



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT AND STORM SEWER INSTALLATIONS
NORTH SHORE BOULEVARD INTERCHANGE
QUEEN ELIZABETH WAY (QEW)
BURLINGTON, ONTARIO
CENTRAL REGION ASSIGNMENT NUMBER: 2017-E-0056-001**

LATITUDE: 43.315100, LONGITUDE: -79.807891

Geocres Number: 30M5-330

Report to

MTO CENTRAL REGION

July 4, 2019
File: 25497



TABLE OF CONTENTS

PART 1: FACTUAL INFORMATION

1.0	INTRODUCTION	1
2.0	SITE DESCRIPTION	1
3.0	INVESTIGATION PROCEDURES	2
4.0	LABORATORY TESTING	5
5.0	DESCRIPTION OF SUBSURFACE CONDITIONS	5
5.1	Culvert 3 (Boreholes C3-01 to C3-04).....	6
5.2	Culvert 6 (Boreholes C6-01 to C6-03).....	9
5.3	Culvert 8 (Boreholes C8-01 to C8-04).....	11
5.4	Trenchless Sewer (Boreholes TRSR1-01 to TRSR1-04)	15
5.5	Corrosivity And Sulphate Test Results.....	17
6.0	MISCELLANEOUS	18
PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS		19
7.0	GENERAL	19
7.1	Open-Cut Culvert Replacement.....	19
7.2	Trenchless Storm Sewer Replacement.....	24
8.0	SOIL CORROSION POTENTIAL	30
9.0	CONSTRUCTION CONCERNS.....	31
10.0	CLOSURE	32

Appendices

Appendix A	Site Photographs
Appendix B	Record of Borehole Sheets
Appendix C	Laboratory Test Results
Appendix D	Corrosivity Testing – Certificates of Analysis
Appendix E	Borehole Location and Soil Strata Drawings
Appendix F	Trenchless Installation Methods Comparison
Appendix G	Instrumentation and Monitoring Plan
Appendix H	List of Standard Specifications and Special Provisions



**FOUNDATION INVESTIGATION REPORT AND DESIGN REPORT
CULVERTS AND STORM SEWER INSTALLATIONS
NORTH SHORE BOULEVARD INTERCHANGE
QUEEN ELIZABETH WAY (QEW)
BURLINGTON, ONTARIO
CENTRAL REGION ASSIGNMENT NUMBER: 2017-E-0056-001**

Geocres Number: 30M5-330

PART 1: FACTUAL INFORMATION

1.0 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) for the proposed design of culverts and storm sewer replacements in the vicinity of QEW and North Shore Boulevard interchange in Burlington (Central Region), Ontario. At the time of the work plan proposal, plans called for the replacement of two culverts (Culvert 4 and 5) and one storm sewer alignment by trenchless installation and the replacement of three culverts (Culverts 3, 6 and 8) by open-cut methodology, including an outfall to Lake Ontario. Due to a utility locate conflict with the Halton Region sanitary sewer, the replacement of Culverts 4 and 5 was cancelled by MTO Central Region during the course of this investigation.

The purpose of the investigation was to explore the subsurface conditions at the proposed culvert and storm sewer locations and, based on the data obtained, to provide borehole location plans, records of boreholes, laboratory test results, and a written description of the subsurface conditions.

Thurber completed this report under the Ministry of Transportation Ontario (MTO) Central Region Assignment Number 2017-E-0056-001.

2.0 SITE DESCRIPTION

The section of the QEW within the study limits presently conveys six lanes of traffic, with three lanes in each direction, separated by a concrete median. Fully paved shoulders are present on both sides of the travel lanes in both directions. Two-lane Toronto and Niagara bound collectors generally run parallel to the mainline and are separated from the mainline with a grass median.



The site is located at the south end of Burlington near the boundary with Hamilton to the south, and along QEW between the James N. Allan Skyway and Fairview street interchange, approximately 300 m north to 500 m south of North Shore Boulevard. The adjacent lands generally comprise industrial and commercial uses to the southeast and residential to the west and northeast. Indian Creek runs parallel to the highway along the west side and outlets in Hamilton Harbour (Lake Ontario) approximately 250 m south of North Shore Boulevard. Photographs of the sites are presented in Appendix A.

Based on a review of the existing site conditions at the time of the investigation, no evidence of embankment slope instability or settlement of the roadway was observed at the existing culverts and embankments.

Based on the information in *The Physiography of Southern Ontario*¹ by Chapman and Putnam (1984), the study area is located within the Iroquois Plain physiographic region. The Iroquois Plain was formed in the late Pleistocene times by a body of water known as Lake Iroquois, which emptied eastward at Rome, New York (Chapman and Putnam, 1984). Lake Iroquois was characterized by higher water levels than the present-day Lake Ontario, caused by an ice sheet blocking the present-day St. Lawrence River valley. When the St. Lawrence valley became free of ice, the water level dropped to a level much lower than the present Lake Ontario levels (*Pleistocene Geology of the Hamilton Map-Area*²).

Based on *Quaternary Geology Map M2509*³ and *Pleistocene Geology Map M2033*⁴, the surficial deposits on the site are lacustrine and outwash sand underlain by Halton clay or silt till. According to *Paleozoic Geology Map M2336*⁵, the bedrock geology consists of red shale of the Queenston Formation.

3.0 INVESTIGATION PROCEDURES

The site investigation was carried out during the period of March 25 to April 17, 2019 and comprised a total of 17 boreholes drilled near the proposed culvert and sewer locations. It is noted that due to a utility locate conflict with the Halton Region sanitary sewer, the replacement

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

² Karrow, P. F., 1959; *Pleistocene Geology of the Hamilton Map-Area*. Ontario; Toronto, Ontario. Ontario Department of Mines

³ Karrow, P.F., 1986: *Quaternary Geology of the Hamilton Area*, Southern Ontario; Ontario Geological Survey, Map 2509, Quaternary Geology Series, scale 1:50,000.

⁴ Karrow, P.F., 1963: *Pleistocene Geology of the Hamilton Area*, Southern Ontario; Ontario Geological Survey, Map M2033, Scale: 1:63,360.

⁵ B.A. Liberty, I.J. Bond and P. G. Telford, 1972 & 1973; *Paleozoic Geology, Hamilton, Southern Ontario*; Ontario Geological Survey, Map M2336, Scale: 1:50 000.



of Culverts 4 (C4) and 5 (C5) were cancelled by MTO Central Region. It is noted that Thurber had initiated the drilling program and completed two boreholes at C5 (C5-01 and C5-04) when the scope was revised; these borehole logs are provided within this report for reference, however, they are not discussed further. The boreholes were advanced to depths of 2.4 m to 12.8 m. Borehole details are provided in Table 3.1 below and in the Record of Borehole sheets included in Appendix B.

Table 3.1 – Borehole Details

Structure	Approximate Location	Borehole No.	Ground Elevation (m)	Borehole Termination Depth (m)	Approx. Borehole Termination Elevation (m)
Open Cut					
Culvert 3 (C3)	QEW South to North Shore East/West Ramp, approximately 100 m north of North Shore Blvd	C3-01	78.0	3.7	74.3
		C3-02	81.1	6.7	74.4
		C3-03	81.1	5.2	75.9
		C3-04	78.8	5.2	73.6
Culvert 6 (C6)	QEW North to North Shore East/West Ramp, approximately 350 m south of North Shore Blvd	C6-01	76.7	5.2	71.5
		C6-02	76.9	5.2	71.8
		C6-03	77.1	5.2	71.9
Culvert 8 (C8)	QEW Niagara Bound Collector, approximately 450 m south of North Shore Blvd	C8-01	76.3	12.8	63.5
		C8-02	76.6	5.2	71.4
		C8-03	77.0	5.2	71.8
		C8-04	76.7	5.2	71.5
Trenchless					
Culvert 5 (C5)	QEW Toronto Bound Collector, approximately 275 m south of North Shore Blvd	C5-01	77.4	2.4	75.0
		C5-04	77.2	6.7	70.5
Trenchless Sewer (TRSR)	QEW Mainline and Niagara Bound Collector, approximately 150 m north of North Shore Blvd	TRSR1-01	84.1	5.0	79.2
		TRSR1-02	84.4	5.2	79.2
		TRSR1-03	84.7	5.2	79.5
		TRSR1-04	84.3	6.7	77.6



The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawings provided in Appendix E.

Thurber positioned the boreholes in the field relative to existing site features and using a handheld GPS receiver, with consideration of site features and access limitations. The ground elevations at the borehole locations were determined using Trimble R10 GNSS surveying equipment with vertical accuracy within 0.1 m and horizontal accuracy within 0.5 m.

All borehole locations were cleared of utilities prior to commencement of drilling. The boreholes were repositioned as necessary in consideration of surface features, underground utilities, and restricted site access.

The boreholes were advanced using continuous flight solid and hollow stem augers powered by track-mounted D50 and truck-mounted CME-75 drilling equipment and NW wash boring using portable tripod equipment. The portable tripod equipment was used in areas that could not be accessed by a drill rig (Boreholes C3-01, C5-01, C5-04 and C6-01).

Soil samples were obtained at selected intervals using a 50 mm outside diameter split-spoon sampler driven in conjunction with the Standard Penetration Test (SPT) completed in accordance with ASTM D1586. Dynamic cone penetration tests (DCPT) were performed adjacent to Boreholes C3-04, C6-03, C8-01, C8-02 and C8-03 where very loose or loose, non-cohesive soils were encountered.

The field investigation was supervised on a full-time basis by a member of Thurber's technical staff who marked/staked the boreholes in the field, arranged for the clearance of subsurface utilities, directed the drilling, sampling and in-situ testing operations, logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Standpipe piezometers (19 and 50 mm diameter) were installed and enclosed in filter sand in selected boreholes to permit groundwater level monitoring.



The details of the piezometers and monitoring wells are shown in Table 3.2.

Table 3.2 – Piezometer and Monitoring Well Details

Borehole	Piezometer/Monitoring Well Tip		Slotted Screen Length (m)
	Depth (m)	Elevation (m)	
C3-01	2.9	75.1	1.5
C3-04	4.6	74.2	3.1
C5-04	6.1	71.1	3.1
C8-01	12.2	64.1	3.1
C8-04	4.6	72.1	3.1
TRSR1-01	4.6	79.5	3.1
TRSR1-04	6.1	78.2	3.1

The boreholes in which no piezometers or monitoring wells were installed were backfilled with bentonite and cuttings to the ground surface in general accordance with MOE Regulation 903 as amended. The asphalt pavement was reinstated at the ground surface of boreholes completed on the paved roadway (Boreholes C3-02, C3-03, C6-02, C6-03, C8-03 and TRSR1-01 to TRSR1-04.)

4.0 LABORATORY TESTING

Routine laboratory testing was carried out at Thurber's laboratory. The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size distribution analysis and Atterberg Limits testing. Results of the laboratory testing are summarized on the Record of Borehole sheets in Appendix B and presented on the figures included in Appendix C.

Selected soil samples were also submitted for analytical testing to assess the potential for soil corrosion and evaluate the potential for sulphate action on concrete. The analyses were carried out by SGS Canada Inc., an independent Canadian Association for Laboratory Accreditation (CALA) accredited laboratory. The results of the analytical testing are presented in Appendix D.

5.0 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference should be made to the Record of Borehole sheets in Appendix B and the Borehole Locations and Soil Strata Drawings in Appendix E. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions. It must be recognized and anticipated that soil conditions may vary between and beyond the borehole locations.



5.1 Culvert 3 (Boreholes C3-01 to C3-04)

In general terms, the subsurface stratigraphy encountered in Boreholes C3-01 to C3-04 consists of a surficial pavement structure or topsoil fill over fill, underlain by native deposits of silty sand overlying clay till. More detailed descriptions of the individual strata are presented below.

5.1.1 Pavement Structure

A flexible pavement structure consisting of 250 and 225 mm of asphalt overlying approximately 750 and 1175 mm of crushed sand and gravel fill was encountered at the ground surface of Boreholes C3-02 and C3-03, respectively.

5.1.2 Topsoil Fill

In Boreholes C3-01 and C3-04, a 125 to 150 mm thick layer of topsoil fill was encountered at the ground surface. Topsoil thickness may vary in other areas of the site and this limited data should not be used to estimate topsoil quantity.

5.1.3 Fill

Silty clay fill was encountered below the topsoil fill and pavement structure at depths of 0.1 to 1.4 m (Elev. 77.8 to 80.1) and extended to depths of 1.2 to 4.1 m (Elev. 76.8 to 77.5) in the boreholes. SPT 'N' values recorded in the fill varied from 7 to 25 blows per 0.3 m, indicating a firm to very stiff condition. Measured moisture contents ranged from 17 to 22%.

The results of grain size distribution tests carried out on the fill are shown on Figure C1 in Appendix C and summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 1
Sand	14 to 23
Silt	36 to 39
Clay	38 to 47

Atterberg limits testing was carried out on two samples of fill. The results indicate that the fill samples tested consist of silty clay of low plasticity (CL).



The results are plotted on Figure C9 in Appendix C and summarized below.

Liquid Limit	31 to 33
Plastic Limit	15 to 16
Plasticity Index	16 to 17

Cobbles, boulders or other obstructions and/or debris may be present within the fill and should be anticipated when excavating during construction.

5.1.4 Silty Sand

A silty sand deposit was encountered below the fill at depths of 1.2 to 4.1 m (Elev. 76.8 to 77.5). Boreholes C3-01 to C3-03 were terminated in the sand at 3.7 to 6.7 m depth (Elev. 74.3 to 75.9). The silty sand layer was 3.0 m thick in Borehole C3-04, with a lower boundary at a depth of 4.3 m (Elev. 74.5). A 0.3 to 0.5 m thick layer of silty clay layer was encountered within the silty sand layer at depths of 2.2 to 5.1 m (Elev. 75.4 to 76.0) in Boreholes C3-01, C3-02 and C3-04. It is noted that occasional partings of silty clay and layers of black organics were observed within the sand deposit. SPT 'N' values recorded in the silty sand ranged from 3 to 13 blows per 0.3 m, indicating a very loose to compact relative density. Measured moisture contents generally ranged from 18 to 23%.

The results of grain size distribution tests carried out on the sand are shown on Figure C2 in Appendix C and summarized below:

Soil Particle	Percentage (%)
Gravel	0
Sand	56 to 69
Silt	20 to 26
Clay	9 to 18

The results of a grain size distribution analyses of the clay layer are provided on Figure C5 Appendix C. The results indicated 0% gravel, 25% sand, 39% silt, and 36% clay. Atterberg limits testing determined the liquid limit, plastic limit and plasticity index to be 32, 17 and 16, respectively. These results, which are plotted on Figure C10 in Appendix C, indicate that the sample tested consists of low plastic clay (CL).



5.1.5 Clay Till

A deposit of silty clay till was encountered underlying the silty sand in Borehole C3-04 at 4.3 m depth (Elev. 74.5) and the layer continued to the termination depth of 5.2 m (Elev. 73.6). An SPT 'N' value of 10 blows per 0.3 m was recorded within the till deposit indicating a stiff consistency. Measured moisture contents within the till was about 25%.

The results of a grain size distribution analyses of the clay till are provided on Figure C6 Appendix C. The results indicated 1% gravel, 22% sand, 50% silt, and 27% clay. Atterberg limits testing was carried out on one sample of the till. The measured liquid limit, plastic limit and plasticity index were 37, 21 and 16, respectively. These results, which are plotted on Figure C11 in Appendix C, indicate that the sample tested consists of intermediate plastic clay (CI).

Till soils frequently contain cobbles and boulders, and these should be anticipated when excavating during construction.

5.1.6 Groundwater Levels

Groundwater conditions were observed in the boreholes during and upon completion of drilling. Upon completion of augering, free water was observed in the open borehole at a depth of 2.1 m (Elev. 76.7) in Borehole C3-04; Boreholes C3-02 and C3-03 were open and dry. The wash boring borehole advancement methodology used for Borehole C3-01 introduces water into the borehole. In this regard, the water level observed at the termination of this borehole may not accurately represent the long-term stabilized ground water level and is not reported here.

The groundwater conditions recorded in the piezometers installed in selected boreholes are summarized in the table below:

Borehole	Date	Water Level (m)	
		Depth	Elev.
C3-01	April 25, 2019	0.9	77.1
	May 2, 2019	0.7	77.3
C3-04	April 25, 2019	1.0	77.8
	May 2, 2019	0.4	78.4

In general, the water level in the vicinity of these boreholes is expected to be governed by the prevailing water level in Indian Creek located approximately 30 m to the west.



The water level measurements are short-term observations and seasonal fluctuations of the groundwater level are to be expected. Water levels may be higher after snowmelt or heavy precipitation events. In general, perched groundwater and wet conditions should be anticipated in the sand deposits above underlying less permeable till materials.

5.2 Culvert 6 (Boreholes C6-01 to C6-03)

In general terms, the subsurface stratigraphy encountered in Boreholes C6-01 to C6-03 consists of a surficial pavement structure or topsoil fill over fill, underlain by native silty sand. More detailed descriptions of the individual strata are presented below.

5.2.1 Pavement Structure

A flexible pavement structure consisting of 275 and 100 mm of asphalt was encountered at the ground surface of Boreholes C6-02 and C6-03, respectively.

5.2.2 Topsoil Fill

In Borehole C6-01, a 125 mm thick layer of topsoil fill was encountered at the ground surface. Topsoil thickness may vary in other areas of the site and this limited data should not be used to estimate topsoil quantity.

5.2.3 Fill

Silty clay fill was encountered below the topsoil fill and extended to a depth of 0.7 m (Elev. 76.0) in Borehole C6-01. An SPT 'N' value of 14 blows per 0.3 m was recorded in the clay fill, indicating a stiff condition. Measured moisture was determined to be about 19%.

Sand and gravel embankment fill was encountered below the asphalt and clay fill and extended to depths of 1.4 to 1.8 m (Elev. 74.9 to 75.7) in the boreholes. SPT 'N' values recorded in the sand and gravel fill varied from 14 to 47 blows per 0.3 m, indicating a compact to dense relative density. Measured moisture contents ranged from 3 to 12%.

Cobbles, boulders or other obstructions and/or debris may be present within the fill and should be anticipated when excavating during construction.

5.2.4 Silty Sand

A silty sand deposit was encountered below the fill at depths of 1.4 to 1.8 m (Elev. 74.9 to 75.7) and the layer extended to the borehole termination depths of 5.2 m depth (Elev. 71.5 to 71.9). A



0.8 m thick layer of sand, with occasional shell fragments, was encountered within the silty sand layer at depths of 2.2 to 3.7 m (Elev. 73.0 to 74.9). It is noted that occasional layers of silt and black organics were observed within the sand deposit. SPT 'N' values recorded in the silty sand ranged from 2 to 39 blows per 0.3 m, indicating a very loose to dense relative density. Measured moisture contents generally ranged from 19 to 32%, locally 41% in Borehole C6-02.

The results of grain size distribution tests carried out on the silty sand are shown on Figures C2 and C3 in Appendix C and summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 20
Sand	50 to 70
Silt	20 to 42
Clay	5 to 7

The results of grain size distribution tests carried out on the sand layer are also shown on Figures C2 and C3 in Appendix C and summarized below:

Soil Particle	Percentage (%)
Gravel	8 to 14
Sand	70 to 84
Silt + Clay	8 to 16

5.2.5 Groundwater Levels

Groundwater conditions were observed in the boreholes during and upon completion of drilling. Upon completion of augering free water and cave was measured at 2.7 m (Elev. 74.2 in Borehole C6-02; free water was observed in the open borehole a depth of 2.2 m (Elev. 74.9) in Borehole C6-03. The wash boring borehole advancement methodology used for Borehole C6-01 introduces water into the borehole. In this regard, the water level observed at the termination of this borehole may not accurately represent the long-term stabilized ground water level and is not reported here.

The water level measurements are short-term observations and seasonal fluctuations of the groundwater level are to be expected. Water levels may be higher after snowmelt or heavy precipitation events. In general, perched groundwater and wet conditions should be anticipated in the sand deposits.



5.3 Culvert 8 (Boreholes C8-01 to C8-04)

In general terms, the subsurface stratigraphy encountered in Boreholes C8-01 to C8-04 consists of a surficial pavement structure or topsoil fill over variable types of fill, underlain by native deposits of silty sand overlying layered silts and sand underlain by organic silt over sand and gravel. More detailed descriptions of the individual strata are presented below.

5.3.1 Pavement Structure

A flexible pavement structure consisting of 125 mm of asphalt overlying approximately 575 mm of crushed sand and gravel fill was encountered at the ground surface of Borehole C8-03.

5.3.2 Topsoil Fill

In Boreholes C8-01, C8-02 and C8-04, a 100 to 225 mm thick layer of topsoil fill was encountered at the ground surface. Topsoil thickness may vary in other areas of the site and this limited data should not be used to estimate topsoil quantity.

5.3.3 Fill

A layer of fill was encountered below the pavement structure and topsoil fill at depths of 0.1 to 0.7 m (Elev. 76.1 to 76.6) and this layer extended to depths of 1.4 to 2.2 m (Elev. 74.5 to 75.1). The fill layer was variable in composition and comprised sand, clayey silt and silty clay. SPT 'N' values recorded in the fill varied from 4 to 29 blows per 0.3 m, indicating a soft to very stiff/compact condition. Measured moisture contents typically ranged from 4 to 20%, locally up to 43%.

The results of grain size distribution tests carried out on the clayey silt and silty clay fill are shown on Figure C1 in Appendix C and summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 1
Sand	27 to 32
Silt	44 to 50
Clay	23

Atterberg limits testing was carried out on two samples of fill. The results are plotted on Figure C9 in Appendix C and summarized below. The results indicate that the fill samples tested consist of clayey silt (CL-ML) and silty clay of low plasticity (CL).

Liquid Limit	21 to 25
Plastic Limit	15
Plasticity Index	6 to 9

Cobbles, boulders or other obstructions and/or debris may be present within the fill and should be anticipated when excavating during construction.

5.3.4 Silty Sand

A 1.9 to 2.3 m thick deposit of silty sand was encountered below the fill at depths of 1.4 to 2.2 m (Elev. 74.5 to 75.1) and this layer extended to depths of 3.7 to 4.2 m (Elev. 72.6 to 72.8). It is noted that occasional partings of silty clay and layers of silt and black organics were observed within the sand deposit. Locally, in Borehole C8-04, occasional cobbles and wood and shell fragments were noted. SPT 'N' values recorded in the silty sand ranged from 3 to 21 blows per 0.3 m, indicating a very loose to compact relative density. Measured moisture contents generally ranged from 20 to 51%.

The results of grain size distribution tests carried out on the sand are shown on Figure C3 in Appendix C and summarized below:

Soil Particle	Percentage (%)
Gravel	0
Sand	43 to 65
Silt	28 to 51
Clay	6 to 7

5.3.5 Layered Silty Sand and Sandy Silt

A deposit consisting of layered silty sand and sandy silt was encountered below the sand at depths of 3.7 to 4.2 m (Elev. 72.6 to 72.8). Boreholes C8-02 to C8-04 were terminated within this stratum at 5.2 m depth (Elev. 71.4 to 71.8). This layer is 2.4 m thick in Borehole C8-01. It is noted that occasional to numerous organic layers were observed within the deposit with thin layers of peat noted in Borehole C8-03. SPT 'N' values recorded in the deposit ranged from 2 to



6 blows per 0.3 m, indicating a very loose to loose relative density. Measured moisture contents generally ranged from 33 to 65%.

The results of grain size distribution tests carried out on the stratum are shown on Figure C3 in Appendix C and summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 1
Sand	14 to 68
Silt	26 to 72
Clay	5 to 13

5.3.6 Organic Silt

A 3.3 m thick layer of organic silt was encountered below the layered sand and silt at a depth of 6.1 m (Elev. 70.2) and this layer extended to a depth of 9.4 m (Elev. 66.8) in Borehole C8-01. It is noted that occasional thin layers of peat, partings of silty clay, thin sand seams and shell fragments were observed within this deposit. SPT 'N' values recorded in the organic silt were 5 blows per 0.3 m, indicating a loose relative density. Measured moisture contents generally ranged from 34 to 89%.

