: 'N' Value - The Standard Penetration Test records the number of blows of a 140 pound (64kg) hammer falling 30 inches (760mm), required to drive a 2 inch (50.8mm) O.D. split spoon sampler 1 foot (305mm). For split spoon samples where full penetration is not achieved, the number of blows is reported over the sampler penetration in meters (e.g. 50/0.15).

## STRATA PLOT

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols:



## WATER LEVEL MEASUREMENT



## ABBREVIATIONS AND SYMBOLS

### FIELD SAMPLING

SS	Split spoon sample (obtained from the Standard Penetration Test)
WS	Wash sample
BS	Bulk sample
TW	Thin wall sample or Shelby tube
PS	Piston sample
AS	Auger sample
VT	Vane test
GS	Grab sample
HQ, NQ, etc.	Rock core samples obtained with the use of standard size diamond drilling bits

### STRESS AND STRAIN

$u_w$	kPa	Pore water pressure
$r_u$	1	Pore pressure ratio
$\sigma$	kPa	Total normal stress
$\sigma'$	kPa	Effective normal stress
$\tau$	kPa	Shear stress
$\sigma_1, \sigma_2, \sigma_3$	kPa	Principal stresses
$\varepsilon$	%	Linear strain
$\varepsilon_1, \varepsilon_2, \varepsilon_3$	%	Principal strains
E	kPa	Modulus of linear deformation
G	kPa	Modulus of shear deformation
$\mu$	1	Coefficient of friction

### MECHANICAL PROPERTIES OF SOIL

$m_v$	kPa <sup>-1</sup>	Coefficient of volume change
$c_c$	1	Compression index
$c_s$	1	Swelling index
$c_r$	1	Recompression index
$c_v$	m <sup>2</sup> /s	Coefficient of consolidation
H	m	Drainage path
$T_v$	1	Time factor
U	%	Degree of consolidation
$\sigma'_{v0}$	kPa	Effective overburden pressure
$\sigma'_p$	kPa	Preconsolidation pressure
$\tau_f$	kPa	Shear strength
$c'$	kPa	Effective cohesion intercept
$\phi'$	—°	Effective angle of internal friction
$c_u$	kPa	Apparent cohesion intercept
$\phi_u$	—°	Apparent angle of internal friction
$\tau_R$	kPa	Residual shear strength
$\tau_r$	kPa	Remoulded shear strength
$S_t$	1	Sensitivity = $c_u/\tau_r$

### PHYSICAL PROPERTIES OF SOIL

$P_s$	kg/m <sup>3</sup>	Density of solid particles
$\gamma_s$	kN/m <sup>3</sup>	Unit weight of solid particles
$\rho_w$	kg/m <sup>3</sup>	Density of water
$\gamma_w$	kN/m <sup>3</sup>	Unit weight of water
$\rho$	kg/m <sup>3</sup>	Density of soil
$\gamma$	kN/m <sup>3</sup>	Unit weight of soil
$\rho_d$	kg/m <sup>3</sup>	Density of dry soil
$\gamma_d$	kN/m <sup>3</sup>	Unit weight of dry soil
$\rho_{sat}$	kg/m <sup>3</sup>	Density of saturated soil
$\gamma_{sat}$	kN/m <sup>3</sup>	Unit weight of saturated soil
$\rho'$	kg/m <sup>3</sup>	Density of submerged soil
$\gamma'$	kN/m <sup>3</sup>	Unit weight of submerged soil
$e$	1, %	Void ratio
$n$	1, %	Porosity
$w$	1, %	Water content
$S_r$	%	Degree of saturation
$W_L$	%	Liquid limit
$W_P$	%	Plastic limit
$W_s$	%	Shrinkage limit
$I_p$	%	Plasticity index = $(W_L - W_P)$
$I_L$	%	Liquidity index = $(W - W_P)/I_p$
$I_C$	%	Consistency index = $(W_L - W)/I_p$
$e_{max}$	1, %	Void ratio in loosest state
$e_{min}$	1, %	Void ratio in densest state
$I_D$	1	Density index = $(e_{max} - e)/(e_{max} - e_{min})$
D	mm	Grain diameter
$D_n$	mm	N percent - diameter
$C_u$	1	Uniformity coefficient
h	m	Hydraulic head or potential
q	m <sup>3</sup> /s	Rate of discharge
v	m/s	Discharge velocity
i	1	Hydraulic gradient
k	m/s	Hydraulic conductivity
j	kN/m <sup>3</sup>	Seepage force

Brampton, Ontario

## RECORD OF BOREHOLE No EXP-BH01

1 OF 2

METRIC

W.P. \_\_\_\_\_ LOCATION N4790903, E271723, NAD83 MTM Zone 10 ORIGINATED BY CA  
 DIST Hamilton HWY 403 BOREHOLE TYPE Continuous Flight HSA COMPILED BY IL  
 DATUM Geodetic DATE 2023.09.06 - 2023.09.06 LATITUDE 43.257274 LONGITUDE -79.907396 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
99.2	ASPHALT, ~ 215 mm						99	20	40	60	80	100					
0.0																	
99.0																	
0.2	GRAVELLY SAND (FILL), trace silt, brown, damp to moist, dense		SS1	SS	32		98										0 3 86 11 non-plastic
98.5																	
0.7																	
	SILT (FILL), some clay, trace sand, mottled dark brown to brown, moist to wet, loose to compact - trace organics at ~ 0.8 m depth		SS2	SS	8		97										
	Proposed HDD Tunneling Alignment (Section A-A)		SS3	SS	11		96										
			SS4	SS	9		95										
	- occasional sandy silt layers at ~ 4.6 m depth		SS5	SS	10		94										Measured vane shear strength greater than 145 kPa at 5.3 m
			SS6	SS	14		93										
			SS7	SS	6		92										Measured vane shear strength greater than 145 kPa at 6.9 m
	CLAYEY SILT (FILL), trace sand, brownish grey, low plasticity, moist to wet, firm to very stiff			VANE			91										
			SS8	SS	6		90										
				VANE													
			SS9	SS	9												0 6 71 23
			SS10	SS	7												Measured vane shear strength greater than 145 kPa at 9.9 m
				VANE													

Continued Next Page

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

ONTARIO MTO H403 HDD TUNNEL LAB RESULTS\_NEW\_DM.GPJ ONTARIO MTO.GDT 10/30/23

Brampton, Ontario

# RECORD OF BOREHOLE No EXP-BH01

2 OF 2

METRIC

W.P. \_\_\_\_\_ LOCATION N4790903, E271723, NAD83 MTM Zone 10 ORIGINATED BY CA  
 DIST Hamilton HWY 403 BOREHOLE TYPE Continuous Flight HSA COMPILED BY IL  
 DATUM Geodetic DATE 2023.09.06 - 2023.09.06 LATITUDE 43.257274 LONGITUDE -79.907396 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT  w <sub>p</sub>	NATURAL MOISTURE CONTENT  w	LIQUID LIMIT  w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES										
SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL P. PENETROMETER															
							20 40 60 80 100								
							20 40 60 80 100								
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Brampton, Ontario

## 1 OF 2

**METRIC**

W.P.	LOCATION		N4790868, E271722, NAD83 MTM Zone 10			ORIGINATED BY	CA				
DIST	Hamilton	HWY	403	BOREHOLE TYPE			Continuous Flight HSA	COMPILED BY	IL		
DATUM	Geodetic			DATE	2023.09.01 - 2023.09.01	LATITUDE	43.256957	LONGITUDE	-79.9074	CHECKED BY	SM

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

ONTARIO MTO H403 HDD TUNNEL LAB RESULTS NEW DM.GPJ ONTARIO MTO.GDT 10/30/23

Brampton, Ontario

## 2 OF 2

METRIC

W.P.	LOCATION		N4790868, E271722, NAD83 MTM Zone 10			ORIGINATED BY	CA				
DIST	Hamilton	HWY	403	BOREHOLE TYPE			Continuous Flight HSA	COMPILED BY	IL		
DATUM	Geodetic		DATE	2023.09.01 - 2023.09.01		LATITUDE	43.256957	LONGITUDE	-79.9074	CHECKED BY	SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE					W <sub>P</sub>			W	W <sub>L</sub>
								● QUICK TRIAXIAL & P. PENETROMETER									
							20	40	60	80	100	20	40	60			
87.0	CLAYEY SILT (FILL), trace sand, trace organics, brown to brownish grey, low plasticity, moist to wet, firm to very stiff (continued)					▽									0 2 58 40		
10.7	CLAYEY SILT (TILL), trace sand, brownish grey, low plasticity, moist to wet, firm to very stiff  - grey below ~ 11.1 m depth		SS12	SS	26												
			SS13	SS	10												
			SS14	SS	7												
				VANE													
															Measured vane shear strength of 123 kPa at 14.5 m		
			SS15	SS	9												
82.0							82										
15.7	BOREHOLE TERMINATED AT ~ 15.7 m DEPTH  Notes: 1. Groundwater measured in open hole at 14.6 m below ground surface upon completion of drilling. 2. Borehole grouted upon completion.																

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

ONTARIO MTO H403 HDD TUNNEL LAB RESULTS NEW\_DM.GPJ ONTARIO MTO.GDT 10/30/23

Brampton, Ontario

## RECORD OF BOREHOLE No EXP-BH03

1 OF 2

METRIC

W.P. \_\_\_\_\_ LOCATION N4790840, E271717, NAD83 MTM Zone 10 ORIGINATED BY CA  
 DIST Hamilton HWY 403 BOREHOLE TYPE Continuous Flight HSA COMPILED BY IL  
 DATUM Geodetic DATE 2023.08.31 - 2023.09.01 LATITUDE 43.256708 LONGITUDE -79.907469 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL P. PENETROMETER												
96.9								20	40	60	80	100								
96.8	GRANULAR (FILL), ~ 100 mm CLAYEY SILT (FILL), trace gravel, trace sand, brown, low plasticity, moist to wet, firm to very stiff		SS1	SS	18															
96.7																				
			SS2	SS	11															
			SS3	SS	12															
			SS4	SS	11												2 1 73 24			
			SS5	SS	14															
	Proposed HDD Tunneling Alignment (Section B-B)		SS6	SS	9												Corrosivity sample			
	Proposed HDD Tunneling Alignment (Section A-A)		SS7	SS	9															
			SS8	SS	7												0 7 68 25			
				VANE													Measured vane shear strength of 123 kPa at 6.0 m			
			SS9	SS	7															
				VANE													Measured vane shear strength greater than 145 kPa at 6.9 m			
			SS10	SS	11															
87.8																				
9.1	CLAYEY SILT (TILL), trace gravel, trace sand, grey, low plasticity, moist to wet, firm to very stiff		SS11	SS	24												1 9 50 40			

Continued Next Page

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

ONTARIO MTO H403 HDD TUNNEL LAB RESULTS\_NEW\_DM.GPJ ONTARIO MTO.GDT 10/30/23

Brampton, Ontario

## RECORD OF BOREHOLE No EXP-BH03

2 OF 2

METRIC

W.P. \_\_\_\_\_ LOCATION N4790840, E271717, NAD83 MTM Zone 10 ORIGINATED BY CA  
 DIST Hamilton HWY 403 BOREHOLE TYPE Continuous Flight HSA COMPILED BY IL  
 DATUM Geodetic DATE 2023.08.31 - 2023.09.01 LATITUDE 43.256708 LONGITUDE -79.907469 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								20   40   60   80   100		W <sub>P</sub> W                      W <sub>L</sub>				
								○ UNCONFINED + FIELD VANE						
								● QUICK TRIAXIAL P. PENETROMETER						
								20   40   60   80   100		20   40   60				
												</		

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

ONTARIO MTO: H403 HDD TUNNEL LAB RESULTS\_NEW\_DM.GPJ ONTARIO MTO.GDT 10/30/23

## 1 OF 2

METRIC

DATUM	Geodetic	DATE	2023.08.31 - 2023.08.31	LATITUDE	43.256354	LONGITUDE	-79.907406	CHECKED BY	SM
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+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3%</sup> STRAIN AT FAILURE

## 2 OF 2

METRIC

W.P.	LOCATION			N4790801, E271721, NAD83 MTM Zone 10		ORIGINATED BY	CA				
DIST	Hamilton	HWY	403	BOREHOLE TYPE		Continuous Flight HSA	COMPILED BY	IL			
DATUM	Geodetic			DATE	2023.08.31 - 2023.08.31	LATITUDE	43.256354	LONGITUDE	-79.907406	CHECKED BY	SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL & P. PENETROMETER										
	CLAYEY SILT (TILL), trace gravel, trace sand, grey, low plasticity, moist to wet, soft to very stiff (continued)						80								3 7 47 43  Measured vane shear strength of 130 kPa at 13.0 m			
			SS11	SS	6													
				VANE					79									
			SS12	SS	8				78									
				VANE														
			SS13	SS	19													
											</							

ONTARIO MTO H403 HDD TUNNEL LAB RESULTS NEW DM.GPJ ONTARIO MTO.GDT 10/30/23

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

Brampton, Ontario

1 OF 2

METRIC

W.P.	LOCATION			N4790765, E271738, NAD83 MTM Zone 10		ORIGINATED BY	CA				
DIST	Hamilton	HWY	403	BOREHOLE TYPE		Continuous Flight HSA	COMPILED BY	IL			
DATUM	Geodetic			DATE	2023.08.24 - 2023.08.25	LATITUDE	43.256027	LONGITUDE	-79.907199	CHECKED BY	SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL & P. PENETROMETER							
								20 40 60 80 100							20 40 60
								20 40 60 80 100							
88.7															
88.9	TOPSOIL, ~ 150 mm														
0.2	GRAVELLY SAND (FILL), some silt, trace clay, trace organics, dark brown, moist to wet, compact		SS1	SS	12										
87.9															
0.8	CLAYEY SILT (FILL), trace to some sand, trace organics, mottled brown and grey, low plasticity, moist to wet, soft to very stiff		SS2	SS	11										
	Proposed HDD Tunneling Alignment (Section A-A)		SS3	SS	12										
			SS4	SS	2									0 4 71 25	
				VANE											
			SS5	SS	3										
				VANE											
	- mottled brown, grey, red, and black at ~ 3.8 m depth		SS6	SS	5									Corrosivity sample	
				VANE											
	Proposed HDD Tunneling Alignment (Section C1-C1)		SS7	SS	15									Measured vane shear strength greater than 145 kPa at 4.6 m 0 16 56 28	
			SS8	SS	9										
82.6															
6.1	CLAYEY SILT (TILL), trace gravel, trace sand, grey, low plasticity, moist to wet, soft to very stiff		SS9	SS	5										
				VANE											
			SS10	SS	4									1 9 45 45	
				VANE											
			SS11	SS	5										
				VANE											
			SS12	SS	15										
						</									

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

ONTARIO MTO H403 HDD TUNNEL LAB RESULTS NEW\_DM.GPJ ONTARIO MTO.GDT 10/30/23

Brampton, Ontario

## RECORD OF BOREHOLE No EXP-BH05

2 OF 2

METRIC

W.P. \_\_\_\_\_ LOCATION N4790765, E271738, NAD83 MTM Zone 10 ORIGINATED BY CA  
 DIST Hamilton HWY 403 BOREHOLE TYPE Continuous Flight HSA COMPILED BY IL  
 DATUM Geodetic DATE 2023.08.24 - 2023.08.25 LATITUDE 43.256027 LONGITUDE -79.907199 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20	40	60	80	100					
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL P. PENETROMETER									
								20	40	60	80	100					
								WATER CONTENT (%)									
								20	40	60	80	100					
								PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>							
	CLAYEY SILT (TILL), trace gravel, trace sand, grey, low plasticity, moist to wet, soft to very stiff (continued)																
			SS13	SS	15		78							○			
							77										
	- hard at ~ 12.2 m depth		SS14	SS	49		76							○			
			SS15	SS	5		75							○			
				VANE										○			
							74										
			SS16	SS	3									○			
73.0							73										
15.7	BOREHOLE TERMINATED AT ~ 15.7 m DEPTH																
	Notes: 1. Groundwater measured in open hole the following day at 2.7 m below ground surface upon completion of drilling. 2. 40 mm inside diameter piezometer installed upon completion screened from approximately 4.6 m to 7.5 m below ground surface. 3. Water level measured in piezometer below ground surface:  Date      Depth (m)      Elev. (m) 06/09/23      1.2      87.5																

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

ONTARIO MTO H403 HDD TUNNEL LAB RESULTS\_NEW\_DM.GPJ ONTARIO MTO.GDT 10/30/23



Brampton, Ontario

## 1 OF 2

METRIC

W.P.	LOCATION			N4790760, E271774, NAD83 MTM Zone 10		ORIGINATED BY	CA				
DIST	Hamilton	HWY	403	BOREHOLE TYPE		Continuous Flight HSA	COMPILED BY	IL			
DATUM	Geodetic			DATE	2023.08.22 - 2023.08.23	LATITUDE	43.25599	LONGITUDE	-79.906755	CHECKED BY	SM

[illegible]

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

ONTARIO MTO H403 HDD TUNNEL LAB RESULTS NEW DM.GPJ ONTARIO MTO.GDT 10/30/23

Brampton, Ontario

## 2 OF 2

METRIC

W.P.	LOCATION		N4790760, E271774, NAD83 MTM Zone 10			ORIGINATED BY	CA			
DIST	Hamilton	HWY	403	BOREHOLE TYPE			Continuous Flight HSA	COMPILED BY	IL	
DATUM	Geodetic		DATE	2023.08.22 - 2023.08.23	LATITUDE	43.25599	LONGITUDE	-79.906755	CHECKED BY	SM

[illegible]

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

ONTARIO MTO H403 HDD TUNNEL LAB RESULTS NEW DM.GPJ ONTARIO MTO.GDT 10/30/23

Brampton, Ontario

## RECORD OF BOREHOLE No EXP-BH07

1 OF 2

METRIC

W.P. \_\_\_\_\_ LOCATION N4790752, E271797, NAD83 MTM Zone 10 ORIGINATED BY CA  
 DIST Hamilton HWY 403 BOREHOLE TYPE Continuous Flight HSA COMPILED BY IL  
 DATUM Geodetic DATE 2023.08.24 - 2023.08.24 LATITUDE 43.255913 LONGITUDE -79.906471 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>P</sub> W   W <sub>L</sub>				
85.8								20	40	60	80	100		
85.0	TOPSOIL, ~ 150 mm		SS1	SS	5									
85.0	GRAVELLY SAND (FILL), some silt, trace to some clay, trace organics, dark brown, wet, loose													
85.0														
0.8	CLAYEY SILT (FILL), some sand, trace gravel, trace organics, mottled brown, grey, and red, low plasticity, moist to wet, firm to stiff		SS2	SS	9									
			SS3	SS	13									
			SS4	SS	6									
				VANE										
			SS5	SS	5									
				VANE										
81.9	CLAYEY SILT (TILL), trace gravel, trace sand, grey, low plasticity, moist to wet, very soft to stiff		SS6	SS	1									
3.8				VANE										
	Proposed HDD Tunneling Alignment (Section D-D)		SS7	SS	2									
				VANE										
			SS8	SS	3									
				VANE										
			SS9	SS	4									
				VANE										
			SS10	SS	24									
			SS11	SS	28									
			SS12	SS	8									

Proposed HDD  
Tunneling Alignment  
(Section D-D)

- firm to very stiff below ~ 6.6 m  
depth

Continued Next Page

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

ONTARIO MTO H403 HDD TUNNEL LAB RESULTS\_NEW\_DM.GPJ ONTARIO MTO.GDT 10/30/23

METRIC

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

ONTARIO MTO H403 HDD TUNNEL LAB RESULTS NEW\_DM.GPJ ONTARIO MTO.GDT 10/30/23

Brampton, Ontario

## 1 OF 2

**METRIC**

W.P. _____		LOCATION <u>N4790719, E271825, NAD83 MTM Zone 10</u>			ORIGINATED BY <u>CA</u>	
DIST <u>Hamilton</u>	HWY <u>403</u>	BOREHOLE TYPE <u>Continuous Flight HSA</u>			COMPILED BY <u>IL</u>	
DATUM <u>Geodetic</u>		DATE <u>2023.08.30 - 2023.08.30</u>	LATITUDE <u>43.255624</u>	LONGITUDE <u>-79.906124</u>	CHECKED BY <u>SM</u>	

[illegible]

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

ONTARIO MTO H403 HDD TUNNEL LAB RESULTS\_NEW\_DM.GPJ ONTARIO MTO.GDT 10/30/23



Brampton, Ontario

# RECORD OF BOREHOLE No EXP-BH08

2 OF 2

METRIC

W.P. \_\_\_\_\_ LOCATION N4790719, E271825, NAD83 MTM Zone 10 ORIGINATED BY CA  
 DIST Hamilton HWY 403 BOREHOLE TYPE Continuous Flight HSA COMPILED BY IL  
 DATUM Geodetic DATE 2023.08.30 - 2023.08.30 LATITUDE 43.255624 LONGITUDE -79.906124 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE									
								● QUICK TRIAXIAL & P. PENETROMETER									
						20	40	60	80	100							
76.5	CLAYEY SILT (TILL), trace gravel, trace sand, grey, low plasticity, moist to wet, very soft to stiff (continued)						77										
10.7	SANDY SILT, some gravel, some clay, reddish brown, moist, compact		SS13	SS	11								o			17 34 37 non-plastic 12	
76.0																	
11.1	BOREHOLE TERMINATED AT ~ 11.1 m DEPTH  Notes: 1. Groundwater measured in open hole at 9.8 m below ground surface upon completion of drilling. 2. Borehole grouted upon completion.																

