



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
SEWER LATERALS
HIGHWAY 404 HOV LANE EXPANSION AND REHABILITATION
CONTRACT 2
FROM HIGHWAY 407 TO MAJOR MACKENZIE DRIVE
MARKHAM, ONTARIO
G.W.P. 2930-17-00**

GEOCRES NO. 30M14-496

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Report

to

WSP Canada Inc.

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Appendix D	Analytical Laboratory Test Results
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Each of Appendices A to C includes:

- Record of Borehole Sheets (present and previous investigations)
- Laboratory Test Results
- Drawings titled “Borehole Locations and Soil Strata



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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted for the proposed sewer laterals (Contract 2) which are to be installed at three specific locations along Highway 404 from Highway 407 to Major Mackenzie Drive in the City of Markham, Ontario.

The purpose of this investigation was to explore the subsurface conditions near the locations of the sewer lateral alignments and based on the data obtained, to provide borehole location plans, stratigraphic profiles, records of boreholes, laboratory test results, and a written description of the subsurface conditions.

Thurber was retained by WSP Canada Inc. (WSP) to carry out this foundation investigation under the MTO Assignment Number 2016-E-0014.

Reference has been made to information on subsurface conditions contained in another foundation report prepared for this section of Highway 404. The title of that report is:

- Draft Foundation Investigation Report, Median Sewer, Highway 404 HOV Lane Expansion and Rehabilitation, Contract 2, from Highway 407 to Major Mackenzie Drive, Markham, Ontario, G.W.P. 2930-02-00, Report to WSP Canada Inc., File: 15786, dated November 2018. (Reference 1).

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2. PROJECT AND SITE DESCRIPTION

The sewer laterals covered in this report are associated with three Stormwater Management (SWM) Ponds 1, 2 and 3 as shown in Table 2.1. The approximate locations of the three proposed sewer laterals are shown on the key plan on the Borehole Locations and Soil Strata Drawings in Appendices A to C.

Table 2.1 - Locations of Proposed Sewer Laterals

Station	Location Hwy 404	Upstream ID	Downstream ID
15+164	SBL	CB52	SWM Pond 1
16+386	SBL	CB19	SWM Pond 2
17+423	SBL	CB33	SWM Pond 3

The land use adjacent to this section of Highway 404 is largely rural and agricultural, although there is increasing residential and commercial developments in recent years. The vegetation cover beyond the paved areas of the highway comprises grass, shrubs and stands of trees.

The sewer laterals are located within the physiographic region known as the Peel Plain. The topography is flat to gently undulating. The soil cover in the region typically comprises silty clay glacial tills with sand and silt layers. Shale bedrock of the Georgian Bay Formation is anticipated at an approximate depth of 50 m.

3. SITE INVESTIGATION AND FIELD TESTING

Site investigation and field testing for the proposed sewer laterals were carried out from July 9, 2017 to October 21, 2018, and consisted of drilling and sampling six (6) boreholes, designated as Boreholes MS2-08, MS2-20, MS2-32, SWM C2-1C, SWM C2-2C and SWM C2-3C, at selected locations near the sewer lateral alignments. These boreholes have also been used to address other aspects of the works including the median sewer and SWM ponds. The boreholes were drilled on the southbound lanes (SBL) of Highway 404 and also at each of the proposed stormwater management ponds (Ponds 1 to 3). The boreholes were terminated at depths ranging from 7.8 m to 12.8 m (Elevations 196.4 to 177.0).



Details of the borehole locations are presented in Table 3.1 below. Borehole location plans and stratigraphic profiles for the sewer laterals are presented on the Borehole Locations and Soil Strata Drawings in Appendices A to C. Records of Borehole sheets, laboratory testing data and drawings relevant to each section are also included in the appendices.

Table 3.1 – Borehole Location and Designation Details

Location	Approximate Hwy. 404 Station	Reference Boreholes	Sewer Lateral Upstream ID	Appendix
Pond 1	15+164	MS2-32	52	A
		SWM C2-1C		
Pond 2	16+386	MS2-20	19	B
		SWM C2-2C		
Pond 3	17+423	MS2-08	33	C
		SWM C2-3C		

The coordinates and elevations of the boreholes are provided on the drawings and on the individual Record of Borehole Sheets in Appendices A to C.

The northing and easting coordinates at the borehole locations were obtained by Thurber using a Trimble GPS Pathfinder ProXRT, and the corresponding ground surface elevations were provided by WSP based on the project DTM survey. The precision of the horizontal survey of the boreholes is rated at within 0.5 m, whereas the precision of the elevation is the same as that of the DTM survey.

The borehole locations were marked in the field and utility clearances were obtained prior to drilling. Lane closures and traffic control were planned and implemented for drilling each borehole.

During this investigation, a truck mounted drill rig was used to advance the boreholes using solid stem augers. Soil samples were obtained at selected intervals using a 50 mm diameter split spoon sampler in conjunction with the Standard Penetration Test (SPT). SPT's were conducted as per ASTM D1586.



Members of Thurber's geotechnical staff supervised the drilling and sampling operations on a full time basis. The supervisors logged the boreholes, visually examined the recovered soil samples, and transported them to Thurber's laboratory for further examination and testing.

Groundwater conditions were observed in the open boreholes during and upon completion of the drilling operations. Four standpipe piezometers were installed in selected boreholes to permit monitoring of groundwater levels. The standpipe piezometers consisted of a 19 mm and 50 mm diameter Schedule 40 PVC pipe with a 3.0 m long slotted screen and were installed within a column of filter sand. Upon completion, the boreholes were abandoned in general accordance with Ontario Regulation 903 amended by Ontario Reg. 372 (O.Reg. 903). Once the final readings are taken, the piezometers will be decommissioned in general accordance with O.Reg. 903. The details of current borehole completion are summarized in Table 3.2.