The results of a grain size distribution analysis of the organic silt layer are provided on Figure C7 Appendix C. The results indicated 0% gravel, 21% sand, 63% silt, and 16% clay.

5.3.7 Sand and Gravel

A deposit of sand and gravel was encountered underlying the organic silt in Borehole C8-01 at a depth of 9.4 m (Elev. 66.8) and this layer extended to the borehole termination depth of 12.8 m (Elev. 63.5). SPT 'N' values ranging from 21 to 58 blows per 0.3 m was recorded within the deposit indicating a compact to very dense relative density. Measured moisture contents within the sand and gravel ranged from 8 to 12%.

The results of a grain size distribution analyses of the sand and gravel are provided on Figure C8 Appendix C. The results indicated 35% gravel, 56% sand and 9% silt and clay.



5.3.8 Groundwater Levels

Groundwater conditions were observed in the boreholes during and upon completion of drilling. Upon completion of augering, free water was observed in the open boreholes at depths of 2.5 and 2.2 m (Elev. 74.1 and 74.8) in Boreholes C8-02 and C8-03, respectively.

The groundwater conditions recorded in the piezometers installed in selected boreholes are summarized in the table below:

Borehole	Date	Water Level (m)	
		Depth	Elev.
C8-01	April 25, 2019	1.7	74.5
	May 2, 2019	1.0	75.3
C8-04	April 25, 2019	1.5	75.2
	May 2, 2019	1.2	75.5

The water level measurements are short-term observations and seasonal fluctuations of the groundwater level are to be expected. Water levels may be higher after snowmelt or heavy precipitation events. Perched groundwater and wet conditions should be anticipated in the sand deposits.

In general, the water level in the vicinity of these boreholes is expected to be governed by the prevailing Lake Ontario water level located immediately to the west.

The water level in Lake Ontario ranged from elevation 75.0 to 75.5, averaging about 75.2 during the month of April 2019. The lake water elevation was obtained from *Fisheries and Oceans Canada Canadian Hydrographic Service*⁶ water level gauging station located in Burlington, Ontario. The elevation is referenced to the International Great Lakes Datum 1985. It is noted that according to the *Canadian Hydrographic Service*⁷, the Lake Ontario water level elevation average ranges from 74.4 to 75.1, with maximums ranging from 75.0 to 75.8.

⁶ Fisheries and Oceans Canada – The Canadian Hydrographic Service; Burlington (#13150) Tidal Observations; <http://www.waterlevels.gc.ca/eng/station/Month?sid=13150&tz=EST&pres=2&type=1> retrieved on April 29, 2019.

⁷ Fisheries and Oceans Canada – The Canadian Hydrographic Service; Historical Monthly Mean Water Levels from the Coordinated network for each of the Great Lakes: Lake Ontario monthly mean water levels in metres referred to IGLD 1985; http://www.tides.gc.ca/C&A/network_means-eng.html; modified dated April 16, 2019; retrieved April 29, 2019.



5.4 Trenchless Sewer (Boreholes TRSR1-01 to TRSR1-04)

In general terms, the subsurface stratigraphy encountered in Boreholes TRSR1-01 to TRSR1-04 consists of a surficial pavement structure over fill, underlain by native deposits of silty sand over clay overlying clay till. More detailed descriptions of the individual strata are presented below.

5.4.1 Pavement Structure

A flexible pavement structure consisting of 100 to 250 mm of asphalt overlying approximately 475 to 1950 mm of crushed sand and gravel fill was encountered at the ground surface of the boreholes.

5.4.2 Fill

Silty clay fill was encountered below the pavement structure at depths of 0.7 to 1.4 m (Elev. 83.0 to 84.0) and extended to depths of 1.3 to 2.7 m (Elev. 81.7 to 83.0) in Boreholes TRSR1-02 to TRSR1-04. SPT 'N' values recorded in the fill varied from 12 to 30 blows per 0.3 m, indicating a stiff to hard condition. Measured moisture contents ranged from 10 to 18%.

The results of a grain size distribution analysis of the clay fill are provided on Figure C1 Appendix C. The results indicated 5% gravel, 25% sand, 37% silt, and 33% clay. Atterberg limits testing was carried out on one sample of the fill. The measured liquid limit, plastic limit and plasticity index were 25, 13 and 12, respectively. These results, which are plotted on Figure C9 in Appendix C, indicate that the sample tested consists of silty clay of low plasticity (CL).

Cobbles, boulders or other obstructions and/or debris may be present within the fill and should be anticipated when excavating during construction.

5.4.3 Silty Sand

A silty sand deposit was encountered below the fill and pavement structure at depths of 1.3 to 2.7 m (Elev. 81.7 to 83.0) and this layer extended to depths of 2.7 to 3.4 m (Elev. 81.0 to 82.0). It is noted that occasional partings of silty clay and were observed within the sand deposit. SPT 'N' values recorded in the silty sand ranged from 6 to 28 blows per 0.3 m, indicating a loose to compact relative density. Measured moisture contents generally ranged from 8 to 20%.



The results of grain size distribution tests carried out on the sand are shown on Figures C3 and C4 in Appendix C and summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 1
Sand	55 to 72
Silt	18 to 36
Clay	8 to 14

5.4.4 Silty Clay

A deposit of silty clay was encountered underlying the silty sand at 2.7 to 3.4 m (Elev. 81.0 to 82.0). The clay layer extended to depths of 4.7 and 6.1 m (Elev. 79.4 and 78.2) in Boreholes TRSR1-01 and TRSR1-04 and extended to the termination depths of 5.2 m (Elev. 79.2 and 79.5) in Boreholes TRSR1-02 and TRSR1-03. SPT 'N' values of 2 to 18 blows per 0.3 m were recorded within the silty clay deposit indicating a soft to very stiff consistency. Measured moisture contents within the clay ranged from 20 to 29%.

The results of grain size distribution tests carried out on the silty clay are shown on Figure C5 in Appendix C and summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 1
Sand	5 to 10
Silt	41 to 46
Clay	43 to 53

Atterberg limits testing was carried out on four samples of clay. The results are plotted on Figure C10 in Appendix C and summarized below. The results indicate that the clay samples tested consist of silty clay of low plasticity (CL).

Liquid Limit	31 to 34
Plastic Limit	15 to 17
Plasticity Index	15 to 18

5.4.5 Clay Till

A deposit of silty clay till was encountered underlying the silty clay in Boreholes TRSR1-01 and TRSR1-04 at 4.7 and 6.1 m depths (Elev. 79.4 and 78.2) and this layer extended to the borehole termination depths of 5.0 and 6.7 m (Elev. 79.2 and 77.6). SPT 'N' values of 29 blows



per 0.3 m and 100 blows for 0.25 m were recorded within the till deposit indicating a very stiff to hard consistency. Measured moisture contents within the till ranged from 9 to 12%.

Till soils frequently contain cobbles and boulders, and these should be anticipated when excavating during construction.

5.4.6 Groundwater Levels

Groundwater conditions were observed in the boreholes during and upon completion of drilling. Upon completion of augering, the boreholes were open and dry. The groundwater conditions recorded in the piezometers installed in selected boreholes are summarized in the table below:

Borehole	Date	Water Level (m)	
		Depth	Elev.
TRSR1-01	April 25, 2019	1.3	82.8
	May 2, 2019	1.2	82.9
TRSR1-04	April 25, 2019	2.2	82.2
	May 2, 2019	3.0	81.3

The water level measurements are short-term observations and seasonal fluctuations of the groundwater level are to be expected. Water levels may be higher after snowmelt or heavy precipitation events. In general, perched groundwater and wet conditions should be anticipated in the sand deposits above underlying less permeable clayey materials.

5.5 Corrosivity And Sulphate Test Results

Samples of the fill and native soils were submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in Table 5.1. The laboratory certificates of analysis are presented in Appendix D.

Table 5.1 – Analytical Test Results

Sample ID	Depth (m)	Description	Sulphide (%)	Chloride (µg/g)	Sulphate (µg/g)	pH	Resistivity (ohm.cm)	Redox Potential (mV)
BH C3-03 SS5	3.0-3.6	Clay Fill	<0.02	120	20	8.79	5890	126
BH C6-03 SS3	1.5-2.1	Sand	<0.02	730	67	8.03	495	220
BH C8-03 SS3	1.5-2.1	Sand Fill	<0.02	3100	60	7.45	309	312
BH TRSR1-04 SS5	3.0-3.6	Clay	0.03	360	62	8.85	2460	227



6.0 MISCELLANEOUS

Thurber positioned the boreholes in the field relative to existing site features and using a handheld GPS receiver, with consideration of site features and access limitations. The ground elevations at the borehole locations were determined using Trimble R10 GNSS surveying equipment. Walker Drilling of Utopia, Ontario and Elite Drilling Services of St. Catharines, Ontario supplied and operated the drilling and sampling equipment for the field program.

Full time supervision of the field activities was carried out by Mr. Kevin Kweon of Thurber Engineering. Overall supervision of the field program was performed by Mr. Karel Furbacher, P.Eng. of Thurber. Interpretation of the field data and preparation of the report was performed by Mr. Karel Furbacher, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.



Karel Furbacher, P.Eng.
Geotechnical Engineer



P.K. Chatterji, P.Eng., Ph.D.
Review Principal



**FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERTS AND STORM SEWER INSTALLATIONS
NORTH SHORE BOULEVARD INTERCHANGE
QUEEN ELIZABETH WAY (QEW)
BURLINGTON, ONTARIO
CENTRAL REGION ASSIGNMENT NUMBER: 2017-E-0056-001**

Geocres Number: 30M5-330

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7.0 GENERAL

This report presents interpretation of the geotechnical data in the factual report and presents geotechnical recommendations for the replacement of one storm sewer alignment by trenchless installation and the replacement of three culverts (Culverts 3, 6 and 8) by open-cut methodology, including an outfall to Lake Ontario.

The discussion and recommendations presented in this report are based on the information provided by MTO Central Region and on the factual data obtained in the course of the investigation.

The interpretation and recommendations are intended for the use of the design consultant and MTO, and shall not be relied upon by any other parties including the construction contractor, or used for any purposes other than development of the project design. Comments on construction methodology and equipment, where presented, are provided only to highlight those aspects that could affect the design of the project. Contractors must make their own assessment of the factual information presented in Part 1 of the report, and the implications on equipment selection, construction methodology, and scheduling.

7.1 Open-Cut Culvert Replacement

Current plans call for the replacement of the existing corrugated steel pipe (CSP) culverts with larger diameter CSP culverts installed by open cut excavation. Details of the proposed culvert designs were provided on the Contract Drawings for Contract No. 2018-2015, GWP No. 2117-15-00, titled "Grading, Drainage, Granular Base, Hot Mix Paving, Electrical, Structural and ATMS" produced by AECOM for MTO Central Region, dated March 2019.



Based on the design drawings, the proposed culvert details are summarized in the table below.

Table 7.1 – Proposed Culvert Design

Structure	Diameter (mm)	Invert Elevation	
		Upstream	Downstream
Culvert 3 (C3)	900	78.5	77.0
Culvert 6 (C6)	1200	75.3	75.2
Culvert 8 (C8)	1050	74.9	74.8

7.1.1 Excavation and Groundwater Control

In general, excavation of trenches for replacement of the culverts is expected to extend through the existing pavement structure or topsoil fill and into the underlying compact to dense sand and gravel, compact sand and/or soft to very stiff clay fill into the underlying native very loose to dense silty sand. In general, the excavation is expected to remain above the water level within the embankment, with the exception of C8; further comment regarding dewatering and cofferdam construction at C8 is provided in Section 7.1.4.

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of assessing excavation slope requirements in compliance with the OHSA, the fill and native deposits above the groundwater level are generally classified as Type 3 soils. Saturated cohesionless soils may be encountered locally, and these should be classified as Type 4 soils if not dewatered.

Where space permits, slopes of temporarily unsupported trenches should conform with the requirements of the OHSA, but should not be steeper than 1H:1V above the groundwater level. Flatter slopes may be required at locations where water seepage or sloughing occurs during excavation.

In general, it is anticipated that sufficient space will not be available for sloped trenches and roadway protection will be required. Based on available subsurface information, where roadway protection and/or an engineered support system (shoring) is not required, a trench box system should be adequate for worker safety for the relatively shallow excavation depths anticipated.



Roadway protection must be provided in accordance with OPSS.PROV 539 and designed for Performance Level 2. An engineered support system consisting of sheet piling or steel H-piles with timber lagging may be considered for temporary shoring. Temporary shoring should be designed by a licensed Professional Engineer experienced in design of shoring with consideration of adjacent traffic loads and any sloping retained surfaces.

Foundations of settlement sensitive structures and/or utilities located within close proximity to the excavation, such as the noise wall and/or light poles near C3 or Halton Region sanitary sewer, may require underpinning to preserve the integrity and lateral stability of these structures' foundations. The foundation system and founding depths supporting the existing features should be reviewed and temporary and/or permanent support measures designed once the temporary shoring design is complete to confirm if underpinning is required.

Based on the water conditions observed in the boreholes at C3 and C6, the long-term stabilized groundwater level is expected to be encountered at or just below the anticipated excavation depth. Dewatering measures such as pumping from filtered sumps should generally be adequate to remove any accumulation of water in trench excavations at C3 and C6. Gravity drains or pumping from sump wells may be required to lower the water level locally. Perched water should be anticipated in the cohesionless fill and sand above the clayey materials, and the contractor must be prepared to pump from sumps, provide drainage of this water, or otherwise dewater prior to excavation to maintain trench stability. Dewatering should be in accordance with OPSS.PROV 517 and SP 517F01. In this regard, the dewatering design Engineer and design-checking Engineer shall have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work.

Should sloughing or caving occur, the contractor must immediately modify the excavating and shoring methods, dewatering technique and construction sequence in order to prevent further sloughing from occurring. In general, excavating from areas of low trench invert elevations to areas of higher elevation (i.e. uphill) is preferred to allow the previously placed sewer to act as a drain for subsequent sections of the trench.

The selection of the equipment and method of excavation is the responsibility of the contractor and must be based on his equipment, experience and interpretation of the site conditions. It is anticipated that a hydraulic excavator will be suitable. Provision must be made for the handling of pavement materials and potential cobbles, boulders and/or other obstructions in the fill and native deposits. The design of the shoring and dewatering system that may be required is also the responsibility of the Contractor and the Contract Documents must alert him to this responsibility.



7.1.2 Subgrade Preparation

After the foundation excavation reaches the design subgrade level, the exposed surface should be inspected to confirm that the subgrade is suitable and uniformly competent. Any topsoil/organics, disturbed soils, loose/soft deposits and deleterious materials within the foundation footprint of the culvert should be removed and replaced with suitable granular material compacted as per OPSS.PROV 501. The subgrade preparation must be carried out in the dry.

A minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements should be provided under the base of the culverts, as shown on OPSD 802.010. It may be necessary to increase the bedding thickness if excessively loose, soft, organic or wet conditions are present at the culvert subgrade. The need for this is best determined during construction. It is critical that the culvert be supported on well compacted bedding overlying a competent and uniform subgrade in order to minimize the potential for differential settlement.

The bedding material should be placed on the prepared subgrade as soon as practicable following its inspection and approval. The bedding material should be placed prior to the potential development of frost penetration and/or deterioration of the subgrade surface or within 12 hours, whichever is less. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction. A separation layer consisting of a non-woven geotextile should be placed between the subgrade soils and the bedding material. The geotextile should meet the specifications for the OPSS Class II (OPSS.PROV 1860), and have a fabric opening size (FOS) not greater than 212 µm.

7.1.3 Backfill

Culvert installation, trenching, backfilling and compacting should be carried out in accordance with OPSS.PROV 401, OPSS.PROV 421, OPSS.PROV 492 and OPSD 802.010.

Culvert bedding and cover materials should consist of compacted OPSS Granular A materials. The remainder of the material used to backfill the trenches should consist of OPSS Granular B Type I material. Excavated silty clay, clay till, wet sandy silt to silty sand, and other deleterious or organic materials should not be reused as trench backfill.



Care must be exercised to avoid damaging the culvert when compacting the fill immediately above the obvert of the culvert. Reference should also be made to OPSS.PROV 501 and OPSS.PROV 1010.

7.1.4 Cofferdam for Outfall at Culvert 8

As of the last recorded water level on May 2, 2019, groundwater was observed in the piezometers installed in Boreholes C8-01 and C8-04 at depths of 1.0 and 1.2 m (Elev. 75.3 and 75.5). In general, the water level in the vicinity of these boreholes is expected to be governed by the prevailing Lake Ontario water level located immediately to the west.

The water level in Lake Ontario ranged from elevation 75.0 to 75.5, averaging about 75.2 during the month of April 2019. The lake water elevation was obtained from *Fisheries and Oceans Canada Canadian Hydrographic Service*⁸ water level gauging station located in Burlington, Ontario. The elevation is referenced to the International Great Lakes Datum 1985. It is noted that according to the *Canadian Hydrographic Service*⁹, the Lake Ontario water level elevation average ranges from 74.4 to 75.1, with maximums ranging from 75.0 to 75.8.

The proposed invert at the outlet for C8 into Hamilton Harbour (Lake Ontario) is Elev. 74.8. Cognizant that the excavations will be below the groundwater and lake water level, it will be necessary to implement measures to control ground water in the excavation during construction.

Current plans call for the construction to include a temporary cofferdam structure at the outlet to minimize water infiltration into the excavation. It is envisaged that a water tight enclosure will be required as a cofferdam to construct the outlet in the dry. At the time of this report, the type of cofferdam structure is unknown. Conventional cofferdam construction typically includes interlocking steel sheet pile enclosure, earthen dams or water inflated barriers. The design of the cofferdam is also the responsibility of the Contractor and the Contract Documents must alert him to this responsibility. The cofferdam should be designed to assist in control of seepage entering the excavation. Conventional sump pumping would still likely be required from within the excavation, however, wells points maybe required to control potential base heave; further

⁸ Fisheries and Oceans Canada – The Canadian Hydrographic Service; Burlington (#13150) Tidal Observations; <http://www.waterlevels.gc.ca/eng/station/Month?sid=13150&tz=EST&pres=2&type=1> retrieved on April 29, 2019.

⁹ Fisheries and Oceans Canada – The Canadian Hydrographic Service; Historical Monthly Mean Water Levels from the Coordinated network for each of the Great Lakes: Lake Ontario monthly mean water levels in metres referred to IGLD 1985; http://www.tides.gc.ca/C&A/network_means-eng.html; modified dated April 16, 2019; retrieved April 29, 2019.



comments in this regard can be provided once the type of cofferdam construction methodology is known. Cofferdam construction and dewatering should be in accordance with OPSS.PROV 182, OPSS.PROV 517, SP 517F01 and OPSS.PROV 805.

The type of outfall design was not available at the time of preparing this report. If geotechnical bearing resistance is required for design of the outfall structure, this office should be contacted for these parameters.

A supplemental hydrogeological assessment would be required to estimate the dewatering rates and complete analytical chemical testing to assess the options for groundwater discharge. If the estimated dewatering rates are greater than 50,000 L/day and less than 400,000 L/day, the water taking must be registered on the Ministry of the Environment, Conservation and Parks (MECP) Environmental Activity and Sector Registry (EASR). A Permit to Take Water (PTTW) may be required if pumping rates are expected to exceed 400,000 L/day.

7.2 Trenchless Storm Sewer Replacement

A storm sewer will be replaced using trenchless methods under the Toronto and Niagara bound mainline and Niagara bound collector lanes, approximately 175 m north of North Shore Boulevard. Based on the provided design drawings, the proposed 450 mm diameter storm sewer will be approximately 75 m in length and installed at invert depths of approximately 2.4 to 3.4 m below existing grade, near elevations 81.8 to 80.7.

Based on past MTO projects, a crown cover of 3.0 m between the top of pavement and the top of pipe, and 2.0 m between the underside of the pavement subbase and the top of pipe, are generally required to minimize the potential for pavement surface settlement and formation of sinkholes. In any case, a minimum crown cover of two (2) times the pipe diameter must be satisfied.

The proposed trenchless sewer and crown cover details are summarized in the table below.

Table 7.2 – Proposed Trenchless Sewer Design

Structure	Pipe Diameter	Invert Elevation		Crown Cover Below Top of Pavement (m)	Crown Cover Comment
		CB41	Outlet		
Trenchless Sewer from CB41 to Outlet	450 mm	81.8	80.7	1.9 to 2.9	< 3 m below pavement < 2 m below pavement subbase > 2 times pipe diameter
	Assumed minimum casing diameter up to 750 mm	-	-	-	> 2 times pipe diameter

Based on boreholes (TRSR1-01 to TRSR1-04), the anticipated soil conditions at the trenchless horizon will comprise compact to very dense sand and gravel fill, stiff to very stiff silty clay fill, loose to compact silty sand and stiff to very stiff silty clay. As of the last reading, groundwater water was observed in the piezometers installed in Boreholes TRSR1-01 and TRSR1-04 at depths of 1.2 and 3.0 m (Elev. 81.3 and 82.9). It is noted that a higher water level was observed at 2.2 m (Elev. 82.2) in Borehole TRSR1-4 on April 25, 2019.

The Tunnelman's Ground Classification System is a framework for describing soil behaviour in an unsupported tunnel heading under atmospheric conditions. Using the Tunnelman's system the cohesionless soils (sand and gravel fill and the silty sand) are expected to exhibit flowing behaviour below the groundwater table and ravelling behaviour above the groundwater table. The silty clay fill and silty clay are expected to exhibit firm to ravelling behaviour above and below the water table.

Based on the borehole information, the trenchless sewer will be advanced in a mixed face condition at the fill and native interface and below the observed groundwater levels, thus increasing the risks of encountering oversized obstructions such as boulders and cobbles consisting of local bedrock and harder igneous/metamorphic rock, and construction debris (e.g. concrete, timbers, etc.) that can be present within the fill embankment and ravelling to flowing



conditions at the bore face where water seepage is present. In this regard, the risks of pavement settlement, formation of sinkholes and encountering obstructions are considered high.

In order to reduce such risks, a combination of the following alternatives may be considered:

- 1) Lower the pipe invert elevation to meet the crown cover criterion and to avoid mixed face conditions between fill and native soils. It is not anticipated that the pipe invert elevation can be lowered.
- 2) Where the pipe alignment crosses under the travelled lanes of the highway, employ a trenchless technique in conjunction with a series of one-lane closures; this methodology would allow remedial measures to be implemented immediately should surficial distress including sinkhole formation be observed and/or settlements be detected from instrumentation monitoring results.
- 3) Lower the groundwater level below the tunnel invert in advance of construction and/or employ a trenchless technology that provides support to the face of the tunnel.
- 4) Select a casing diameter that will facilitate obstruction removal.

7.2.1 Trenchless Installation Methods

Trenchless installations should be carried out in general accordance with the requirements of the Non-Standard Special Provision (NSSP) "Pipe Installation by Trenchless Methods". A copy of this NSSP is attached in Appendix H.

Trenchless installation methods that are typically considered to install pipes under highways include:

- Jack and bore
- Pipe ramming
- Micro-tunnelling (MTBM)
- Hand mining
- Horizontal directional drilling

Selection of an appropriate trenchless method should be the responsibility of the Contractor and will depend upon the relative costs and risks associated with each method. The experience of



the Contractor is of primary importance for trenchless installation. The Contractor must submit a detailed work plan, including the proposed methodology, maintenance of alignment, removal of obstructions such as cobbles and boulders, and disposal of cuttings, all in accordance with the NSSP in Appendix H. Further details and comments on each method are provided in the following paragraphs.