Brampton, Ontario

## RECORD OF BOREHOLE No EXP-BH09

1 OF 2

METRIC

W.P. \_\_\_\_\_ LOCATION N4790696, E271864, NAD83 MTM Zone 10 ORIGINATED BY CA  
 DIST Hamilton HWY 403 BOREHOLE TYPE Continuous Flight HSA COMPILED BY IL  
 DATUM Geodetic DATE 2023.08.22 - 2023.08.22 LATITUDE 43.255417 LONGITUDE -79.905647 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>P</sub>	W	W <sub>L</sub>			WATER CONTENT (%)
								20 40 60 80 100	20 40 60						
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL P. PENETROMETER								
93.3								20 40 60 80 100		20 40 60					
90.2	TOPSOIL, ~ 130 mm														
0.1	GRAVELLY SAND (FILL), trace silt, brown, moist to wet, loose to compact		SS1	SS	16		93								
92.3															
0.9	CLAYEY SILT (FILL), some sand, trace gravel, reddish brown, low plasticity, moist to wet, firm to very stiff		SS2	SS	9		92								
	- brownish grey below ~ 1.7 m depth		SS3	SS	15										
			SS4	SS	5		91								
90.1															
3.2	CLAYEY SILT (TILL), trace gravel, trace sand, grey, low plasticity, moist to wet, firm to very stiff		SS5	SS	20		90								
			SS6	SS	21		89								
			SS7	SS	12		88								
			SS8	SS	6										
			VANE												
			SS9	SS	6		87								
			VANE												
			SS10	SS	8		86								
			SS11	SS	6										
			VANE				85								
			SS12	SS	5										
			VANE												
			SS13	SS	7		84								
			VANE												

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

ONTARIO MTO H403 HDD TUNNEL LAB RESULTS\_NEW\_DM.GPJ ONTARIO MTO.GDT 10/30/23



Brampton, Ontario

# RECORD OF BOREHOLE No EXP-BH09

2 OF 2

METRIC

W.P. \_\_\_\_\_ LOCATION N4790696, E271864, NAD83 MTM Zone 10 ORIGINATED BY CA  
 DIST Hamilton HWY 403 BOREHOLE TYPE Continuous Flight HSA COMPILED BY IL  
 DATUM Geodetic DATE 2023.08.22 - 2023.08.22 LATITUDE 43.255417 LONGITUDE -79.905647 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)	
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL & P. PENETROMETER										
							20	40	60	80	100		20	40	60			
	CLAYEY SILT (TILL), trace gravel, trace sand, grey, low plasticity, moist to wet, firm to very stiff (continued)					▽	83											
			SS14	SS	10													
							82											
			SS15	SS	20													
			SS16	SS	13													
							80											
			SS17	SS	25													
77.4	- sandy silt, trace clay at ~ 15.5 m depth						79											
15.9	BOREHOLE TERMINATED AT ~ 15.9 m DEPTH						78											
	Notes: 1. Groundwater measured in open hole at 11.9 m below ground surface upon completion of drilling. 2. Borehole grouted upon completion.																	

Brampton, Ontario

## RECORD OF BOREHOLE No EXP-BH10

1 OF 2

METRIC

W.P. \_\_\_\_\_ LOCATION N4790683, E271877, NAD83 MTM Zone 10 ORIGINATED BY CA  
 DIST Hamilton HWY 403 BOREHOLE TYPE Continuous Flight HSA COMPILED BY IL  
 DATUM Geodetic DATE 2023.08.21 - 2023.08.22 LATITUDE 43.255296 LONGITUDE -79.905483 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE		○				
								● QUICK TRIAXIAL P. PENETROMETER		W <sub>P</sub> W   W <sub>L</sub>				
92.6														
92.4														
0.2														
90.3														
2.3														

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

ONTARIO MTO H403 HDD TUNNEL LAB RESULTS\_NEW\_DM.GPJ ONTARIO MTO.GDT 10/30/23

METRIC

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

Brampton, Ontario

## RECORD OF BOREHOLE No EXP-BH11

1 OF 2

METRIC

W.P. \_\_\_\_\_ LOCATION N4790641, E271898, NAD83 MTM Zone 10 ORIGINATED BY CA  
 DIST Hamilton HWY 403 BOREHOLE TYPE Continuous Flight HSA, NW Casing, NQ Core Barrel COMPILED BY IL  
 DATUM Geodetic DATE 2023.08.28 - 2023.08.28 LATITUDE 43.254919 LONGITUDE -79.905227 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)					
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL P. PENETROMETER							W <sub>P</sub>	W	W <sub>L</sub>			
							20	40	60	80	100	20	40	60		GR	SA	SI	CL	
94.6																				
94.6 0.1	ASPHALT, ~ 75 mm SAND AND GRAVEL (FILL), some silt, brown, damp, compact		SS1	SS	27							○								
93.8																				
93.8 0.8	CLAYEY SILT (FILL), some sand, trace gravel, reddish brown, moist, compact		SS2	SS	10							○								
93.0																				
93.0 1.5	CLAYEY SILT (TILL), trace gravel, trace sand, grey, low plasticity, moist to wet, stiff to hard		SS3	SS	19							○								
			SS4	SS	30							○					0	6	46	48
			SS5	SS	27							○								
			SS6	SS	9							○					0	7	49	44
			SS7	SS	11							○								
89.2																				
89.2 5.3	RESIDUAL SOIL, clayey silt, some sand, some shale fragments, red, low plasticity, damp to moist, hard		SS8	SS	100/ 0.13m							○								
88.5																				
88.5 6.1	BEDROCK, Queenston shale, R1 to R2, red with grey interbeds, occasional clayey silt seam alterations																			
	Run 1: Start/End: 6.1 to 7.6 m Recovery: 100% RQD: 59%		RUN 1	NQ															UCS test on Run 1 = 6.5 MPa	
	Run 2: Start/End: 7.6 to 9.1 m Recovery: 100% RQD: 48%																			
	Run 3: Start/End: 9.1 to 10.7 m Recovery: 100% RQD: 42%		RUN 2	NQ																

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

ONTARIO MTO H403 HDD TUNNEL ALL LAB RESULTS CA.GPJ ONTARIO MTO.GDT 10/31/23

Brampton, Ontario

RECORD OF BOREHOLE No EXP-BH11										2 OF 2		METRIC					
W.P. _____			LOCATION <u>N4790641, E271898, NAD83 MTM Zone 10</u>				ORIGINATED BY <u>CA</u>										
DIST <u>Hamilton</u> HWY <u>403</u>			BOREHOLE TYPE <u>Continuous Flight HSA, NW Casing, NQ Core Barrel</u>				COMPILED BY <u>IL</u>										
DATUM <u>Geodetic</u>			DATE <u>2023.08.28 - 2023.08.28</u>		LATITUDE <u>43.254919</u>		LONGITUDE <u>-79.905227</u>		CHECKED BY <u>SM</u>								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20	40	60	80	100					
								20	40	60	80	100					
83.9							84										
10.7	BOREHOLE TERMINATED AT ~ 10.7 m DEPTH  Notes: 1. Open hole dry prior to rock coring. 2. Borehole grouted upon completion.																

ONTARIO MTO H403 HDD TUNNEL\_ALL LAB RESULTS\_CA.GPJ ONTARIO MTO.GDT 10/31/23

Brampton, Ontario

## RECORD OF BOREHOLE No EXP-BH12

1 OF 1

METRIC

W.P. \_\_\_\_\_ LOCATION N4790607, E271919, NAD83 MTM Zone 10 ORIGINATED BY CA  
 DIST Hamilton HWY 403 BOREHOLE TYPE Continuous Flight HSA, NW Casing, NQ Core Barrel COMPILED BY IL  
 DATUM Geodetic DATE 2023.08.29 - 2023.08.29 LATITUDE 43.254612 LONGITUDE -79.904964 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						GR SA SI CL
96.1														
95.9	ASPHALT, ~ 180 mm													
0.2	SAND AND GRAVEL (FILL), trace to some silt, brown, damp, compact to dense		SS1	SS	30									
95.2														
0.9	CLAYEY SILT (FILL), sandy, trace gravel, red, low plasticity, moist, stiff		SS2	SS	14									1 30 54 15
94.6														
1.5	RESIDUAL SOIL, clayey silt, some sand, some shale fragments, red, low plasticity, damp to moist, hard		SS3	SS	63									
			SS4	SS	63									
			SS5	SS	100/ 0.13m									
92.5														
3.7	BEDROCK, Queenston shale, R1 to R2, red with grey interbeds, occasional clayey silt seam alterations		RUN 1	NQ										
	Run 1: Start/End: 3.7 to 4.3 m Recovery: 100% RQD: 0%													
	Run 2A: Start/End: 4.3 to 5.2 m Recovery: 83% RQD: 15%		RUN 2A	NQ										
	Run 2B: Start/End: 5.2 to 6.1 m Recovery: 67% RQD: 0%		RUN 2B	NQ										
	Run 3: Start/End: 6.1 to 7.2 m Recovery: 100% RQD: 43%		RUN 3	NQ										
88.5														
7.6	BOREHOLE TERMINATED AT ~ 7.6 m DEPTH													
	Notes: 1. Open hole dry prior to rock coring. 2. Borehole grouted upon completion.													

Proposed HDD  
Tunneling Alignment  
(Section D-D)

ONTARIO MTO: H403 HDD TUNNEL - ALL LAB RESULTS - CA.GPJ - ONTARIO MTO.GDT - 10/31/23

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

Brampton, Ontario

## RECORD OF BOREHOLE No EXP-BH13

1 OF 1

METRIC

W.P. \_\_\_\_\_ LOCATION N4790612, E271903, NAD83 MTM Zone 10 ORIGINATED BY CA  
 DIST Hamilton HWY 403 BOREHOLE TYPE Continuous Flight HSA, NW Casing, NQ Core Barrel COMPILED BY IL  
 DATUM Geodetic DATE 2023.08.21 - 2023.08.21 LATITUDE 43.254659 LONGITUDE -79.905153 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)		
95.7								20	40	60	80	100					
95.7	TOPSOIL, ~ 150 mm																
95.4	GRAVELLY SAND (FILL), some silt, trace organics, brown, moist, loose		SS1	SS	7												
94.9	CLAYEY SILT (TILL), some sand, mottled brown and grey, low plasticity, moist, firm						95										
94.9	RESIDUAL SOIL, clayey silt, some sand, some shale fragments, red, low plasticity, damp to moist, hard		SS2	SS	65												0 12 68 20
			SS3	SS	91		94										
			SS4	SS	100/ 0.08m												
92.9							93	Proposed HDD Tunneling Alignment (Section D-D)									
2.7	BEDROCK, Queenston shale, R1 to R2, red with grey interbeds, occasional clayey silt seam alterations																
	Run 1: Start/End: 2.7 to 4.3 m Recovery: 80% RQD: 21%		RUN 1A	NQ			92										
	Run 2: Start/End: 4.3 to 5.8 m Recovery: 98% RQD: 28%																
	Run 3: Start/End: 5.8 to 7.3 m Recovery: 100% RQD: 46%		RUN 2	NQ			91										
							90										
			RUN 3	NQ			89										
88.4																	
7.3	BOREHOLE TERMINATED AT ~ 7.3 m DEPTH																
	Notes: 1. Open hole dry prior to rock coring. 2. Borehole grouted upon completion.																

Proposed HDD  
Tunneling Alignment  
(Section D-D)

UCS test on Run  
2 = 6.7 MPa



Brampton, Ontario

# RECORD OF BOREHOLE No EXP-BH14

1 OF 2

METRIC

W.P. \_\_\_\_\_ LOCATION N4790869, E271713 NAD83 MTM Zone 10 ORIGINATED BY CA  
 DIST Hamilton HWY 403 BOREHOLE TYPE Continuous Flight HSA COMPILED BY IL  
 DATUM Geodetic DATE 2023.09.07 - 2023.09.07 LATITUDE 43.256964 LONGITUDE -79.907513 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
98.6	ASPHALT, ~ 180 mm													
98.4														
0.2	GRAVELLEY SAND (FILL), trace to some silt, brown, damp to moist, dense		SS1	SS	33		98							
97.8														
0.8	CLAYEY SILT (FILL), trace to some sand, trace gravel, trace organics, brown, low plasticity, moist to wet, firm to stiff		SS2	SS	14									
			SS3	SS	7		97							
			SS4	SS	10		96							1 2 75 22
			SS5	SS	11		95							
			SS6	SS	11									
94.0							94							
4.6	SILT AND SAND (FILL), trace gravel, trace clay, brown, wet, compact		SS7	SS	15									3 37 53 7 non plastic
93.2														
5.3	CLAYEY SILT (FILL), trace to some sand, trace organics, brown to brownish grey, slight to low plasticity, moist to wet, firm to stiff		SS8	SS	11		93							
	- occasional reddish brown sand seams at ~ 6.1 m depth		SS9	SS	10		92							
	- silt layer at ~ 7.6 m depth		SS10	SS	5		91							0 12 67 21
	~ very stiff at ~ 8.1 m depth			VANE										Measured vane shear strength greater than 145 kPa at 8.4 m
							90							
	- sandy silt layer at ~ 9.1 m depth													
89.2			SS11	SS	6		89							Measured vane shear strength greater than 145 kPa at 9.9 m
9.4	CLAYEY SILT (FILL), trace gravel, trace sand, grey, low plastic, moist to wet, firm to very stiff			VANE										

Continued Next Page

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

ONTARIO MTO H403 HDD TUNNEL LAB RESULTS\_NEW\_DM.GPJ ONTARIO MTO.GDT 10/30/23

METRIC

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

Brampton, Ontario

## RECORD OF BOREHOLE No EXP-BH15

1 OF 2

METRIC

W.P. \_\_\_\_\_ LOCATION N4790773, E271686 NAD83 MTM Zone 10 ORIGINATED BY CA  
 DIST Hamilton HWY 403 BOREHOLE TYPE Continuous Flight HSA COMPILED BY IL  
 DATUM Geodetic DATE 2023.09.05 - 2023.09.05 LATITUDE 43.256104 LONGITUDE -79.907839 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL P. PENETROMETER					
90.2													
90.0	TOPSOIL, ~ 150 mm												
0.2	GRAVELLY SAND (FILL), some silt, trace oraganics, brown, damp to moist, compact		SS1	SS	18		90						
89.4													
0.8	CLAYEY SILT (FILL), trace gravel, trace sand, trace organics, mottled brown, grey, red, and black, low plasticity, damp to moist, stiff to very stiff		SS2	SS	15		89						
	- brown below ~ 1.5 m depth												
			SS3	SS	18								
							88						
			SS4	SS	10								1 2 72 25
			SS5	SS	12		87						
			SS6	SS	10		86						Corrosivity sample
			SS7	SS	11		85						
							84						
			SS8	SS	9								
							83						
82.6													
7.6	CLAYEY SILT (TILL), trace to some sand, grey, low plasticity, wet, very soft		SS9	SS	0		82						0 6 49 45
				VANE									
							81						
80.6			SS10	SS	0								
9.6	BOREHOLE TERMINATED AT ~ 9.6 m DEPTH												

Continued Next Page

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

ONTARIO MTO H403 HDD TUNNEL LAB RESULTS\_NEW\_DM.GPJ ONTARIO MTO.GDT 10/30/23

Brampton, Ontario

## 2 OF 2

METRIC

W.P.	LOCATION			N4790773, E271686 NAD83 MTM Zone 10		ORIGINATED BY	CA
DIST	Hamilton	HWY	403	BOREHOLE TYPE		Continuous Flight HSA	
COMPILED BY				IL			
DATUM	Geodetic			DATE	2023.09.05 - 2023.09.05	LATITUDE	43.256104
LONGITUDE				-79.907839		CHECKED BY	SM

[illegible]

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

ONTARIO MTO H403 HDD TUNNEL LAB RESULTS NEW\_DM.GPJ ONTARIO MTO.GDT 10/30/23

## Appendix E – Laboratory Data and Bedrock Core Photographs



Photograph 1. Bedrock core samples, EXP-BH11, Run 1 (bottom), Run 2 (middle), Run 3 (top), August 28, 2023



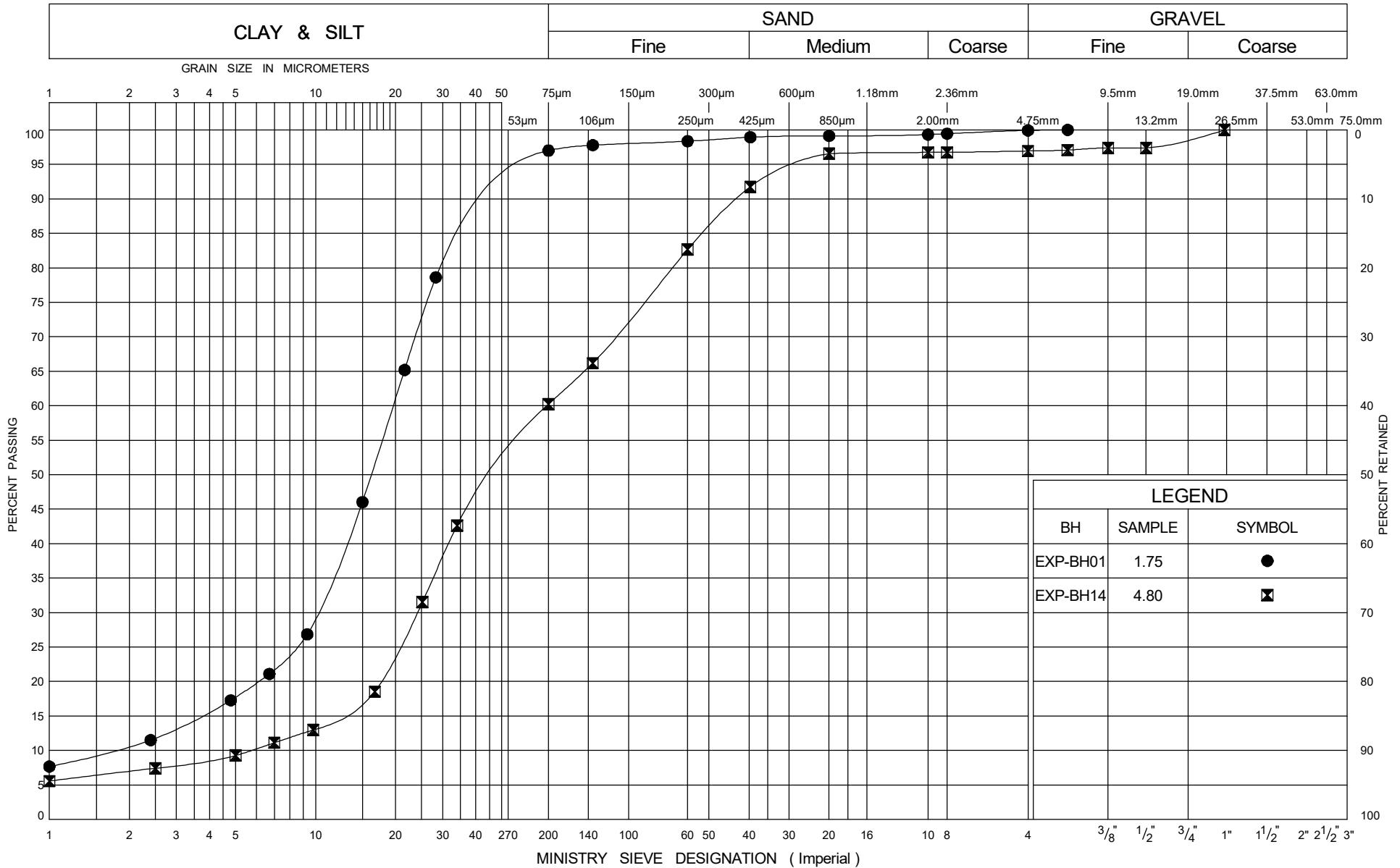
Photograph 2. Bedrock core samples, EXP-BH12, Run 1 (bottom), Run 2A/2B (middle), Run 3 (top), August 29, 2023