Table 3.2 – Borehole Completion Details

Lateral Sewer	Borehole	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth/ Elevation (m)	Completion Details
Pond 1	MS2-32	12.5/177.0	6.2/183.3	Piezometer with 3.0 m slotted screen installed with auger cuttings from 12.5 m to 6.6 m, sand filter from 6.6 m to 2.4 m, bentonite holeplug from 2.4 m to 0.15 m, then auger cuttings to ground surface.
	SWM C2-1C	9.8/179.5	8.5/180.8	Piezometer with 3.0 m slotted screen installed with auger cuttings from 9.8 m to 8.5 m, sand filter from 8.5 m to 4.9 m, bentonite holeplug from 4.9 m to ground surface.
Pond 2	MS2-20	12.8/184.4	None installed	Borehole caved to 4.3 m. Borehole backfilled with bentonite holeplug to 3.0 m, auger cuttings from 3.0 m to 0.6 m, bentonite holeplug from 0.6 m to 0.1 m, then asphalt to surface.

	SWM C2-2C	9.8/187.8	9.1/188.5	Piezometer with 3.0 m slotted screen installed with sand from 9.8 m to 5.5 m, then bentonite holeplug from 5.5 m to ground surface.
Pond 3	MS2-08	8.2/196.0	None installed	Borehole backfilled with bentonite holeplug from 8.2 m to 7.0 m, auger cuttings from 7.0 m to 0.8 m, bentonite holeplug from 0.8 m to 0.2 m, then asphalt to surface.
	SWM C2-3C	7.8/196.4	7.6/196.6	Piezometer with 3.0 m slotted screen installed with sand from 7.8 m to 3.9 m, bentonite holeplug from 3.9 m to 2.7 m, bentonite and auger cuttings from 2.7 m to 0.6 m, then concrete to ground surface.

4. LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size analysis and Atterberg Limits testing. All the laboratory tests were carried out in accordance to MTO and/or ASTM Standards, as appropriate. The results of the laboratory testing are summarized on the Record of Borehole sheets and on the accompanying figures in Appendices A to C.

In order to assess the potential for sulphate attack on the concrete pipes, as well as the potential for metal corrosion associated with pipes, selected samples of the soils were submitted to SGS Canada Inc., a CALA accredited analytical laboratory in Lakefield, Ontario, for analytical testing of corrosivity parameters and sulphate content. The results of the analytical testing are summarized in Section 6 and are presented in Appendix D.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

This section presents a generalized summary of the subsurface conditions encountered at the borehole locations drilled for the proposed sewer laterals.



It is important to note that the soil strata drawings presented in this report are for illustrative purposes and for providing a general description of the stratigraphy near the locations of the sewer laterals. The factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions. It must be recognized that soil conditions may vary between and beyond the borehole locations.

In general, the soil stratigraphy encountered at the sewer laterals consists of pavement structure (asphalt on granular base) and fill overlying native stiff to very stiff silty clay and silty clay till, which is underlain by compact to dense sands and silts. A lower deposit of very stiff to hard silty clay till was contacted below the cohesionless soils.

More detailed descriptions of the stratigraphy are presented below.

5.1 Sewer Lateral 52 at Pond 1 (Station 15+164) Boreholes MS2-32 and SWM C2-1C

Two boreholes, numbered MS2-32 and SWM C2-1C, were drilled near the alignment of Sewer Lateral 52 at Pond 1 located at approximately 1.0 km north of Highway 7. Records of boreholes, laboratory testing results and stratigraphic drawings are presented in Appendix A.

5.1.1 Topsoil

A 75 mm thick layer of topsoil was encountered surficially in Borehole SWM C2-1C, which was drilled at the perimeter of the proposed Pond 1.

The topsoil thickness may vary between and beyond the borehole locations, and the data is not intended for the purpose of estimating quantities.

5.1.2 Asphalt

Asphalt of 150 mm in thickness was encountered surficially in Borehole MS2-32.

5.1.3 Sand and Gravel Fill, Silty Clay Fill

Pavement granular fill consisting of brown sand and gravel, trace silt and trace clay was contacted below the asphalt in Borehole MS2-32. The thickness of the granular fill was 1.2 m. The depth to the base of the cohesionless fill was 1.4 m (Elevation 188.1).



A layer of cohesive fill, consisting of brown silty clay with sand, some gravel and occasional cobbles was contacted below the topsoil, in Borehole SWM C2-1C. The thickness of the silty clay fill was 1.9 m. The depth to the base of the silty clay fill was at 2.0 m (Elevation 187.3).

SPT 'N' values within the sand and gravel fill were 12 and 18 blows per 0.3 m penetration indicating a compact condition. An SPT 'N' value of 10 blows per 0.3 m of penetration, was measured surficially in the silty clay fill, indicating a stiff consistency. SPT 'N' values greater than 50 blows for less than 0.3 m of penetration were measured in the silty clay fill indicating the presence of cobbles, boulders or debris, and possibly in layers. The measured moisture contents of samples of the cohesionless fill were 7 and 9 percent. Moisture contents in the silty clay fill ranged from 3 to 17 percent.

5.1.4 Silty Clay to Clayey Silt Till

An upper deposit of native brown silty clay till, containing some sand and trace gravel, was contacted below the fill at 1.4 m and 2.0 m depths in Boreholes MS2-32 and SWM C2-1C, respectively. The thickness of the upper silty clay till ranged from 2.3 m to 2.7 m. The base of the upper silty clay till was at 4.1 m and 4.3 m depths (Elevations 185.4 and 185.0) in Boreholes MS2-32 and SWM C2-1C, respectively.

A lower layer of grey silty clay to clayey silt till, some sand to with sand and trace gravel, was encountered at 10.0 m and 6.5 m depths in Boreholes MS2-32 and SWM C2-1C, respectively. Where fully penetrated, the thickness of the lower clayey silt till was 2.6 m in Borehole SWM C2-1C. The base of the lower clayey silt till was at 9.1 m depth (Elevation 180.2) in Borehole SWM C2-1C. Borehole MS2-32 was terminated within the lower silty clay till at 12.5 m depth (Elevation 177.0).

SPT 'N' values recorded in the silty clay to clayey silt till typically ranged from 8 blows to 28 blows per 0.3 m of penetration, indicating a stiff to very stiff consistency. SPT 'N' values of 62 blows for 0.3 m of penetration and greater than 100 blows for less than 0.3m of penetration, indicating a hard consistency and possible presence of cobbles or boulders, were measured in the lower silty clay till in Borehole MS2-32. The measured moisture contents of samples of the cohesive till varied between 9 percent and 30 percent. A moisture content of 64 percent was measured in a selected sample of this till which contains organics in Borehole MS2-32.