Jack-and-bore methods may be considered for this project provided the potential risks of face instability and surface settlement are controlled. This method involves simultaneously jacking a casing while removing soil spoil by means of an auger. For the mainly cohesionless soil conditions at this site, it is critical that the casing be advanced such that the auger head will be recessed within the casing to ensure a soil plug remains to maintain the hole stability and prevent loss of material. This method is not suitable below groundwater in cohesionless soils, and dewatering must be implemented in advance of augering.

Pipe ramming is considered feasible for this installation. During pipe ramming, a sleeve pipe is driven from the access point to the exit point using an air-powered percussion hammer. After the sleeve has been fully or partially driven, the soil inside is removed by augering. In this situation, it is recommended that the sleeve be fully driven to the exit pit prior to removing the soil. This technique has a further advantage in that only a small over-cut is created around the pipe, resulting in a lower potential for settlement of the pavement surface above the installation. It is noted that the length of this installation is approaching the maximum feasible length for this installation methodology.

Depending on the ground conditions and construction methods, either of these trenchless techniques carries a certain degree of risk including the potential of highway settlement due to the relatively shallow soil crown cover. The presence of cobbles in the granular fills may also impact tunnel advance and increase the potential for surface settlement. It is noted that a minimum casing diameter of 750 mm is required for removal of obstructions. Instrumentation and monitoring for potential settlements on the highway will be required for these trenchless construction methods.

Micro-tunnelling using a MTBM (with face pressure balance if required) may be used to advance the bore after which the pipe can be installed. Micro-tunnelling is technically feasible for the soil and groundwater conditions at the sewer lateral locations but is unlikely to be cost effective due to the relatively short pipe lengths.

Hand-mining is not considered practical for this project due to the relatively small tunnel diameter and shallow crown cover.



Horizontal directional drilling procedures are not suitable for installation of the sewer pipe since the method may encounter difficulties maintaining the required pipe invert elevations especially if oversized obstructions such as cobbles and boulders are encountered.

A comparison of the technical advantages and disadvantages of the trenchless installation methods schemes is presented in Appendix F.

From a foundations perspective, it is considered that micro-tunnelling is preferred as it carries the lowest risks of the installation methods considered. Pipe ramming is considered to be feasible but carries a certain degree of risk associated with potential surface settlement due to the relatively shallow soil crown cover below the pavement. Jack and bore is considered feasible provided the groundwater level is lowered to below the invert level prior to installation to reduce the risk of face instability. The relative cost effectiveness of these methods should be assessed. The suitability of these trenchless techniques depends on factors including soil types, groundwater conditions, equipment availability, contractor's expertise and experience.

7.2.2 Instrumentation and Monitoring Program

The potential for settlement and heave should be considered in selection of the trenchless installation method. Ground surface settlement during and post construction induced by the advancement of the trenchless installation methods. The order of magnitude of the possible settlement for the feasible methods presented previously, namely micro-tunnelling, pipe ramming and jack and bore is provided in the following table:

Method of Installation	Estimated Order of Magnitude of Potential Settlement (mm)
Micro-tunnelling	Up to 5
Pipe Ramming	10 to 15
Jack and Bore	15 to 20

The magnitude of potential settlement will be based on the contractor's experience, construction techniques, sequencing and efficiency of work force.

It is noted that heave may occur during pipe ramming and jack and bore installation if an obstruction such as a cobble or boulder is encountered and/or due to stress changes in the soil. Due to the inherent variability in cobble and boulder size, it is not possible to accurately predict



the order of magnitude of heave due to obstructions. Provided appropriate cutting shoes are used and obstructions are not encountered, heave from pipe-ramming is anticipated to be less than 25 mm.

Monitoring of the MTO right-of-way should be carried out during the trenchless installation. The settlement monitoring program and condition survey should be in accordance with the NSSP "Pipe Installation by Trenchless Method". A copy of the NSSP is provided in Appendix H.

Layout of instrumentation and monitoring should be in accordance with the NSSP. A preliminary schematic of instrumentation for the monitoring program is provided in Drawing G1 in Appendix G. The Contractor is required to select a suitable method for the installation of pipe such that the ground settlement review and alert levels of 10 mm and 15 mm, respectively, stipulated in the instrumentation and monitoring program in Appendix G, can be satisfied.

The impact of the proposed installation on existing nearby structures and underground utilities should be assessed. A pre-construction condition survey should be carried out to document the existing condition of the highway pavement and assess the potential for damage to all facilities and underground services along the alignments of the trenchless crossings.

Monitoring of the roadway surface and underground utilities should be carried out during construction.

7.2.3 Temporary Pits and Temporary Protection (Shoring)

Temporary launching and receiving pit excavations at either end of the trenchless sewer crossing will be required. Excavation, groundwater control, temporary protection (shoring) and roadway protection should be in accordance with Section 7.1.1 of this report. As per Section 7.1.1, roadway protection must be provided in accordance with OPSS.PROV 539 and designed for Performance Level 2.

Cognizant that the installation will be below the observed groundwater level, dewatering may require additional or higher capacity sump pumps, wellpoints or educator wells, depending on the installation methodology chosen and the groundwater conditions at the time of construction. A dewatering specialist should be consulted to provide input on the required dewatering system once the trenchless methodology is known. Dewatering should be in accordance with OPSS.PROV 517 and SP 517F01.



The following parameters should be used for temporary protection:

Soil Type	Saturated/ Submerged Unit Weight (kN/m ³)	Undrained Shear Strength (kPa) (Short Term)	Undrained Friction Angle (°) (Long Term)	Rankine Coefficient of Active Earth Pressure (K _a)	Rankine Coefficient of Passive Earth Pressure (K _p)*
Granular Fill	21.0 / 11.2	NA	30	0.33	3.0
Clay Fill, Native Silty Clay/Silty Clay Till	20.0 / 10.2	NA	27	0.38	2.7
Sand Fill, Native Sand	21.0 / 11.2	NA	29	0.35	2.9

The ground water level at this site should be assumed to occur at the ground surface, for design purposes.

Removal of temporary shoring should be in accordance with the conditions set out in Section 539.07.02 of OPSS.PROV 539.

8.0 SOIL CORROSION POTENTIAL

Low resistivity values and high chloride concentrations measured in samples of the fill and native soils from the site indicate that the soils are potentially corrosive to steel, cast iron, and other metals. It is believed that these values result from the application of de-icing salt to the highway. Protective measures to resist corrosion are therefore recommended.

The measured sulphate concentrations indicate that buried concrete structures will not be subject to sulphate attack.



9.0 CONSTRUCTION CONCERNS

Potential construction concerns include, but are not necessarily limited to:

- Trenchless installations at relatively shallow depth below a highway inherently include some risk of loss of ground into the bore and can potentially result in settlement of the pavement surface. Selection of the trenchless technique employed for installing the sewer must take into account the need to avoid settlement and loss of ground below the QEW. Confirmatory monitoring of the roadway surface should be carried out during construction, and contingency plans should be prepared to manage any adverse impacts that may arise.
- Trenching may result in adjacent ground movements depending on the trenching methodology and subsurface conditions. The Contractor must recognize that construction sequencing including the implementation of roadway protection (shoring) and groundwater control will be critical to limiting ground movements to within tolerable limits.
- Groundwater control may be required for installation of the culverts and sewers in some locations. Proper construction drainage and potentially sump pumping, well points, cofferdam construction, or additional dewatering measures will be required.
- Cobbles, boulders or other obstructions may be present within the existing highway embankment fill and native tills. The Contractor's equipment and methodology must be able to handle and remove such obstructions. It is noted that a minimum casing diameter of 750 mm is required for removal of obstructions.
- The Contractor must accurately establish the locations and depths of all buried utilities in the vicinity of the excavations and tunnelling.



10.0 CLOSURE

Engineering analysis and preparation of the foundation design report were carried out by Mr. Karel Furbacher, P.Eng. and Mr. Murray Anderson, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.



Karel Furbacher, P.Eng.
Geotechnical Engineer



P.K. Chatterji, P.Eng., Ph.D.
Review Principal



Appendix A

Site Photographs

**CULVERTS AND STORM SEWER INSTALLATIONS
NORTH SHORE BOULEVARD INTERCHANGE
Site Photographs**



Photograph 1 – View of west outlet of Culvert 3



**Photograph 2 – Borehole C3-02 on the ramp from the QEW to North Shore Boulevard
along alignment of Culvert 3 facing southwest**

**CULVERTS AND STORM SEWER INSTALLATIONS
NORTH SHORE BOULEVARD INTERCHANGE
Site Photographs**



Photograph 3 – View of portable tripod equipment drilling at Borehole C6-01, west of inlet of Culvert 6



Photograph 4 – East end of Culvert 6 looking north towards Borehole C5-04

**CULVERTS AND STORM SEWER INSTALLATIONS
NORTH SHORE BOULEVARD INTERCHANGE
Site Photographs**



Photograph 5 – View looking east towards QEW Niagara collector lanes along the Culvert 8 alignment



Photograph 6 – West outlet of Culvert 8 into Hamilton Harbour (Lake Ontario) near Borehole C8-01



**CULVERTS AND STORM SEWER INSTALLATIONS
NORTH SHORE BOULEVARD INTERCHANGE
Site Photographs**



Photograph 7 – View looking northeast towards west outlet of TRSR



Photograph 8 – View looking east along alignment of TRSR from west outlet of TRSR



**CULVERTS AND STORM SEWER INSTALLATIONS
NORTH SHORE BOULEVARD INTERCHANGE
Site Photographs**



Photograph 9 – View looking west along alignment of TRSR from east end of TRSR



Appendix B
Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT ⁽¹⁾ 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$

 Water Level
 Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

RECORD OF BOREHOLE No C3-01

1 OF 1

METRIC

GWP# 2117-15-00 LOCATION MTM NAD83 Zone 10: N 4 797 327.1 E 279 664.6 ORIGINATED BY KK
 DIST Central HWY QEW BOREHOLE TYPE NW Wash Boring COMPILED BY MP
 DATUM Geodetic DATE 2019.03.26 - 2019.03.26 LATITUDE 43.315407 LONGITUDE -79.809875 CHECKED BY KF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT							UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
78.0	GROUND SURFACE							20	40	60	80	100						
0.0	TOPSOIL FILL (150mm)																	
0.2	Silty CLAY , trace sand and gravel, occasional organics, contains rootlets Very Stiff Brown Moist (FILL)		1	SS	19													
76.8			2	SS	25		77											
1.2	Silty SAND , with occasional to numerous partings and layers of silty clay Compact Grey Wet		3	SS	13		76									0 69 20 11		
75.8																		
2.2	layer of silty CLAY		4	SS	8											0 25 39 36		
75.4																		
2.6			5	SS	7		75											
74.3																		
3.7	END OF BOREHOLE AT 3.7m. Monitoring well installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.5m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2019.04.25 0.9 77.1 2019.05.02 0.7 77.3																	

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No C3-02

1 OF 1

METRIC

GWP# 2117-15-00 LOCATION MTM NAD83 Zone 10: N 4 797 328.3 E 279 676.6 ORIGINATED BY KK
 DIST Central HWY QEW BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2019.04.17 - 2019.04.17 LATITUDE 43.315418 LONGITUDE -79.809727 CHECKED BY KF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						WATER CONTENT (%)			
								20 40 60 80 100						20 40 60			
81.1	GROUND SURFACE																
0.0 80.8	ASPHALT: (250mm)						81										
0.3	SAND and GRAVEL Compact Brown Moist (FILL)		1	SS	14												
80.1																	
1.0	Silty CLAY, some sand, trace gravel Stiff Brown Moist (FILL)		2	SS	14		80										
			3	SS	9		79										
			4	SS	9		78										
			5	SS	10												
77.0																	
4.1	Silty SAND, with occasional to numerous partings and layers of silty clay Loose to Compact Grey/Brown Moist		6	SS	9		77										
76.0																	
5.1	layer of silty CLAY						76										
75.5																	
5.6																	
			7	SS	12		75										
74.4																	
6.7	END OF BOREHOLE AT 6.7m. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE TO 0.2m, THEN CONCRETE AND COLD PATCH ASPHALT TO SURFACE.																

ONTMT4S2 MTO-25497.GPJ 2017TEMPLATE(MTO).GDT 5/22/19

RECORD OF BOREHOLE No C3-03

1 OF 1

METRIC

GWP# 2117-15-00 LOCATION MTM NAD83 Zone 10: N 4 797 324.8 E 279 685.4 ORIGINATED BY KK
 DIST Central HWY QEW BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2019.04.17 - 2019.04.17 LATITUDE 43.315387 LONGITUDE -79.809619 CHECKED BY KF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						PLASTIC LIMIT w _p NATURAL MOISTURE CONTENT w LIQUID LIMIT w _L WATER CONTENT (%)				
81.1	GROUND SURFACE							20	40	60	80	100						
0.0	ASPHALT: (225mm)						81											
0.2	SAND and GRAVEL Loose to Compact Brown Moist (FILL)		1	SS	8													
			2	SS	17													
79.6							80											
1.4	Silty, sandy CLAY, trace gravel Stiff to Firm Brown Moist (FILL)		3	SS	13													
			4	SS	10													
			5	SS	12													
77.0							78											
4.1	Silty SAND; with occasional to numerous partings and layers of silty clay Compact Brown Moist		6	SS	5													
75.9			7	SS	6													
5.2	END OF BOREHOLE AT 5.2m. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE TO 0.2m, THEN CONCRETE COLD PATCH ASPHALT TO SURFACE.						76											

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No C3-04

1 OF 1

METRIC

GWP# 2117-15-00 LOCATION MTM NAD83 Zone 10: N 4 797 331.6 E 279 694.9 ORIGINATED BY KK
 DIST Central HWY QEW BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2019.04.04 - 2019.04.04 LATITUDE 43.315448 LONGITUDE -79.809502 CHECKED BY KF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)									
78.8	GROUND SURFACE							20	40	60	80	100	W _P	W	W _L	kN/m ³	GR	SA	SI	CL	
0.0	TOPSOIL FILL: (125mm)																				
0.1	Silty CLAY , some sand, trace gravel Firm Brown Moist (FILL)		1	SS	7																
77.5			2	SS	7																
1.3	Silty SAND ; with occasional to numerous partings and layers of silty clay, occasional black organic layers Loose to Very Loose Brown Moist		3	SS	10																
			4	SS	3																
75.4			5	SS	5																
3.4	layer of silty CLAY																				
75.1																					
3.7																					
74.5																					
4.3	Silty CLAY , some sand to sandy, trace gravel Stiff Reddish Brown Moist (TILL)		6	SS	10																
73.6																					
5.2	END OF BOREHOLE AT 5.2m. BOREHOLE OPEN AND WATER LEVEL AT 2.1m UPON COMPLETION. Monitoring well installation consists of 25mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2019.04.25 1.0 77.8 2019.05.02 0.4 78.4																				

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No C5-01

1 OF 1

METRIC

GWP# 2117-15-00 LOCATION MTM NAD83 Zone 10: N 4 797 137.1 E 280 106.8 ORIGINATED BY KK
 DIST Central HWY QEW BOREHOLE TYPE NW Wash Boring COMPILED BY MP
 DATUM Geodetic DATE 2019.03.25 - 2019.03.25 LATITUDE 43.313711 LONGITUDE -79.804415 CHECKED BY KF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
77.4	GROUND SURFACE							20 40 60 80 100						
0.0	TOPSOIL FILL: (150mm)							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
0.2	Silty CLAY , some sand to sandy, trace gravel Firm to Stiff Reddish Brown Moist (FILL)		1	SS	8		77							2 40 34 24
			2	SS	52		76							
			3	SS	36									
75.2														
78.4	Silty SAND , trace gravel		4	SS	100/									
2.4	Very Dense Brown Moist END OF BOREHOLE AT 2.4m UPON PRACTICAL REFUSAL TO ADVANCE. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.				0.075									

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

METRIC

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No C6-01

1 OF 1

METRIC

GWP# 2117-15-00 LOCATION MTM NAD83 Zone 10: N 4 797 064.8 E 280 068.7 ORIGINATED BY KK
 DIST Central HWY QEW BOREHOLE TYPE NW Wash Boring COMPILED BY MP
 DATUM Geodetic DATE 2019.03.28 - 2019.03.28 LATITUDE 43.313059 LONGITUDE -79.804882 CHECKED BY KF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa													
76.7	GROUND SURFACE							20	40	60	80	100									
0.0	TOPSOIL FILL (125mm)																				
0.1	Silty CLAY , some sand, trace gravel Stiff Brown		1	SS	14	▽	76														
76.0	Moist (FILL)																				
0.7	SAND and GRAVEL , trace to some silt and clay Compact Brown		2	SS	18																
	Moist (FILL)																				
74.9			3	SS	47			75													
1.8	Silty SAND , trace gravel; with occasional layers of silt, black organic layers Compact to Dense Brown to Grey Moist to Wet																				
			4	SS	39				74												
			5	SS	24																
73.0						73															
3.7	layer of SAND , trace to some silt and gravel; occasional shell fragments		6	SS	22																
72.2																					
4.5	Loose					72															
71.5			7	SS	8																
5.2	END OF BOREHOLE AT 5.2m. BOREHOLE BACKFILLED WITH BENTONITE TO SURFACE.																				

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No C6-02

1 OF 1

METRIC

GWP# 2117-15-00 LOCATION MTM NAD83 Zone 10: N 4 797 068.6 E 280 077.6 ORIGINATED BY KK
 DIST Central HWY QEW BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2019.04.16 - 2019.04.16 LATITUDE 43.313093 LONGITUDE -79.804772 CHECKED BY KF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)						
								○ UNCONFINED + FIELD VANE	20	40	60	80	100	W _P			W	W _L
								● QUICK TRIAXIAL × LAB VANE	20	40	60	80	100					
76.9	GROUND SURFACE																	
0.0	ASPHALT: (275mm)																	
76.7																		
0.3	SAND and GRAVEL, some silt Dense to Compact Brown Moist (FILL)		1	SS	41													
			2	SS	14													
75.3																		
1.6	Silty SAND, trace gravel; with occasional black organic layers Loose to Very Loose Grey Moist		3	MB/CDSS	18													
			4	SS	4													
			5	SS	5													
73.2																		
3.7	layer of SAND, trace to some silt and gravel; with occasional shell fragments		6	SS	3													
72.4																		
4.5	with occasional layers of silt		7	SS	2													
71.8																		
5.2	END OF BOREHOLE AT 5.2m. BOREHOLE CAVED AND WATER LEVEL TO 2.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE TO 0.2m, THEN CONCRETE AND COLD PATCH ASPHALT TO SURFACE.																	

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No C6-03

1 OF 1

METRIC

GWP# 2117-15-00 LOCATION MTM NAD83 Zone 10: N 4 797 072.6 E 280 087.1 ORIGINATED BY KK
 DIST Central HWY QEW BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2019.04.15 - 2019.04.15 LATITUDE 43.313130 LONGITUDE -79.804655 CHECKED BY KF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)				
77.1	GROUND SURFACE					∇								GR SA SI CL	
0.0	ASPHALT: (100mm)														
0.1	SAND and GRAVEL Dense to Compact Brown Moist (FILL)		1	SS	31										
75.7			2	SS	17										
1.4	Silty SAND, trace to some gravel; with occasional black organic layers Compact to Very Loose Brownish Grey Moist		3	SS	12										
74.9	layer of SAND, trace to some silt and gravel; occasional shell fragments		4	SS	7										
2.2															
74.1															
3.0			5	SS	4										
			6	SS	3										
71.9															
5.2	END OF BOREHOLE AT 5.2m. BOREHOLE OPEN AND WATER LEVEL AT 2.2m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.2m, THEN CONCRETE COLD PATCH ASPHALT TO SURFACE.														

RECORD OF BOREHOLE No C8-01

1 OF 2

METRIC

GWP# 2117-15-00 LOCATION MTM NAD83 Zone 10: N 4 796 882.7 E 280 037.1 ORIGINATED BY KK
 DIST Central HWY QEW BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2019.04.01 - 2019.04.01 LATITUDE 43.311419 LONGITUDE -79.805263 CHECKED BY KF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED + FIELD VANE							
						● QUICK TRIAXIAL × LAB VANE									
76.3	GROUND SURFACE							20 40 60 80 100		20 40 60					
0.0	TOPSOIL FILL: (225mm)														
0.2	Silty CLAY , some sand, trace gravel Soft to Firm Dark Brown to Reddish Brown Moist (FILL)		1	SS	5		76								
			2	SS	4		75							0 27 50 23	
74.8															
1.4	Silty SAND ; with occasional layers of silt, black organic layers Very Loose Grey Moist		3	SS	8		74							0 65 28 7	
			4	SS	4										
73.3															
3.0	with occasional partings of silty clay		5	SS	3		73								
72.6															
3.7	Layered silty SAND and sandy SILT ; with occasional to numerous organic layers Very Loose to Loose Black, Brown and Grey Wet		6	SS	4		72							0 55 40 5	
			7	SS	4		71								
70.2															
6.1	ORGANIC SILT , some sand to sandy inclusions, occasional thin layers of peat, partings of silty clay, thin sand seams, and shell fragments Loose Grey Moist		8	SS	5		70								
							69								
			9	SS	5		68							0 21 63 16	
66.8															
9.4	Sand and GRAVEL , trace to some silt Compact to Very Dense Grey		10	SS	21		67								

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No C8-01

2 OF 2

METRIC

GWP# 2117-15-00 LOCATION MTM NAD83 Zone 10: N 4 796 882.7 E 280 037.1 ORIGINATED BY KK
 DIST Central HWY QEW BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2019.04.01 - 2019.04.01 LATITUDE 43.311419 LONGITUDE -79.805263 CHECKED BY KF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)													
	Continued From Previous Page																					
	Wet		11	SS	58																	
			12	SS	54									35 56 9 (SI+CL)								
63.5																						
12.8	END OF BOREHOLE AT 12.8m. Monitoring well installation consists of 25mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS <table border="1"> <thead> <tr> <th>DATE</th> <th>DEPTH(m)</th> <th>ELEV.(m)</th> </tr> </thead> <tbody> <tr> <td>2019.04.25</td> <td>1.7</td> <td>74.5</td> </tr> <tr> <td>2019.05.02</td> <td>1.0</td> <td>75.3</td> </tr> </tbody> </table>	DATE	DEPTH(m)	ELEV.(m)	2019.04.25	1.7	74.5	2019.05.02	1.0	75.3												
DATE	DEPTH(m)	ELEV.(m)																				
2019.04.25	1.7	74.5																				
2019.05.02	1.0	75.3																				

RECORD OF BOREHOLE No C8-02

1 OF 1

METRIC

GWP# 2117-15-00 LOCATION MTM NAD83 Zone 10: N 4 796 888.4 E 280 050.4 ORIGINATED BY KK
 DIST Central HWY QEW BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2019.04.03 - 2019.04.03 LATITUDE 43.311470 LONGITUDE -79.805099 CHECKED BY KF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL LIMIT MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			W _P	W	W _L		
76.6	GROUND SURFACE					▽									GR SA SI CL
0.0	TOPSOIL FILL: (125mm)														
0.1	Silty CLAY , some sand to sandy, trace gravel Firm Dark Brown to Reddish Brown Moist (FILL)		1	SS	6										
			2	SS	6										
75.1															
1.4	Silty SAND , trace gravel; with occasional black organic layers Loose to Compact Brown Moist		3	SS	10										
74.4															
2.2	Very Loose Grey Wet		4	SS	3										
			5	SS	4										
72.8															
3.7	Layered silty SAND and sandy SILT ; with occasional to numerous organic layers Loose Grey Moist		6	SS	4										
			7	SS	2										
71.4															
5.2	END OF BOREHOLE AT 5.2m. BOREHOLE OPEN AND WATER LEVEL AT 2.5m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE TO SURFACE.														