Photograph 3. Bedrock core samples, EXP-BH13, Run 1 (bottom), Run 2 (middle), Run 3 (top), August 21, 2023

Ministry of  
Transportation

## UNIFIED SOIL CLASSIFICATION SYSTEM



## GRAIN SIZE DISTRIBUTION

Cohesionless Fill: Sand and Silt / Silt

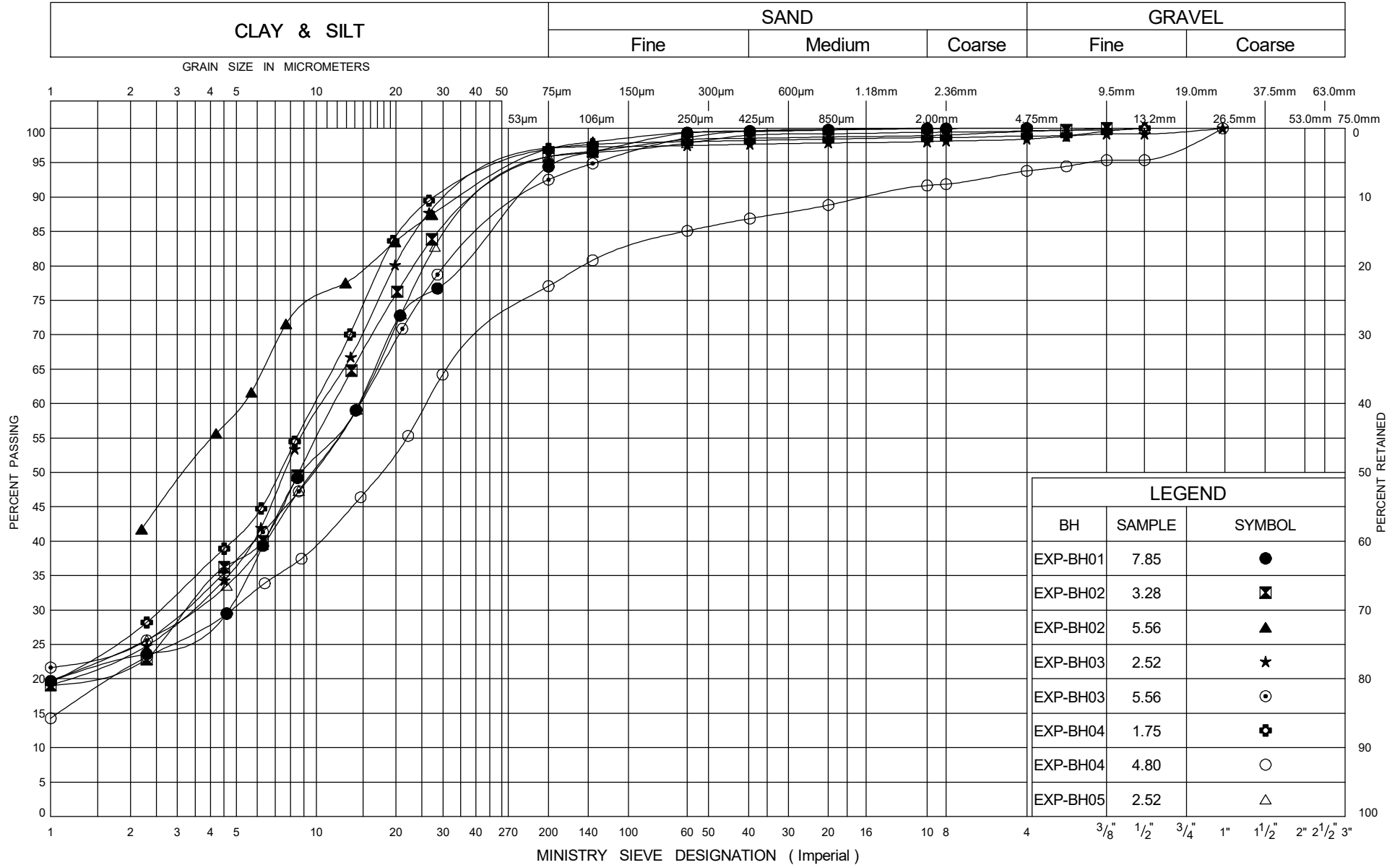
FIG No 1

W P

Hwy 403 & Aberdeen Ave. Underground Crossing for Alectra Utilities
--



# UNIFIED SOIL CLASSIFICATION SYSTEM



## GRAIN SIZE DISTRIBUTION

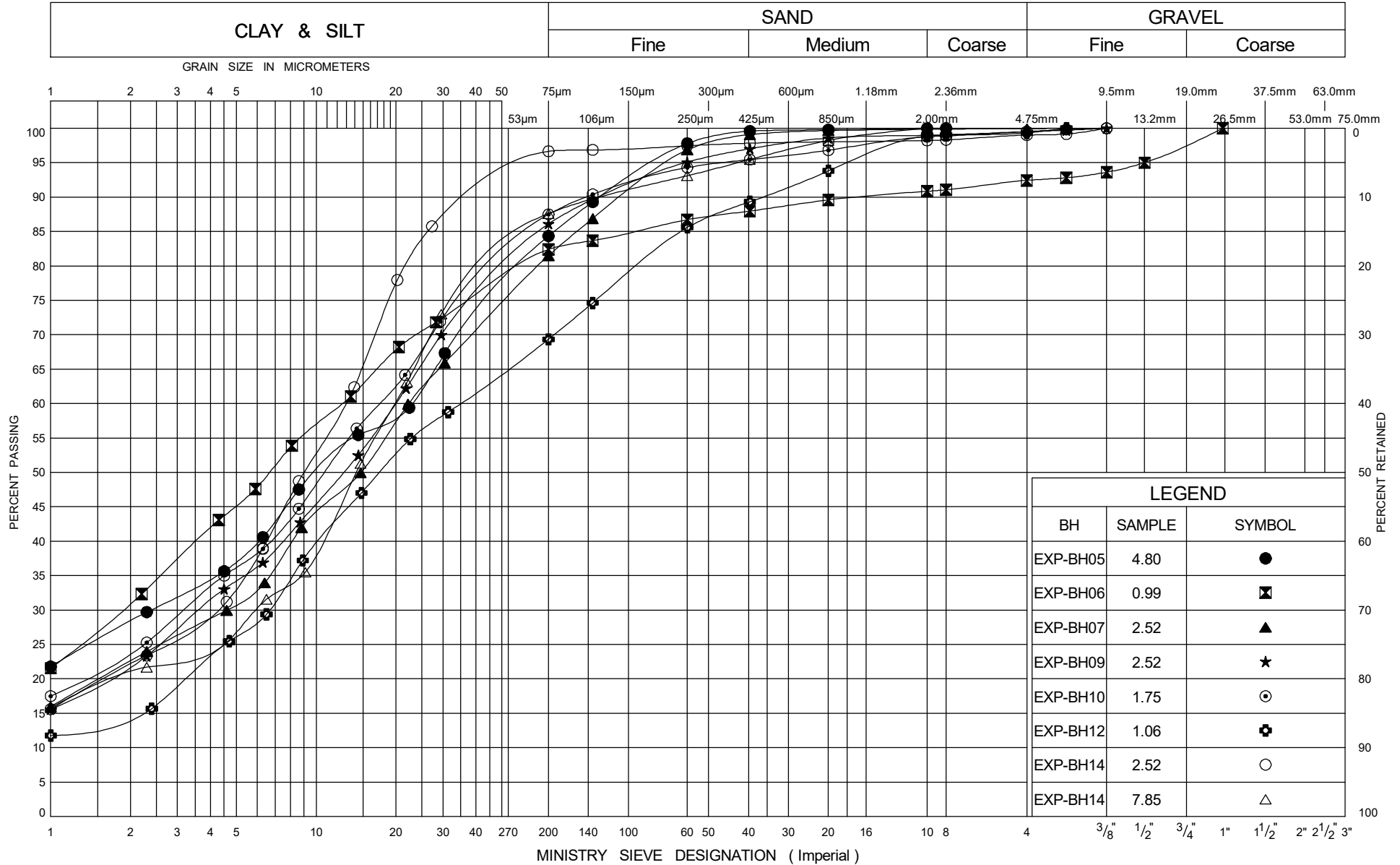
Cohesive Fill: Clayey Silt

FIG No 2

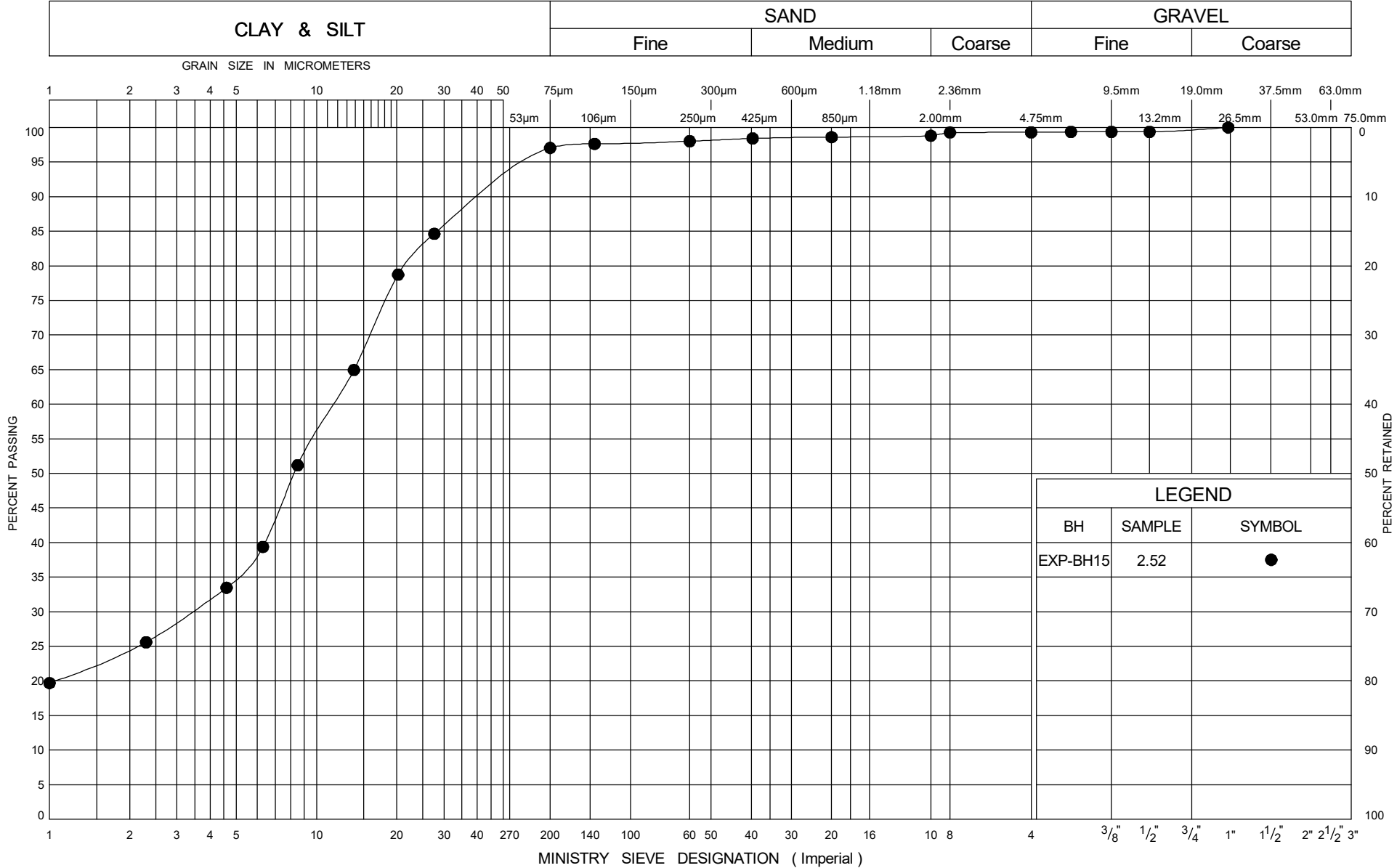
W P

Hwy 403 & Aberdeen Ave. Underground  
Crossing for Alectra Utilities

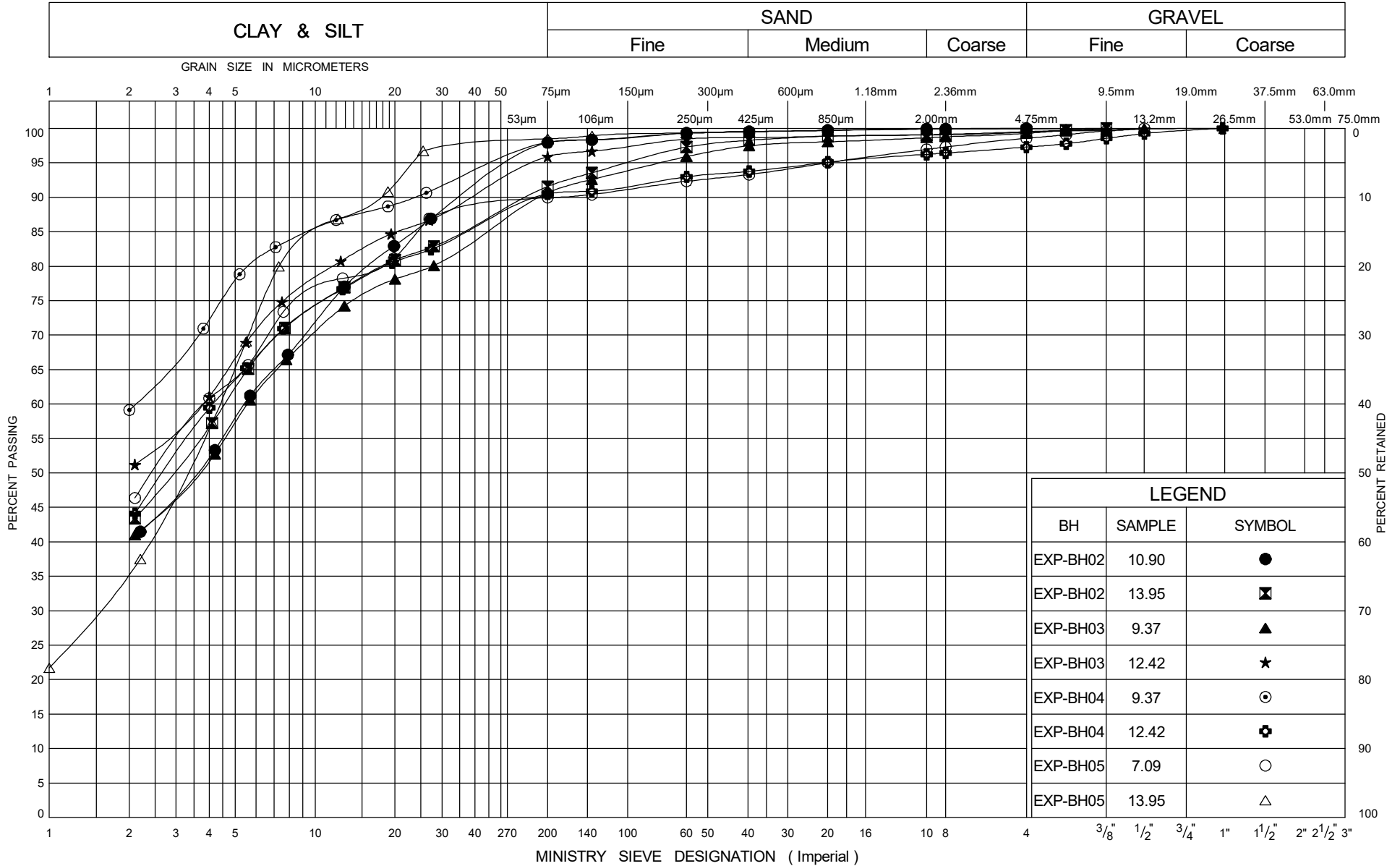