The results of grain size distribution analyses carried out on selected samples of the cohesive till are presented on the Record of Borehole Sheets included in Appendix A and in Figure A1 of Appendix A. Results of the gradation testing are summarized below:

Soil Particles	Percentage (%)
Gravel	0 to 3
Sand	14 to 49
Silt	27 to 33
Clay	18 to 55

The results of Atterberg Limits testing on a silty clay till sample are presented on the Record of Borehole sheets and in Figure A4 included in Appendix A. The results of Atterberg Limits testing are summarized below:

Index Property	Percentage (%)
Liquid Limit	29
Plasticity Index	13

The above results show that the silty clay till is of low plasticity with a group symbol of CL.

Glacial tills inherently contain cobbles and boulders.

5.1.5 Sandy Silt to Silty Sand

Layers of grey sandy silt to silty sand containing trace to some clay and trace gravel were encountered below the upper silty clay till at 4.1 m and 4.3 m depth in Boreholes MS2-32 and SWM C2-1C, respectively. The thickness of the sandy silt to silty sand were 5.9 m and 2.2 m in Boreholes MS2-32 and SWM C2-1C, respectively. The depth to the base of the sandy silt to silty sand was at 10.0 m and 6.5 m (Elevations 179.5 and 182.8) in Boreholes MS2-32 and SWM C2-1C, respectively.

SPT 'N' values measured in the cohesionless soil ranged from 10 to 41 blows per 0.3 m of penetration indicating a compact to dense state. The measured moisture contents ranged from 10 percent to 27 percent.



Grain size distribution results of a sandy silt sample tested are presented on the Record of Borehole sheets and on Figure A2 of Appendix A. The results of laboratory gradation tests are summarized as follows:

Soil Particles	Sandy Silt Percentage (%)
Gravel	0
Sand	23
Silt	67
Clay	10

5.1.6 Sand

A layer of brown sand containing trace gravel, trace silt and clay was contacted below the lower clayey silt till at 9.1 m depth in Borehole SWM C2-1C. Borehole SWM C2-1C was terminated within this sand layer at 9.8 m depth (Elevation 179.5).

An SPT 'N' value measured in this sand was 16 blows per 0.3 m of penetration, indicating a compact state. The measured moisture content in the sand was 21 percent.

Grain size distribution results of a sand sample tested are presented on the Record of Borehole sheets and on Figure A3 of Appendix A. The results of laboratory gradation tests are summarized as follows:

Soil Particles	Sand Percentage (%)
Gravel	3
Sand	90
Silt and clay	7

5.1.7 Water Levels

The groundwater levels in the open boreholes were observed and noted during and upon completion of drilling. The water levels measured in the installed piezometers and in the open boreholes upon completion of drilling, are summarized in Table 5.1.

Table 5.1.- Measured Groundwater Levels

Borehole	Date	Water Level (m)		Comments
		Depth	Elevation	
MS2-32	September 30, 2018	2.2	187.3	Piezometer
	November 22, 2018	2.9	186.6	
SWM C2-1C	November 22, 2018	2.8	186.5	Piezometer

The above values are short term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

5.2 Sewer Lateral 19 at Pond 2 (Station 16+386) Boreholes MS2-20 and SWM C2-2C

Two boreholes, numbered MS2-20 and SWM C2-2C, were drilled near the alignment of Sewer Lateral 19 at Pond 2 located at the northwest quadrant of the Highway 404 and 16th Avenue interchange. Records of boreholes, laboratory testing results and stratigraphic drawings are presented in Appendix B.

5.2.1 Topsoil

A 175 mm thick layer of topsoil was encountered surficially in Borehole SWM C2-2C, which was drilled near the perimeter of Pond 2.

The topsoil thickness may vary between and beyond the borehole locations, and the data is not intended for the purpose of estimating quantities.

5.2.2 Asphalt

Asphalt of 75 mm in thickness was encountered surficially in Borehole MS2-20.

5.2.3 Sand and Gravel Fill and Silty Sand Fill

Pavement granular fill consisting of brown sand and gravel was encountered below the asphalt in Borehole MS2-20. The thickness of the sand and gravel fill was 1.0 m. A



300mm thick layer of silty sand fill containing trace gravel and trace clay, was contacted below the sand and gravel fill at 1.1 m depth in Borehole MS2-20. The depth to the base of the cohesionless fill was at 1.4 m (Elevation 195.7).

SPT 'N' values within the cohesionless fill were 27 and 42 blows per 0.3 m penetration, indicating compact to dense condition. The measured moisture contents of samples of the cohesionless fill varied between 13 percent and 18 percent.

5.2.4 Silty Clay Till

An upper layer of brown silty clay till, some sand to with sand and trace gravel, was contacted below the fill and the sandy silt till, at 1.4 m and 1.8 m depths in Boreholes MS2-20 and SWM C2-2C, respectively. The thickness of this deposit ranged from 2.4 m to 3.2 m. The depth to the base of the upper silty clay till was at 3.8 m and 5.0 m (Elevations 193.4 and 192.6), in Boreholes MS2-20 and SWM C2-2C, respectively.

A lower layer of grey silt clay till, with sand and trace gravel, was contacted at 7.2 m and 7.5 m depth in Boreholes MS2-20 and SWM C2-2C, respectively. Boreholes MS2-20 and SWM C2-2C were terminated within the lower silty clay till at 12.8 m and 9.8 m depth (Elevations 184.4 and 187.8), respectively.

SPT 'N' values recorded in the cohesive till typically ranged from 11 blows per 0.3 m penetration to 50 blows for 0.125 m penetration, indicating a stiff to hard consistency. The measured moisture contents of samples of the cohesive till varied between 11 percent and 26 percent.

Grain size distribution results for the cohesive till samples tested are presented on the Record of Borehole sheets and on Figure B1 of Appendix B. Results of the gradation testing are summarized below:

Soil Particles	Percentage (%)
Gravel	0 to 2
Sand	19 to 31
Silt	31 to 40
Clay	29 to 48



The results of Atterberg Limits in the silty clay till are presented on the Record of Borehole sheets and in Figure B3 included in Appendix B. The results of Atterberg Limits testing are summarized below:

Index Property	Percentage (%)
Liquid Limit	18 to 26
Plasticity Index	7 to 12

The above results show that the cohesive till have typically low plasticity with a group symbol of CL.