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No C8-03

1 OF 1

METRIC

GWP# 2117-15-00 LOCATION MTM NAD83 Zone 10: N 4 796 900.0 E 280 064.3 ORIGINATED BY KK
 DIST Central HWY QEW BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2019.04.11 - 2019.04.11 LATITUDE 43.311575 LONGITUDE -79.804929 CHECKED BY KF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)				
77.0	GROUND SURFACE							20 40 60 80 100							
0.0	ASPHALT: (125mm)							20 40 60 80 100							
0.1	SAND and GRAVEL Compact Brown Moist (FILL)		1	SS	17	▽									
76.3															
0.7	Clayey SILT, some sand to sandy, trace gravel Stiff Brown Moist (FILL)		2	SS	11										
75.5															
1.4	Brown Moist (FILL)		3	SS	8										
74.8	SAND, some gravel, trace silt Loose Brown Moist (FILL)		4	SS	9										
2.2	Silty SAND, trace gravel; with occasional layers of silt, black organic layers Loose Grey Wet		5	SS	6										
72.8															
4.2	Layered silty SAND and sandy SILT; with occasional to numerous organic layers and thin layers of peat Loose Grey Moist		6	SS	3										
71.8															
5.2	END OF BOREHOLE AT 5.2m. BOREHOLE OPEN AND WATER LEVEL AT 2.2m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE AND CUTTINGS TO 0.2m, THEN CONCRETE AND ASPHALT TO SURFACE.														

+³, ×³: Numbers refer to Sensitivity
 20
 15
 10
 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No C8-04

1 OF 1

METRIC

GWP# 2117-15-00 LOCATION MTM NAD83 Zone 10: N 4 796 910.9 E 280 082.3 ORIGINATED BY KK
 DIST Central HWY QEW BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2019.04.04 - 2019.04.04 LATITUDE 43.311674 LONGITUDE -79.804707 CHECKED BY KF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
76.7	GROUND SURFACE															
0.0	TOPSOIL FILL: (100mm)															
0.1	SAND, trace to some gravel, some silt Compact Brown Moist (FILL)		1	SS	10											
			2	SS	29											
	gravelly, trace silt		3	SS	27											
74.5																
2.2	Silty SAND, some gravel, occasional cobbles, wood and shell fragments Compact to Loose Brown Moist		4	SS	18											
			5	SS	21											
72.6																
4.1	Layered silty SAND and sandy SILT; with occasional to numerous organic layers Loose Grey Moist		6	SS	6											
71.5																
5.2	END OF BOREHOLE AT 5.2m. Monitoring well installation consists of 25mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.															

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No TRSR1-01

1 OF 1

METRIC

GWP# 2117-15-00 LOCATION MTM NAD83 Zone 10: N 4 797 423.6 E 279 754.2 ORIGINATED BY KK
DIST Central HWY QEW BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
DATUM Geodetic DATE 2019.04.15 - 2019.04.15 LATITUDE 43.316278 LONGITUDE -79.808775 CHECKED BY KF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)					
84.1	GROUND SURFACE							20	40	60	80	100					
0.0 83.9	ASPHALT: (250mm)																
0.3	SAND and GRAVEL Dense to Very Dense Brown Moist (FILL)		1	SS	31												
			2	SS	100/ 0.125												
			3	SS	56												
81.9																	
2.2	Silty SAND Compact Brown Moist		4	SS	15												
81.4																	
2.7	Silty CLAY, trace sand Stiff Brown Moist		5	SS	14												
79.4																	
4.7 79.2	Silty CLAY, trace sand; with numerous shale fragments		6	SS	100/ 0.250												
5.0	Hard Reddish Brown Moist (TILL) END OF BOREHOLE AT 5.0m. Monitoring well installation consists of 50mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.																
WATER LEVEL READINGS																	
DATE		DEPTH(m)		ELEV.(m)													
2019.04.25		1.3		82.8													
2019.05.02		1.2		82.9													

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No TRSR1-02

1 OF 1

METRIC

GWP# 2117-15-00 LOCATION MTM NAD83 Zone 10: N 4 797 398.8 E 279 735.0 ORIGINATED BY KK
 DIST Central HWY QEW BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2019.04.16 - 2019.04.16 LATITUDE 43.316054 LONGITUDE -79.809011 CHECKED BY KF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
84.4	GROUND SURFACE												
0.0	ASPHALT: (100mm)												
0.1	SAND and GRAVEL Dense Brown Moist (FILL)		1	SS	34		84						
			2	SS	14		83						
83.0													
1.4	Silty CLAY, some sand, trace gravel Very Stiff Brown Moist (FILL)		3	SS	18		82						
			4	SS	15		81						
81.7													
2.7	Silty SANDto SILT and SAND, trace gravel Compact Brown Moist		5	SS	15		80						
81.0													
3.4	Silty CLAY, trace sand Stiff to Very Stiff Grey Moist												
			6	SS	8								
79.2													
5.2	END OF BOREHOLE AT 5.2m. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.2m, THEN CONCRETE AND COLD PATCH ASPHALT TO SURFACE.												

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No TRSR1-03

1 OF 1

METRIC

GWP# 2117-15-00 LOCATION MTM NAD83 Zone 10: N 4 797 377.3 E 279 726.9 ORIGINATED BY KK
 DIST Central HWY QEW BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2019.04.16 - 2019.04.16 LATITUDE 43.315861 LONGITUDE -79.809110 CHECKED BY KF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
84.7	GROUND SURFACE												
0.0	ASPHALT: (225mm)												
0.2	SAND and GRAVEL Compact Brown Moist (FILL)		1	SS	26		84						
84.0													
0.7	Silty CLAY, some sand, trace gravel Very Stiff Brown Moist (FILL)		2	SS	17		83						5 25 37 33
82.8			3	SS	30								
1.9	Silty SAND Compact to Dense Brown Moist												
82.0			4	SS	13		82						
2.7	Silty CLAY, trace sand, oxidized Stiff to Very Stiff Brown to Grey Moist		5	SS	18		81						1 10 46 43
			6	SS	16		80						
79.5													
5.2	END OF BOREHOLE AT 5.2m. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.2m, THEN CONCRETE AND COLD PATCH ASPHALT TO SURFACE.												

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No TRSR1-04

1 OF 1

METRIC

GWP# 2117-15-00 LOCATION MTM NAD83 Zone 10: N 4 797 374.2 E 279 714.2 ORIGINATED BY KK
DIST Central HWY QEW BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
DATUM Geodetic DATE 2019.04.11 - 2019.04.11 LATITUDE 43.315831 LONGITUDE -79.809266 CHECKED BY KF

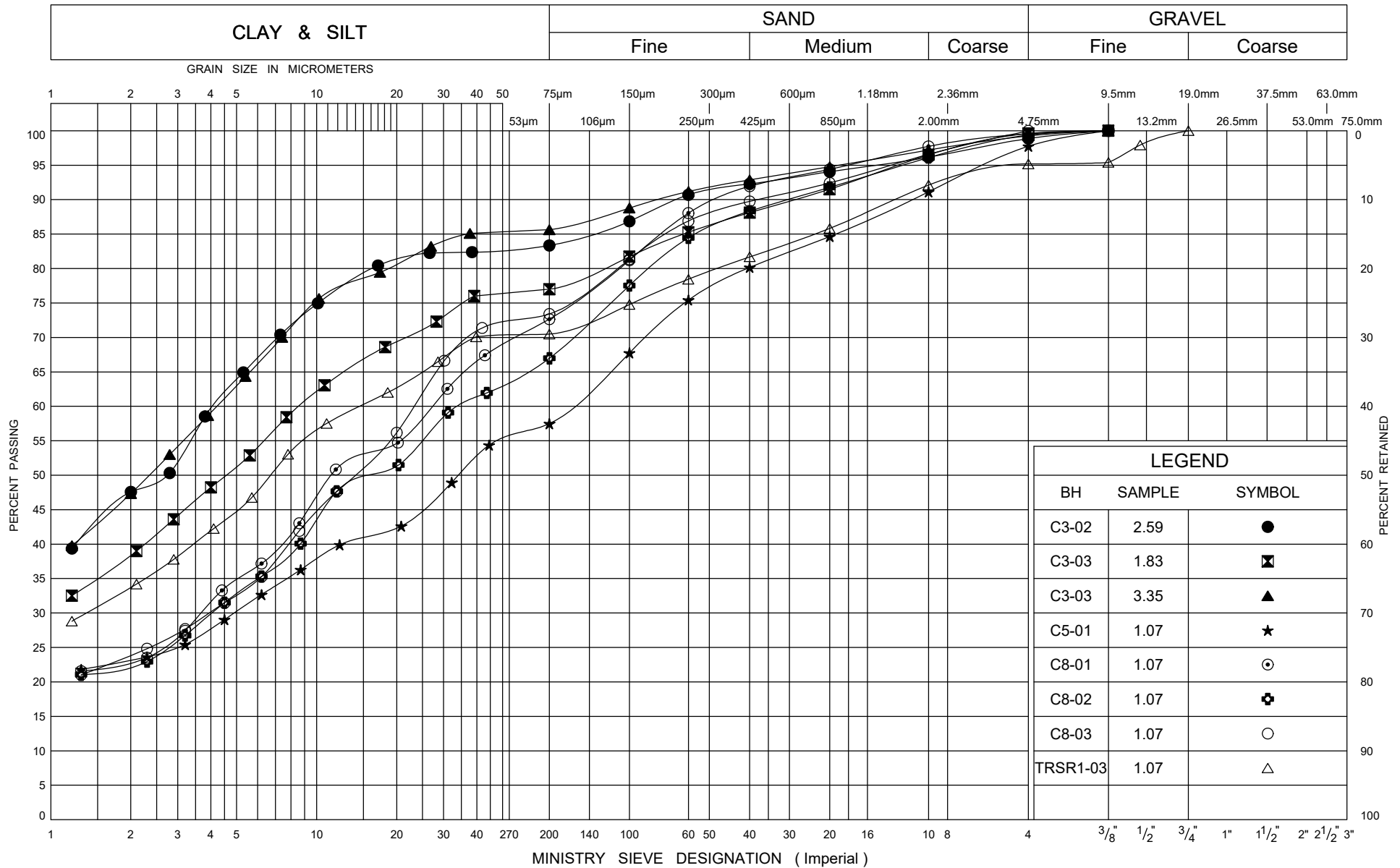
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
84.3	GROUND SURFACE							20 40 60 80 100					
0.0	ASPHALT: (150mm)							20 40 60 80 100					
0.2	SAND and GRAVEL Compact Brown Moist (FILL)		1	SS	18		84						
83.7													
0.7	Silty CLAY, some sand, trace gravel Stiff to Very Stiff Brown Moist (FILL)		2	SS	12		83						
83.0													
1.3	Silty SAND Loose Reddish Brown Moist		3	SS	28		82						
			4	SS	6		81						1 72 19 8
81.4													
3.0	Silty CLAY, trace sand Stiff to Soft Brown to Grey Moist		5	SS	9		80						0 6 42 52
			6	SS	2		79						
							78.2						
6.1	Silty CLAY, trace sand and gravel, occasional shale fragments Very Stiff Reddish Brown Moist (TILL)		7	SS	29		78						
77.6													
6.7	END OF BOREHOLE AT 6.7m. Monitoring well installation consists of 50mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.												
WATER LEVEL READINGS													
DATE		DEPTH(m)		ELEV.(m)									
2019.04.25		2.2		82.2									
2019.05.02		3.0		81.3									