# UNIFIED SOIL CLASSIFICATION SYSTEM



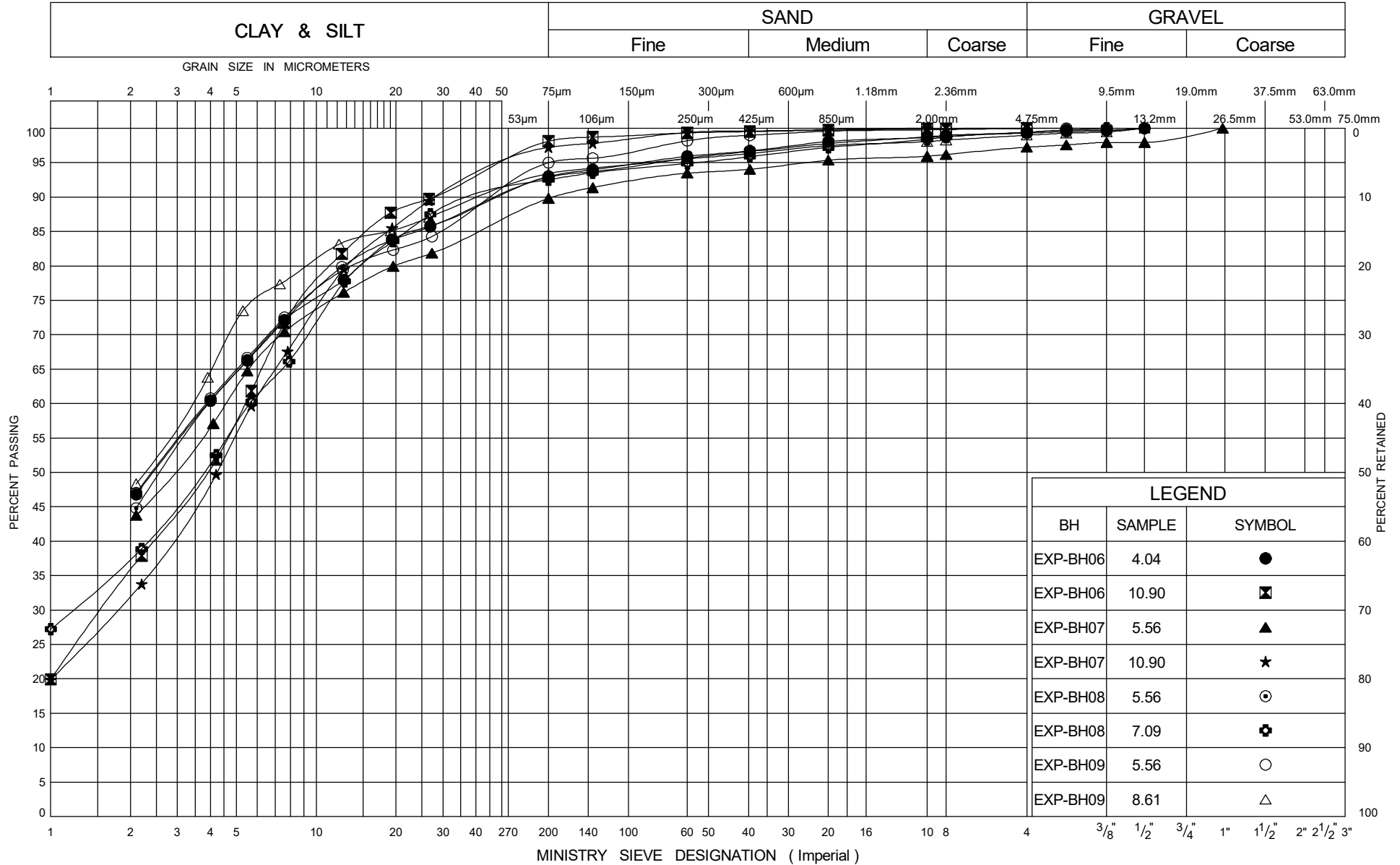
UNIFIED SOIL CLASSIFICATION SYSTEM



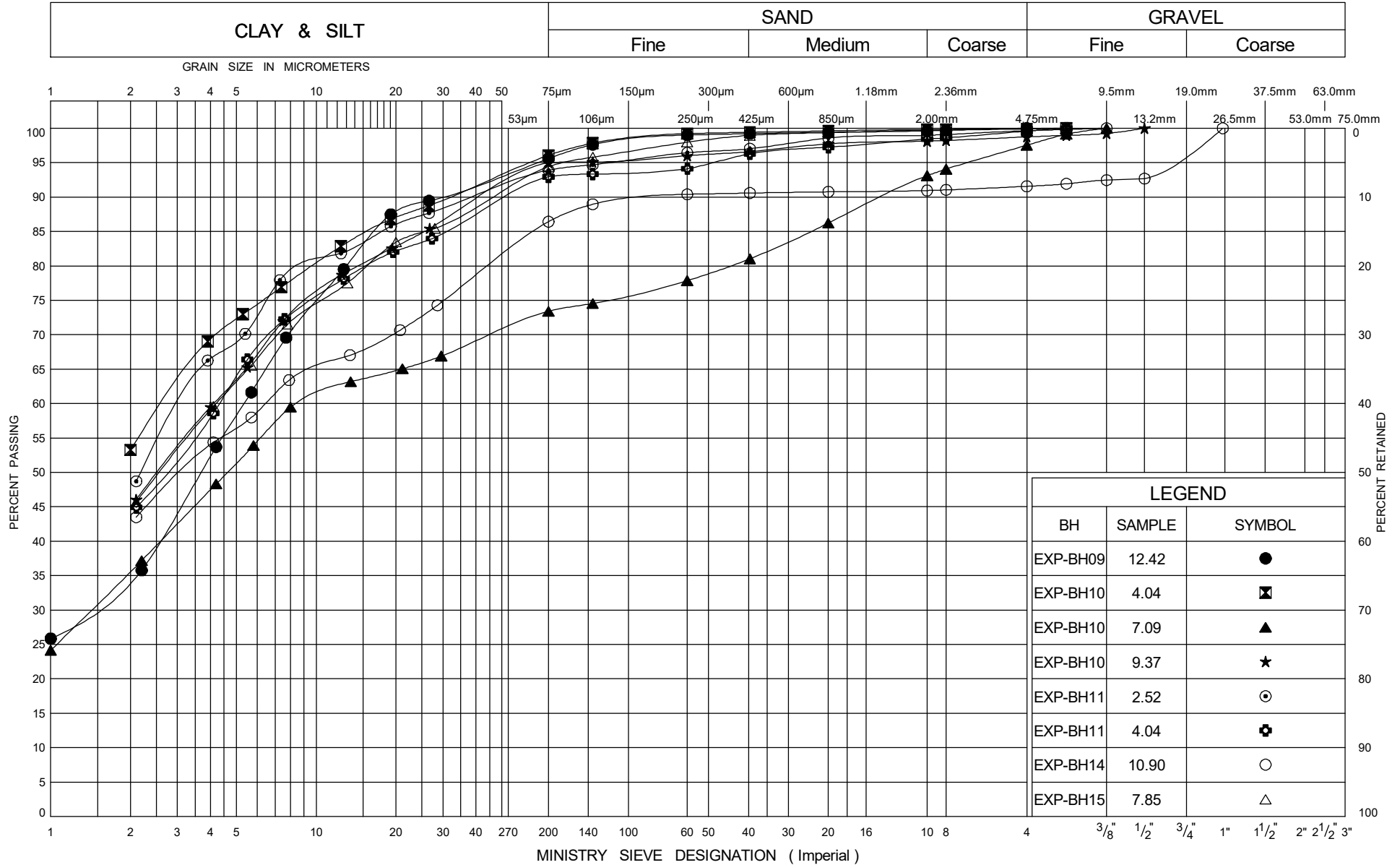
# UNIFIED SOIL CLASSIFICATION SYSTEM



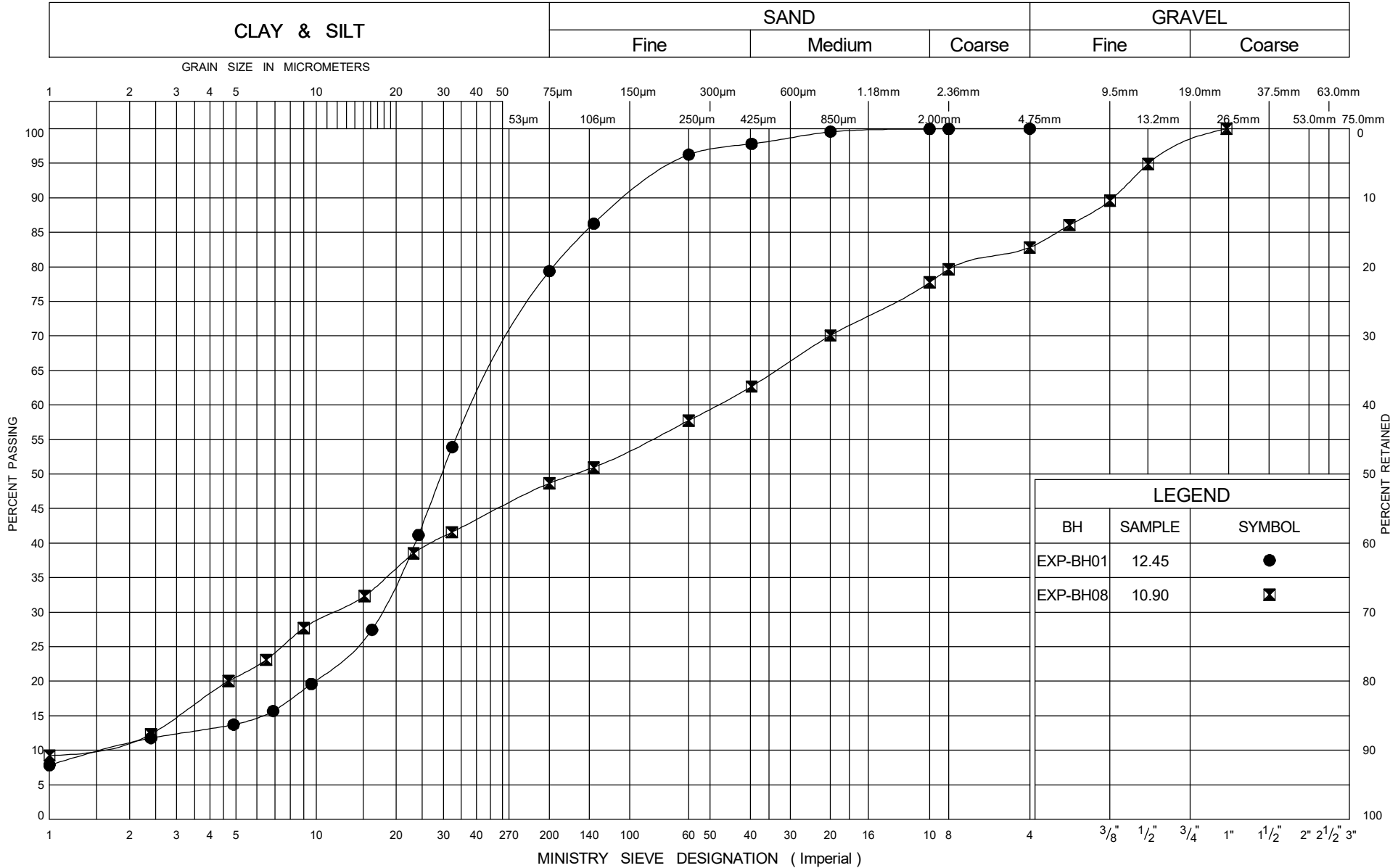
# UNIFIED SOIL CLASSIFICATION SYSTEM



# UNIFIED SOIL CLASSIFICATION SYSTEM



UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION

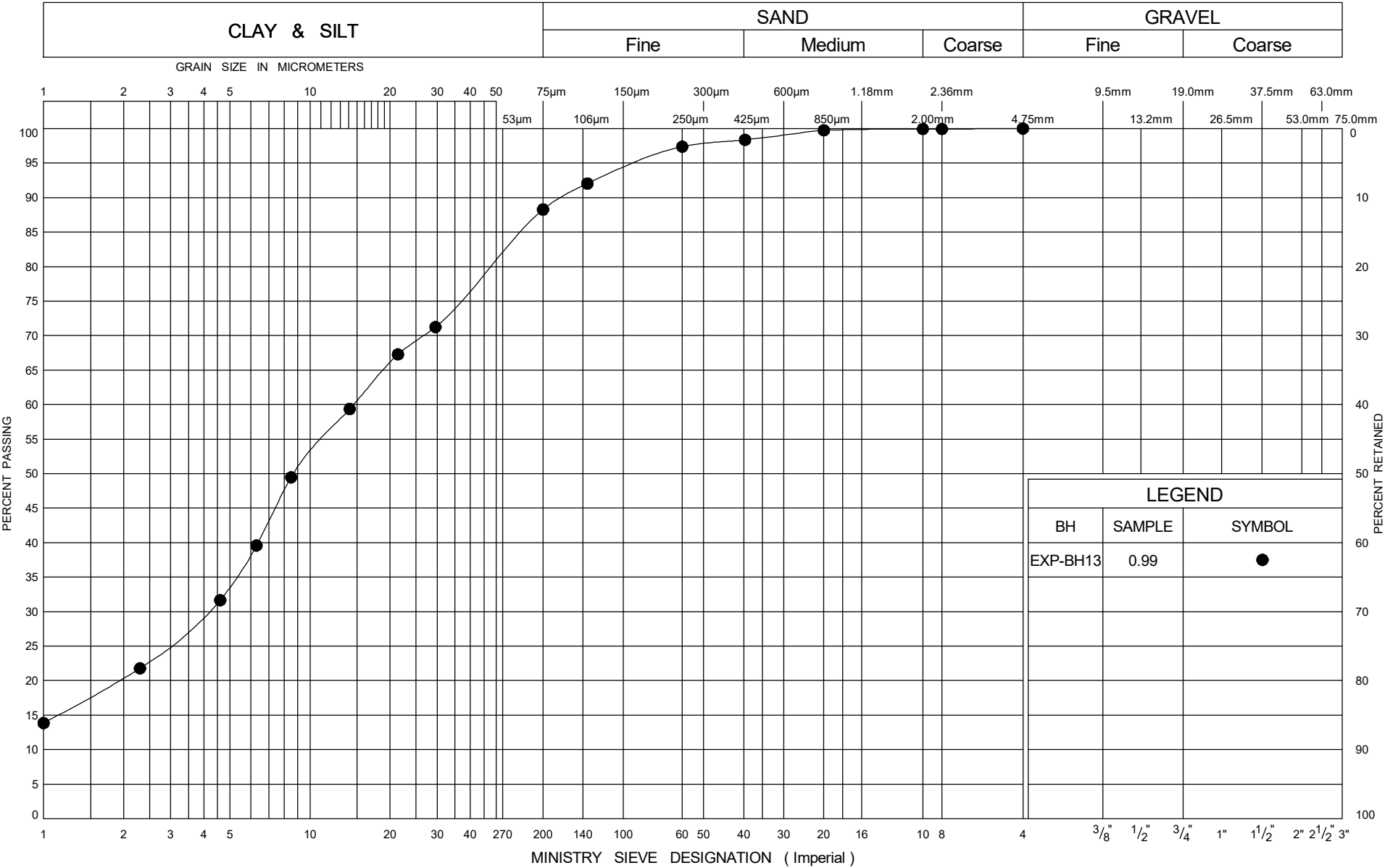
Sandy Silt / Sand and Gravel

FIG No 8

W P

Hwy 403 & Aberdeen Ave. Underground  
Crossing for Alectra Utilities

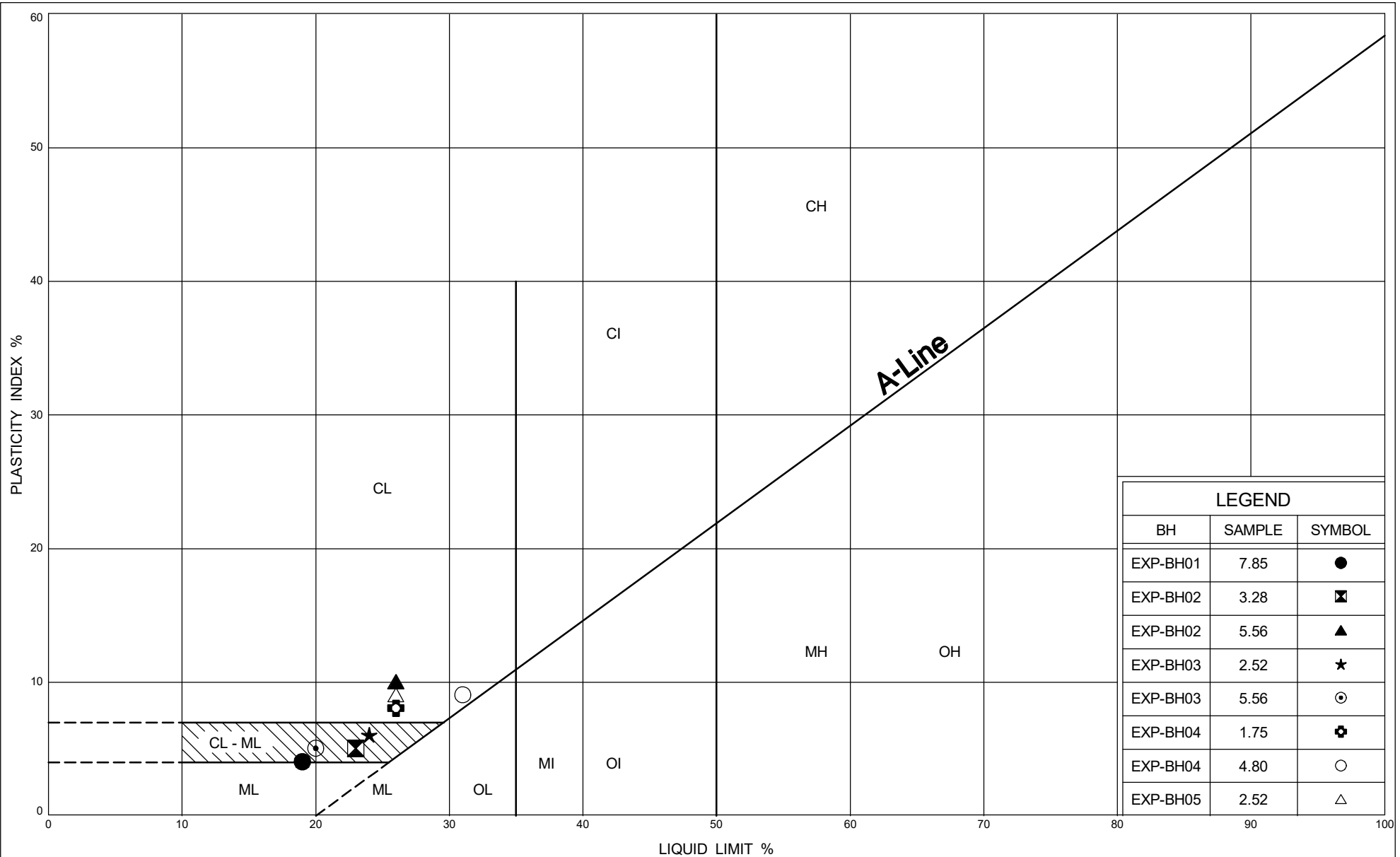
UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION  
Residual Soil: Clayey Silt

FIG No 9  
W P  
Hwy 403 & Aberdeen Ave. Underground  
Crossing for Alectra Utilities