Glacial tills inherently contain cobbles and boulders.

5.2.5 Sandy Silt Till

A 1.6-m thick layer of native brown sandy silt till containing some clay and trace gravel, was contacted below the topsoil in Borehole SWM C2-2C.

The depth to the base of the sandy silt till was at 1.8 m (Elevation 195.8).

SPT 'N' values recorded in the sandy silt till were 11 and 12 blows per 0.3 m penetration, indicating a compact condition.

Glacial tills inherently contain cobbles and boulders.

5.2.6 Sand and Silt

A layer of brown to grey sand and silt containing trace clay was contacted between the upper and lower silty clay tills at 3.8 m and 5.0 m depths in Boreholes MS2-20 and SWM C2-2C. The thickness of the sand and silt was 2.5 m and 3.4 m. The depth to the base of the sand and silt was at 7.2 m and 7.5 m (Elevations 190.0 and 190.1).

SPT 'N' values in the sand and silt varied from 12 to 20 blows per 0.3 m of penetration, indicating a compact state. Measured moisture contents of the sand and silt ranged from 17 percent to 23 percent.

Grain size distribution results of tested sand and silt samples are presented on the Record of Borehole sheets and on Figure B2 of Appendix B. The results of laboratory gradation tests are summarized as follows:



Soil Particles	Percentage (%)
Gravel	0
Sand	51 to 66
Silt	31 to 46
Clay	3

5.2.7 Water Levels

The groundwater levels in the open boreholes were observed and noted during and upon completion of drilling. The water levels measured in the installed piezometer and in the open boreholes upon completion of drilling are summarized in Table 5.2.

Table 5.2.- Measured Groundwater Levels

Borehole	Date	Water Level (m)		Comments
		Depth	Elevation	
MS2-20	July 9, 2018	4.6	192.6	Open borehole
SWM C2-2C	September 13, 2018	5.6	192.0	Piezometer
	September 17, 2018	4.7	192.9	
	November 21, 2018	3.2	194.4	

The above values are short term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

5.3 Sewer Lateral 33 at Pond 3 (Station 17+423) Boreholes MS2-08 and SWM C2-3C

Two boreholes, numbered MS2-08 and SWM C2-3C, were drilled near the alignment of Sewer Lateral 33 at Pond 3 located approximately 800 m south of Major Mackenzie Drive. Records of boreholes, laboratory testing results and stratigraphic drawings are presented in Appendix C.

5.3.1 Asphalt

Asphalt of between 150 mm and 200 mm in thickness was encountered surficially in Boreholes MS2-08 and SWM C2-3C.



5.3.2 Sand and Gravel Fill and Silty Clay Fill

Pavement granular fill materials consisting of brown sand and gravel, trace silt and trace clay were encountered below the asphalt in Boreholes MS2-08 and SWM C2-3C. The thickness of the granular fill was 600 mm. The depth to the base of the cohesionless fill was at 0.8 m (Elevations 203.4 to 203.5).

A 600 mm thick layer of brown silty clay fill containing trace sand, trace gravel and occasional organics and rootlets was contacted below the sand and gravel fill in Borehole SWM C2-3C.

SPT 'N' values in the granular fill ranged from 23 to 35 blows per 0.3 m of penetration, indicating a compact to dense state. An SPT 'N' value measured in the cohesive fill was 12 blows per 0.3 m of penetration, indicating a stiff consistency. The measured moisture contents of cohesionless fill samples ranged between 2 percent and 5 percent. A moisture content measured in the silty clay fill was 12 percent.

5.3.3 Silty Clay

A layer of native brown silty clay containing trace sand, was contacted below the silty clay fill at 1.4 m depth in Borehole SWM C2-3C. The thickness of the silty clay was 2.7 m. The depth to the base of the silty clay was at 4.1 m (Elevation 200.1).

SPT 'N' values measured in the silty clay ranged from 5 to 20 blows per 0.3 m of penetration indicating a firm to very stiff consistency. The measured moisture contents of samples of the cohesive soils varied between 20 percent and 34 percent.

Grain size distribution results for a cohesive soil sample are presented on the Record of Borehole sheets and on Figure C1 of Appendix C.

Soil Particles	Percentage (%)
Gravel	0
Sand	3
Silt	33
Clay	64

The results of Atterberg Limits testing in the silty clay are presented on the Record of Borehole sheets and in Figure C3 included in Appendix C. The results of Atterberg Limits testing are summarized below:



Index Property	Percentage (%)
Liquid Limit	42
Plasticity Index	21

The above results show that the silty clay has a medium plasticity with a group symbol of CI.

5.3.4 Sand and Silt

A layer of brown sand and silt containing trace gravel was contacted at 4.1 m depth in Borehole SWM C2-3C. The thickness of the sand and silt was 1.5 m. The depth to the base of the sand and silt was at 5.6 m (Elevations 198.6).

An SPT 'N' value recorded in the sand and silt layer was 37 blows per 0.3 m penetration, indicating a dense condition. The measured moisture content of a sample of the cohesionless soil was 12 percent.

5.3.5 Silty Clay Till

Brown to grey silty clay till with sand and trace gravel, was contacted below the sand and gravel in Borehole MS2-08 and below the sand and silt at 5.6 m depth in Borehole SWM C2-3C. Boreholes MS2-08 and SWM C2-3C were terminated at 8.2 m and 7.8m depths (Elevations 196.0 and 196.4), respectively.

SPT 'N' values measured in the silty clay till typically ranged from 14 to 42 blows per 0.3 m of penetration indicating a stiff to hard consistency. An SPT 'N' value of 100 blows for less than 0.3 m of penetration was measured in Borehole SWM C2-3C, near borehole termination depth indicating a hard consistency. This high 'N' value may also indicate the presence of cobbles or boulders. The measured moisture contents of samples of the cohesive till varied between 9 percent and 23 percent.

Grain size distribution results for the tested silty clay till samples are presented on the Record of Borehole sheets and on Figure C2 of Appendix C.