ONTMT452 MTO-25497.GPJ 2017TEMPLATE(MTO).GDT 5/22/19

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE



Appendix C
Laboratory Test Results



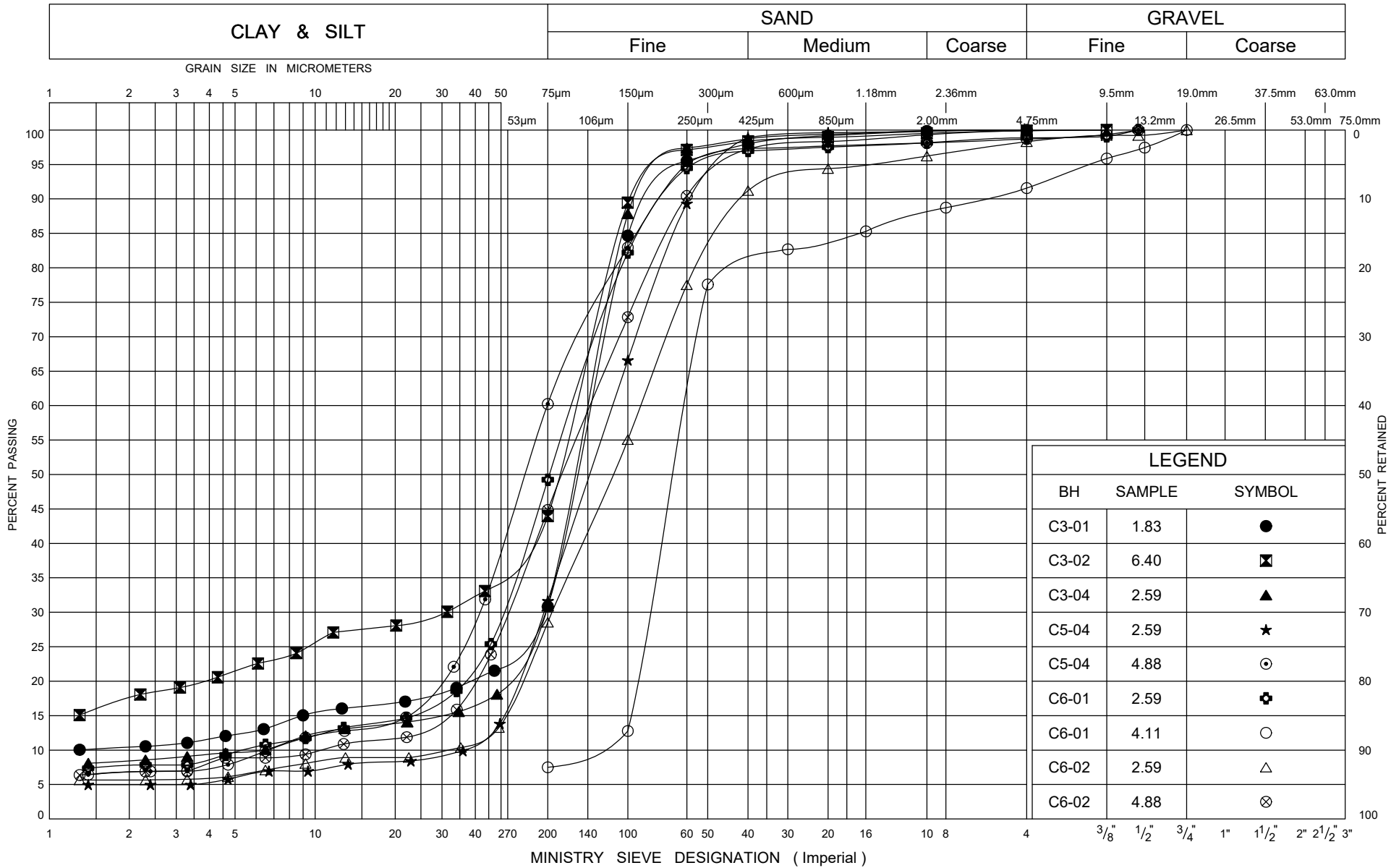
Ministry of
Transportation

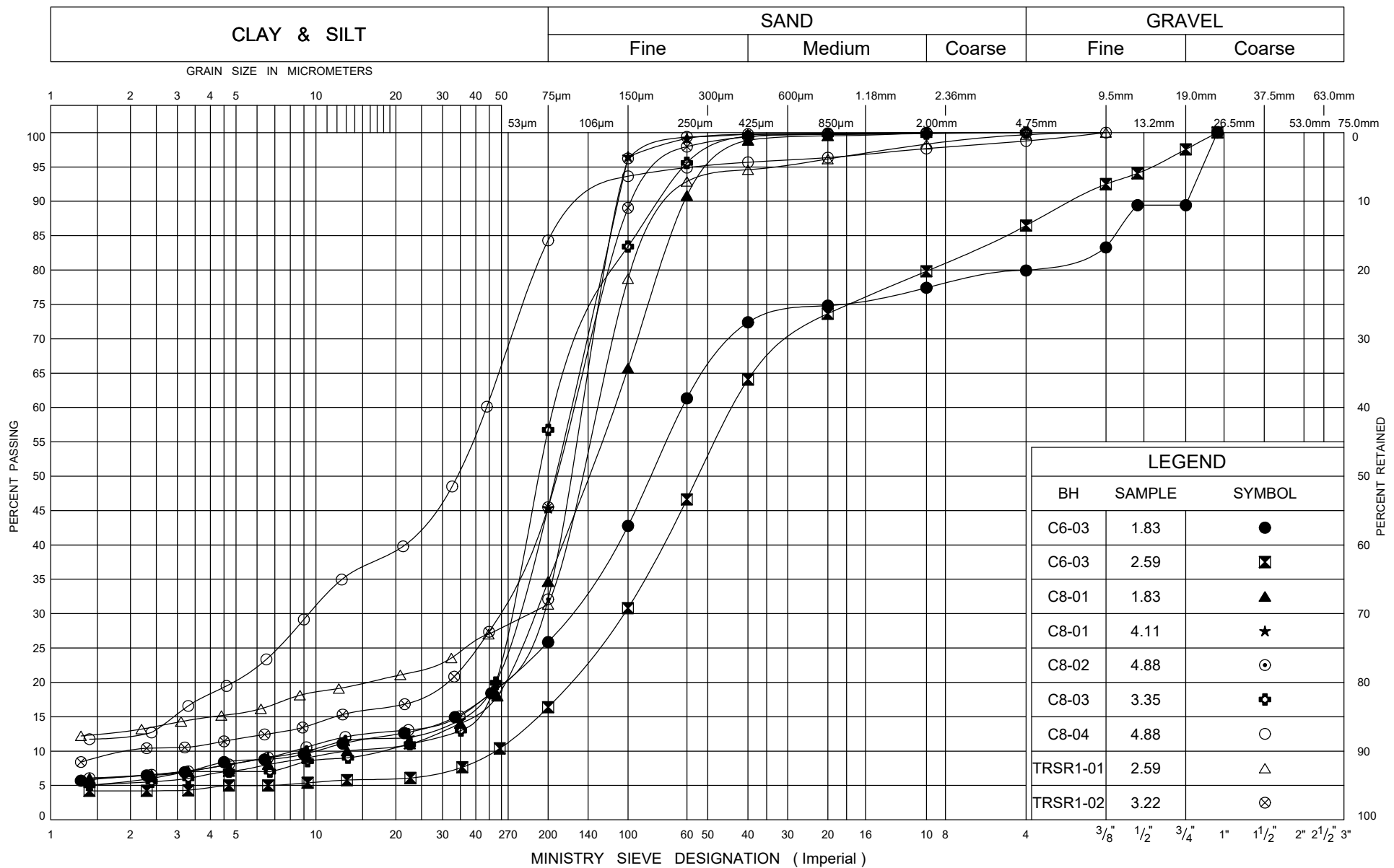
GRAIN SIZE DISTRIBUTION

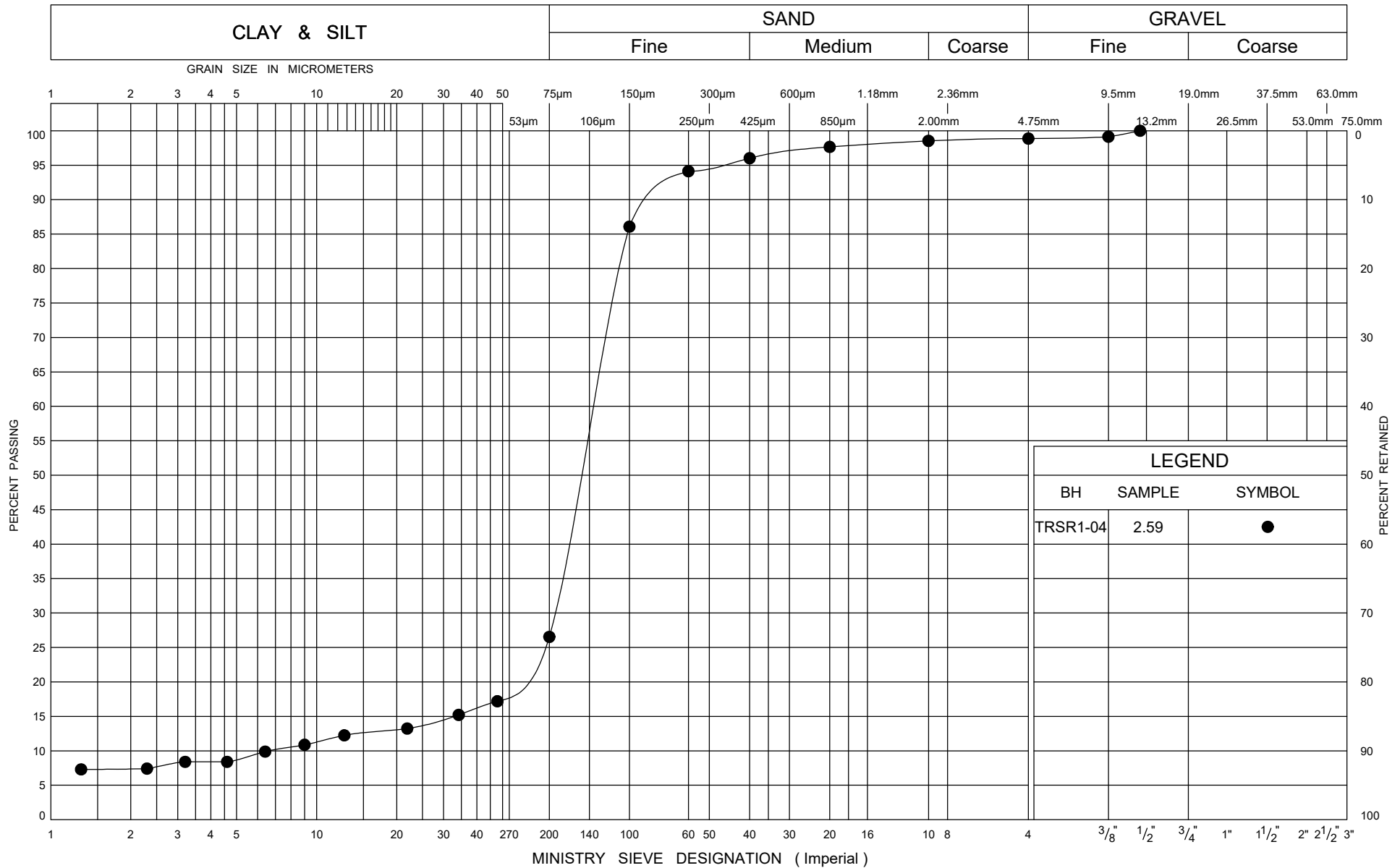
Silty CLAY and Clayey SILT FILL

FIG No C1

W P 2117-15-00







Ministry of
Transportation

GRAIN SIZE DISTRIBUTION

Silty SAND

FIG No C4

W P 2117-15-00

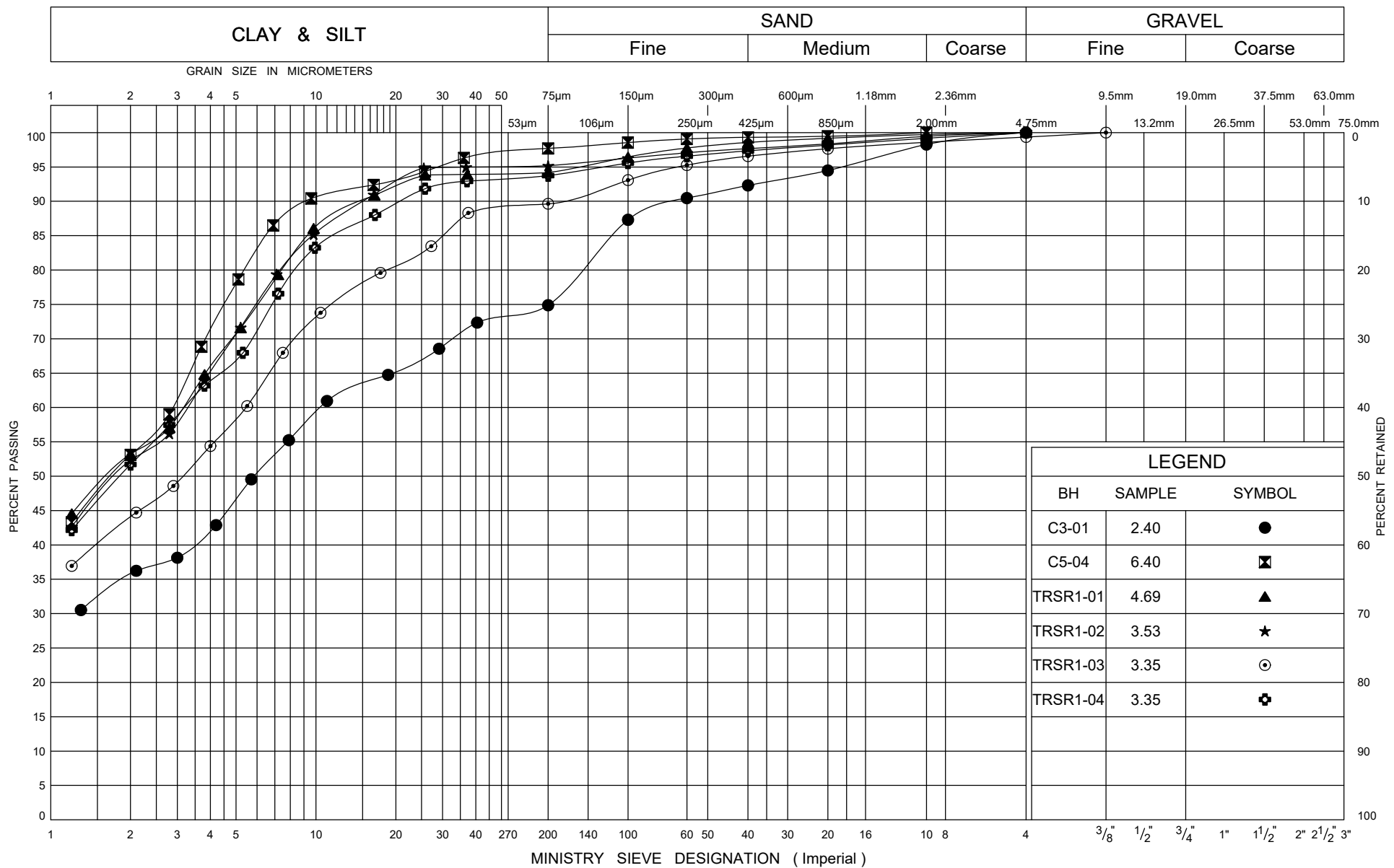
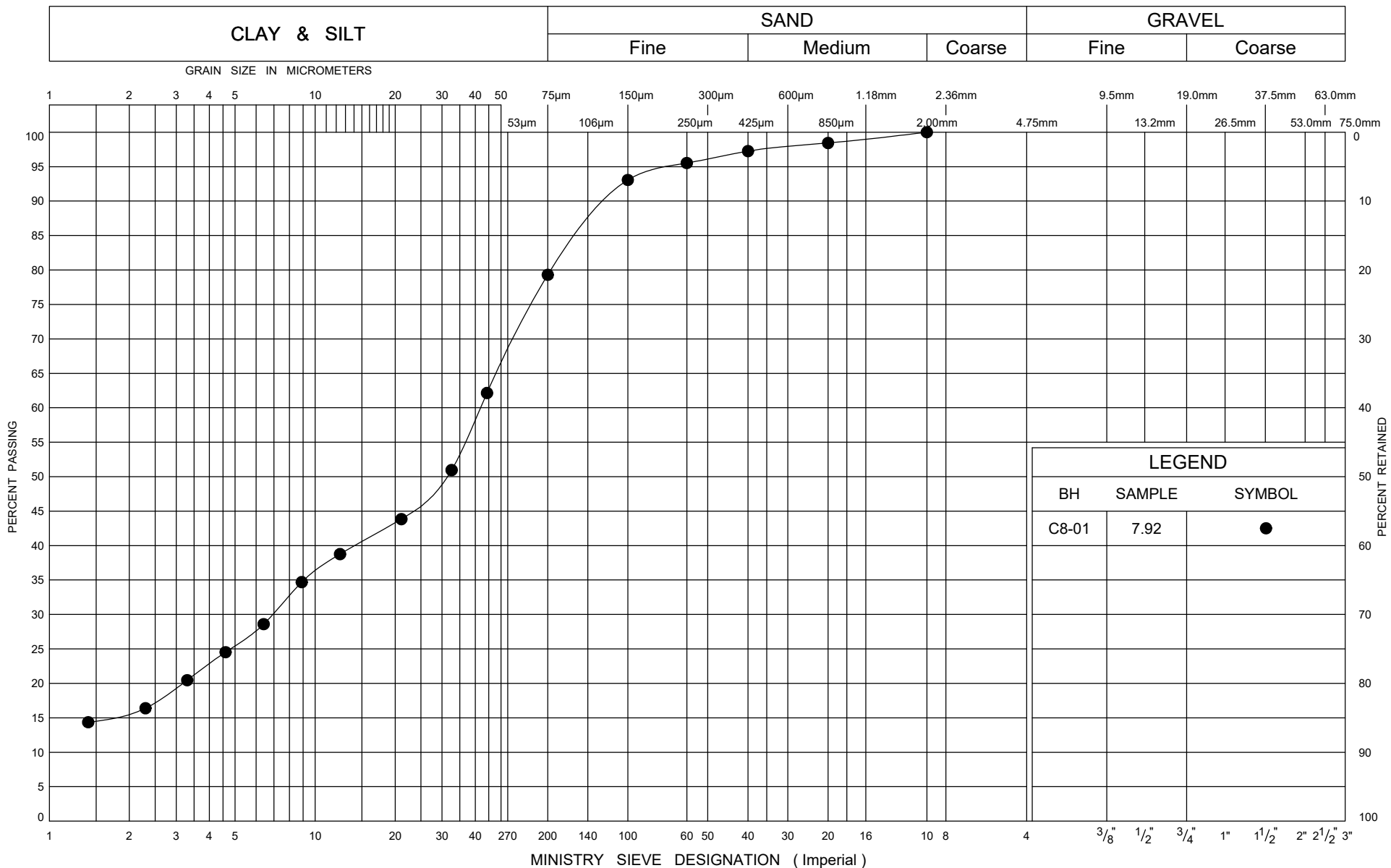
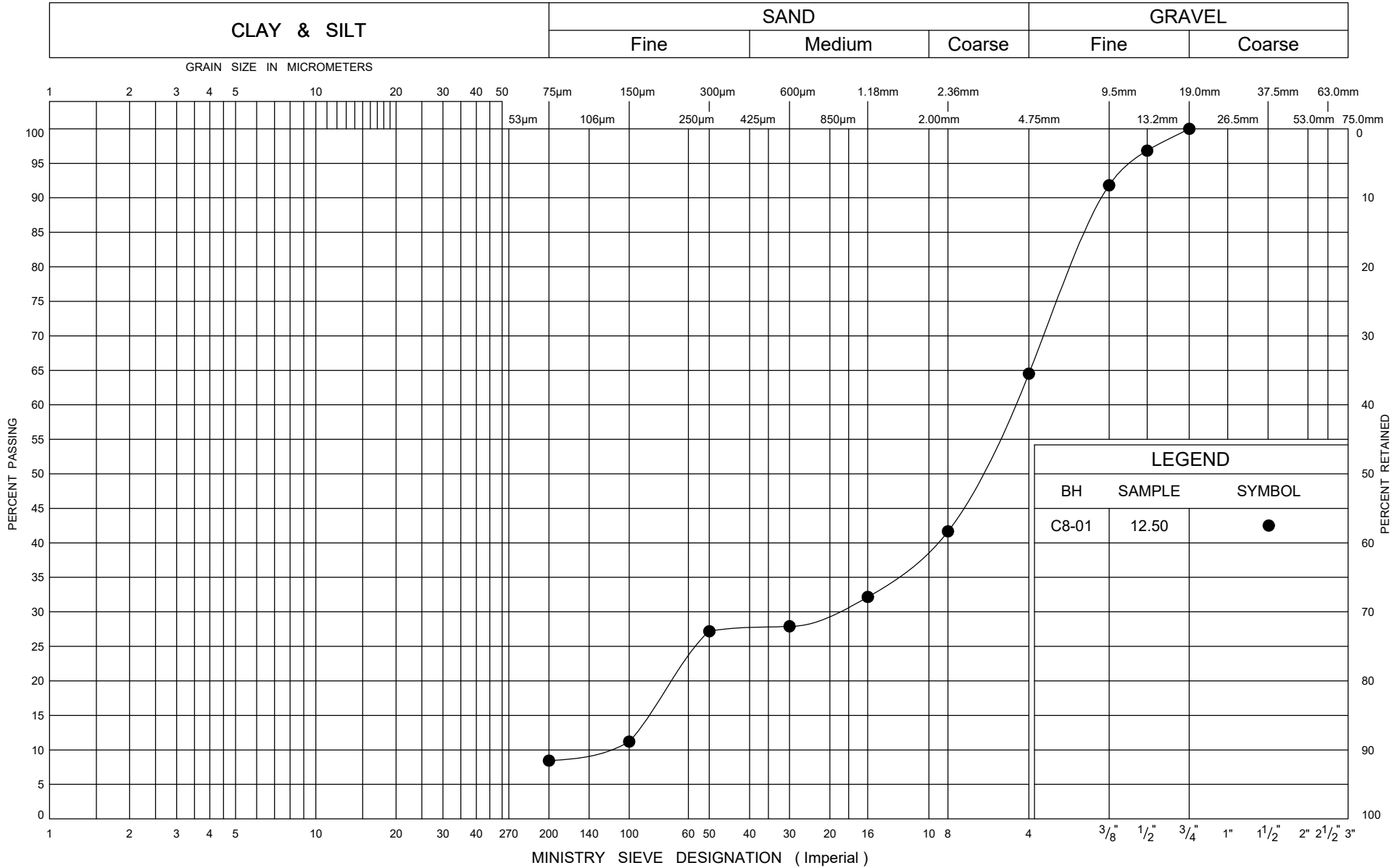
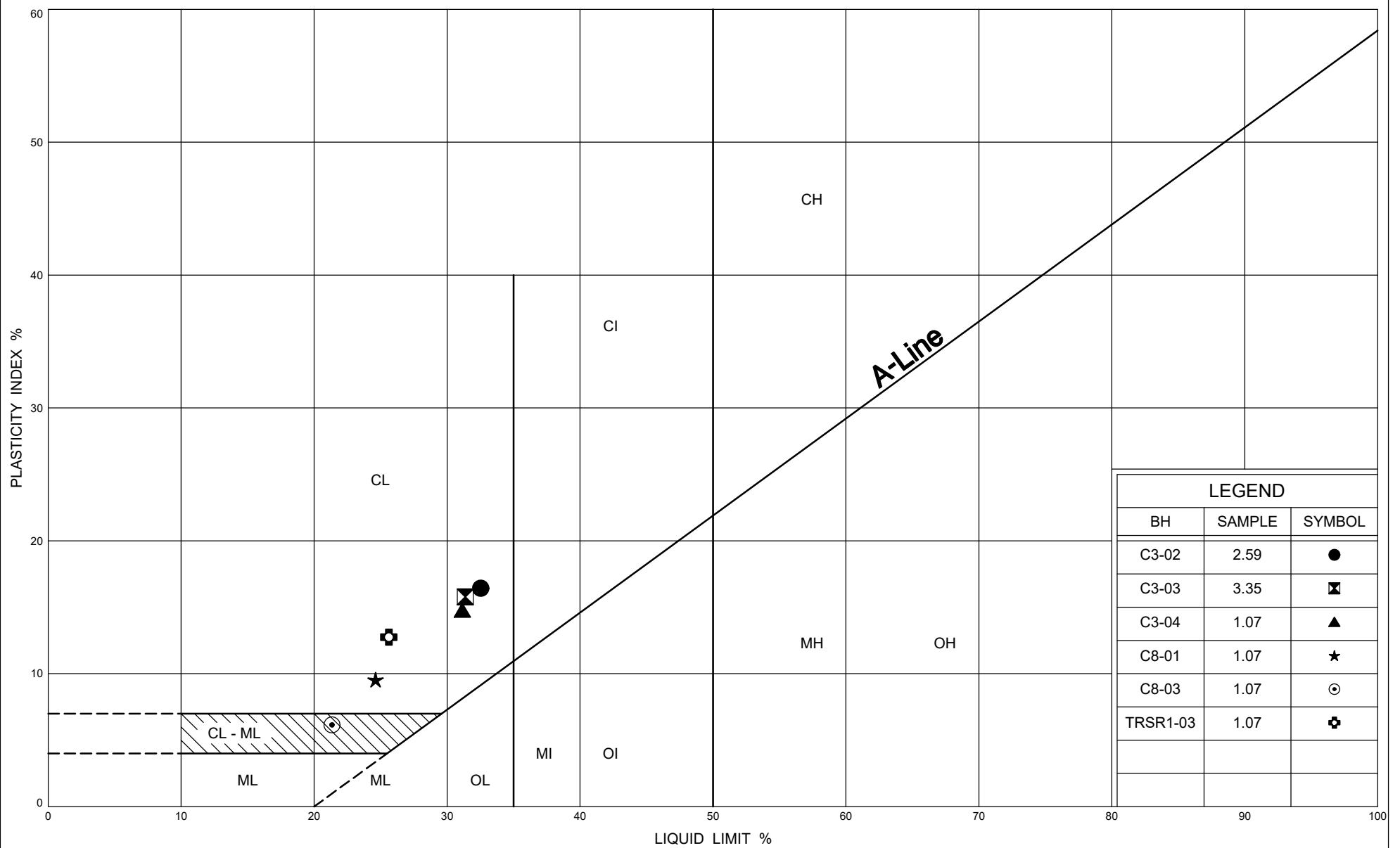




FIG No C6
W P 2117-15-00







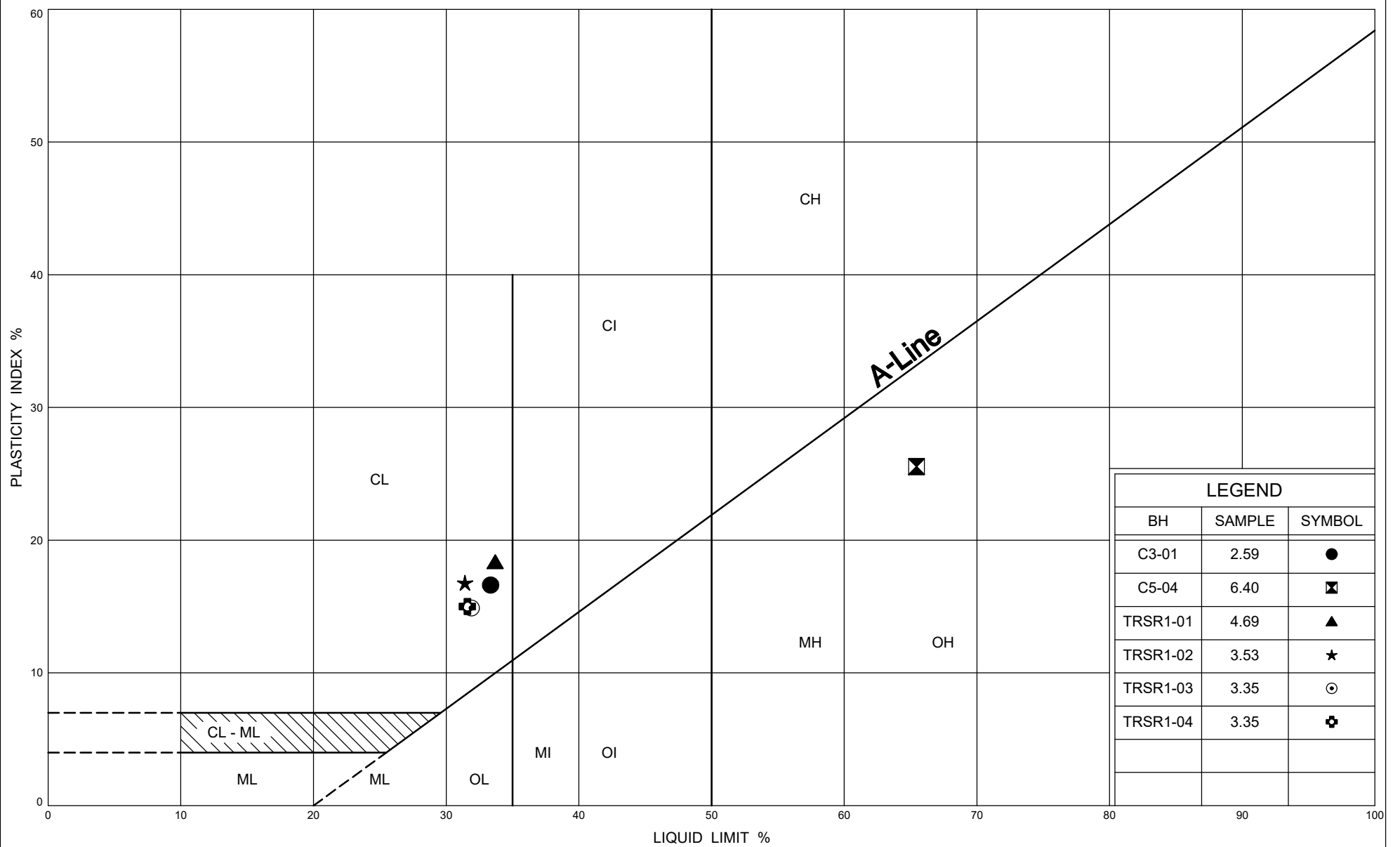
Ministry of
Transportation

PLASTICITY CHART

Silty CLAY and Clayey SILT FILL

FIG No C9

W P 2117-15-00



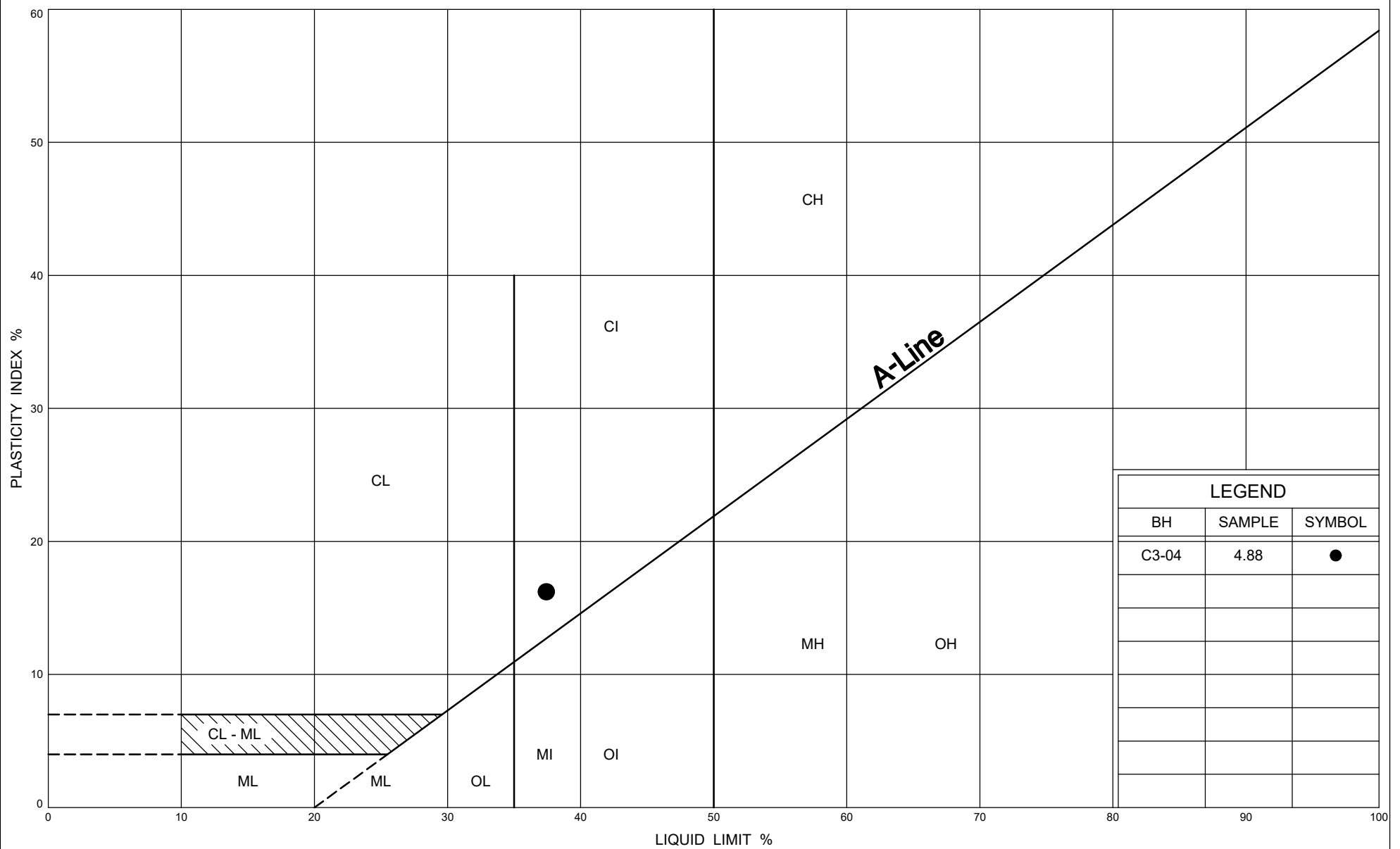
Ministry of
Transportation

PLASTICITY CHART

Silty CLAY

FIG No C10

W P 2117-15-00



LEGEND		
BH	SAMPLE	SYMBOL
C3-04	4.88	●



Ministry of
Transportation

PLASTICITY CHART CLAY TILL

FIG No C11

W P 2117-15-00



Appendix D

Corrosivity Testing – Certificate of Analysis



FINAL REPORT

CA14706-APR19 R2

25497 QEW North Shore

Prepared for

Thurber Engineering Ltd.

First Page

CLIENT DETAILS

Client Thurber Engineering Ltd.

Address 103, 2010 Winston Park Drive
Oakville, ON
L6H 5R7, Canada

Contact Karel Furbacher

Telephone 289-455-7296

Facsimile

Email kfurtbacher@thurber.ca

Project 25497 QEW North Shore

Order Number

Samples Soil (2)

LABORATORY DETAILS

Project Specialist Brad Moore Hon. B.Sc

Laboratory SGS Canada Inc.

Address 185 Concession St., Lakefield ON, K0L 2H0

Telephone 705-652-2000

Facsimile 705-652-6365

Email

SGS Reference CA14706-APR19

Received 04/18/2019

Approved 05/06/2019

Report Number CA14706-APR19 R2

Date Reported 05/06/2019

COMMENTS

Temperature of Sample upon Receipt: 3 degrees C

Cooling Agent Present: yes

Custody Seal Present: no

Chain of Custody Number: N/A

Corrosivity Index is based on the American Water Works Corrosivity Scale according to AWWA C-105. An index greater than 10 indicates the soil matrix may be corrosive to cast iron alloys.

SIGNATORIES

Brad Moore Hon. B.Sc

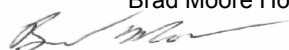




TABLE OF CONTENTS

First Page..... 1

Index..... 2

Results..... 3-4

QC Summary..... 5-7

Legend..... 8

Annexes..... 9



FINAL REPORT

CA14706-APR19 R2

Client: Thurber Engineering Ltd.