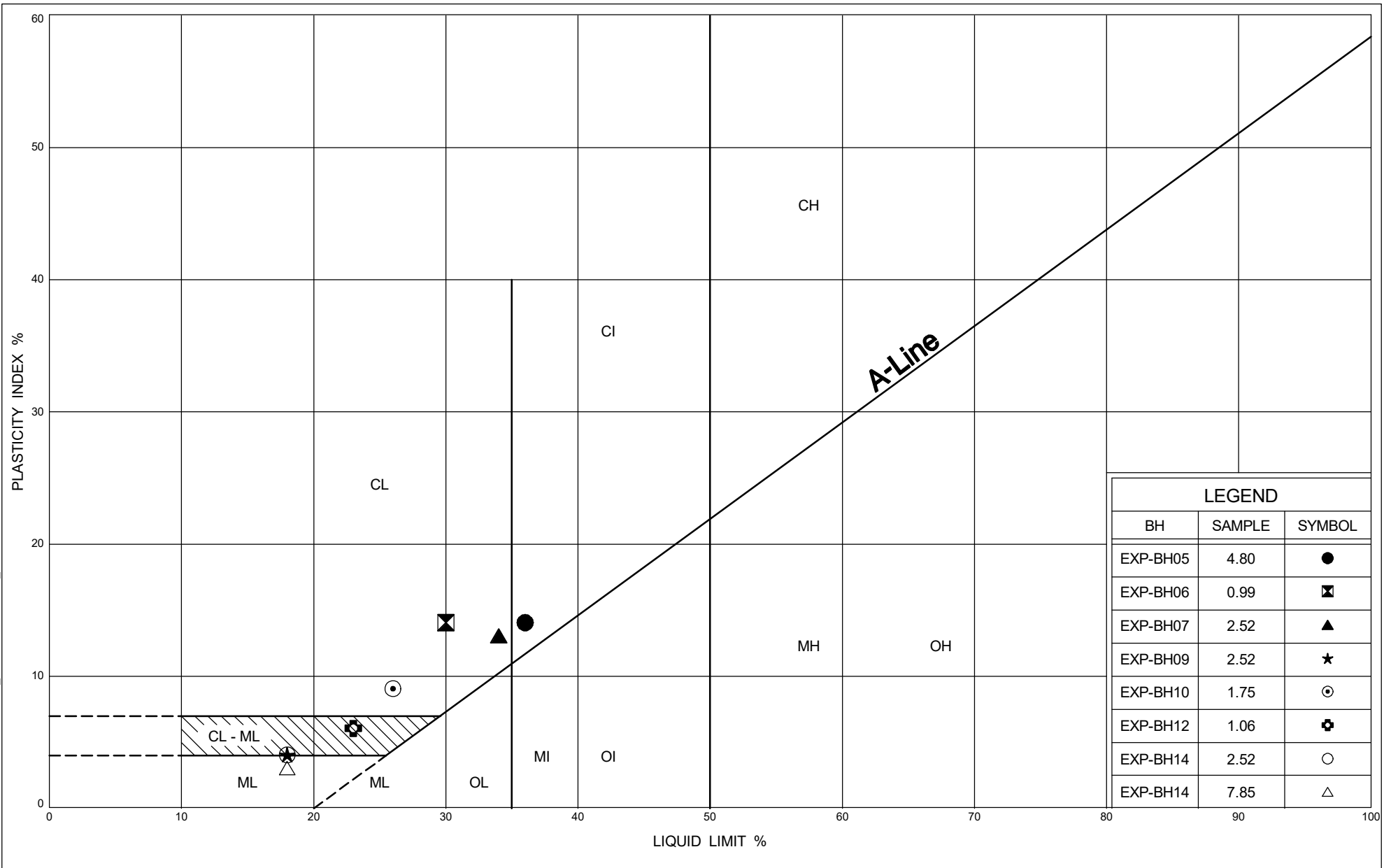
Ministry of  
Transportation

## PLASTICITY CHART

FIG No 10

W P

Hwy 403 & Aberdeen Ave. Underground  
Crossing for Alectra Utilities



Ministry of  
Transportation

## PLASTICITY CHART

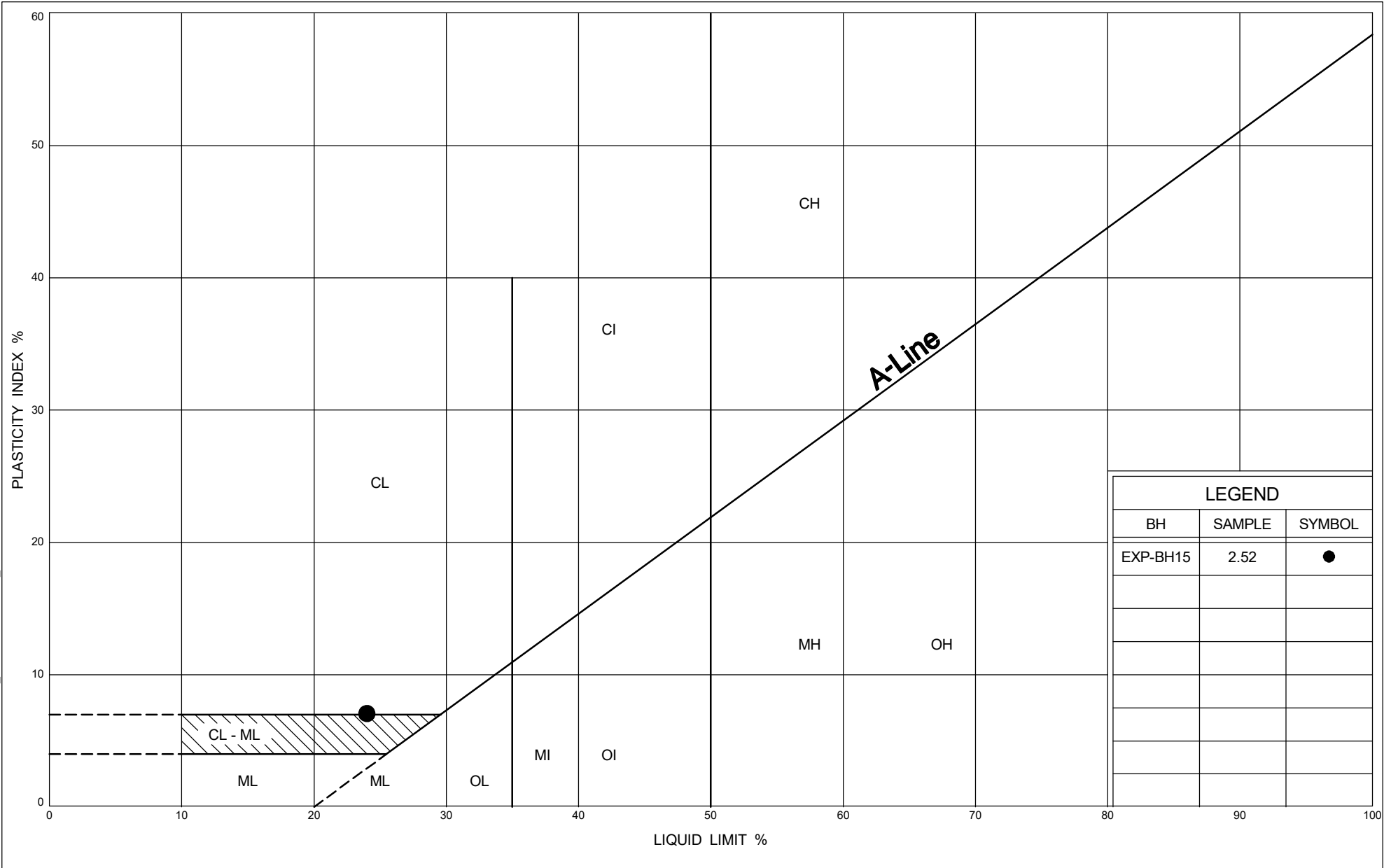
Cohesive Fill: Clayey Silt

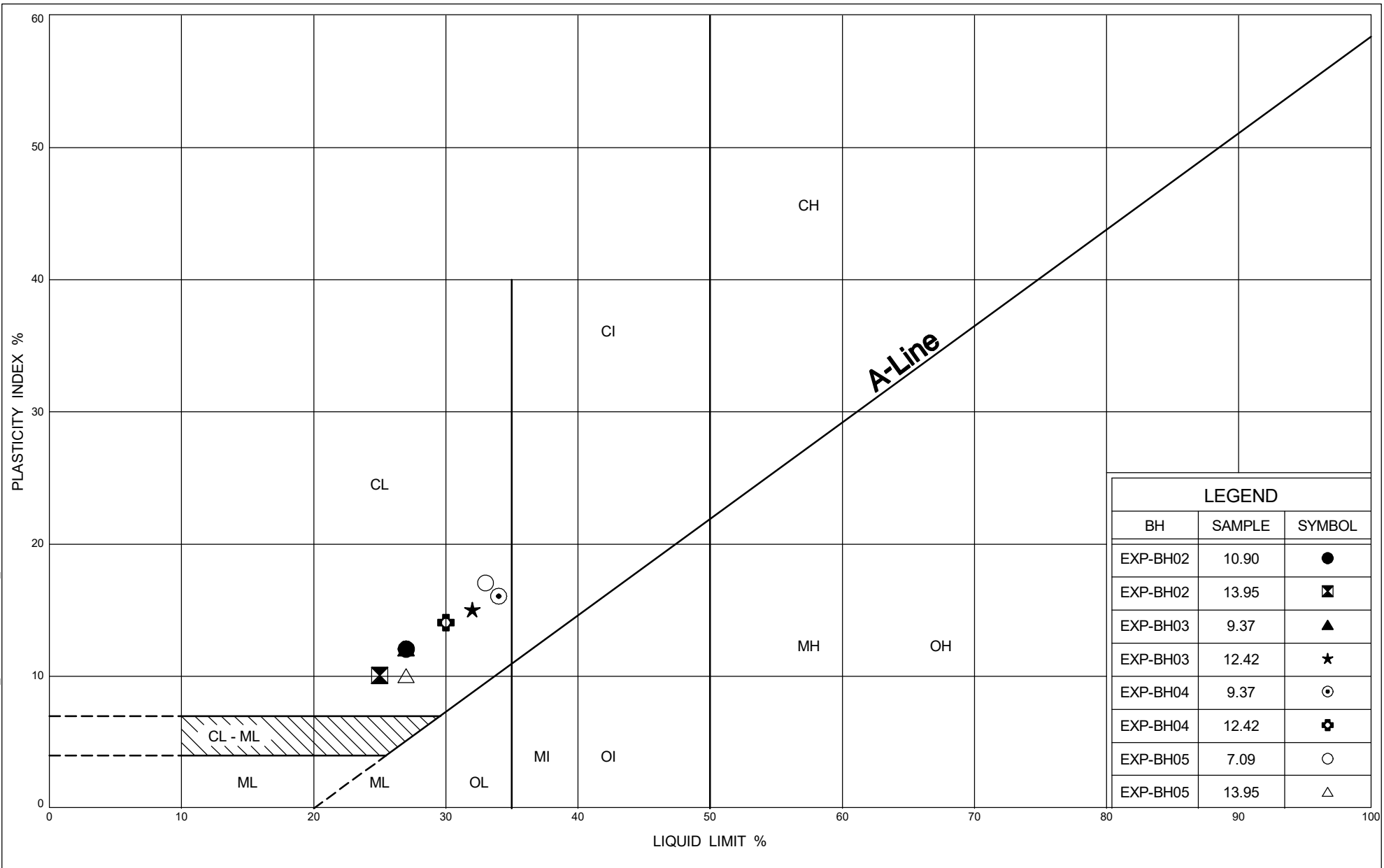
FIG No 11

W P

Hwy 403 & Aberdeen Ave. Underground  
Crossing for Alectra Utilities

ONTARIO MOT PLASTICITY CHART H403 HDD TUNNEL\_ALL LAB RESULTS\_CA.GPJ ONTARIO MOT.GDT 10/31/23





Ministry of  
Transportation

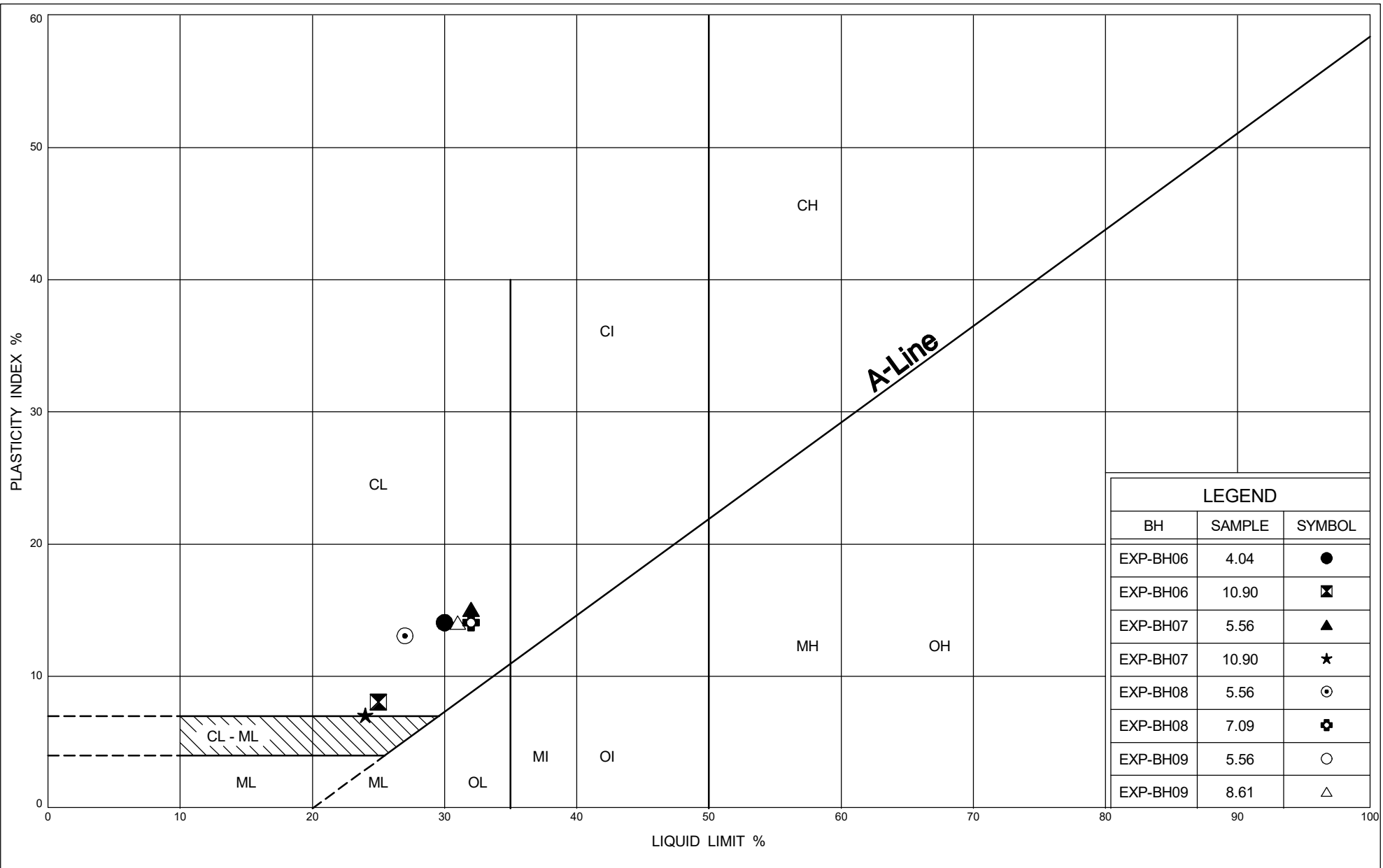
## PLASTICITY CHART

Clayey Silt (Till)

FIG No 13

W P

Hwy 403 & Aberdeen Ave. Underground  
Crossing for Alectra Utilities



Ministry of  
Transportation

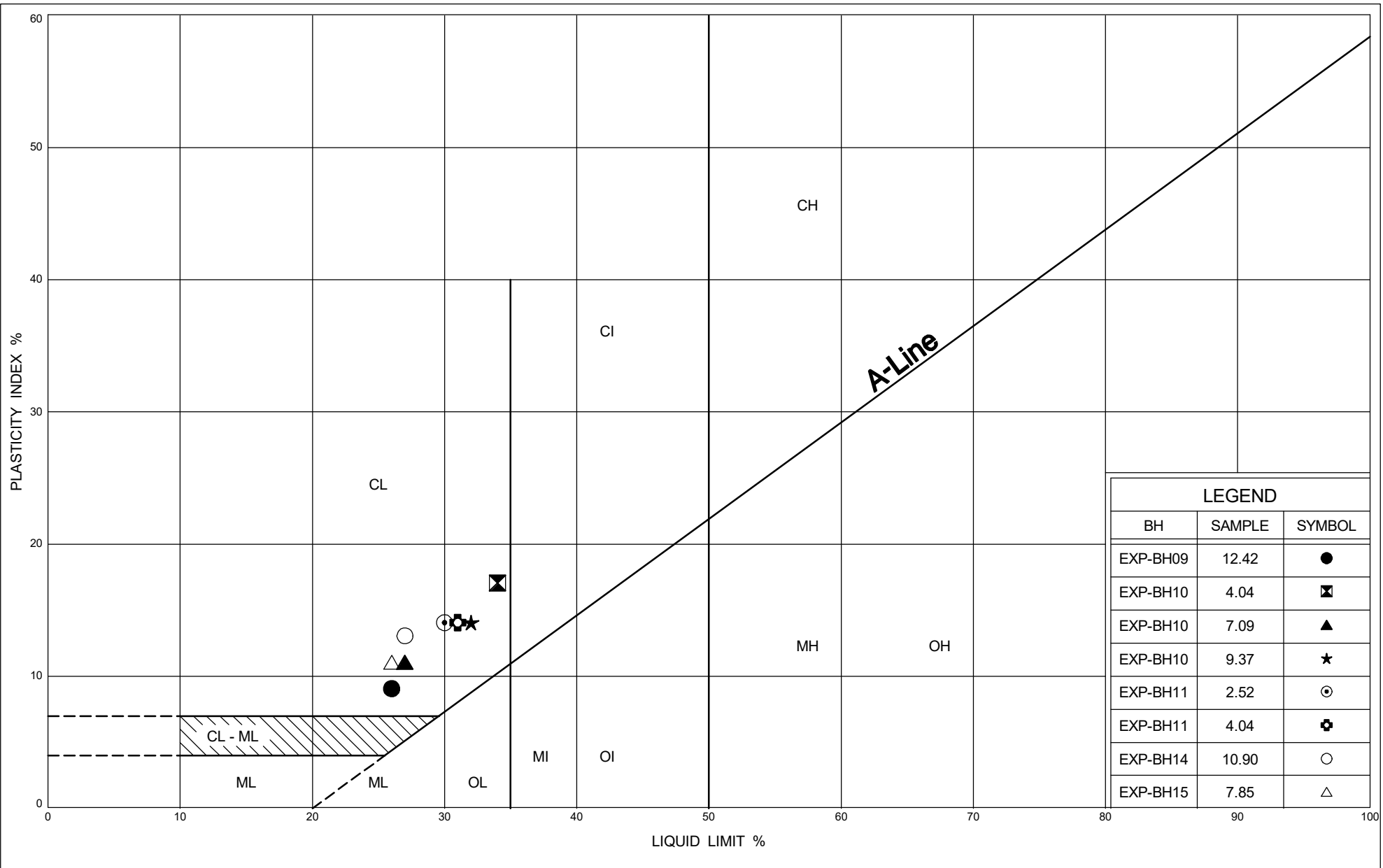
## PLASTICITY CHART

Clayey Silt (Till)

FIG No 14

W P

Hwy 403 & Aberdeen Ave. Underground  
Crossing for Alectra Utilities



Ministry of  
Transportation

## PLASTICITY CHART

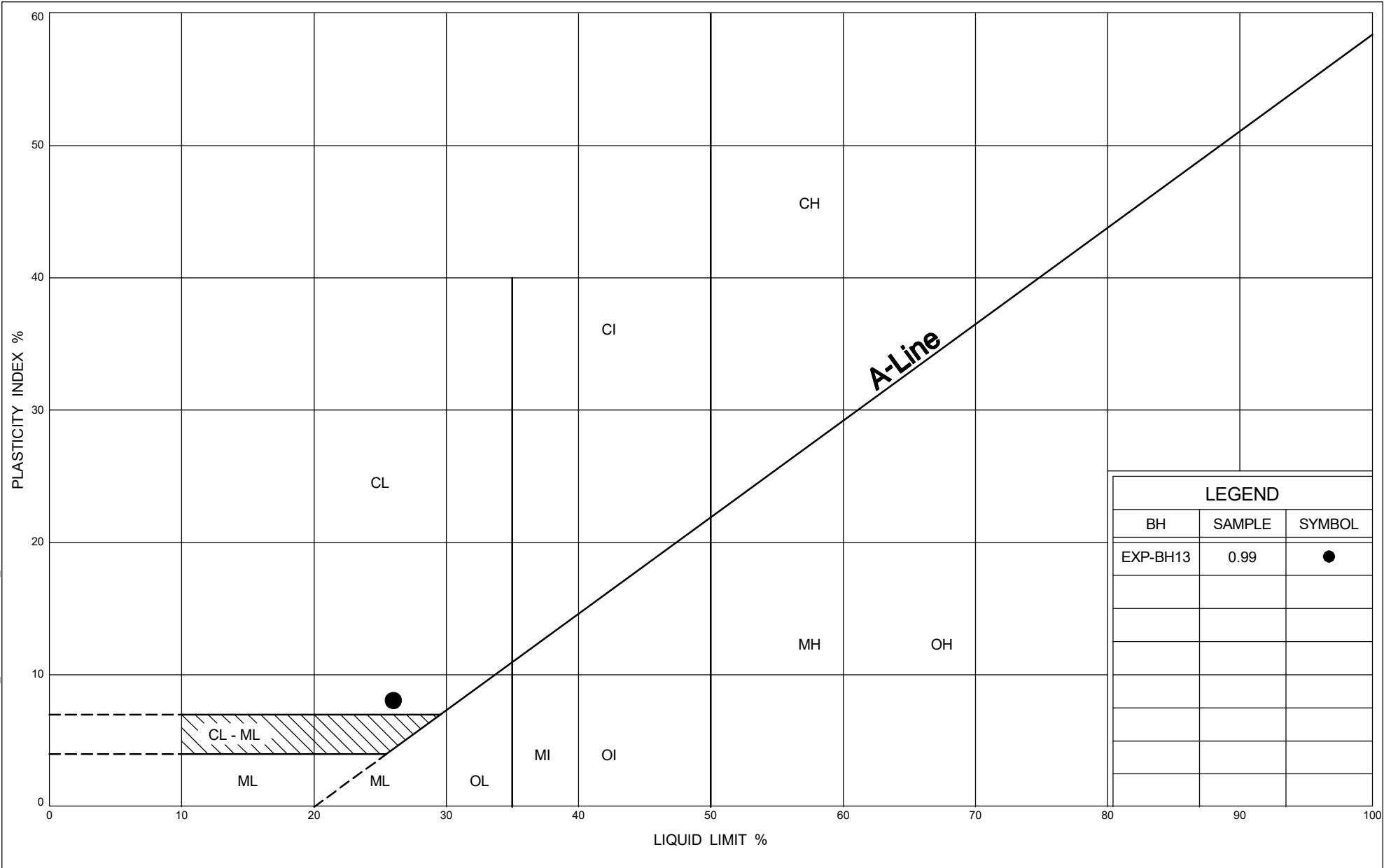
Clayey Silt (Till)

FIG No 15

W P

Hwy 403 & Aberdeen Ave. Underground  
Crossing for Alectra Utilities

ONTARIO MOT PLASTICITY CHART H403 HDD TUNNEL\_ALL LAB RESULTS\_CA.GPJ ONTARIO MOT.GDT 10/31/23





# CONCRETE CORE TESTING

exp Services Inc.

15701 Robin's Hill Road, Unit 2  
London, ON N5V 0A5  
tel: 519.983.3000  
fax: 519.983.1152

405 Maple Grove Rd., Unit 6  
Cambridge, ON N3E 1B6  
tel: 519.650.4918  
fax: 519.650.4603

2199 Blackacre Drive, Unit 600  
Oldcastle (Windsor), ON N0R 1L0  
tel: 519.737.0588  
fax: 519.737.0751

265 Front Street North, Suite 411N  
Samia, ON N7T 7X1  
tel: 519.332.1550  
fax: 519.332.5662

Project No.: 23006096

Client: —

Project Name: Hwy 403 HDD Tunnels

Project Location: Hwy 403 + Aberdeen Ave  
Hamilton, ON

Core No.	BH 11 Run 1	BH 12 Run 3	BH 13 Run 2		
Date Tested	Oct 13/23	Oct 13/ 23	Oct 13/ 23		
As Received Height (mm)	85 84 87 85	89 87 88 86	85 84 86 88		
Trimmed Height (mm)	80	85	80		
Average Diameter (mm)	45	45	45		
Area (mm <sup>2</sup> )	1590	1590	1590		
Weight in Air (g)	—	—	—		
Weight in Water (g)	—	—	—		
Density (kg/m <sup>3</sup> )	—	—	—		
Load Reading (kN)	10.51	2.82	10.87		
Compressive Strength (MPa)	6.61	1.8	6.84		
Length / Diameter	1.78	—	1.78		
Correction Factor	0.984	—	0.984		
Corrective Compressive Strength (MPa)	6.5	—	6.7		
Age of Core (days)					

Comments

Technician:

A. AXFORD





Your Project #: ADM-23006096-A0  
Site Location: Hwy 403 at Main-St/Aberdeen in Hamilton  
Your C.O.C. #: N/A

**Attention: Silvana Micic**

exp Services Inc  
Brampton Branch  
1595 Clark Blvd  
Brampton, ON  
CANADA L6T 4V1

**Report Date: 2023/09/12**  
Report #: R7809003  
Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**BUREAU VERITAS JOB #: C3R2807**

**Received: 2023/09/05, 16:42**

Sample Matrix: Soil  
# Samples Received: 4

Analyses	Quantity	Date	Date	Laboratory Method	Analytical Method
		Extracted	Analyzed		
Chloride (20:1 extract)	4	2023/09/08	2023/09/11	CAM SOP-00463	MOE E3013 m
Conductivity	4	2023/09/08	2023/09/08	CAM SOP-00414	OMOE E3530 v1 m
Moisture (Subcontracted) (1, 2)	4	N/A	2023/09/12	AB SOP-00002	CCME PHC-CWS m
Sulphide in Soil (1)	4	N/A	2023/09/12	AB SOP-00080	EPA9030B/SM4500S2-DF
pH CaCl2 EXTRACT	4	2023/09/11	2023/09/11	CAM SOP-00413	EPA 9045 D m
Redox Potential (3)	4	2023/09/11	2023/09/12	CAM SOP-00421	SM 2580 B
Resistivity of Soil	4	2023/09/07	2023/09/08	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	4	2023/09/08	2023/09/11	CAM SOP-00464	MOE E3013 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, MELCCFP, 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.