Soil Particles	Percentage (%)
Gravel	0 to 4
Sand	31 to 33
Silt	33 to 48
Clay	19 to 32



The results of Atterberg Limits for a sample of silty clay till are presented on the Record of Borehole sheets and in Figure C4 included in Appendix C. The results of Atterberg Limits testing are summarized below:

Index Property	Percentage (%)
Liquid Limit	20
Plasticity Index	8

The above results show that the silty clay till has a low plasticity with a group symbol of CL.

Glacial tills inherently contain cobbles and boulders.

5.3.6 Water Levels

The groundwater levels in the open boreholes were observed and noted during and upon completion of drilling. The water levels measured in the installed piezometer and in the open boreholes upon completion of drilling are summarized in Table 5.3.

Table 5.3.- Measured Groundwater Levels

Borehole	Date	Water Level (m)		Comments
		Depth	Elevation	
MS2-08	July 19, 2018	7.3	196.9	Open borehole
SWM C2-3C	October 21, 2018	dry	-	Piezometer
	November 21, 2018	7.5	196.7	

The above values are short term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

6. CORROSIVITY TEST RESULTS

Samples of the native silty clay till from Boreholes MS2-08, MS2-20 and MS2-32, were submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in Table 6.1 below. The laboratory certificates of analysis are presented in Appendix D.

Table 6.1- Analytical Test Results

Parameter	Units (Soil)	Test Results		
		MS2-08 SS 2 Depth 0.9 m	MS2-20 SS 4 Depth 2.4 m	MS2-32 SS 4 Depth 2.4 m
		Silty Clay Till	Silty Clay Till	Silty Clay Till
Sulphide	%	<0.02	<0.02	<0.02
Chloride	µg/g	250	190	880
Sulphate	µg/g	37	43	160
pH	-	9.43	8.54	8.23
Electrical Conductivity	µS/cm	447	293	688
Resistivity	Ohm.cm	2,240	3,410	1,450
Redox Potential	mV	253	252	260

7. MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. WSP provided the northing and easting coordinates and ground surface elevations.

Drill Tech Drilling of Newmarket, Ontario and Walker Drilling Ltd. of Utopia, Ontario, supplied and operated the drill rigs to carry out the drilling, sampling and in-situ testing operations for the boreholes.

The drilling and sampling operations in the field were supervised on a full time basis by Ms. Jacqueline Pigeon, Mr. Kevin Kweon and Mr. Saeed Bastan of Thurber. Geotechnical laboratory testing was carried out by Thurber in its MTO-approved laboratory. Overall supervision of the field program was carried out by Mr. Stephane Loranger, CET.

Overall project management was provided by Dr. Sydney Pang, P.Eng. Interpretation of the field data and preparation of this report was completed by Ms. Rocio Palomeque Reyna, P.Eng. The report was reviewed by Messrs. Sydney Pang, P.Eng. and P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



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Client: WSP
File No.: 15786

E file: H:\15000-15999\15786 Hwy 404 Widening 2016-E-0014\Reports and Memos\Contract 2\Lateral Sewers\FINAL\15786 Contract 2 Sewer
Laterals Hwy 404 FIDR feb 19.docx

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**FOUNDATION INVESTIGATION AND DESIGN REPORT
SEWER LATERALS
HIGHWAY 404 HOV LANE EXPANSION AND REHABILITATION
CONTRACT 2
FROM HIGHWAY 407 TO MAJOR MACKENZIE DRIVE
MARKHAM, ONTARIO
G.W.P. 2930-17-00**

GEOCRES NO. 30M14-496

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8. GENERAL

This section of the report presents interpretation of the geotechnical data presented in the factual information section and provides foundation recommendations for the design and installation of the sewer laterals along Highway 404 from Highway 407 to Major Mackenzie Drive (Contract 2) in the City of Markham, Ontario.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction contractor. The contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

Information on the general layout of the proposed sewer lateral locations was provided to Thurber by WSP prior to the commencement of the field work.

The subsurface stratigraphy revealed in the boreholes drilled near the proposed sewer laterals generally consists of surficial topsoil or pavement structure (asphalt, granular base/subbase) overlying embankment fill (silty clay, sandy silt), which is underlain by native, upper deposit of stiff to very stiff silty clay till overlying layers of compact sands and silts. A lower deposit of



very stiff to hard silty clay till was encountered below the cohesionless soils. Groundwater levels measured in piezometers installed in the vicinities of the sewer laterals ranged in the order of 2 m to 7 m depths below ground surface.

It is noted that the pipe bores as currently designed will be advanced through native glacial tills and existing highway fill of which both are known to contain oversized obstructions including boulders, cobbles and debris. Some of these obstructions may exist in clusters.

A summary of design information on the sewer laterals are presented in Tables 8.1 and 8.2 below which includes the soil types through which each pipe is anticipated to be installed. The locations and the soil stratigraphy near the proposed pipes are shown on the Borehole Locations and Soil Strata Drawings in Appendices A to C.

8.1 Median Sewer Lateral Design Information

Borehole	Station	Sewer Lateral ID	Pipe Invert Elevation (m)		Approx. Trenchless Length (m)	Pipe Diameter (mm)
			Inlet	Outlet		
MS2-32 SWM C2-1C	15+164	52 Pond1	186.4	186.2	42	900
MS2-20 SWM C2-2C	16+386	19 Pond 2	194.6	194.5	36	825
MS2-08 SWM C2-3C	17+423	33 Pond 3	201.9	201.8	39	750

8.2 Bore Face Size, Soil Conditions and Behaviour

Borehole	Station	Sewer Lateral ID	Pipe Diameter (mm)	Estimated Temporary Casing Diameter (mm)	Soil Type ⁽¹⁾ Around Pipe	Tunnelman's Ground Classification System
MS2-32 SWM C2-1C	15+164	52 Pond1	900	1,200 to 1,600 (possible)	Stiff silty clay till; possible mixed face with variable fill containing layers of boulders and cobbles	Firm to Ravelling (native) Running (cohesionless fill) Ravelling (cohesive fill)

MS2-20 SWM C2- 2C	16+386	19 Pond 2	825	1,200 to 1,600 (possible)	Stiff to very stiff silty clay till; possible mixed face with variable fill containing boulders and cobbles	Firm to Ravelling (native) Running (cohesionless fill)
MS2-08 SWM C2- 3C	17+423	33 Pond 3	750		Very stiff to hard silty clay to silty clay till: possible mixed face with variable fill containing boulders and cobbles	Firm to Ravelling (native) Running (cohesionless fill) Ravelling (cohesive fill)

(1) Reference must be made to the records of boreholes for detailed descriptions of soil type around the pipe.