Project: 25497 QEW North Shore

Project Manager: Karel Furbacher

Samplers: Kevin Kweon

PACKAGE: - Corrosivity Index (SOIL)

Sample Number	5	6
Sample Name	BH C3-03-SS5	BH C6-03 SS3
Sample Matrix	Soil	Soil
Sample Date	17/04/2019	15/04/2019

Parameter	Units	RL		Result	Result
Corrosivity Index					
Corrosivity Index	none	1		4	11
Soil Redox Potential	mV	-		126	220
Sulphide	%	0.02		< 0.02	< 0.02
pH	pH Units	0.05		8.79	8.03
Resistivity (calculated)	ohms.cm	-9999		5890	495

PACKAGE: - General Chemistry (SOIL)

Sample Number	5	6
Sample Name	BH C3-03-SS5	BH C6-03 SS3
Sample Matrix	Soil	Soil
Sample Date	17/04/2019	15/04/2019

Parameter	Units	RL		Result	Result
General Chemistry					
Conductivity	uS/cm	2		170	2020

PACKAGE: - Metals and Inorganics (SOIL)

Sample Number	5	6
Sample Name	BH C3-03-SS5	BH C6-03 SS3
Sample Matrix	Soil	Soil
Sample Date	17/04/2019	15/04/2019

Parameter	Units	RL		Result	Result
Metals and Inorganics					
Moisture Content	%	0.1		16.2	20.5
Sulphate	µg/g	0.4		20	67



FINAL REPORT

CA14706-APR19 R2

Client: Thurber Engineering Ltd.

Project: 25497 QEW North Shore

Project Manager: Karel Furbacher

Samplers: Kevin Kweon

PACKAGE: - Other (ORP) (SOIL)

Sample Number	5	6
Sample Name	BH C3-03-SS5	BH C6-03 SS3
Sample Matrix	Soil	Soil
Sample Date	17/04/2019	15/04/2019

Parameter	Units	RL		Result	Result
Other (ORP)					
Chloride	µg/g	0.4		120	730



FINAL REPORT

CA14706-APR19 R2

QC SUMMARY

Anions by IC
Method: EPA300/MA300-Ions1.3 | Internal ref.: ME-CA-IENVIIC-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Chloride	DIO0349-APR19	µg/g	0.4	<0.4	1	20	94	80	120	NV	75	125
Sulphate	DIO0349-APR19	µg/g	0.4	<0.4	1	20	96	80	120	93	75	125

Carbon/Sulphur
Method: ASTM E1915-07A | Internal ref.: ME-CA-IENVIARD-LAK-AN-020

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Sulphide	ECS0034-APR19	%	0.02	<0.02	ND	20	106	80	120			



FINAL REPORT

CA14706-APR19 R2

QC SUMMARY

Conductivity

Method: SM 2510 | Internal ref.: ME-CA-1ENVIEWL-LAK-AN-006

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Conductivity	EWL0394-APR19	uS/cm	2	< 0.002	0	10	99	90	110	NA		
Conductivity	EWL0414-APR19	uS/cm	2	< 0.002	0	10	99	90	110	NA		

pH

Method: SM 4500 | Internal ref.: ME-CA-1ENVIEWL-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
pH	EWL0394-APR19	pH Units	0.05	NA	0		101			NA		
pH	EWL0414-APR19	pH Units	0.05	NA	0		101			NA		

QC SUMMARY

Method Blank: a blank matrix that is carried through the entire analytical procedure. Used to assess laboratory contamination.

Duplicate: Paired analysis of a separate portion of the same sample that is carried through the entire analytical procedure. Used to evaluate measurement precision.

LCS/Spike Blank: Laboratory control sample or spike blank refer to a blank matrix to which a known amount of analyte has been added. Used to evaluate analyte recovery and laboratory accuracy without sample matrix effects.

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

Reference Material: a material or substance matrix matched to the samples that contains a known amount of the analyte of interest. A reference material may be used in place of a matrix spike.

RL: Reporting limit

RPD: Relative percent difference

AC: Acceptance criteria

Multielement Scan Qualifier: as the number of analytes in a scan increases, so does the chance of a limit exceedance by random chance as opposed to a real method problem. Thus, in multielement scans, for the LCS and matrix spike, up to 10% of the analytes may exceed the quoted limits by up to 10% absolute and the spike is considered acceptable.

Duplicate Qualifier: for duplicates as the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

Matrix Spike Qualifier: for matrix spikes, as the concentration of the native analyte increases, the uncertainty of the matrix spike recovery increases. Thus, the matrix spike acceptance limits apply only when the concentration of the matrix spike is greater than or equal to the concentration of the native analyte.

LEGEND

FOOTNOTES

NSS Insufficient sample for analysis.

RL Reporting Limit.

↑ Reporting limit raised.

↓ Reporting limit lowered.

NA The sample was not analysed for this analyte

ND Non Detect

Samples analysed as received. Solid samples expressed on a dry weight basis. "Temperature Upon Receipt" is representative of the whole shipment and may not reflect the temperature of individual samples.

Analysis conducted on samples submitted pursuant to or as part of Reg. 153/04, are in accordance to the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act" published by the Ministry and dated March 9, 2004 as amended.

SGS provides criteria information (such as regulatory or guideline limits and summary of limit exceedances) as a service. Every attempt is made to ensure the criteria information in this report is accurate and current, however, it is not guaranteed. Comparison to the most current criteria is the responsibility of the client and SGS assumes no responsibility for the accuracy of the criteria levels indicated. This document is issued, on the Client's behalf, by the Company under its General Conditions of Service available on request and accessible at http://www.sgs.com/terms_and_conditions.htm. The Client's attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein. Any other holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents.

This report must not be reproduced, except in full. This report supersedes all previous versions.

-- End of Analytical Report --

Request for Laboratory Services and CHAIN OF CUSTODY

- Lakefield: 185 Concession St., Lakefield, ON K0L 2H0 Phone: 705-652-2000 Fax: 705-652-6365 Web: www.sgs.com/environment
 - London: 657 Consortium Court, London, ON, N6E 2S8 Phone: 519-672-4500 Toll Free: 877-848-8060 Fax: 519-672-0361

No:

Page 1 of 1

Received By: Oleg Mozhiw
 Received Date (mm/dd/yy): 04/18/2019
 Received Time: 14:00

Received By (signature): [Signature]
 Custody Seal Present: ☒
 Custody Seal Intact: ☒

Cooling Agent Present: ☒
 Temperature Upon Receipt (°C): 40.0

Laboratory Information Section - Lab use only

ice applied by daniel

LAB LIMS #: CN47066

REPORT INFORMATION
 Company: Thurber Engineering Ltd.
 Contact: Karel Furbacher
 Address: 103-2010 Winston Park Drive
Oakville, Ontario
 Phone: 289-455-7296
 Email: kfurbacher@thurber.ca
 Email: manderson@thurber.ca

INVOICE INFORMATION
☒ (same as Report Information)
 Company: _____
 Contact: _____
 Address: _____
 Phone: _____
 Email: _____

PROJECT INFORMATION

Quotation #: _____ P.O. #: _____
 Project #: 25497 Site Location/ID: QEW/North Shore

TURNAROUND TIME (TAT) REQUIRED

☒ Regular TAT (5-7days) TAT's are quoted in business days (exclude statutory holidays & weekends).
 Samples received after 6pm or on weekends: TAT begins next business day

RUSH TAT (Additional Charges May Apply): ☐ 1 Day ☐ 2 Days ☐ 3 Days ☐ 4 Days
 PLEASE CONFIRM RUSH FEASIBILITY WITH SGS REPRESENTATIVE PRIOR TO SUBMISSION

Specify Due Date: _____ Rush Confirmation ID: _____

NOTE: DRINKING (POTABLE) WATER SAMPLES FOR HUMAN CONSUMPTION MUST BE
 SUBMITTED WITH SGS DRINKING WATER CHAIN OF CUSTODY

REGULATIONS

Regulation 153/04:

Table 1 ☐ R/I/P ☐ Soil Texture: _____
 Table 2 ☐ I/C/C ☐ Coarse _____
 Table 3 ☐ A/O ☐ Medium _____
 Table ☐ Fine _____

Other Regulations:

☐ Reg 347/558 (3 Day min TAT)
☐ PWQO ☐ MMER ☐ Other: _____
☐ CCME ☐ MISA _____

Sewer By-Law:

☐ Sanitary _____
☐ Storm _____
 Municipality: _____

RECORD OF SITE CONDITION (RSC)

YES ☐ NO ☐

SAMPLE IDENTIFICATION

1 BH C3-03 SS5
 2 BH C6-03 SS3
 3
 4
 5
 6
 7
 8
 9
 10
 11
 12

DATE SAMPLED
 4/17/19
 4/15/19

TIME SAMPLED
 1:00 am.
 11:00 p.m.

OF BOTTLES
 1
 1

MATRIX
 SOIL
 SOIL

Field Filtered (Y/N)

Metals & Inorganics

PAH ☐ ABN ☐ SVOC(alt)

PCB Total ☐ Aroclor ☐

PHC F1-F4 ☐ VOC ☐

BTEX ☐ BTEX/F1 ☐ F2-F4 ☐

VOC ☐ BTEX ☐ THM ☐

Pesticides OC ☐ OP ☐

TCLP M&I ☐ VOC ☐ PCB ☐

B(a)P ☐ ABN ☐ Ignit. ☐

Water Pkg Gen. ☐ Ext. ☐

Use: _____

Corrosivity/Resistivity

COMMENTS:

Observations/Comments/Special Instructions

Sampled By (NAME): Kevin Kweon
 Relinquished by (NAME): Karel Furbacher

Signature: [Signature]
 Signature: [Signature]

Date: 04/18/19
 Date: 04/18/19

(mm/dd/yy)
 (mm/dd/yy)

Pink Copy - Client
 Yellow & White Copy - SGS



FINAL REPORT

CA14543-APR19 R1

25497 QEW/North Shore

Prepared for

Thurber Engineering Ltd.

First Page

CLIENT DETAILS

Client Thurber Engineering Ltd.

Address 103, 2010 Winston Park Drive
Oakville, ON
L6H 5R7, Canada

Contact Karel Furbacher

Telephone 289-455-7296

Facsimile

Email kfurtbacher@thurber.ca

Project 25497 QEW/North Shore

Order Number

Samples Soil (2)

LABORATORY DETAILS

Project Specialist Brad Moore Hon. B.Sc

Laboratory SGS Canada Inc.

Address 185 Concession St., Lakefield ON, K0L 2H0

Telephone 705-652-2000

Facsimile 705-652-6365

Email

SGS Reference CA14543-APR19

Received 04/15/2019

Approved 04/22/2019

Report Number CA14543-APR19 R1

Date Reported 04/22/2019

COMMENTS

Temperature of Sample upon Receipt: 7 degrees C

Cooling Agent Present: Yes

Custody Seal Present: No

Chain of Custody Number: NA

Corrosivity Index is based on the American Water Works Corrosivity Scale according to AWWA C-105. An index greater than 10 indicates the soil matrix may be corrosive to cast iron alloys.

SIGNATORIES

Brad Moore Hon. B.Sc

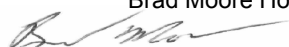




TABLE OF CONTENTS

First Page..... 1

Index..... 2

Results..... 3-4

QC Summary..... 5-6

Legend..... 7

Annexes..... 8



FINAL REPORT

CA14543-APR19 R1

Client: Thurber Engineering Ltd.

Project: 25497 QEW/North Shore

Project Manager: Karel Furbacher

Samplers: Kevin Kweon

PACKAGE: REG153 - Corrosivity Index (SOIL)

Sample Number	5	6
Sample Name	BH C8-03 SS3	BH TRSR1-04 SS5
Sample Matrix	Soil	Soil
Sample Date	11/04/2019	11/04/2019

Parameter	Units	RL		Result	Result
Corrosivity Index					
Corrosivity Index	none	1		11	9.5
Soil Redox Potential	mV	-		312	227
Sulphide	%	0.02		< 0.02	0.03
pH	pH Units	0.05		7.45	8.85
Resistivity (calculated)	ohms.cm	-9999		309	2460

PACKAGE: REG153 - General Chemistry (SOIL)

Sample Number	5	6
Sample Name	BH C8-03 SS3	BH TRSR1-04 SS5
Sample Matrix	Soil	Soil
Sample Date	11/04/2019	11/04/2019

Parameter	Units	RL		Result	Result
General Chemistry					
Conductivity	uS/cm	2		3240	407

PACKAGE: REG153 - Metals and Inorganics (SOIL)

Sample Number	5	6
Sample Name	BH C8-03 SS3	BH TRSR1-04 SS5
Sample Matrix	Soil	Soil
Sample Date	11/04/2019	11/04/2019

Parameter	Units	RL		Result	Result
Metals and Inorganics					
Moisture Content	%	0.1		18.6	18.1



FINAL REPORT

CA14543-APR19 R1

Client: Thurber Engineering Ltd.
Project: 25497 QEW/North Shore
Project Manager: Karel Furbacher
Samplers: Kevin Kweon

PACKAGE: REG153 - Metals and Inorganics (SOIL)

Sample Number	5	6
Sample Name	BH C8-03 SS3	BH TRSR1-04 SS5
Sample Matrix	Soil	Soil
Sample Date	11/04/2019	11/04/2019

Parameter	Units	RL		Result	Result
Metals and Inorganics (continued)					
Sulphate	µg/g	0.4		60	62

PACKAGE: REG153 - Other (ORP) (SOIL)

Sample Number	5	6
Sample Name	BH C8-03 SS3	BH TRSR1-04 SS5
Sample Matrix	Soil	Soil
Sample Date	11/04/2019	11/04/2019

Parameter	Units	RL		Result	Result
Other (ORP)					
Chloride	µg/g	0.4		3100	360



FINAL REPORT

CA14543-APR19 R1

QC SUMMARY

Anions by IC

Method: EPA300/MA300-Ions1.3 | Internal ref.: ME-CA-IENVIIC-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Chloride	DIO0281-APR19	µg/g	0.4	<0.4	5	20	93	80	120	102	75	125
Sulphate	DIO0281-APR19	µg/g	0.4	<0.4	2	20	95	80	120	101	75	125

Carbon/Sulphur

Method: ASTM E1915-07A | Internal ref.: ME-CA-IENVIARD-LAK-AN-020

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Sulphide	ECS0028-APR19	%	0.02	<0.02	11	20	118	80	120			

Conductivity

Method: SM 2510 | Internal ref.: ME-CA-IENVIEWL-LAK-AN-006

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Conductivity	EWL0283-APR19	uS/cm	2	< 2	0	10	101	90	110	NA		



QC SUMMARY

pH
Method: SM 4500 | Internal ref.: ME-CA-IENVIEWL-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
pH	EWL0283-APR19	pH Units	0.05	NA	0		100			NA		

Method Blank: a blank matrix that is carried through the entire analytical procedure. Used to assess laboratory contamination.

Duplicate: Paired analysis of a separate portion of the same sample that is carried through the entire analytical procedure. Used to evaluate measurement precision.

LCS/Spike Blank: Laboratory control sample or spike blank refer to a blank matrix to which a known amount of analyte has been added. Used to evaluate analyte recovery and laboratory accuracy without sample matrix effects.

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

Reference Material: a material or substance matrix matched to the samples that contains a known amount of the analyte of interest. A reference material may be used in place of a matrix spike.

RL: Reporting limit

RPD: Relative percent difference

AC: Acceptance criteria

Multielement Scan Qualifier: as the number of analytes in a scan increases, so does the chance of a limit exceedance by random chance as opposed to a real method problem. Thus, in multielement scans, for the LCS and matrix spike, up to 10% of the analytes may exceed the quoted limits by up to 10% absolute and the spike is considered acceptable.

Duplicate Qualifier: for duplicates as the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

Matrix Spike Qualifier: for matrix spikes, as the concentration of the native analyte increases, the uncertainty of the matrix spike recovery increases. Thus, the matrix spike acceptance limits apply only when the concentration of the matrix spike is greater than or equal to the concentration of the native analyte.

LEGEND

FOOTNOTES

NSS Insufficient sample for analysis.

RL Reporting Limit.

↑ Reporting limit raised.

↓ Reporting limit lowered.

NA The sample was not analysed for this analyte

ND Non Detect

Samples analysed as received. Solid samples expressed on a dry weight basis. "Temperature Upon Receipt" is representative of the whole shipment and may not reflect the temperature of individual samples.

Analysis conducted on samples submitted pursuant to or as part of Reg. 153/04, are in accordance to the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act" published by the Ministry and dated March 9, 2004 as amended.

SGS provides criteria information (such as regulatory or guideline limits and summary of limit exceedances) as a service. Every attempt is made to ensure the criteria information in this report is accurate and current, however, it is not guaranteed. Comparison to the most current criteria is the responsibility of the client and SGS assumes no responsibility for the accuracy of the criteria levels indicated. This document is issued, on the Client's behalf, by the Company under its General Conditions of Service available on request and accessible at http://www.sgs.com/terms_and_conditions.htm. The Client's attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein. Any other holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents.

This report must not be reproduced, except in full. This report supersedes all previous versions.

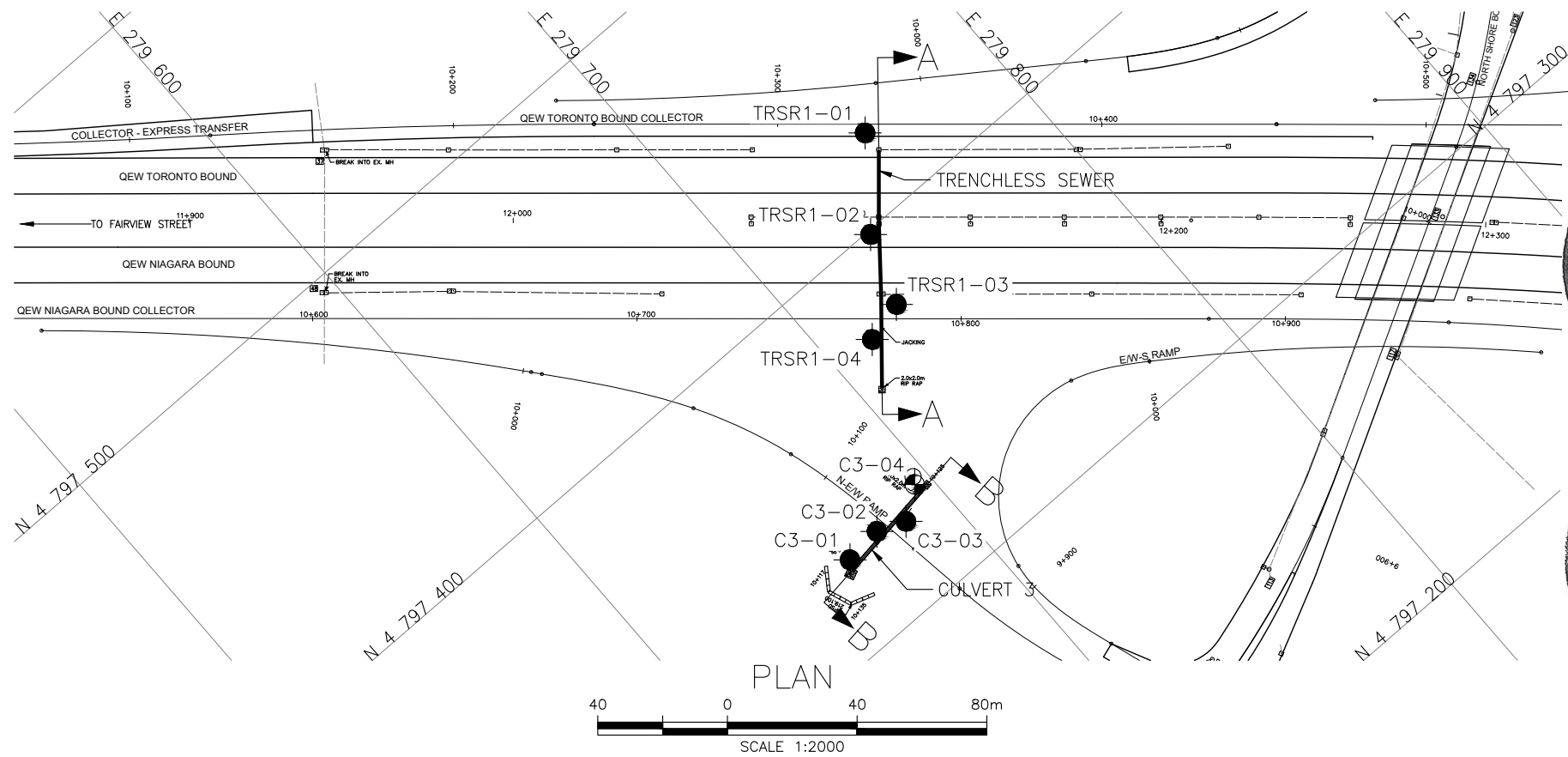
-- End of Analytical Report --

Received By: <u>Oleg Mozhiuk</u>		Received Date (mm/dd/yyyy): <u>04/15/2019</u>		Received Time: <u>11:45</u>		Laboratory Information Section - Lab use only		Page _____ of _____	
Received By (signature): <u>[Signature]</u>		Cooling Agent Present: <input checked="" type="checkbox"/>		Temperature Upon Receipt (°C): <u>8° 8' 8"</u>				<u>1cc applied by drinker</u> <u>CA14543-Ad</u>	
Custody Seal Present: <input checked="" type="checkbox"/>		Custody Seal Intact: <input checked="" type="checkbox"/>							
REPORT INFORMATION		INVOICE INFORMATION		PROJECT INFORMATION					
Company: <u>Thurber Engineering Ltd.</u>		<input checked="" type="checkbox"/> (same as Report Information)		Quotation #: _____					
Contact: <u>Karel Furbacher</u>		Company: _____		Project #: <u>25497</u>					
Address: <u>103-2010 Winston Park Drive</u>		Contact: _____		Site Location/ID: <u>QEW/North Shore</u>					
<u>Oakville, Ontario</u>		Address: _____							
Phone: <u>289-455-7296</u>		Phone: _____							
Email: <u>kfurbacher@thurber.ca</u>		Email: _____							
Email: <u>manderson@thurber.ca</u>		Email: _____							
REGULATIONS		RECORD OF SITE CONDITION (RSC)		Other Regulations:		Sewer By-Law:			
Regulation 153/04:		Soil Texture: Coarse <input type="checkbox"/> Medium <input type="checkbox"/> Fine <input type="checkbox"/>		<input type="checkbox"/> Reg 347/558 (3 Day min TAT) PWQO <input type="checkbox"/> CCME <input type="checkbox"/> MISA <input type="checkbox"/> Other: _____		<input type="checkbox"/> Sanitary <input type="checkbox"/> Storm Municipality: _____			
Table 1 <input checked="" type="checkbox"/> R/P/I		YES <input type="checkbox"/> NO <input type="checkbox"/>							
Table 2 <input checked="" type="checkbox"/> I/C/C									
Table 3 <input checked="" type="checkbox"/> A/O									
Table 4 <input type="checkbox"/>									
SAMPLE IDENTIFICATION		DATE SAMPLED		TIME SAMPLED		# OF BOTTLES		MATRIX	
1 BH C8-03 SS3		4/11/19		12:00 am.		1		SOIL	
2 BH TRSR1-04 SS5		4/11/19		11:00 p.m.		1		SOIL	
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
Observations/Comments/Special Instructions									
Sampled By (NAME): <u>Kevin Kweon</u>		Signature: <u>[Signature]</u>		Date: <u>04/12/19</u>		(mm/dd/yyyy)		Pink Copy - Client	
Requisitioned by (NAME): <u>Karel Furbacher</u>		Signature: <u>[Signature]</u>		Date: <u>04/12/19</u>		(mm/dd/yyyy)		Yellow & White Copy - SGS	