(1) This test was performed by Bureau Veritas Calgary (19th), 4000 19th Street NE, Calgary, AB, T2E 6P8

(2) Offsite analysis requires that subcontracted moisture be reported.



Your Project #: ADM-23006096-A0  
Site Location: Hwy 403 at Main-St/Aberdeen in Hamilton  
Your C.O.C. #: N/A

**Attention: Silvana Micic**

exp Services Inc  
Brampton Branch  
1595 Clark Blvd  
Brampton, ON  
CANADA L6T 4V1

**Report Date: 2023/09/12**  
Report #: R7809003  
Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**BUREAU VERITAS JOB #: C3R2807**

**Received: 2023/09/05, 16:42**

(3) Oxidation-Reduction Potential (ORP) values are determined using a Ag/AgCl reference electrode. The test is therefore, not SCC accredited for this matrix.

Encryption Key



**AUTHORIZED REPORT  
RAPPORT AUTORISÉ**

Bureau Veritas

12 Sep 2023 19:51:58

Please direct all questions regarding this Certificate of Analysis to:

Patricia Legette, Project Manager

Email: Patricia.Legette@bureauveritas.com

Phone# (905)817-5799

=====

This report has been generated and distributed using a secure automated process.

Bureau Veritas has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation, please refer to the Validation Signatures page if included, otherwise available by request. For Department specific Analyst/Supervisor validation names, please refer to the Test Summary section if included, otherwise available by request. This report is authorized by Rodney Major, General Manager responsible for Ontario Environmental laboratory operations.

Total Cover Pages : 2

Page 2 of 11

Bureau Veritas 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.bvna.com

Microbiology testing is conducted at 6660 Campobello Rd. Chemistry testing is conducted at 6740 Campobello Rd.



Bureau Veritas Job #: C3R2807  
Report Date: 2023/09/12

exp Services Inc  
Client Project #: ADM-23006096-A0  
Site Location: Hwy 403 at Main-St/Aberdeen in Hamilton  
Sampler Initials: EL

### SOIL CORROSIVITY PACKAGE (SOIL)

Bureau Veritas ID		WXJ002			WXJ002			WXJ003	WXJ004		
Sampling Date		2023/08/31 12:00			2023/08/31 12:00			2023/08/30 10:00	2023/08/25 10:00		
COC Number		N/A			N/A			N/A	N/A		
	UNITS	BH3-SA6	RDL	QC Batch	BH3-SA6 Lab-Dup	RDL	QC Batch	BH8-SA9	BH5-SA6	RDL	QC Batch
<b>Calculated Parameters</b>											
Resistivity	ohm-cm	2100		8901046				1400	1400		8901046
<b>CONVENTIONALS</b>											
Redox Potential	mV	450	N/A	8908461				430	370	N/A	8908461
<b>Inorganics</b>											
Soluble (20:1) Chloride (Cl-)	ug/g	130	20	8903800				250	340	20	8903800
Conductivity	umho/cm	468	2	8904196				708	727	2	8904196
Available (CaCl2) pH	pH	7.84		8907763				7.84	7.58		8907763
Soluble (20:1) Sulphate (SO4)	ug/g	75	20	8903811				210	66	20	8903811
Sulphide	mg/kg	3.8 (1)	0.5	8912361	1.5 (2)	0.5	8912361	3.0	<0.5 (3)	0.5	8912361
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate N/A = Not Applicable (1) Duplicate exceeds acceptance criteria due to sample matrix. Reanalysis yields similar results. (2) Recovery or RPD for this parameter is outside control limits. The overall quality control for this analysis meets acceptability criteria. (3) Extracted past method specified hold time											



Bureau Veritas Job #: C3R2807  
Report Date: 2023/09/12

exp Services Inc  
Client Project #: ADM-23006096-A0  
Site Location: Hwy 403 at Main-St/Aberdeen in Hamilton  
Sampler Initials: EL

### SOIL CORROSIVITY PACKAGE (SOIL)

Bureau Veritas ID		WXJ004			WXJ005		
Sampling Date		2023/08/25 10:00			2023/09/01 11:00		
COC Number		N/A			N/A		
	UNITS	BH5-SA6 Lab-Dup	RDL	QC Batch	BH10-SA9	RDL	QC Batch
<b>Calculated Parameters</b>							
Resistivity	ohm-cm				1100		8901046
<b>CONVENTIONALS</b>							
Redox Potential	mV	420	N/A	8908461	430	N/A	8908461
<b>Inorganics</b>							
Soluble (20:1) Chloride (Cl-)	ug/g				250	20	8903800
Conductivity	umho/cm	748	2	8904196	940	2	8904196
Available (CaCl2) pH	pH				7.99		8907763
Soluble (20:1) Sulphate (SO4)	ug/g				500	20	8903811
Sulphide	mg/kg				2.2	0.5	8912361
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate N/A = Not Applicable							



Bureau Veritas Job #: C3R2807  
Report Date: 2023/09/12

exp Services Inc  
Client Project #: ADM-23006096-A0  
Site Location: Hwy 403 at Main-St/Aberdeen in Hamilton  
Sampler Initials: EL

### RESULTS OF ANALYSES OF SOIL

Bureau Veritas ID		WXJ002	WXJ003	WXJ004	WXJ005		
Sampling Date		2023/08/31 12:00	2023/08/30 10:00	2023/08/25 10:00	2023/09/01 11:00		
COC Number		N/A	N/A	N/A	N/A		
	<b>UNITS</b>	<b>BH3-SA6</b>	<b>BH8-SA9</b>	<b>BH5-SA6</b>	<b>BH10-SA9</b>	<b>RDL</b>	<b>QC Batch</b>
<b>Physical Testing</b>							
Moisture-Subcontracted	%	17	19	22	30	0.30	8912362
RDL = Reportable Detection Limit							
QC Batch = Quality Control Batch							



Bureau Veritas Job #: C3R2807  
Report Date: 2023/09/12

exp Services Inc  
Client Project #: ADM-23006096-A0  
Site Location: Hwy 403 at Main-St/Aberdeen in Hamilton  
Sampler Initials: EL

## TEST SUMMARY

**Bureau Veritas ID:** WXJ002  
**Sample ID:** BH3-SA6  
**Matrix:** Soil

**Collected:** 2023/08/31  
**Shipped:**  
**Received:** 2023/09/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8903800	2023/09/08	2023/09/11	Massarat Jan
Conductivity	AT	8904196	2023/09/08	2023/09/08	Leily Karimi
Moisture (Subcontracted)	BAL	8912362	N/A	2023/09/12	Surinder Singh
Sulphide in Soil	SPEC	8912361	N/A	2023/09/12	Ly Vu
pH CaCl2 EXTRACT	AT	8907763	2023/09/11	2023/09/11	Gurpartee K AUR
Redox Potential	COND	8908461	2023/09/11	2023/09/12	Gurpartee K AUR
Resistivity of Soil		8901046	2023/09/08	2023/09/08	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8903811	2023/09/08	2023/09/11	Massarat Jan

**Bureau Veritas ID:** WXJ002 Dup  
**Sample ID:** BH3-SA6  
**Matrix:** Soil

**Collected:** 2023/08/31  
**Shipped:**  
**Received:** 2023/09/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Sulphide in Soil	SPEC	8912361	N/A	2023/09/12	Ly Vu

**Bureau Veritas ID:** WXJ003  
**Sample ID:** BH8-SA9  
**Matrix:** Soil

**Collected:** 2023/08/30  
**Shipped:**  
**Received:** 2023/09/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8903800	2023/09/08	2023/09/11	Massarat Jan
Conductivity	AT	8904196	2023/09/08	2023/09/08	Leily Karimi
Moisture (Subcontracted)	BAL	8912362	N/A	2023/09/12	Surinder Singh
Sulphide in Soil	SPEC	8912361	N/A	2023/09/12	Ly Vu
pH CaCl2 EXTRACT	AT	8907763	2023/09/11	2023/09/11	Gurpartee K AUR
Redox Potential	COND	8908461	2023/09/11	2023/09/12	Gurpartee K AUR
Resistivity of Soil		8901046	2023/09/08	2023/09/08	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8903811	2023/09/08	2023/09/11	Massarat Jan

**Bureau Veritas ID:** WXJ004  
**Sample ID:** BH5-SA6  
**Matrix:** Soil

**Collected:** 2023/08/25  
**Shipped:**  
**Received:** 2023/09/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8903800	2023/09/08	2023/09/11	Massarat Jan
Conductivity	AT	8904196	2023/09/08	2023/09/08	Leily Karimi
Moisture (Subcontracted)	BAL	8912362	N/A	2023/09/12	Surinder Singh
Sulphide in Soil	SPEC	8912361	N/A	2023/09/12	Ly Vu
pH CaCl2 EXTRACT	AT	8907763	2023/09/11	2023/09/11	Gurpartee K AUR
Redox Potential	COND	8908461	2023/09/11	2023/09/12	Gurpartee K AUR
Resistivity of Soil		8901046	2023/09/08	2023/09/08	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8903811	2023/09/08	2023/09/11	Massarat Jan



Bureau Veritas Job #: C3R2807  
Report Date: 2023/09/12

exp Services Inc  
Client Project #: ADM-23006096-A0  
Site Location: Hwy 403 at Main-St/Aberdeen in Hamilton  
Sampler Initials: EL

## TEST SUMMARY

**Bureau Veritas ID:** WXJ004 Dup  
**Sample ID:** BH5-SA6  
**Matrix:** Soil

**Collected:** 2023/08/25  
**Shipped:**  
**Received:** 2023/09/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Conductivity	AT	8904196	2023/09/08	2023/09/08	Leily Karimi
Redox Potential	COND	8908461	2023/09/11	2023/09/12	Gurparteek KAUR

**Bureau Veritas ID:** WXJ005  
**Sample ID:** BH10-SA9  
**Matrix:** Soil

**Collected:** 2023/09/01  
**Shipped:**  
**Received:** 2023/09/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8903800	2023/09/08	2023/09/11	Massarat Jan
Conductivity	AT	8904196	2023/09/08	2023/09/08	Leily Karimi
Moisture (Subcontracted)	BAL	8912362	N/A	2023/09/12	Surinder Singh
Sulphide in Soil	SPEC	8912361	N/A	2023/09/12	Ly Vu
pH CaCl2 EXTRACT	AT	8907763	2023/09/11	2023/09/11	Gurparteek KAUR
Redox Potential	COND	8908461	2023/09/11	2023/09/12	Gurparteek KAUR
Resistivity of Soil		8901046	2023/09/08	2023/09/08	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8903811	2023/09/08	2023/09/11	Massarat Jan



Bureau Veritas Job #: C3R2807  
Report Date: 2023/09/12

exp Services Inc  
Client Project #: ADM-23006096-A0  
Site Location: Hwy 403 at Main-St/Aberdeen in Hamilton  
Sampler Initials: EL

GENERAL COMMENTS

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

Package 1	8.7°C
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Results relate only to the items tested.





## QUALITY ASSURANCE REPORT

exp Services Inc  
Client Project #: ADM-23006096-A0  
Site Location: Hwy 403 at Main-St/Aberdeen in Hamilton  
Sampler Initials: EL

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
8903800	Soluble (20:1) Chloride (Cl <sup>-</sup> )	2023/09/11	NC	70 - 130	97	70 - 130	<20	ug/g	4.0	35
8903811	Soluble (20:1) Sulphate (SO <sub>4</sub> )	2023/09/11	100	70 - 130	99	70 - 130	<20	ug/g	NC	35
8904196	Conductivity	2023/09/08			101	90 - 110	<2	umho/cm	2.9	10
8907763	Available (CaCl <sub>2</sub> ) pH	2023/09/11			98	97 - 103			2.5	N/A
8908461	Redox Potential	2023/09/12			102	95 - 105			14	35
8912361	Sulphide	2023/09/12	52 (1)	75 - 125	83	75 - 125	<0.5	mg/kg	88 (1)	30
8912362	Moisture-Subcontracted	2023/09/12					<0.30	%		

N/A = Not Applicable

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

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

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

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

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

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

(1) Recovery or RPD for this parameter is outside control limits. The overall quality control for this analysis meets acceptability criteria.



Bureau Veritas Job #: C3R2807  
Report Date: 2023/09/12

exp Services Inc  
Client Project #: ADM-23006096-A0  
Site Location: Hwy 403 at Main-St/Aberdeen in Hamilton  
Sampler Initials: EL

### VALIDATION SIGNATURE PAGE

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

Anastassia Hamanov, Scientific Specialist

Ghayasuddin Khan, M.Sc., P.Chem., QP, Scientific Specialist, Inorganics

Veronica Falk, B.Sc., P.Chem., QP, Scientific Specialist, Organics

---

Bureau Veritas has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation, please refer to the Validation Signatures page if included, otherwise available by request. For Department specific Analyst/Supervisor validation names, please refer to the Test Summary section if included, otherwise available by request. This report is authorized by {0}, {1} responsible for {2} {3} laboratory operations.

C3R2807

ENY-1618

HELD IN LONDON



Your Project #: ABM-23006096-A0  
Site Location: Hwy 403 at Main-St/Aberdeen, Hamilton, ON  
Your C.O.C. #: n/a

**Attention: Silvana Micic**

exp Services Inc  
Brampton Branch  
1595 Clark Blvd  
Brampton, ON  
CANADA L6T 4V1

**Report Date: 2023/10/23**

Report #: R7875335

Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**BUREAU VERITAS JOB #: C3W2931**

**Received: 2023/10/16, 15:35**

Sample Matrix: Soil  
# Samples Received: 1

Analyses	Quantity	Date	Date	Laboratory Method	Analytical Method
		Extracted	Analyzed		
Chloride (20:1 extract)	1	2023/10/20	2023/10/23	CAM SOP-00463	MOE E3013 m
Conductivity	1	2023/10/19	2023/10/19	CAM SOP-00414	OMOE E3530 v1 m
Moisture (Subcontracted) (1, 2)	1	N/A	2023/10/20	AB SOP-00002	CCME PHC-CWS m
Sulphide in Soil (1)	1	N/A	2023/10/20	AB SOP-00080	EPA9030B/SM4500S2-DF
pH CaCl2 EXTRACT	1	2023/10/20	2023/10/20	CAM SOP-00413	EPA 9045 D m
Redox Potential (3)	1	2023/10/19	2023/10/20	CAM SOP-00421	SM 2580 B
Resistivity of Soil	1	2023/10/17	2023/10/19	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	1	2023/10/20	2023/10/23	CAM SOP-00464	MOE E3013 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, MELCCFP, 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.

(1) This test was performed by Bureau Veritas Calgary (19th), 4000 19th Street NE, Calgary, AB, T2E 6P8

(2) Offsite analysis requires that subcontracted moisture be reported.



Your Project #: ABM-23006096-A0  
Site Location: Hwy 403 at Main-St/Aberdeen, Hamilton, ON  
Your C.O.C. #: n/a

**Attention: Silvana Micic**

exp Services Inc  
Brampton Branch  
1595 Clark Blvd  
Brampton, ON  
CANADA L6T 4V1

**Report Date: 2023/10/23**

**Report #: R7875335**

**Version: 1 - Final**

**CERTIFICATE OF ANALYSIS**

**BUREAU VERITAS JOB #: C3W2931**

**Received: 2023/10/16, 15:35**

(3) Oxidation-Reduction Potential (ORP) values are determined using a Ag/AgCl reference electrode. The test is therefore, not SCC accredited for this matrix.

Encryption Key

Patricia Legette  
Project Manager  
23 Oct 2023 18:55:32

Please direct all questions regarding this Certificate of Analysis to:

Patricia Legette, Project Manager

Email: Patricia.Legette@bureauveritas.com

Phone# (905)817-5799

=====

This report has been generated and distributed using a secure automated process.

Bureau Veritas has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation, please refer to the Validation Signatures page if included, otherwise available by request. For Department specific Analyst/Supervisor validation names, please refer to the Test Summary section if included, otherwise available by request. This report is authorized by Rodney Major, General Manager responsible for Ontario Environmental laboratory operations.



Bureau Veritas Job #: C3W2931  
Report Date: 2023/10/23

exp Services Inc  
Client Project #: ABM-23006096-A0  
Site Location: Hwy 403 at Main-St/Aberdeen, Hamilton, ON  
Sampler Initials: SM

### SOIL CORROSIVITY PACKAGE (SOIL)

Bureau Veritas ID		XHX279			XHX279		
Sampling Date		2023/10/12 11:00			2023/10/12 11:00		
COC Number		n/a			n/a		
	UNITS	BH8-SS9	RDL	QC Batch	BH8-SS9 Lab-Dup	RDL	QC Batch
<b>Calculated Parameters</b>							
Resistivity	ohm-cm	3400		8986934			
<b>CONVENTIONALS</b>							
Redox Potential	mV	110	N/A	8992418			
<b>Inorganics</b>							
Soluble (20:1) Chloride (Cl-)	ug/g	21	20	8995005	<20	20	8995005
Conductivity	umho/cm	295	2	8992975			
Available (CaCl2) pH	pH	8.07		8994733			
Soluble (20:1) Sulphate (SO4)	ug/g	130	20	8995020	130	20	8995020
Sulphide	mg/kg	1.6	0.5	8997030	1.0	0.5	8997030
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate N/A = Not Applicable							



Bureau Veritas Job #: C3W2931  
Report Date: 2023/10/23

exp Services Inc  
Client Project #: ABM-23006096-A0  
Site Location: Hwy 403 at Main-St/Aberdeen, Hamilton, ON  
Sampler Initials: SM

### RESULTS OF ANALYSES OF SOIL

Bureau Veritas ID		XHX279		
Sampling Date		2023/10/12 11:00		
COC Number		n/a		
	<b>UNITS</b>	<b>BH8-SS9</b>	<b>RDL</b>	<b>QC Batch</b>
<b>Physical Testing</b>				
Moisture-Subcontracted	%	15	0.30	8997031
RDL = Reportable Detection Limit				
QC Batch = Quality Control Batch				





Bureau Veritas Job #: C3W2931  
Report Date: 2023/10/23

exp Services Inc  
Client Project #: ABM-23006096-A0  
Site Location: Hwy 403 at Main-St/Aberdeen, Hamilton, ON  
Sampler Initials: SM

## TEST SUMMARY

**Bureau Veritas ID:** XHX279  
**Sample ID:** BH8-SS9  
**Matrix:** Soil

**Collected:** 2023/10/12  
**Shipped:**  
**Received:** 2023/10/16

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8995005	2023/10/20	2023/10/23	Massarat Jan
Conductivity	AT	8992975	2023/10/19	2023/10/19	Leily Karimi
Moisture (Subcontracted)	BAL	8997031	N/A	2023/10/20	Margarita Aguilera
Sulphide in Soil	SPEC	8997030	N/A	2023/10/20	Bailey Morrison
pH CaCl2 EXTRACT	AT	8994733	2023/10/20	2023/10/20	Gurparteek KAUR
Redox Potential	COND	8992418	2023/10/19	2023/10/20	Gurparteek KAUR
Resistivity of Soil		8986934	2023/10/19	2023/10/19	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8995020	2023/10/20	2023/10/23	Alina Dobreanu

**Bureau Veritas ID:** XHX279 Dup  
**Sample ID:** BH8-SS9  
**Matrix:** Soil

**Collected:** 2023/10/12  
**Shipped:**  
**Received:** 2023/10/16

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8995005	2023/10/20	2023/10/23	Massarat Jan
Sulphide in Soil	SPEC	8997030	N/A	2023/10/20	Bailey Morrison
Sulphate (20:1 Extract)	KONE/EC	8995020	2023/10/20	2023/10/23	Alina Dobreanu





Bureau Veritas Job #: C3W2931  
Report Date: 2023/10/23

exp Services Inc  
Client Project #: ABM-23006096-A0  
Site Location: Hwy 403 at Main-St/Aberdeen, Hamilton, ON  
Sampler Initials: SM

### GENERAL COMMENTS

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

Package 1	6.7°C
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**Results relate only to the items tested.**



QUALITY ASSURANCE REPORT

exp Services Inc  
Client Project #: ABM-23006096-A0  
Site Location: Hwy 403 at Main-St/Aberdeen, Hamilton, ON  
Sampler Initials: SM

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
8992418	Redox Potential	2023/10/20			99	95 - 105			2.1	35
8992975	Conductivity	2023/10/19			105	90 - 110	<2	umho/cm	0.48	10
8994733	Available (CaCl2) pH	2023/10/20			100	97 - 103			0.21	N/A
8995005	Soluble (20:1) Chloride (Cl-)	2023/10/23	104	70 - 130	98	70 - 130	<20	ug/g	4.5	35
8995020	Soluble (20:1) Sulphate (SO4)	2023/10/23	NC	70 - 130	94	70 - 130	<20	ug/g	4.4	35
8997030	Sulphide	2023/10/20	79	75 - 125	92	75 - 125	<0.5	mg/kg	NC	30
8997031	Moisture-Subcontracted	2023/10/20					<0.30	%		

N/A = Not Applicable

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

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

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

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

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

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



Bureau Veritas Job #: C3W2931  
Report Date: 2023/10/23

exp Services Inc  
Client Project #: ABM-23006096-A0  
Site Location: Hwy 403 at Main-St/Aberdeen, Hamilton, ON  
Sampler Initials: SM

### VALIDATION SIGNATURE PAGE

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

---

Cristina Carriere, Senior Scientific Specialist

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Veronica Falk, B.Sc., P.Chem., QP, Scientific Specialist, Organics

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Suwan (Sze Yeung) Fock, B.Sc., Scientific Specialist

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Bureau Veritas has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation, please refer to the Validation Signatures page if included, otherwise available by request. For Department specific Analyst/Supervisor validation names, please refer to the Test Summary section if included, otherwise available by request. This report is authorized by Rodney Major, General Manager responsible for Ontario Environmental laboratory operations.