The discussion and recommendations presented in this report are based on information provided by WSP to Thurber, and on the factual data obtained during the course of this investigation.

9. SEWER LATERAL INSTALLATION

Installation of the sewer laterals will be carried out as part of the highway reconstruction. The sewer laterals will be perpendicular to the Highway 404 centreline, and run under the Highway 404 SBL, from the new median sewer towards the proposed Ponds 1 to 3 which will be located on the west side of the highway.

9.1 Installation in Open Cut

Staged open excavation is technically feasible and generally carries lesser risk than the trenchless methods in terms of potential ground settlement. This method also facilitates removal of obstructions such as boulders and cobbles. However, open cut construction would result in disruption to Highway 404 traffic flow amongst other logistics issues. Temporary protection (shoring) systems and groundwater control will be required. This approach will require MTO approval and it is understood that the current design approach avoids open excavation. Trenchless techniques are currently being considered for the installation of the sewer lateral pipes.



Since open cutting is not considered practical at these sites, foundation recommendations for sewer laterals installed by supported open cuts were not developed in this report.

From a foundation engineering standpoint, concrete, steel and HDPE pipes are technically feasible alternatives, provided that other design issues including flow capacity, hydraulic properties and durability can also be satisfied.

The new sewer lateral pipes should be designed to resist external loadings including lateral earth pressures, weight of embankment fill, hydrostatic pressure, frost forces, traffic loadings and surcharges due to construction equipment.

9.2 Trenchless Methods

Consideration may be given to installing the pipes by trenchless techniques provided that there is sufficient crown cover. 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. Table 9.1 summarizes the crown cover for the proposed pipes under the various criteria.

Table 9.1 – Crown Cover for the Proposed Pipes

Median Sewer Lateral ID	Pipe Diameter (m)	Invert Elevation (m)	Crown Cover Below Top of Pavement and Ground Surface (m)	Crown Cover Below U/S of Pavement (m)	Comments on Crown Cover ⁽¹⁾
52 (Pond 1)	900	186.4 (inlet)	2.2	0.8	< 3 m below pavement top < 2 m below pavement u/s > 2 times pipe diameter
		186.2 (outlet)	2.4 ⁽²⁾	-	> 2 times pipe diameter
	Casing diameter up to 1.6m	-	-	-	< 2 times casing diameter

19 (Pond 2)	825	194.6 (inlet)	1.8	0.7	< 3 m below pavement top < 2 m below pavement u/s > 2 times pipe diameter
		194.5 (outlet)	1.9 ⁽²⁾	-	> 2 times pipe diameter
	Casing diameter up to 1.6m	-	-	-	< 2 times casing diameter
33 (Pond 3)	750	201.9 (inlet)	1.5	0.7	< 3 m below pavement top < 2 m below pavement u/s > 2 times pipe diameter
		201.8 (outlet)	1.6	0.8	< 3 m below pavement top < 2 m below pavement u/s > 2 times pipe diameter
	Casing diameter up to 1.6m	-	-	-	< 2 times casing diameter

(1) Reference must be made to the records of boreholes for detailed descriptions of soil type around the pipe.

(2) Crown cover below existing ground surface.

Most sewer lateral pipes placed at the proposed invert elevations will not meet some of the criteria as indicated in the table above. Given that the casing used during installation will be larger than the pipe diameter and can be up to 1.6 m based on the Contract 1 construction, which resulted in an actual crown cover of less than 2 times the casing diameter, the risks of pavement settlement and formation of sinkholes become high. Moreover, the large casing diameter would likely result in a mixed face condition of fill overlying native till, thus increasing the risks of encountering oversized obstructions such as boulders and cobbles that can be present within the fill embankment. In order to reduce such risks, a combination of the following alternatives may be considered:

- 1) Lower the pipe invert elevations to meet the criterion. WSP has confirmed that the pipe invert elevations cannot be lowered.
- 2) Replace larger diameter pipes with multiple smaller diameter pipes that would sufficiently increase the crown cover.



- 3) 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.
- 4) Construct the pipe crossings using staged open cutting.

All work must be carried out in 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 F.

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

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

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 F.

Based on the available subsurface information, the majority of the sewer lateral pipes under Highway 404 in Contract 2 will be installed through the cohesive stiff to very stiff upper silty clay to silty clay till (see Table 8.1). It must be noted that there is a possibility of the cohesionless fill daylighting at the tunnel face at some locations. Cobbles and boulders should be anticipated within the glacial till deposits. Where casings, especially larger diameter ones, are used during installation, it is likely that mixed face conditions of fill overlying native tills would be encountered. This scenario involves relatively high risks of encountering oversized obstructions such as boulders and cobbles that may be present within the fill embankment, and ravelling to running conditions at the bore face where water seepage is present.



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

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.

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

Pipe ramming involves advancing a liner (typically steel casing or sleeve) along the proposed alignment. Once the liner is in place, the new pipes may then be threaded through the liner and grouted in place. Should obstructions be encountered during installation, however, the potential of pipe mis-alignment would be increased. This method may generally be considered at locations where the pipes are to be installed through sands and silts below the groundwater level.

Conventional jack and bore technique involves augering and jacking a steel liner in place, although direct jacking of concrete pipes is possible in some situations. The jack and bore technique is considered feasible for installing the sewer lateral pipes where cohesive soils are anticipated, but the equipment must be capable of excavating and advancing through cobbles and boulders and any other obstructions that may be present in the fill and glacial till materials. It is recommended that preference be given to using equipment with alignment adjustment capabilities. At locations where cohesionless fill may daylight at the tunnel face with water seepage, groundwater control will be required and the risk of tunnel face instability increases.