Appendix E

Borehole Location and Soil Strata Drawings



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



CONT No
WP No 2117-15-00

Q.E.W.
CULVERT AND STORM
SEWER INSTALLATIONS
BOREHOLE LOCATIONS AND SOIL STRATA



KEYPLAN

LEGEND

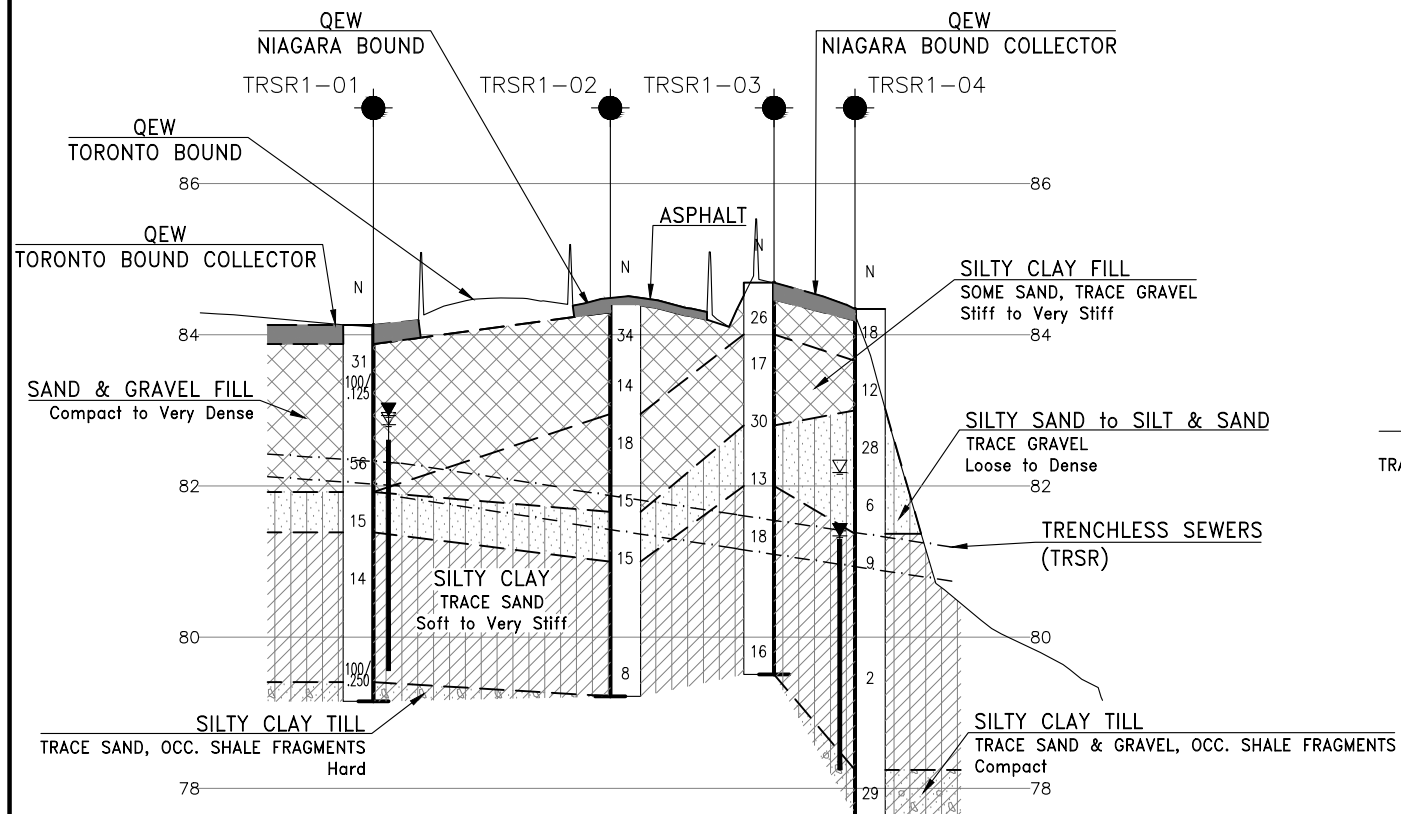
●	Borehole
⊙	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
W	Water Level
⊕	Head Artesian Water
⊕	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
TRSR1-01	84.1	4797423.6	279 754.2
TRSR1-02	84.4	4797398.8	279 735.0
TRSR1-03	84.7	4797377.3	279 726.9
TRSR1-04	84.3	4797374.2	279 714.2
C3-01	78.0	4797327.1	279 664.6
C3-02	81.1	4797328.3	279 676.6
C3-03	81.1	4797324.8	279 685.4

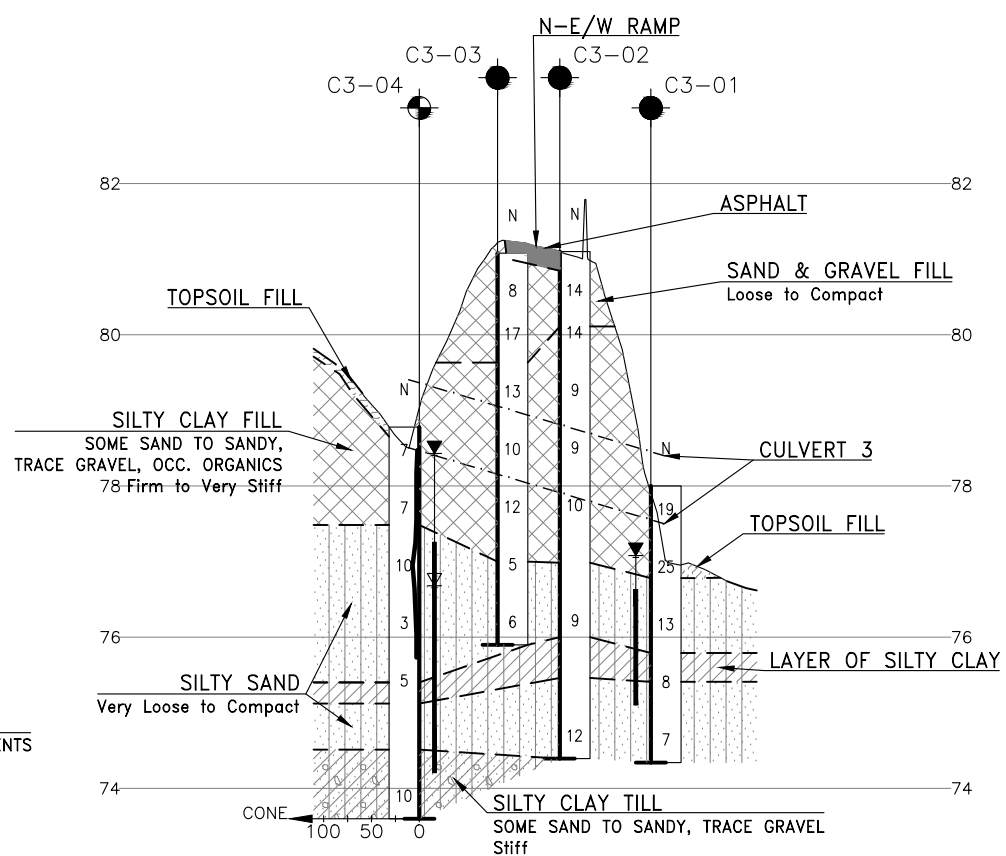
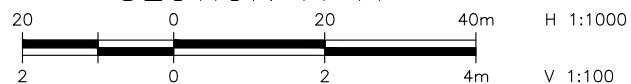
-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 10.

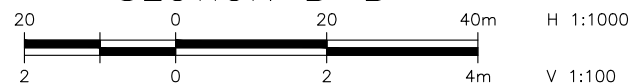
GEOCRES No. 30M5-330



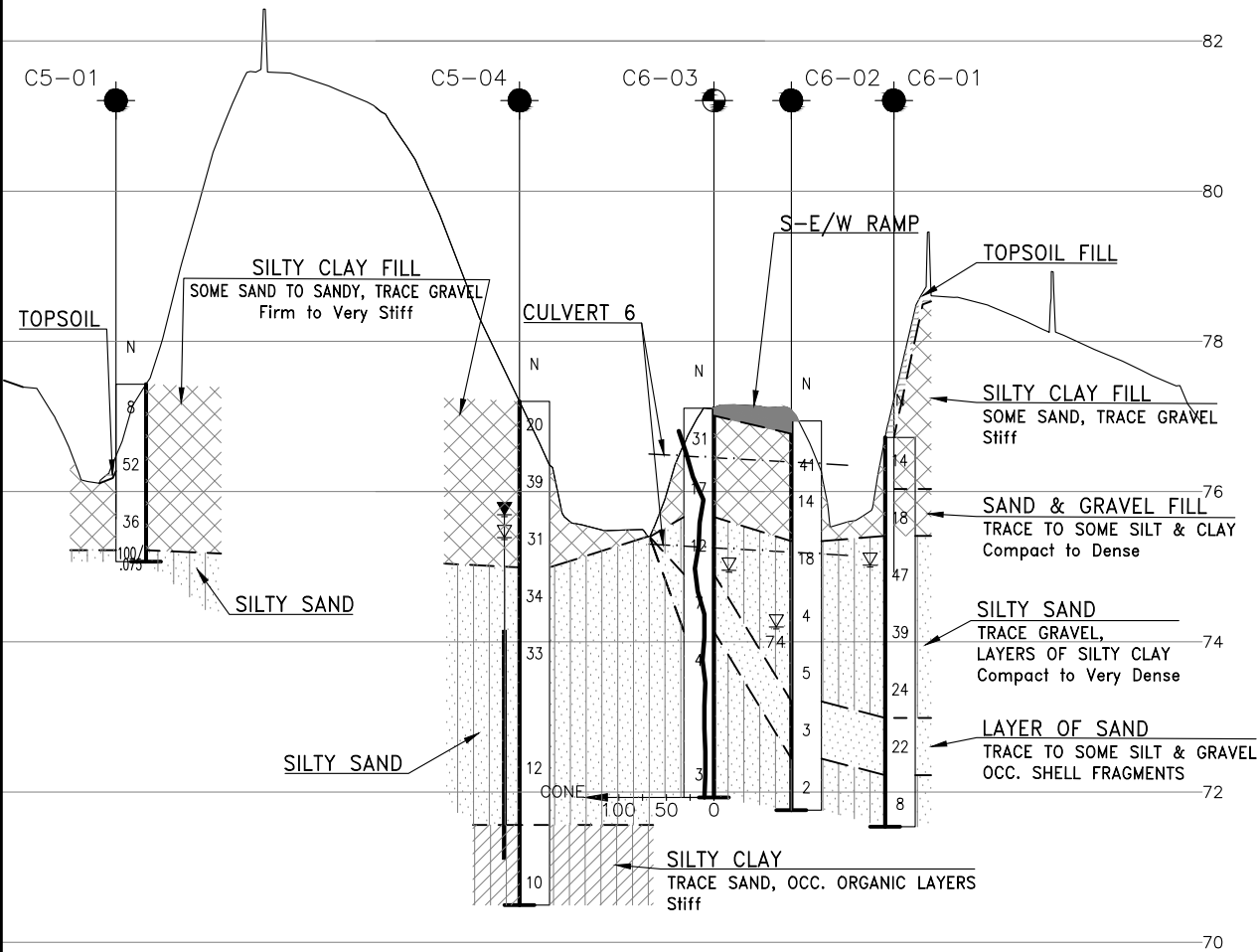
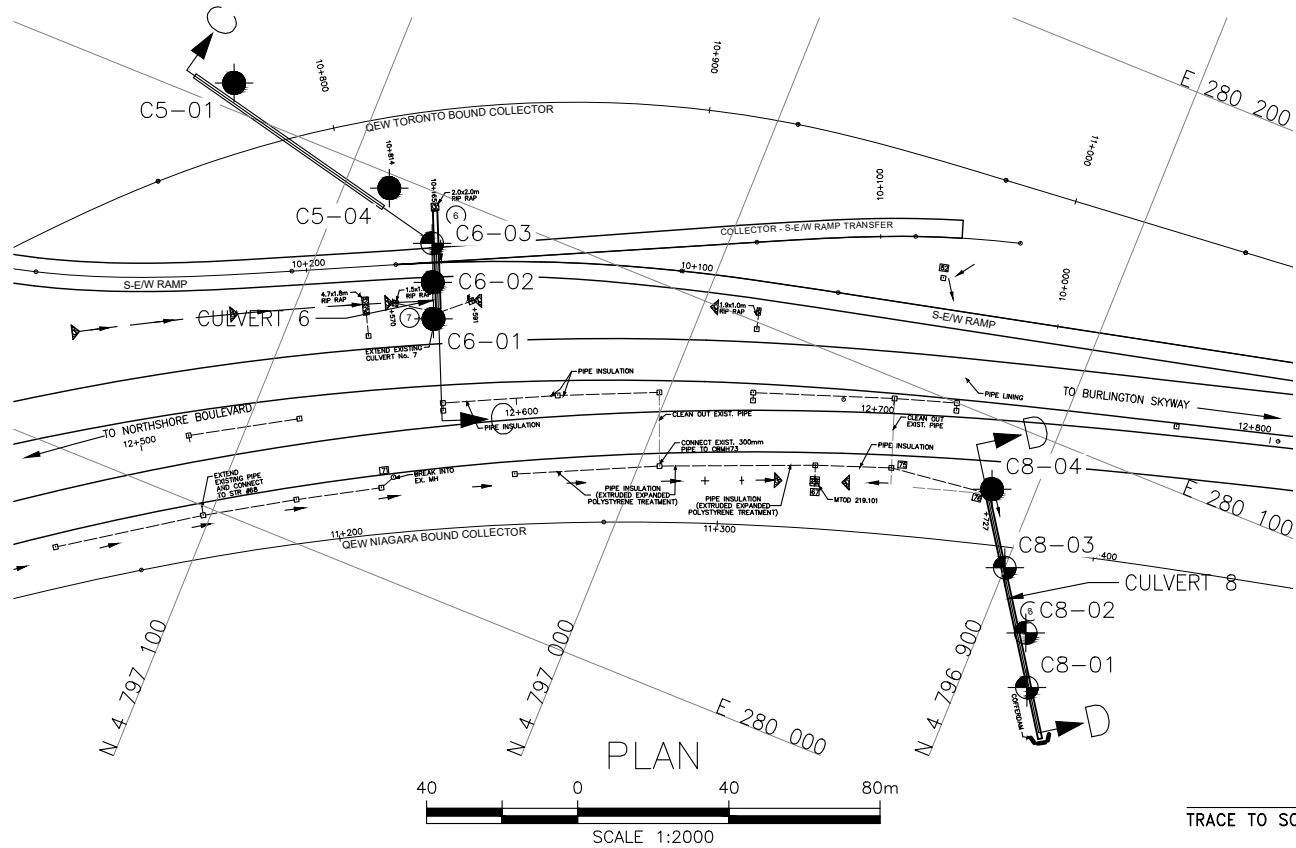
SECTION A-A



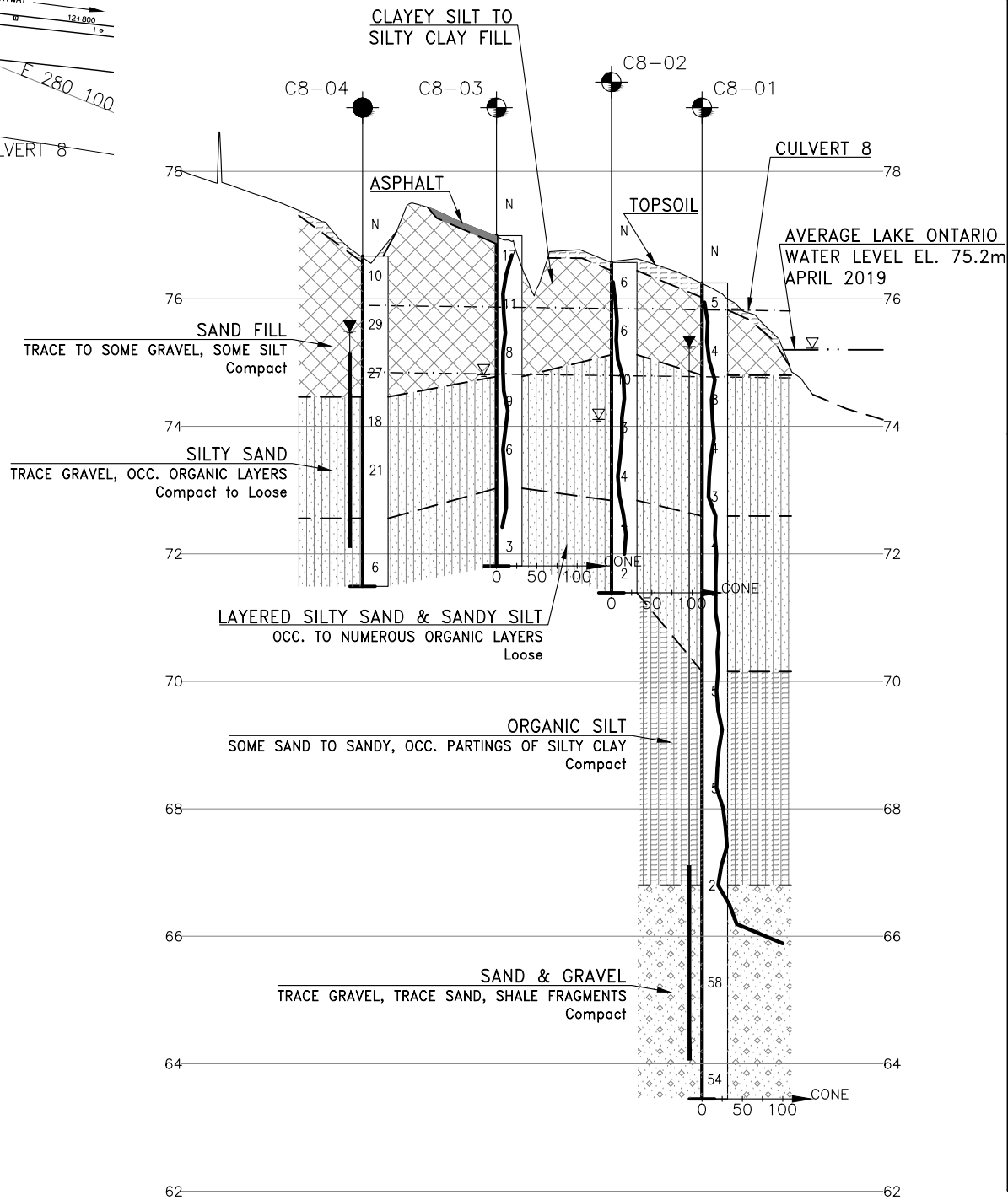
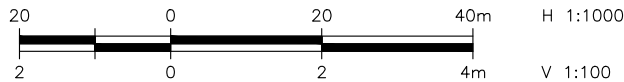
SECTION B-B



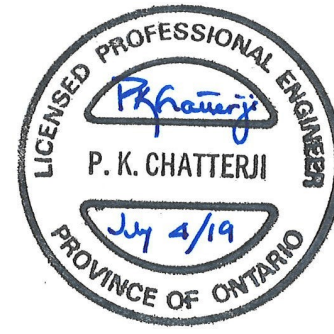
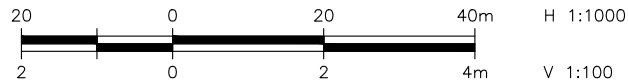
REVISIONS	DATE	BY	DESCRIPTION
DESIGN	KF	CHK MRA	CODE
DRAWN	MFA	CHK KF	SITE
			STRUCT
			DWG 1



SECTION C-C



SECTION D-D



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

CONT No
WP No 2117-15-00

Q.E.W.
CULVERT AND STORM
SEWER INSTALLATIONS
BOREHOLE LOCATIONS AND SOIL STRATA



KEYPLAN
LEGEND

●	Borehole
○	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
⊥	Head Artesian Water
⊥	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
C5-01	77.4	4797137.1	280 106.8
C5-04	77.2	4797088.6	280 096.4
C6-01	76.7	4797064.8	280 068.7
C6-02	76.9	4797068.6	280 077.6
C8-04	76.7	4796910.9	280 082.3
TRSR1-01	84.1	4797423.6	279 754.2
TRSR1-02	84.4	4797398.8	279 735.0
TRSR1-03	84.7	4797377.3	279 726.9
TRSR1-04	84.3	4797374.2	279 714.2

-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 10.

GEOCRES No. 30M5-330

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	KF	CHK MRA	CODE
DRAWN	MFA	CHK KF	SITE
LOAD			
STRUCT			
DATE	MAY 2019		
DWG	2		



Appendix F

Trenchless Installation Methods Comparison



COMPARISON OF TRENCHLESS INSTALLATION METHODS

Trenchless Method	Advantages	Disadvantages	Feasibility	Relative Risks	Relative Cost
Jack and Bore	<ul style="list-style-type: none"> • No uncased bore at any time • Equipment and crew readily available locally • Generally more suitable for clayey silt to silty clay soils with minimal water seepage 	<ul style="list-style-type: none"> • Subject to misalignment due to oversized obstructions, although specialized equipment allows for alignment adjustments • Generally less suitable for sands and gravel with water seepage problems, and locations of high groundwater table where dewatering would be required • Requires entry and exit pits 	FEASIBLE	<p>HIGH (sands and silts)</p> <p>MEDIUM (clayey silt / silty clay)</p>	LOW
Pipe Ramming	<ul style="list-style-type: none"> • Versatility in accommodating various subsurface conditions • Generally suitable for soils with water seepage problems • Dewatering is usually not required 	<ul style="list-style-type: none"> • Minimal alignment control especially if oversized obstructions are encountered • May only advance steel casing/ sleeve within which pipe is threaded through and grouted 	FEASIBLE	MEDIUM	MEDIUM
Micro-tunnelling	<ul style="list-style-type: none"> • High precision alignment control is possible • Versatility in accommodating Various subsurface conditions • Dewatering is usually not required • Concrete pipe (with appropriate reinforcement) may be installed as part of the tunnelling operation. 	<ul style="list-style-type: none"> • If oversized obstructions are anticipated, cutter heads on the MTBM must be designed to accommodate the situation • Wet spoil management requires adequate space and access 	FEASIBLE & PREFERRED FROM A GEOTECHNICAL PERSPECTIVE	LOW	HIGH



COMPARISON OF TRENCHLESS INSTALLATION METHODS (Cont'd)

Trenchless Method	Advantages	Disadvantages	Feasibility	Relative Risks	Relative Cost
Hand Mining	<ul style="list-style-type: none">• Allows for handling of oversize obstructions	<ul style="list-style-type: none">• Only for larger pipe diameters (man accessible)• Slower progress	NOT RECOMMENDED	HIGH	LOW
Horizontal directional drilling	<ul style="list-style-type: none">• Entry and exit pits not required, no temporary shoring required	<ul style="list-style-type: none">• Minimal alignment control especially if oversized obstructions are encountered	NOT RECOMMENDED	MEDIUM	MEDIUM



Appendix G

Instrumentation and Monitoring Plan



MONITORING PROGRAM
PROPOSED TRENCHLESS CROSSING

- Item No.

Special Provision

GENERAL

1.1 Scope

This special provision contains the requirements for the supply, installation and monitoring of the following instruments:

- Surface Monitoring Point (SMP)
- Settlement Rod (SR)

The instruments shall be installed along the centreline of the trenchless crossing and in array. Each array consists of a group of instruments installed approximately perpendicular to the trenchless crossing.

1.2 Purpose

The purpose of these instruments is to monitor settlements during trenchless installation of the proposed sewer under the Q.E.W.

The methodologies and rate of installation may need to be adjusted as a result of the instrumentation readings.

1.3 Contractor's Scope of Work

The Contractor shall be fully responsible to procure, install, protect, monitor, reduce and transmit data for all monitoring instruments and to decommission the instruments as described herein.

The required survey of all the instruments shall be carried out by the Contractor's qualified surveyors.



1.4 Or equal

The term 'or equal' shall be understood to indicate that the equal product is the same or better than the specified product in function, performance, reliability, quality and general configuration.