6740 Campedella Road, Mesquite, Dallas, TX 75206  
Phone: 905-317-5700 Fax: 905-417-5719 Toll Free: 800-563-6286

CHAIN OF CUSTODY RECORD  
ENV CDC - 00014V3

16-Oct-23 15:35  
Patricia Legette  
C3W2931



Invoice Information		Report Information (if differs from Invoice)		Project Information	
Company:	EXP Services Inc.	Company:	Silvana M. Leticia	Question #	
Contact:	AP	Contact:		P.O. #/ A/E/C:	
Address:	1595 Clark Blvd.	Address:		Project #:	ADW-2306096-A0
City:	Brampton	City:		Site #:	
Prov:	ON	Prov:		Site Location:	
Postal Code:	L6T	Postal Code:		Site Location:	
Phone:	905-793-9800	Phone:	416-464-3042	Province:	
E-mail:	AP@exp.com	E-mail:	silvana.m.leticia@exp.com	Sampled By:	
Copies:		Copies:			

Regulatory Criteria		Regulatory Criteria	
<input type="checkbox"/> Table 1	<input type="checkbox"/> Rec/Ark	<input type="checkbox"/> CCLME	<input type="checkbox"/> Reg 406, Table 1
<input type="checkbox"/> Table 2	<input type="checkbox"/> Rec/Conn	<input type="checkbox"/> Reg 558*	<input type="checkbox"/> Secondary Sewer Bylaw
<input type="checkbox"/> Table 3	<input type="checkbox"/> Appl/Other	<input type="checkbox"/> For BDC	<input type="checkbox"/> Storm Sewer Bylaw
<input type="checkbox"/> Table 4	<input type="checkbox"/> Other	<input type="checkbox"/> PMOD	<input type="checkbox"/> Other

SAMPLES MUST BE KEPT COOL (4°C) FROM TIME OF SAMPLING UNTIL DELIVERY TO BUREAU VERITAS

Sample Identification		Date Sampled		Time (24hr)		Method	
1	348-SS9	2023	10	12	11	00	Soil

	FIELD FILTERED	FIELD PRESERVED	LAB FILTRATION REQUIRED	ETEX/F1	F2 / F4	VOCs	Reg 155 metals and inorganics	Reg 155 ICPMS metals	Reg 155 metals (Hg, Cr, VI, ICPMS metals, HWS - B)	Soil Corrosivity
1										✓
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										

LAB USE ONLY		LAB USE ONLY		LAB USE ONLY		LAB USE ONLY	
Seal present	Yes	No	Seal intact	Yes	No	Seal present	Yes
Seal intact	Yes	No	Seal intact	Yes	No	Seal present	Yes
Cooling media present	Yes	No	Cooling media present	Yes	No	Seal present	Yes
Requisitioned By: (Signature/ Print)	2023	10	16	15	35	Seal present	Yes
Received By: (Signature/ Print)	2023	10	17	15	35	Seal present	Yes



Your Project #: ADM-23006096-A0  
Site Location: HWY 403 - MAIN ST - HAMILTON  
Your C.O.C. #: na

**Attention: Silvana Micic**

exp Services Inc  
Brampton Branch  
1595 Clark Blvd  
Brampton, ON  
CANADA L6T 4V1

**Report Date: 2023/09/20**  
Report #: R7822202  
Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**BUREAU VERITAS JOB #: C3R8637**

**Received: 2023/09/11, 14:57**

Sample Matrix: Soil  
# Samples Received: 1

Analyses	Quantity	Date	Date	Laboratory Method	Analytical Method
		Extracted	Analyzed		
Chloride (20:1 extract)	1	2023/09/15	2023/09/15	CAM SOP-00463	MOE E3013 m
Conductivity	1	2023/09/14	2023/09/14	CAM SOP-00414	OMOE E3530 v1 m
Moisture (Subcontracted) (1, 2)	1	N/A	2023/09/19	AB SOP-00002	CCME PHC-CWS m
Sulphide in Soil (1)	1	N/A	2023/09/19	AB SOP-00080	EPA9030B/SM4500S2-DF
pH CaCl2 EXTRACT	1	2023/09/14	2023/09/14	CAM SOP-00413	EPA 9045 D m
Redox Potential (3)	1	2023/09/14	2023/09/14	CAM SOP-00421	SM 2580 B
Resistivity of Soil	1	2023/09/12	2023/09/14	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	1	2023/09/15	2023/09/15	CAM SOP-00464	MOE E3013 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, MELCCFP, 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.

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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.

(1) This test was performed by Bureau Veritas Calgary (19th), 4000 19th Street NE, Calgary, AB, T2E 6P8

(2) Offsite analysis requires that subcontracted moisture be reported.



Your Project #: ADM-23006096-A0  
Site Location: HWY 403 - MAIN ST - HAMILTON  
Your C.O.C. #: na

**Attention: Silvana Micic**

exp Services Inc  
Brampton Branch  
1595 Clark Blvd  
Brampton, ON  
CANADA L6T 4V1

**Report Date: 2023/09/20**  
Report #: R7822202  
Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**BUREAU VERITAS JOB #: C3R8637**

**Received: 2023/09/11, 14:57**

(3) Oxidation-Reduction Potential (ORP) values are determined using a Ag/AgCl reference electrode. The test is therefore, not SCC accredited for this matrix.

Encryption Key

Christine Gripton  
Senior Project Manager  
20 Sep 2023 17:57:55

Please direct all questions regarding this Certificate of Analysis to:

Patricia Legette, Project Manager  
Email: Patricia.Legette@bureauveritas.com  
Phone# (905)817-5799

=====

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Bureau Veritas Job #: C3R8637  
Report Date: 2023/09/20

exp Services Inc  
Client Project #: ADM-23006096-A0  
Site Location: HWY 403 - MAIN ST - HAMILTON  
Sampler Initials: EL

### SOIL CORROSIVITY PACKAGE (SOIL)

Bureau Veritas ID		WYO299			WYO299		
Sampling Date		2023/09/09 11:00			2023/09/09 11:00		
COC Number		na			na		
	<b>UNITS</b>	<b>BH15-SS6</b>	<b>RDL</b>	<b>QC Batch</b>	<b>BH15-SS6 Lab-Dup</b>	<b>RDL</b>	<b>QC Batch</b>
<b>Calculated Parameters</b>							
Resistivity	ohm-cm	3400		8912335			
<b>CONVENTIONALS</b>							
Redox Potential	mV	340	N/A	8915857			
<b>Inorganics</b>							
Soluble (20:1) Chloride (Cl-)	ug/g	<20	20	8919234			
Conductivity	umho/cm	290	2	8916619	284	2	8916619
Available (CaCl2) pH	pH	7.08		8916448			
Soluble (20:1) Sulphate (SO4)	ug/g	89	20	8919338			
Sulphide	mg/kg	0.7 (1)	0.5	8928861	<0.5	0.5	8928861
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate N/A = Not Applicable (1) Matrix spike exceeds acceptance limits due to matrix interference.							



Bureau Veritas Job #: C3R8637  
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exp Services Inc  
Client Project #: ADM-23006096-A0  
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Sampler Initials: EL

### RESULTS OF ANALYSES OF SOIL

Bureau Veritas ID		WYO299		
Sampling Date		2023/09/09 11:00		
COC Number		na		
	<b>UNITS</b>	<b>BH15-SS6</b>	<b>RDL</b>	<b>QC Batch</b>
<b>Physical Testing</b>				
Moisture-Subcontracted	%	18	0.30	8928862
RDL = Reportable Detection Limit				
QC Batch = Quality Control Batch				





Bureau Veritas Job #: C3R8637  
Report Date: 2023/09/20

exp Services Inc  
Client Project #: ADM-23006096-A0  
Site Location: HWY 403 - MAIN ST - HAMILTON  
Sampler Initials: EL

## TEST SUMMARY

**Bureau Veritas ID:** WYO299  
**Sample ID:** BH15-SS6  
**Matrix:** Soil

**Collected:** 2023/09/09  
**Shipped:**  
**Received:** 2023/09/11

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8919234	2023/09/15	2023/09/15	Massarat Jan
Conductivity	AT	8916619	2023/09/14	2023/09/14	Leily Karimi
Moisture (Subcontracted)	BAL	8928862	N/A	2023/09/19	Ashley Henderson
Sulphide in Soil	SPEC	8928861	N/A	2023/09/19	Bailey Morrison
pH CaCl2 EXTRACT	AT	8916448	2023/09/14	2023/09/14	Gurparteek KAUR
Redox Potential	COND	8915857	2023/09/14	2023/09/14	Gurparteek KAUR
Resistivity of Soil		8912335	2023/09/14	2023/09/14	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8919338	2023/09/15	2023/09/15	Massarat Jan

**Bureau Veritas ID:** WYO299 Dup  
**Sample ID:** BH15-SS6  
**Matrix:** Soil

**Collected:** 2023/09/09  
**Shipped:**  
**Received:** 2023/09/11

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Conductivity	AT	8916619	2023/09/14	2023/09/14	Leily Karimi
Sulphide in Soil	SPEC	8928861	N/A	2023/09/19	Bailey Morrison



Bureau Veritas Job #: C3R8637  
Report Date: 2023/09/20

exp Services Inc  
Client Project #: ADM-23006096-A0  
Site Location: HWY 403 - MAIN ST - HAMILTON  
Sampler Initials: EL

GENERAL COMMENTS

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

Package 1	10.3°C
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Results relate only to the items tested.



QUALITY ASSURANCE REPORT

exp Services Inc  
Client Project #: ADM-23006096-A0  
Site Location: HWY 403 - MAIN ST - HAMILTON  
Sampler Initials: EL

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
8915857	Redox Potential	2023/09/14			101	95 - 105			4.6	35
8916448	Available (CaCl2) pH	2023/09/14			101	N/A			0.12	N/A
8916619	Conductivity	2023/09/14			100	90 - 110	<2	umho/cm	2.1	10
8919234	Soluble (20:1) Chloride (Cl-)	2023/09/15	95	70 - 130	92	70 - 130	<20	ug/g	NC	35
8919338	Soluble (20:1) Sulphate (SO4)	2023/09/15	NC	70 - 130	103	70 - 130	<20	ug/g	2.7	35
8928861	Sulphide	2023/09/19	24 (1)	75 - 125	113	75 - 125	<0.5	mg/kg	NC	30
8928862	Moisture-Subcontracted	2023/09/19					<0.30	%		

N/A = Not Applicable

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

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

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

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

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

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

(1) Recovery or RPD for this parameter is outside control limits. The overall quality control for this analysis meets acceptability criteria.



Bureau Veritas Job #: C3R8637  
Report Date: 2023/09/20

exp Services Inc  
Client Project #: ADM-23006096-A0  
Site Location: HWY 403 - MAIN ST - HAMILTON  
Sampler Initials: EL

### VALIDATION SIGNATURE PAGE

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

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Cristina Carriere, Senior Scientific Specialist

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Ghayasuddin Khan, M.Sc., P.Chem., QP, Scientific Specialist, Inorganics

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Gita Pokhrel, Senior Analyst

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C3R8637

ENV-1695

[illegible]

## Appendix F – NSSPs

## **NSSP FOR OBSTRUCTIONS**

### **Scope of Work**

The Contractor shall be alerted to the potential presence of cobbles and boulders in the fill and native soils encountered in few boreholes advanced at the site. Therefore, appropriate equipment and procedures will be required for open cut excavation and installation of roadway protection systems and temporary dewatering/unwatering systems.

### **Basis of Payment**

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.



## **NSSP FOR INTERFACE BETWEEN MIXED FACE SOIL CONDITIONS AND SHALE BEDROCK**

### **Scope of Work**

The Contractor shall be alerted to the interface between mixed faced soil conditions and sloping residual soil/weathered shale bedrock which exists approximately at Station 0+170 along Section D-D. Therefore, appropriate equipment and procedures will be required for tunneling at/through this location.

### **Basis of Payment**

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.

**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 m<sup>3</sup> 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 m<sup>3</sup> or greater.

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

**Slurry Pressure Balance (SPB)** means a tunnelling system that provides support to the excavated face of the ground and resistance to groundwater inflow through the pressure of slurry as maintained by and in a chamber behind the cutting face of a 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 OSHA 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)  $\pm 2$  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.

## **Guidelines for Foundation Engineering – Tunnelling Specialty For Corridor Encroachment Permit Application**

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### **General**

These guidelines specify MTO requirements for the Foundation Engineering – Tunnelling Specialty component of submissions from proponents of development within the Ministry of Transportation's (MTO) corridor permit control area. The Foundation Engineering – Tunnelling Specialty component of submissions is a requirement for the permit application only and does not cover all the design requirements.

All applications containing tunnelling proposals shall be forwarded to the regional Geotechnical Section for review. Applications containing Low Complexity tunnelling proposals will typically be reviewed by the regional Geotechnical Section. The Geotechnical Section will forward applications involving Medium and High Complexity tunnelling proposals to the Foundation Section of the Structures Office for review.

Foundations Engineering consultants that are registered in the MTO consultant acquisition system (RAQS) at complexity ratings identified in Table 1 are eligible to provide Foundations Engineering services for this project. Alternatively, the proponents may propose a Foundations Engineering consultant that is not registered in RAQS, in which case, the proponent must submit sufficient documentation to demonstrate that the consultant's qualifications meet or exceed the RAQS complexity requirements. The submission for RAQS exemption shall demonstrate that the proponent has successfully completed tunnelling/trenchless projects on projects of similar scope and complexity. The proponent shall submit a minimum of three (3) Foundation Investigation and Design Reports on projects of similar scope and complexity produced in the last five (5) years. The proponent shall submit any supplementary engineering and construction experience to demonstrate their qualifications.

For Engineering Materials Testing and Evaluation, the consultant shall be qualified for Soil and Rock testing of complexity level at least equal to that identified for this project.

Please refer to Table 1 on Page 2 for the Foundation Engineering Complexity of Work guideline.

**Table 1: Complexity ratings for tunnelling specialty services**

Excavation Diameter (Ø)	≤ 300 mm		1 m ≥ Ø > 300 mm		2 m ≥ Ø > 1 m		Ø > 2 m
Design Cover* (m)	≥ 1.5 m	< 1.5 m	≥ 3 Ø and > 1.5 m	< 3 Ø or < 1.5 m	≥ 3 Ø	< 3 Ø	N/A
King's Highway	<b>Low</b>	<b>Medium</b>	<b>Low</b>	<b>Medium</b>	<b>Medium</b>	<b>High</b>	<b>High</b>
400 Series Freeway	<b>Low</b>	<b>High</b>	<b>Medium</b>	<b>High</b>	<b>High</b>	<b>High</b>	<b>High</b>

\* Design cover is the proposed vertical distance measured from the lowest ground elevation to the crown of the tunnel

## **Site Investigation, Field Testing and Monitoring**

### **General**

This section describes requirements for site investigation, field/laboratory testing and monitoring programs for a proposed tunnelling projects. For low complexity projects, some or all of these requirements may not be necessary. Foundation field investigation, laboratory analyses and monitoring for low complexity projects with an excavation diameter of 300 mm or less will generally only be required on an exception basis. The applicant's Foundation Engineering service can contact MTO Geotechnical staff for clarification regarding appropriate levels of investigation, testing and monitoring.

### **Field Testing**

A minimum of one borehole is required at each end of tunnel crossing. The boreholes shall be located outside but within two metres of the tunnel's excavated footprint.

Spacing between the boreholes shall not exceed 50 m. In case of larger spacing between the boreholes, additional boreholes shall be advanced except where significant traffic disruptions might occur and where consistent conditions are evident.

Boreholes shall be advanced to 3 tunnel diameters (excavated diameters) below invert. If bedrock is encountered earlier, the borehole shall advance to at least 3 m below the invert of tunnel into the bedrock.



The investigations, if required, shall be supplemented with additional and deeper boreholes to verify consistent conditions and existence of boulders within critical foundation zones.

Sampling and testing, consisting of Standard Penetration Test, thin wall tube sample, rock cores, and MTO Field Vane Test where appropriate, shall be conducted to develop a comprehensive subsurface model. Semi-continuous sampling at 0.75m (2.5ft) intervals is required within overburden; whereas, sampling interval of 1.5m (5.0ft) is required below the tunnel invert.

Where encountered, the bedrock-soil interface shall be determined by geological definition and not by the material properties.

All aspects of implementation of means of subsurface investigations including, but not limited to, planning, licensing, construction, maintenance, abandonment, and reporting, shall be in accordance with Ministry of the Environment Regulation 903 and its amendments (the water well regulation under the OWRA).

Boreholes and piezometer tubes shall be backfilled with a suitable bentonite/cement mixture. Test pits shall be backfilled with suitable material and either re-vegetated or otherwise protected from erosion. Temporary open holes shall be adequately covered. Holes in roads shall be backfilled as required to prevent future settlement and acceptably patched where pavement surfaces have been damaged. Backfilling requirements shall be described in the Foundation Investigation and Design Report.

Where encountered, artesian groundwater conditions shall be sealed. Details of the artesian condition and the sealing operation shall be included in the Foundation Investigation Report.

Fieldwork, including any Traffic Protection Plans required, shall be carried out in accordance with the Occupational Health and Safety Act.

Traffic Control in accordance with Ontario Traffic Manual Book 7 shall be provided during the course of any field investigations. However, where significant traffic disruptions might occur, boreholes may be relocated or numbers reduced with MTO's approval.

The locations and ground surface elevations of all boreholes, test pits and soundings shall be surveyed and referred to fixed reference points and data. Locations are to be identified by co-ordinates (Northing and Easting). The vertical accuracy of survey readings shall be within 0.1m; whereas, horizontal accuracy shall be within 0.5m.

The site investigation shall be of sufficient scope to verify design assumptions and to provide the contractor with adequate subsurface information for design and construction planning.

Sufficient subsurface (factual) information is required to determine the vertical and horizontal extent of subsurface materials (including both soil and rock) and their pertinent engineering properties and groundwater conditions.

Subsurface information is usually acquired by advancing boreholes, laboratory testing of soil samples and rock core samples, performing in-situ tests such as standard penetration tests, dynamic cone tests, and piezocone tests (CPTU) and test pits.

### **Minimum Laboratory Testing Requirements**

Laboratory testing shall consist of routine testing of 25% of samples. One routine lab test is defined as natural water content plus Atterberg Limits plus grain size distribution tests. Complex laboratory testing is defined by all other tests including compressive strength, shear strength, consolidation, permeability and triaxial testing. Laboratory testing requirements shall be supplemented with additional routine and complex tests if required to verify strata boundaries and properties and behaviour of critical subsurface zones.