From a foundations technical, constructability and risk management perspective, it is considered that micro-tunnelling carries relatively lower risks. Pipe ramming carries a certain degree of risk associated with potential surface settlement due to the relatively shallow soil crown cover below the pavement at most locations. Jack and bore techniques are feasible for cohesive soils, but carry a higher risk of causing surface settlement if used at locations where sands and silts, especially under the groundwater level, are present and also a higher risk of causing delay if oversized obstructions are encountered at the tunnel face. 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. Relative advantages and disadvantages of these methods are summarized in Appendix E.

In addition to the NSSP referenced above, it is recommended that the Contractor be alerted to the following points, either by a further NSSP or otherwise by inclusion in the Contract Documents in an appropriate manner:

- The fill materials and glacial till deposits may contain cobbles and boulders. In particular, fill inherently has a variable composition and may contain large boulders at this site. The Contractor must select a methodology that can adapt to varying composition and behaviour of the fill, and must be equipped to dislodge, remove and otherwise handle such obstructions at the tunnel face should it be required. Open cutting disrupts highway traffic operation and introduces risks of post construction settlement and, therefore, should not be considered until other available means of dealing with obstructions are exhausted.
- The Contractor shall maintain the soil cover above the crown of the casing at a minimum two (2) times the casing diameter at all times.
- The pipe installation will largely be carried out through cohesive stiff to hard silty clay to silty clay till. The Contractor's equipment must be capable of advancing the pipes through the cohesive deposit.
- It must be noted that there is a possibility of cohesionless fill daylighting at the tunnel face at some locations. Such occurrence carries risks of loss of ground due to sloughing or caving especially if water seepage is present. The Contractor's methodology must include means of handling potential sloughing of these soils and water seepage at the tunnel face.

A NSSP for the above is included in Appendix F.

Based on groundwater observations and measurements in the boreholes, groundwater control will be required during construction where sands and silts are present below the groundwater level or where water seepage is anticipated. Dewatering will be required at the launching and receiving pits at these locations.

Groundwater seepage from the cohesive soils is anticipated to be minimal. It is anticipated that sumps and pumps should be adequate to handle groundwater and surface runoff entering the launching and receiving pits.

The Contractor is responsible for maintaining dry excavations during construction.



10. INSTRUMENTATION AND MONITORING PROGRAM

Instrumentation and monitoring for potential settlements on the highway will be required for trenchless construction methods.

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.

A monitoring program and condition survey of the Highway 404 pavement in the proximity of the sewer lateral pipes has been prepared in general accordance with MTO's Guidelines for Foundation Engineering - Tunnelling Specialty for Corridor Encroachment Permit Application.

Detailed specifications and drawings for the implementation of the monitoring program are presented in Appendix G.

11. TEMPORARY PITS AND TEMPORARY PROTECTION (SHORING)

Temporary launching and receiving pit excavations at either end of each sewer lateral crossing will extend through the embankment fill to the upper very stiff to hard silty clay till and very stiff silty clay. All temporary excavations must be carried out in accordance with the current Occupational Health and Safety Act (OHSA) of Ontario and local regulations. The native soils at this site are classified as Type 3 soils under OHSA. The cohesionless fill with anticipated water seepage, and sands and silts below the groundwater level are classified as Type 4 soils.

Where temporary pit excavation for the pipe installation is located in close proximity to live traffic lanes or existing buried utilities, temporary protection (shoring) will be required. Given the subsurface conditions, a braced soldier pile and wood lagging system may be considered as an option at these sites. It is envisaged that shoring piles should be embedded within the native stiff to hard silty clay till, or compact sands and silts. A soldier pile and lagging system will need to be implemented in conjunction with adequate groundwater control including dewatering. It is anticipated that sump pumping will be required at all work locations to maintain reasonably dry excavations throughout construction.



Design of the temporary protection (shoring) system is the responsibility of the Contractor. The temporary shoring should be designed by a licensed Professional Engineer experienced in such designs, with consideration of adjacent traffic loads and any sloping retained surfaces. Protection systems should be provided as per OPSS.PROV 539, which should be included in the contract documents. Performance Level 2 corresponding to not more than 25 mm ground movement should be specified.

The parameters given below should be used for roadway protection design:

Soil Bulk Unit Weight	γ	=	20 kN/m ³
Soil Submerged Unit Weight (below gwl)	γ'	=	10 kN/m ³
Coefficient of Active Pressure	K_a	=	0.33 (embankment fill)
		=	0.31 (native silty clay/silty clay till)
		=	0.33 (native sands and silts)
Coefficient of Passive Pressure	K_p	=	3.0 (embankment fill)
		=	3.2 (native silty clay/silty clay till)
		=	3.0 (native sands and silts)

12. CORROSION POTENTIAL

The results of corrosivity testing conducted on three soil samples of the silty clay till are summarized in the previous Section 6 and the full results are included in Appendix D. Based on the test results, the following statements can be made.

- There is moderate potential for corrosion on metals due to the relatively low resistivity values and the chloride concentrations.
- The potential for sulphate attack on concrete from the surrounding soils is considered negligible due to the low concentration of sulphate in the samples tested.
- The effects of road de-icing salts should be considered when selecting the corrosion mitigation measures.

13. CONSTRUCTION CONCERNS

Potential construction concerns that have been identified for this project include the following:



13.1 Loss of ground

Trenchless installations with relatively shallow soil crown cover below the highway top of pavement and daylighting of cohesionless fill with water seepage inherently include risks of loss of ground into the bore. If it is significant, this loss of ground can create settlement of the pavement surface and safety hazards. Pipe horizontal alignment control is also important to confirm that the design of the sewer lateral alignments remains intact. The Contractor's methodology selection must recognize these facts and take into consideration these inherent risks. Contingency plans should be in place to manage any adverse impacts on the highway.

Each of the feasible trenchless methods discussed in Section 9 above carries varying degree of risks of loss of ground. The higher risks are associated with cohesionless fill with water seepage. The Contractor is required to select a suitable method for the installation of the sewer laterals 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.

13.2 Obstructions and Face Conditions

Glacial tills typically contain cobbles and boulders, and the existing highway embankment fill may contain similar and other obstructions. The Contractor's equipment and methodology must be capable of adapting to varying composition and behaviour of the fill, and to handle such obstructions and successfully remove them without jeopardizing the highway. The selected trenchless installation methodology should be capable of mitigating potential pipe mis-alignments (horizontal and vertical) due to such obstructions. Methods of removal of oversized obstructions should attempt to avoid disruption of highway traffic (such as open cutting) and lengthy delays to the installation schedule.