1.5 Notification

The Owner, the Ontario Ministry of Transportation (MTO), the Contract Administrator (CA), and CA's Geotechnical Consultant, shall be notified five days in advance of commencing the installation of instruments. All instruments shall be installed and their baseline readings (see Section 6.3) established to the satisfaction of all parties listed above not less than five days in advance of the trenchless installation operations.

1.6 Instrument Installation and Monitoring Requirements

The Contractor shall be prepared to install and monitor all instruments.

1.7 Drawings

Reference shall be made to Drawings G1 in Appendix G for instrument locations.

1.8 Subsurface Conditions

The subsurface conditions at the site are described in Thurber's Report titled: "Foundation Investigation Report, Culvert and Storm Sewer Installations, North Shore Boulevard Interchange, Queen Elizabeth Way (QEW), Burlington, Ontario, Central Region Assignment Number: 2017-E-0056-001, by Thurber Engineering Ltd., Reference No. 25497, dated June 25, 2019".

2 **INSTALLATION**

2.1 Generals

SMPs will be installed along the centreline of traffic lanes and / or paved shoulders in arrays of either three (3) instruments or one (1) single instrument. SRs will be installed on the side slopes along the proposed sewer centreline.



2.2 Instrument Location

The Contractor's surveyors shall accurately survey the location of each instrument to obtain coordinates and elevations.

2.3 Survey Benchmarks

The Contractor's surveyors shall identify or establish non-yielding survey benchmarks (BM) at the site in order to carry out elevation surveying and achieve the accuracy specified below.

2.4 Accuracy of Surveying for Elevations

Elevations shall be surveyed to an accuracy of ± 2 millimetres or better.

2.5 Materials and Equipment

The Contractor shall supply all materials and equipment required for installation of the instrumentation.

2.6 Protection of Instruments

All instruments shall be adequately protected by the Contractor such that they are not damaged during construction. Any instrument damaged directly or indirectly by the Contractor's work shall be immediately replaced by the Contractor at the Contractor's expense.

Instruments installed in the travelled portion of the roadway (lanes and shoulders) shall be protected to avoid puncturing of vehicle tires.

2.7 Installation Program

Instrument installation and baseline readings shall be completed before any trenchless installation operations.



3 SURFACE MONITORING POINT (SMP) - SUPPLY & INSTALLATION

3.1 General

3.1.1 Scope

This Section contains the requirements for the supply and installation of SMPs.

The purpose of SMP is to monitor settlement of asphalt paved surface. The ground movement readings shall assist in assessing the sewer performance and any need to modify the installation methodology as required. Settlement is measured by level surveying the SMPs with reference to stable, non-settling benchmarks.

3.1.2 General Procedure

SMPs shall be rigidly affixed so as not to move relative to the asphalt pavement surface to which they are attached.

3.1.3 Location

The locations of SMPs are shown on Drawing G1.

3.2 Materials

3.2.1 General

The Contractor shall supply all materials and equipment required for the installation of the SMPs.

3.2.2 Steel Markers

The Contractor shall supply hardened steel markers with an exposed convex head, similar to surveyor's PK nails, treated or coated to resist corrosion. The steel markers shall have a minimum diameter of 12 mm and have sufficient length for anchoring in the pavement and to withstand the weather conditions and effects of traffic.

The exposed nail head shall be equipped with reflective paint or reflective tape to allow for measurements with total-station equipment.

3.3 Installation

3.3.1 General

Traffic shall be managed by the Contractor using short term lane closures in accordance with the Ontario Traffic Manual (OTM), Book 7.



3.4 Documentation

Relevant installation details shall be recorded and documented. These include, but are not limited to:

- SMP easting, northing and elevation;
- Dates of installation;
- Installation notes / sketches.

4 SETTLEMENT ROD (SR) - SUPPLY & INSTALLATION

4.1 General

4.1.1 Scope

This Section contains the requirements for the supply and installation of SRs.

The purpose of SR is to monitor the settlement of the ground and highway embankments along the proposed sewer alignment. The settlement readings shall assist in assessing the sewer performance and any need to modify the installation methodology as required. Settlement is measured by surveying the top of the rod with reference to stable, non-settling benchmarks.

4.1.2 General Procedure

The SR shall consist of a 12 to 18 mm diameter rebar encased in a PVC pipe used as a friction reducing sleeve.

The assembly shall be placed in a drilled hole and backfilled with anchor grout and clean washed sand.

4.1.3 Location

The locations of SRs are shown on Drawing G1.

4.2 Materials

4.2.1 General

The Contractor shall supply all materials and equipment required for the installation of the SRs.

4.2.2 Rod



The Contractor shall supply 12 to 18 mm diameter steel rebars in the required lengths in order to complete this installation.

The top end of each rod shall be equipped with reflective paint or reflective tape to allow for measurements with total-station equipment.

4.2.3 Anchor

The Contractor shall supply concrete for anchoring the lower end of the steel rebar. The concrete shall be prepared in accordance with OPSS 1350 with a minimum compressive strength of 10 MPa.

4.2.4 Sand

The Contractor shall supply clean washed sand. The sand will be Sakcrete washed general purpose sand, or equal.

4.2.5 Friction Reducing Sleeve

The Contractor shall supply a friction reducing sleeve consisting of Schedule 40, 50 mm O.D. PVC pipe cut perpendicular to the axis of the pipe.

4.2.6 Protective Casing

The Contractor shall supply protective steel casings installed flush with the ground surface where the SRs are installed in shoulders that can be travelled by vehicles.

4.3 **Installation**

4.3.1 General

The Contractor shall install SRs as stated or emphasized below. Traffic control for instrument installation shall be managed by the Contractor, as required, using short term lane closures in accordance with the Ontario Traffic Manual (OTM), Book 7.

4.3.2 Rod

The rod shall be centred in the borehole.

4.3.3 Friction Reducing Sleeve

The friction reducing sleeve shall extend for the length of the rod above the anchor grout.



4.4 Documentation

Relevant installation details shall be recorded and documented. These include, but are not limited to:

- SR location, easting and northing;
- Elevation of top of rod;
- Dates of installation;
- Installation notes / sketches.

5 DECOMMISSIONING OF INSTRUMENTS

5.1 General

The Contractor shall decommission all SMPs and SRs after the completion of the monitoring program as directed by CA and CA's Geotechnical Consultant.

6.1 General

The instrumentation monitoring services specified herein apply to all the SMPs and SPs for this site. The requirements include data collection, reporting, data reduction and data transmission.

The Monitoring Consultant shall carry out the monitoring program for this project. The required tasks include the following:

- Supply materials and equipment required for monitoring;
- Survey the instruments with no interference with the traffic on the highway and its ramps;
- Compile and reduce the survey data as described in Section 6.4.2;
- Transmit the settlement data and associated pipe installation / construction activities to CA, CA's Geotechnical Consultant and MTO;
- Notify CA, CA's Geotechnical Consultant and MTO of any required modifications to the construction procedures;
- Notify CA, CA's Geotechnical Consultant and MTO of any modifications of the original site conditions related to pipe installation or otherwise, including appearance of cracks on the pavement and shoulder, concrete barriers etc;
- Notify immediately CA, CA's Geotechnical Consultant and MTO if Review or Alert Levels have been reached or exceeded and follow the procedures outlined in Section 6.5.



6.2 Purpose

The purpose of this program is to monitor settlement of the paved surfaces and embankments at selected locations during the trenchless installation of the sewer

The rate and / or methodology of trenchless installation may need to be adjusted based on the instrumentation readings.

6.3 Reading Schedule and Frequency

The Contractor shall keep a complete record in electronic and hard copy formats of all instrumentation survey and associated data, including the location of the advancing face at the time of each survey.

Monitoring shall commence after the installation of an instrument. Monitoring is to continue as specified in this document and as required by CA and CA's Geotechnical Consultant.

The minimum monitoring frequencies along with the anticipated number of readings are given in Table 6.1 below. The monitoring frequency is the same for each individual instrument. Instruments shall be read more frequently as required by CA and CA's Geotechnical Consultant.

Table 6.1 - Minimum Monitoring Frequency

STAGE	FREQUENCY	ANTICIPATED NO. OF READINGS PER INSTRUMENT (**)
Baseline Readings (*)	3 readings on 2 consecutive days	3
Just prior to start of trenchless installation	Once	1
During trenchless installation	A minimum of three (3) sets of readings be taken daily for all instruments located, provided that movements are within anticipated limits. Monitoring of movements is also required during work stoppages, such as during non-operation periods (off-shifts) or weekends.	Variable
After completion of installation	After the end of installation, all instruments shall be read weekly for the first month.	4



- (*) Baseline Readings: Instrument elevation readings taken prior to trenchless installation to provide a baseline against which all subsequent readings are compared to assess settlements of the ground.
- (**) Number of readings may vary.

6.4 Specific Requirements

6.4.1 Surveying

The elevations of the instruments shall be surveyed to an accuracy of plus/minus two (± 2) millimetres or better, and shall be reported to the nearest millimetre. Shoulder and lane closures for instrument readings are not permitted.

6.4.2 Data Recording and Data Reduction

For every instrument elevation reading the following information shall be recorded electronically in an Excel spreadsheet containing the following information:

- Date and time of the day
- Location of the advancing face (i.e. distance from launching point) at the time of data recording
- Construction activities (e.g. sewer installation underway; weekend – no construction; boulder encountered at the advancing face of installation, etc)
- Pavement visual survey (e.g.: No visual pavement distress; 1 mm wide, 3 m long pavement crack parallel to west shoulder and close to instruments No. A, B and C, sketches and photos, etc.)
- Instrument Number
- Settlement Array Number
- Horizontal distance measured along the sewer alignment between the advancing face of installation and the instrument or array of instruments that contains the instrument being monitored
- Instrument elevation
- Instrument settlement

The settlement data shall be presented in X-Y charts as follows:

- Settlement versus Time for each instrument
- Settlement versus Distance from the advancing face of installation for each instrument
- Settlement profile for different dates along each of the sewer alignment
- Settlement profile for different dates along each of the settlement arrays

Reported information should be supplemented by sketches, diagrams and plots as necessary.



6.4.3 Data Transmission

All settlement data obtained on a particular day shall be reported in electronic format to CA, CA's Geotechnical Consultant and MTO not later than mid-day on the next calendar day. Any unusual movements deduced from the field data must be reported immediately before leaving the site.

6.5 Criteria for Assessment

The following settlement levels are to be observed:

Review Level – A maximum value of 10 mm relative to the baseline or zero readings. If the Review Level is exceeded, the Contractor shall immediately notify CA, CA's Geotechnical Consultant and MTO, and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Level from being reached. All construction work shall be continued such that Alert Level is not reached.

Alert Level – A maximum value of 15 mm relative to the baseline or zero readings. If the Alert Level is reached or exceeded, or lesser ground settlements cause or threaten to cause damage to utilities or the highway pavement, as indicated by monitoring instruments or direct observation, the Contractor shall cease installation operation immediately and inform CA, CA's Geotechnical Consultant and MTO. No construction shall take place until all the following conditions are satisfied:

- The cause of the settlement has been identified;
- The Contractor submits a corrective / preventive plan;
- Any corrective and / or preventive measure deemed necessary by the Contractor is implemented;
- CA, CA's Geotechnical Consultant and MTO deem it is safe to proceed.

7 CONTRACTOR'S RESPONSIBILITY FOR RESTORATION

Notwithstanding the monitoring program to assess the adequacy of the trenchless installation method to control potential ground movements and groundwater, the Contractor is responsible for reinstatement (such as surface paving and fill placement) should ground movements or other surface distress occurs.

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

CONT No
WP No 2117-15-00



Q.E.W.
TRENCHLESS SEWER
INSTRUMENTATION & MONITORING PLAN

SHEET



KEYPLAN

LEGEND

- Proposed Trenchless Sewer
- Surface Monitoring Point (SMP)
- Settlement Point (SP)

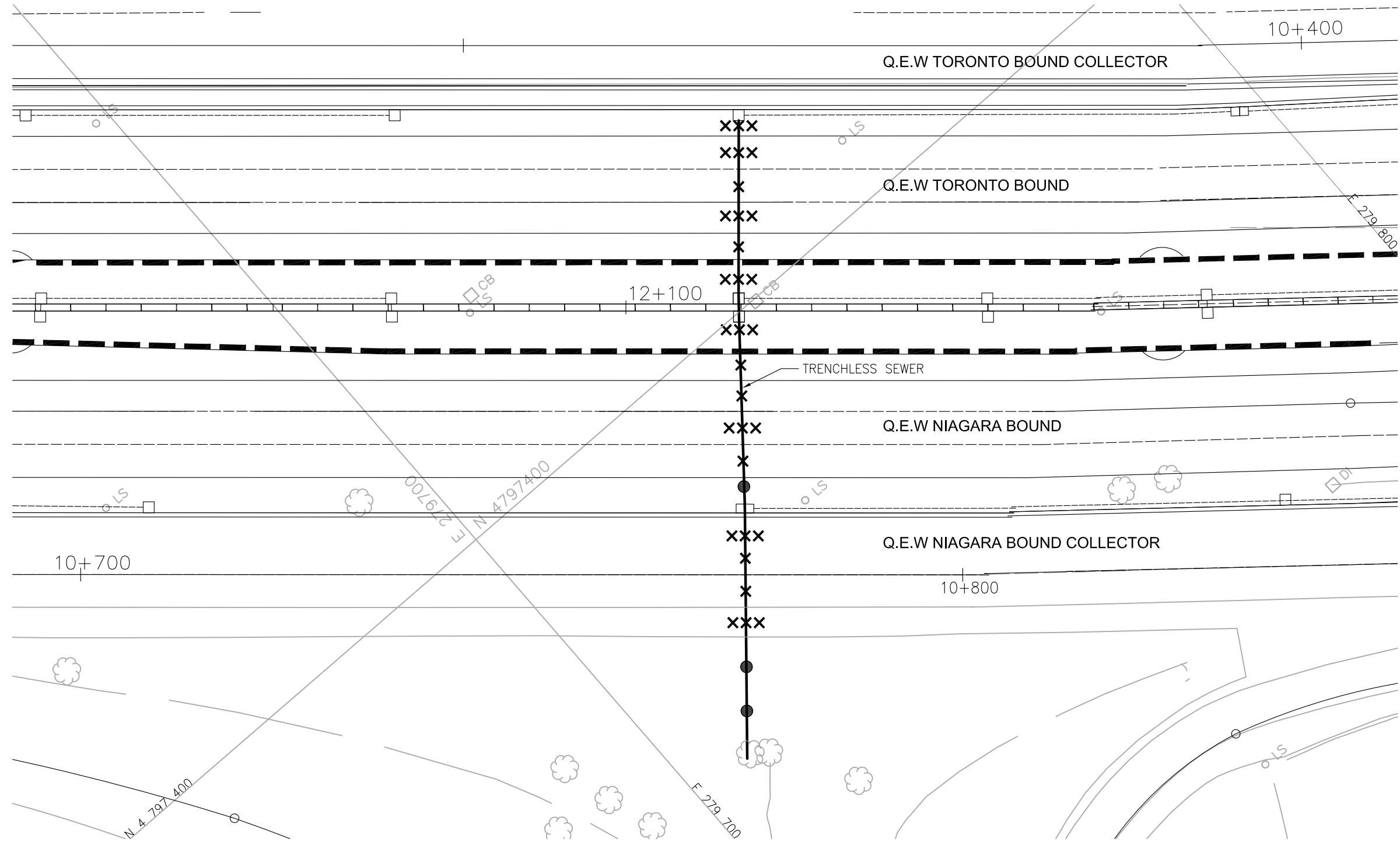
NO	ELEVATION	NORTHING	EASTING

-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 10.

GEOCRES No. 30M5-330

REVISIONS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
-----------	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--



PLAN





Appendix H

List of Standard Specifications, Special Provisions, NSSP and Suggested Text for NSSP



List of OPSS and OPSD Referenced in this Report

OPSS.PROV 182

OPSS.PROV 401

OPSS.PROV 421

OPSS.PROV 492

OPSS.PROV 501

OPSS.PROV 517

SP 517F01

OPSS.PROV 539

OPSS.PROV 805

OPSS.PROV 1010

OPSS.PROV 1860

OPSD 802.010

Non-Standard Special Provision

Pipe Installation by Trenchless Method
Instrumentation and Monitoring Program

Suggested Text for NSSP on “Pipe Installation by Trenchless Method”

Cobbles, boulders or other obstructions may be present within the existing highway embankment fill and native tills. The Contractor's equipment and methodology must be able to handle and remove such obstructions. It is noted that a minimum casing diameter of 750 mm is required for removal of obstructions.

Suggested Text for SP517F01 on “Dewatering System – Design Storm Return Period and Preconstruction Survey Distance”

Preconstruction Survey Distance: 250 m

Dewatering Engineer Requirements: Yes

PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Special Provision

November 2018

CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY TRENCHLESS METHODS

TABLE OF CONTENTS

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

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

2.0 REFERENCES

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

Ontario Provincial Standard Specifications, General

OPSS 180 Management of Disposal of Excess Material

Ontario Provincial Standard Specifications, Construction

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

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

Ontario Provincial Standard Specifications, Material

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

CSA Standards

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

American Society for Testing and Materials (ASTM) International Standards

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

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

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

3.0 DEFINITIONS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Reaming means a process for enlarging the bore path

Rock means natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a volume of 0.5 m³ or greater.

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

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

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

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

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

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

Trenchless Installation means an underground method of constructing a passage open at both ends that

involves installing a pipe product by auger jack & boring, pipe ramming, horizontal directional drilling, or tunnelling.

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

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

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

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.01 Design

4.01.01 General

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

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

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

4.02 Submission Requirements

4.02.01 Qualifications

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

4.02.01.01 Project Superintendent

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

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

4.02.01.02 Trenchless Contractor

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

4.02.01.03 Design Engineer

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

4.02.01.04 Design Checking Engineer

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

4.02.02 Working Drawings

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

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

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

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

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

a) Plans and Details:

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

- x. Excavated materials disposal plan.
- xi. Locations of protection systems.

b) Designs

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

c) Materials:

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

chemical admixtures or physical treatment employed to achieve required physical properties;

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

d) Upstream/Downstream Portal Installation Procedure:

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

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

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

f) Excavation and Dewatering:

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

g) Monitoring Method:

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

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

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

4.02.03 Quality Control Certificate

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

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

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

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

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

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

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

5.0 MATERIALS

5.01 Pipe

5.01.01 General

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

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

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

All fittings shall be designed to be watertight.

5.01.02 Steel Pipe

Steel pipe shall be according to ASTM A252.

All steel casing pipe shall be square cut.

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

5.01.03 HDPE Pipe

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

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

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

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

5.01.04 Concrete Pipe

Concrete pipe shall be according to OPSS 1820.

5.02 Concrete

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

5.03 Steel Reinforcement

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

5.04 Wood

Wood shall be according to OPSS 1601.

5.05 Drilling Fluids

Drilling fluid shall be mixed according to the working drawings.

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

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

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

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

5.06 Grout

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

6.0 EQUIPMENT

6.01 Auger Jack & Bore

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

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

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

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

6.02 Pipe Ramming

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

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

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

6.03 Horizontal Directional Drilling

6.03.01 General

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

6.03.02 Drilling Rig

The horizontal directional drilling rig shall:

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

6.03.03 Drill Head

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

6.03.04 Guidance System

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

6.03.05 Drilling Fluid Mixing System

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

6.03.06 Drilling Fluid Delivery System

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

6.04 Tunnelling

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

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

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

6.05 Microtunnelling Equipment

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

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

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

- a) Remote Control System – The Contractor shall provide a MTBM that includes a remote control system with the following features:
 - i. Allows for operation of the system without the need for personnel to enter the microtunnel. Has a display available to the operator, at a remote operation console, showing the position of the shield in relation to a design reference together with other information such as face pressure, roll, pitch, steering attitude, valve positions, thrust force cutter head torque, rate of advance and installed length.
 - ii. Integrates the system of excavation and removal of spoil and its simultaneous replacement by Product Pipe. As each pipe section is jacked forward, the control system shall synchronize all of the operational functions of the system.
 - iii. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.

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

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

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

6.05.01 Pipe Jacking Equipment

Provide a pipe jacking system with the following features:

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

6.05.02 Spoil Separation System

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

6.05.03 Electrical Equipment, Fixtures and Systems

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

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

7. CONSTRUCTION

7.01 General

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

The Project Superintendent shall supervise the work at all times.

7.01.01 Layout, Alignment and Depth Control

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

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

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

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

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

7.01.02 Construction Shafts

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

Shafts shall be maintained in a drained condition.

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

7.01.03 Protection Systems

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

7.01.04 Settlement or Heave

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

7.01.05 Stability of Excavation

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

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

7.01.06 Preservation and Protection of Existing Facilities

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

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

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

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer's handling and storage recommendations shall be followed.

7.01.08 Trenching, Backfilling and Compacting

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

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

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

7.01.10 Dewatering

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

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

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

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

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

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Cobbles and Boulders

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

7.01.14 Management of Excess Material

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

7.01.15 Site Restoration

Site restoration shall be according to OPSS 492.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

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

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

7.02.02 Pipe Installation

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

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

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

7.03 Pipe Ramming Installation

For pipe ramming installation the following requirements apply:

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

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

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

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

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

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

7.04 Horizontal Directional Drilling Installation

7.04.01 General

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

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

7.04.02 Site Preparation

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

7.04.03 Pilot Bore

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

In the event the pilot bore deviates from the submitted path, the Contract Administrator shall be notified. The

Contract Administrator may require the Contractor to pullback, fill and abandon the hole and re-drill from the location along the bore path before the deviation.

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

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

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

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

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

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

7.04.05 Reaming

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

7.04.06 Product Installation

7.04.06.0 General

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

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

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

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

7.04.06.02 Pullback and Grouting

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

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

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

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

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

7.05 Tunnelling Installation

7.05.01 General

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

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

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

The Contractor shall provide ventilation and lighting in accordance with 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.

7.05.01 Tunnelling Method

The tunnelling method shall be suitable to provide face support in changing ground conditions that may be encountered during the progress of the work. The selection of the tunnelling method should consider the soil

conditions at each pipe crossing and the presence of obstructions, such as cobbles and boulders, with respect to the tunnel alignment.

7.05.02 Primary Liner (Support System)

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

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

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

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

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

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

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

7.05.03 Secondary Liner

7.05.03.01 Placing of Grout

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

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

7.06 Microtunnelling

7.06.01 General

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

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

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

The Contractor shall maintain clean working conditions at all times.

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

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

7.06.02 Method of Installation

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

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

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

7.06.03 Casing Installation

Casing must withstand the jacking forces determined by the Contractor.

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

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

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

7.07 Instrumentation and Monitoring

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

7.07.01 Surface Monitoring Points

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

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

7.07.02 In-Ground Monitoring Points

In-ground settlement monitoring points shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe,

set to a depth of 1.5 m below ground surface or below frost penetration depth whichever is greater. The assembly shall be placed in a drill hole, backfilled with uniform sand and provided with protective covers suitable for high vehicular traffic areas.

7.07.03 Installation, Replacement and Abandonment

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

7.07.03 Monitoring and Reporting Frequency

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

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

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

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

7.07.03 Benchmarks

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

7.08 Criteria for Assessment of Roadway Subsidence/Heave

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

- a) Review Level: If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate or sequence of construction or ground stabilization measures to mitigate further ground displacement. If this Review Level is exceeded, the Contractor shall immediately notify the CA and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.

- b) Alert Level: If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic. No construction shall take place until all of the following conditions are satisfied:
- i. The cause of the settlement has been identified.
 - ii. The Contractor submits a corrective/preventive plan.
 - iii. Any corrective and/or preventive measure deemed necessary by the Contractor is implemented.
 - iv. The CA deems it is safe to proceed.

9. MEASUREMENT FOR PAYMENT

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

10. BASIS OF PAYMENT

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

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

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

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

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

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