A minimum of one (1) soil chemical test shall be conducted at maximum of 100 m spacing. A soil chemical test includes pH, water soluble sulphate, sulphide, chloride, resistivity and electrical conductivity analyses.

### **Borehole Log Preparation and Foundation Drawing**

Borehole log sheets, figures and drawings shall be prepared in accordance with MTO standards. The Foundation Drawing shall consist of a plan showing the locations of all borings, test pits and soundings and various stratigraphical longitudinal profiles and stratigraphical cross-sections at each tunnel structure foundation element and groundwater levels.

### **Requirements for the Foundation Investigation and Design Report**

A Foundation Investigation and Design Report shall consist of the factual subsurface information (including the field and laboratory test information) and the recommendations required for foundation design.

Service Provider services shall be in accordance with the most recent editions of the Canadian Highway Bridge Design Code (CHBDC), and the 'Guideline for Professional Engineers Providing Geotechnical Engineering Services' published by the Professional Engineers of Ontario.

The designated principal contact identified for Foundations Engineering services by MTO shall sign, and where required, seal, all submissions and correspondence that are submitted to MTO.

The report shall be signed and sealed by two professional engineers, registered with the Professional Engineers of Ontario, representing the consulting firm; one of them shall be the firm's designated principal contact for MTO's Foundations Engineering projects.

The Foundation Investigation component of the report shall contain:

- Site Description - including topography, vegetation, drainage, existing land use, and structures.
- Investigation Procedures - including site investigation and lab testing procedures.
- Description of Subsurface Conditions - including soil, boulders, rock and groundwater conditions.
- Miscellaneous Section - that identifies the name of the drilling company, the laboratory where testing was performed, the persons who carried out the field supervision, and those who wrote and reviewed the report.

The Foundation Design component of the report shall present discussion and recommendations for design. The Service Provider shall analyse field data and test results and make comprehensive and practical recommendations pertaining to temporary, interim and permanent conditions at the Project.

The Service Provider shall identify and evaluate all reasonable and appropriate alternatives for the proposed tunnel crossing. Alternatives may include, but not limited to, jack & bore, pipe jacking using TBM, pipe ramming, micro-tunnelling, utility tunnelling using TBM (two pass system), Horizontal Directional Drilling (HDD) and cut and cover methods.

The Service Provider shall identify and present overview assessments of the advantages, disadvantages, relative costs and risks/consequences of alternative tunnelling methods in a table. The report should conclude a preferred alternative from foundation engineering and cost effectiveness perspective.

In the development and design of the preferred alternative, the Service Provider shall, as applicable, address:

- impacts on the land use and property, traffic and transportation, and environment,
- length and diameter constraints
- control of face stability
- capability of boulder excavation
- evaluation of temporary and permanent support
- alignment control
- estimated settlements and heave and management of these deformations

- special access and egress requirements for TBM's and other similar equipment such as those used for the Jack & Bore method including recommendations for vertical shafts and jacking pits;
- shored and un-shored alternatives for open-cut excavation;
- groundwater control & dewatering;
- the long-term stability of the tunnel;
- relative costs; and
- traffic management and contractor access for each alternative.

If borehole logs available from previous projects are included to meet the requirements of field investigations then the accuracy of subsurface information from these boreholes remains the responsibility of Service Provider except in situations where MTO specify the use of previous boreholes. Borehole logs from previous studies that are appended to the report shall be reformatted to meet the MTO's requirements.

The final foundation recommendations shall detail the geometric, material and strength properties of the new tunnel crossing plus the liner, bedding and backfill requirements, and slope and embankment restoration requirements. The invert elevation should be assessed in view of the subsurface conditions and the anticipated open face stability control.

The Service Provider is responsible for developing contract documents sufficient to implement the design. This typically includes:

- Contract specifications for materials and specialized construction activities, and
- Recommendations for methods of overcoming anticipated construction problems, in particular, those relating to dewatering, boulder excavation, alignment control and the stability of excavations and embankments.

The Service Provider shall develop a detailed instrumentation and monitoring program that meets the requirements of these guidelines. (see Appendix for typical settlement monitoring guidelines).

The Service Provider is responsible for preparing Traffic Control Plans, Traffic Protection Plans and to obtain approvals and an Encroachment Permit from the Ministry, which are required for lane closures necessary to install the settlement monitoring points.

The tunnelling Service Provider shall ensure that the foundations engineering component of the project is adequately reflected in the design drawings, specifications and related contract documents.

Written confirmation is required from the Proponent and the tunnelling Service Provider that the design package submitted to MTO have been reviewed by the tunnelling Service Provider and that all recommendations have been satisfactorily incorporated in the contract package.

## **APPENDIX: SETTLEMENT MONITORING GUIDELINES - TUNNELING**

**The purpose of settlement monitoring is to prevent damage to existing utilities and highway structures along the tunnel alignment. Ground settlement include settlement due to lost ground and dewatering/drainage.**

Daily visual monitoring of the road surface and shoulders shall be carried out for any evidence of movements (e.g. cracks, bulges, heaves, depressions, ponding, etc.)

### **Instrumentation Arrays**

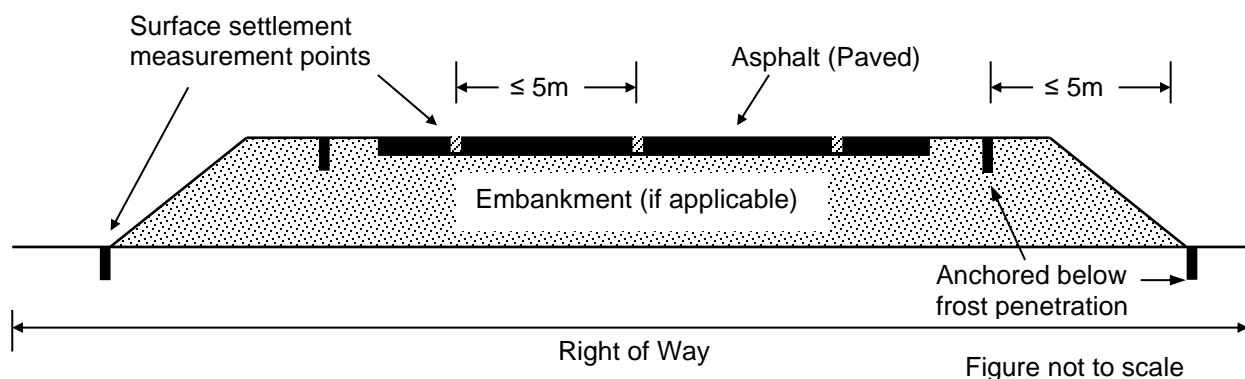
All measurement points shall be installed and surveyed before the start of excavation to establish benchmarks/baseline.

#### **Surface Monitoring Points**

Surface monitoring points will be installed to cover the whole length of the tunnel with in the right of way under the jurisdiction of MTO (Figure 1).

Surface monitoring points will be located at not greater than 5m intervals along the tunnel alignment. The surface monitoring will be identified using paint marks on the pavement. Surface monitoring points installed on the unpaved right of way shall be founded below frost penetration depths. The interval and/or marking of the points should be changed with MTO's approval where traffic disruptions might occur.

The final instrumentation plan should be finalised when Contractor's proposed construction method is available.



**Figure 1:** Typical configuration of surface settlement monitoring points along the tunnel alignment.

## **Condition Survey**

A condition survey for the pavement will be carried out prior to commencement of construction and documented for the purpose of requirement of restoration. The condition survey shall document visible flaws such as cracks, distortions and deviations, heaves, and depressions. This surface survey will be completed during the installation of the monitors and again once the tunnel has been completed.

## **Reading Frequency**

An average of at least two readings shall be taken to establish the initial conditions.

The reading and collection of data from the surface monitoring points shall be read and recorded by the Contractor during the construction period and after construction for period of at least 2 weeks provided that further settlement has stopped.

A minimum of three (3) sets of reading be taken daily, provided that movements are within anticipated limits. Otherwise, the frequencies should increase according to a pre-planned interval.

Monitoring of movements is required during work stoppages, such as during non-operation period (off-shifts) or weekends. A minimum of three (3) sets of readings should be taken daily.

Measurements of the monitoring points shall be reported promptly to MTO for review.

## **Data Collection and Data Transfer**

A procedure is required to be established in consultation with MTO so that the monitoring data and the interpreted data will reach all parties as soon as necessary. The contract administrator/Service Provider and the Contractor should interpret monitoring data as needed for the purpose of on-going construction. The Foundation Engineer should be contacted for technical support to the prime Service Provider in the interpretation of ground movements and review of the Contractor's response when Review and Alert Levels are reached.

## **Criteria for Assessment**

The acceptable surface settlement (or heave) will be according to criteria as specified below.

**Baseline Reading** – A baseline reading of the instrumentation shall be taken prior to commencement of the work. An average of at least two initial readings shall be recorded as baseline reading.

Review Level – A maximum value of 10 mm relative to the baseline readings is suggested for this project. If this level is reached, the method, rate or sequence of construction, or ground stabilization measures should be reviewed or modified to mitigate further ground displacements.

Alert Level – A maximum value of 15mm relative to the baseline readings is suggested for this project. If this level is reached, the Contractor shall cease construction operations and to execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic.

### **Review of Contractor's Proposed Method**

MTO, the Proponent's prime Service Provider and Foundation Engineer should review the Contractor's proposed method of construction. The proposed method should include a description of the potential loss of ground, and calculation of the maximum settlement in relation to the Contractor's procedure and equipment, alternative/remedial measures when review level of measurement is reached; and contingency/remedial measures when alert level of measurement is reached.

### **Contractor's Responsibility for Restoration and Warranty Provision**

In addition to the monitoring program to assess the adequacy of the construction method to control potential ground movements and groundwater, the Contractor is responsible for reinstatement (such as surface paving) should movements or other surface distress occur, and provide a reasonable warranty period acceptable to MTO. Remedial measures shall be approved by MTO; however, MTO maintains the right to perform the maintenance at the proponent's expense.

### **Construction Monitoring**

The Proponent shall retain a RAQS qualified Geotechnical Service Provider – Medium Complexity to supervise the installation of surface settlement points on site and to provide direction, technical input and field inspection on this project.

## Appendix G – Selected Boreholes from Previous Geotechnical Investigations



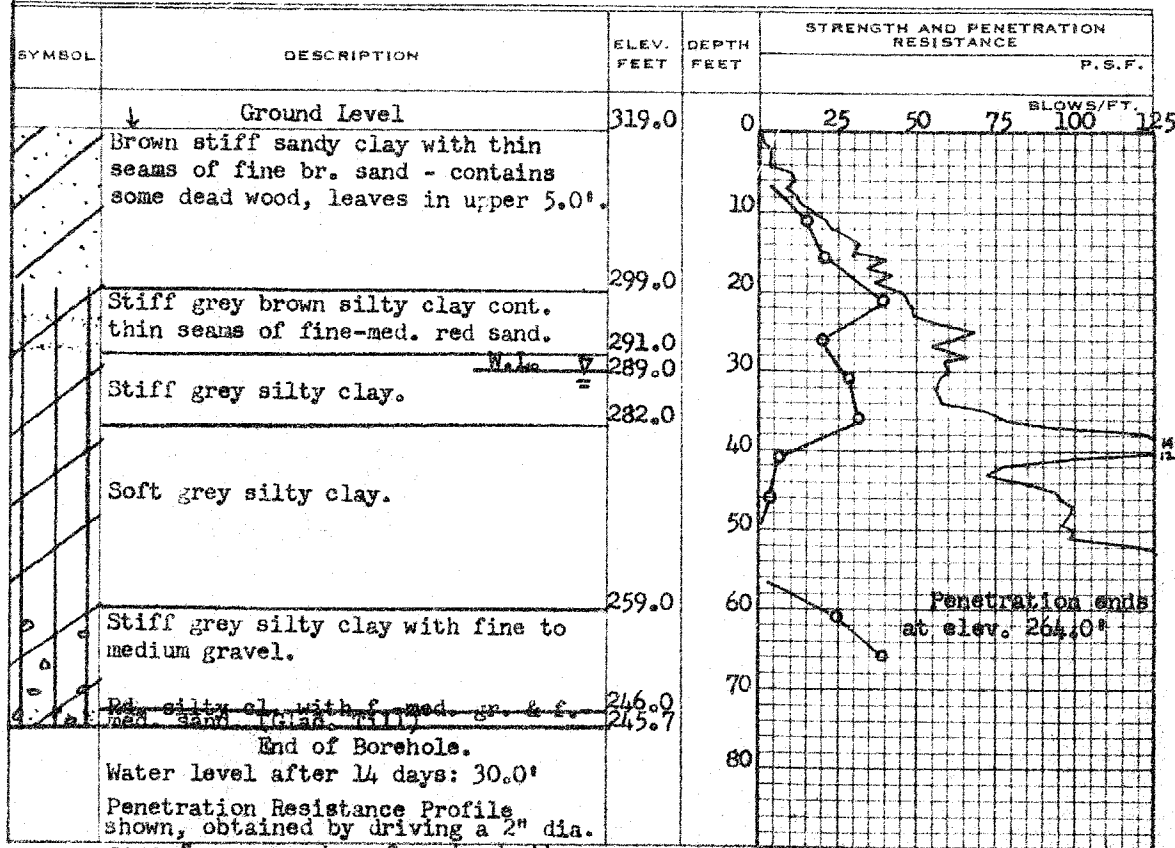
DEPARTMENT OF HIGHWAYS - ONTARIO  
MATERIALS AND RESEARCH SECTION

W.P. 266-60 BORE HOLE NO. 10  
 JOB 60-F-6 STATION 13+60 & Ramp 'D'  
 DATUM G. S. C. COMPILED BY B. K.  
 BORING DATE 8/4/60 CHECKED BY K. G. S.

2" DIA. SPLIT TUBE  
 2" SHELBY TUBE  
 2" SPLIT TUBE  
 2" DIA. CONE  
 2" SHELBY  
 CASING

## LEGEND

1/2 UNCONFINED COMPRESSION ( $Q_u$ ) O  
 VANE TEST (C) AND SENSITIVITY (S) +  
 NATURAL MOISTURE AND LIQUIDITY INDEX LI  
 LIQUID LIMIT X  
 PLASTIC LIMIT



CONSISTENCY	SAMPLE	NATURAL UNIT WT. P.C.F.
MOIST. CONTENT - % DRY WT.		
	S1	
	S2	
	S3	
	S4	
	S5	
	S6	
	S7	
	S8	
	S9	
	S10	
	S11	
	S12	
	S13	
	S14	

## METRIC

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 15-06

2 OF 2

METRIC

W.P. 2054-14-00 LOCATION N 4 790 761.2 E 271 825.0 ORIGINATED BY ES  
HWY 403 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2015.07.07 - 2015.07.07 CHECKED BY MRA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
	Continued From Previous Page													
	<p>Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.04m slotted screen.</p> <p>WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2015.10.04 2.8 82.1</p>													

PROJECT <u>08-1132-013-0</u>		<b>RECORD OF BOREHOLE No 32</b>		1 OF 1 <b>METRIC</b>	
G.W.P. <u>2172-06-00</u>		LOCATION <u>N 4790722.1 ; E 271759.1</u>		ORIGINATED BY <u>MA</u>	
DIST <u>          </u> HWY <u>403</u>		BOREHOLE TYPE <u>POWER AUGER/SOLID STEM AUGERS</u>		COMPILED BY <u>LMK</u>	
DATUM <u>GEODETIC</u>		DATE <u>July 15, 2008</u>		CHECKED BY <u>          </u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE   LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>P</sub>	W	W <sub>L</sub>		
								○ UNCONFINED   + FIELD VANE ● QUICK TRIAXIAL   × LAB VANE	WATER CONTENT (%)					
							20   40   60   80   100							
84.58	GROUND SURFACE													
0.00	TOPSOIL, sandy													
0.15	Brown													
0.30	FILL, clayey silt, trace sand, some gravel													
83.82	Brown													
0.76	FILL, sand and gravel, crushed, some silt		1	SS	12									
	Brown													
	FILL, clayey silt, trace sand, trace gravel, trace topsoil, wood		2	SS	12									
82.45	Stiff													
	Brown													
2.13	CLAYEY SILT, trace sand, trace gravel		3	SS	6									
	Firm to stiff													
	Brown to grey at about elev. 81.7m		4	SS	5									
			5	SS	5									
			6	SS	13									
78.48														
6.10	END OF BOREHOLE													
	Borehole dry during drilling on July 15, 2008.													

<b>PROJECT</b> 08-1132-013-1		<b>RECORD OF BOREHOLE No 101</b>		1 OF 2	<b>METRIC</b>
<b>W.P.</b> 2172-06-00		<b>LOCATION</b> N 4790785.8 E 271737.0		<b>ORIGINATED BY</b> MR	
<b>DIST</b> HWY 403		<b>BOREHOLE TYPE</b> POWER AUGER/HOLLOW STEM AUGERS/TRICONE		<b>COMPILED BY</b> DMB	
<b>DATUM</b> GEODETIC		<b>DATE</b> April 22, 2009 - April 23, 2009		<b>CHECKED BY</b> <i>[Signature]</i>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	*N VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)			
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE										
20	40	60	80	100	20	40	60	80	100	10	20	30	GR	SA	SI	CL		
86.67	GROUND SURFACE																	
0.09	TOPSOIL, clayey Dark brown FILL, clayey silt, trace to some sand and gravel, topsoil, rock fragments Firm to very stiff Grey to brown		1	SS	13													
			2	SS	11													
			3	SS	6													
			4	SS	9													
82.86																		
3.81	FILL, silt, trace to some sand, clay, topsoil, trace rootlets, slag Loose to compact Grey to brown		5	SS	16													
			6	SS	7													
			7	SS	14													
80.73																		
5.94	CLAYEY SILT, trace sand, trace gravel Firm Grey		8	SS	4													
			9	SS	3													
			10	SS	5													
			11	SS	11													
			12	SS	17													
			13	SS	14													
72.12																		
14.55																		

LDN MTO.01 08-1132-013-1.GPJ LDN MTO.GDT 7/21/09

Continued Next Page

+ 3 x 3 Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT 08-1132-013-1			<b>RECORD OF BOREHOLE No 101</b>			2 OF 2		<b>METRIC</b>	
W.P. 2172-06-00			LOCATION N 4790785.8 : E 271737.0			ORIGINATED BY MR			
DIST HWY 403			BOREHOLE TYPE POWER AUGER/HOLLOW STEM AUGERS/TRICONE			COMPILED BY DMB			
DATUM GEODETIC			DATE April 22, 2009 - April 23, 2009			CHECKED BY <i>[Signature]</i>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	*N VALUES			20	40					
70.67	SILT, some clay, trace sand Compact Grey		14	SS	15									
16.00	CLAYEY SILT, trace sand, gravel Firm Grey													
69.45	SILTY CLAY Firm to stiff Grey		15	SS	6									6 7 63 24
17.22														
68.23	SILTY SAND AND GRAVEL Compact Brown to grey		16	SS	28									
18.44														
67.77	SHALE BEDROCK (weathered)		17	WS	-									
18.90														
66.95	END OF BOREHOLE		18	SS	45									
19.72														



<b>PROJECT</b> 08-1132-013-1		<b>RECORD OF BOREHOLE No 106</b>		1 OF 1	<b>METRIC</b>
<b>W.P.</b> 2172-06-00		<b>LOCATION</b> N 4790762 2 E 271688 1		<b>ORIGINATED BY</b> TZ/MR	
<b>DIST</b> HWY 403		<b>BOREHOLE TYPE</b> WASH BORING/BW CASING		<b>COMPILED BY</b> DMB	
<b>DATUM</b> GEODETIC		<b>DATE</b> April 29, 2009		<b>CHECKED BY</b>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT  Y  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W <sub>p</sub> W W <sub>L</sub>					
SHEAR STRENGTH kPa								WATER CONTENT (%)							
							○ UNCONFINED + FIELD VANE								
							● QUICK TRIAXIAL × LAB VANE								
87.72 0.00	GROUND SURFACE FILL, clayey silt, trace gravel, trace sand, containing organics Stiff to very stiff Brown to grey		1	SS	18										
			2	SS	15										1 4 51 24
			3	SS	24										
			4	SS	10										
			5	SS	10										
			6	SS	24										
			7	SS	11										
			8	SS	12										
80.40 7.32	CLAYEY SILT, trace gravel, trace sand Firm to hard Grey		9	SS	7										
			10	SS	15										9 6 49 36
			11	SS	43										
			12	SS	28										
			13	SS	41										
			14	SS	17										
74.77 12.95	END OF BOREHOLE														

LDN\_MTO\_01\_08-1132-013-1.GPJ LDN\_MTO.GDT 6/19/09

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