Mixed face conditions of fill overlying native tills should be anticipated. This scenario involves relatively high risks of encountering oversized obstructions such as boulders and cobbles that may be present within the fill embankment, and ravelling to running conditions at the bore face where water seepage is present.



13.3 Buried Utilities

The Contractor must accurately establish, in three dimensions, the locations of all buried utilities crossing or closely paralleling the path of the bore. Any discrepancy from the Contract Drawings must be reported to the Contract Administrator.

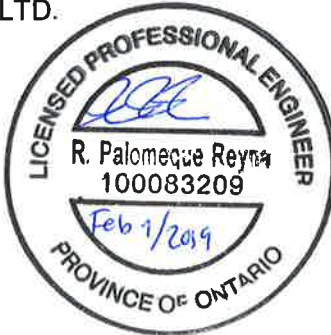
14. CLOSURE

Engineering analysis and preparation of the foundation design report was conducted by Ms. Rocío Palomeque Reyna, P.Eng and Dr. Sydney Pang, P.Eng.

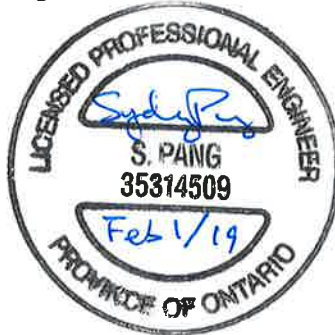
Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects, reviewed the report.



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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

C_{pen} 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.

UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS W _L < 50%	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. (W _L < 30%).
		CI	Inorganic clays of medium plasticity, silty clays. (30% < W _L < 50%).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS W _L > 50%	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

EXPLANATION OF ROCK LOGGING TERMS

<u>ROCK WEATHERING CLASSIFICATION</u>		<u>SYMBOLS</u>	
Fresh (FR)	No visible signs of weathering.		
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.		CLAYSTONE
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SILTSTONE
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.		SANDSTONE
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.		COAL
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.		Bedrock (general)

<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Very thinly bedded	20 to 60mm				
Laminated	6 to 20mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Thinly Laminated	Less than 6mm				

<u>TERMS</u>						
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty Can be peeled by a pocket knife, crumbles under firm blows of geological pick. Indented by thumbnail	
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Very Weak	1.0 to 5.0	150 to 750		
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150		
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen					
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.					



Appendix A

Sewer Lateral 52 at Pond 1 - (Station 15+164) Boreholes MS2-32 and SWM C2-1C

- Record of Borehole Sheets
- Laboratory Test Results
- Drawings titled "Borehole Locations and Soil Strata"

RECORD OF BOREHOLE No MS 2-32

1 OF 2

METRIC

GWP# 2930-17-00 LOCATION N 4 857 318.0 E 314 994.2 ORIGINATED BY BL
 HWY 404 BOREHOLE TYPE Hollow Stem Augers/Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.08.09 - 2018.08.09 LATITUDE 43.855762 LONGITUDE -79.373194 CHECKED BY RD

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										
189.5	GROUND SURFACE							20	40	60	80	100						
0.0	ASPHALT (150mm)							20	40	60	80	100						
0.2	SAND and GRAVEL, trace silt, trace clay Compact Brown Moist (FILL)		1	SS	12		189											
			2	SS	18													
188.1	Silty CLAY, some sand, trace gravel Very Stiff to Stiff Brown Moist (TILL)		3	SS	28		188											
1.4	occasional organics at 2.4m		4	SS	8		187											
			5	SS	8		186											
185.4	Sandy SILT, trace to some clay Compact Grey Wet		6	SS	10		185											
4.1							184											
			7	SS	25		183											
	trace gravel						182											
			8	SS	21		181											
							180											
			9	SS	41													
179.5																		

Borehole was initially terminated at 6.7m and piezometer installed. Another adjacent borehole was advanced without sampling to 6.7m below which sampling was continued.

Continued Next Page

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

RECORD OF BOREHOLE No MS 2-32

2 OF 2

METRIC

GWP# 2930-17-00 LOCATION N 4 857 318.0 E 314 994.2 ORIGINATED BY BL
 HWY 404 BOREHOLE TYPE Hollow Stem Augers/Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.08.09 - 2018.08.09 LATITUDE 43.855762 LONGITUDE -79.373194 CHECKED BY RD

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%) W _p W W _L				
10.0	Continued From Previous Page Silty CLAY , some sand, trace gravel Hard Grey Moist (TILL)						179										
			10	SS	62												
							178										
177.0			11	SS	100/												
12.5	END OF BOREHOLE AT 12.5m. WATER LEVEL AT 2.0m DEPTH BEFORE BOREHOLE CAVING TO 1.5m UPON COMPLETION. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2018.09.30 2.2 187.3 2018.11.22 2.9 186.6				0.250												

RECORD OF BOREHOLE No SWM C2-1C 1 OF 2 METRIC

GWP# 2930-17-00 LOCATION N 4 857 314.9 E 314 942.1 ORIGINATED BY JNP
 HWY 404 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.09.24 - 2018.09.24 LATITUDE 43.855735 LONGITUDE -79.373842 CHECKED BY RD

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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
189.3	GROUND SURFACE							20	40	60	80	100				
0.0 0.1	TOPSOIL: (75mm)															
	Silty CLAY , with sand, some gravel, some cobbles and boulders Stiff to Very Stiff Brown Moist (FILL)		1	SS	10		189									
			2	SS	50/ 0.075											
			3	SS	100/ 0.075		188									
187.3	Silty CLAY , some sand, trace gravel Stiff Brown Moist (TILL)		4	SS	14		187									
			5	SS	12		186									3 15 27 55
185.0	Silty SAND , trace clay, trace gravel Compact Grey Wet		6	SS	16		185									
							184									
182.8	Clayey SILT , with sand, trace gravel Very Stiff Grey Moist (TILL)		7	SS	17		183									
6.5			8	SS	22		182									0 49 33 18
180.2	SAND , trace gravel, trace silt and clay Compact Brown Wet		9	SS	16		180									3 90 7 (SI+CL)
9.1																
179.5																
9.8	END OF BOREHOLE AT 9.8m															

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

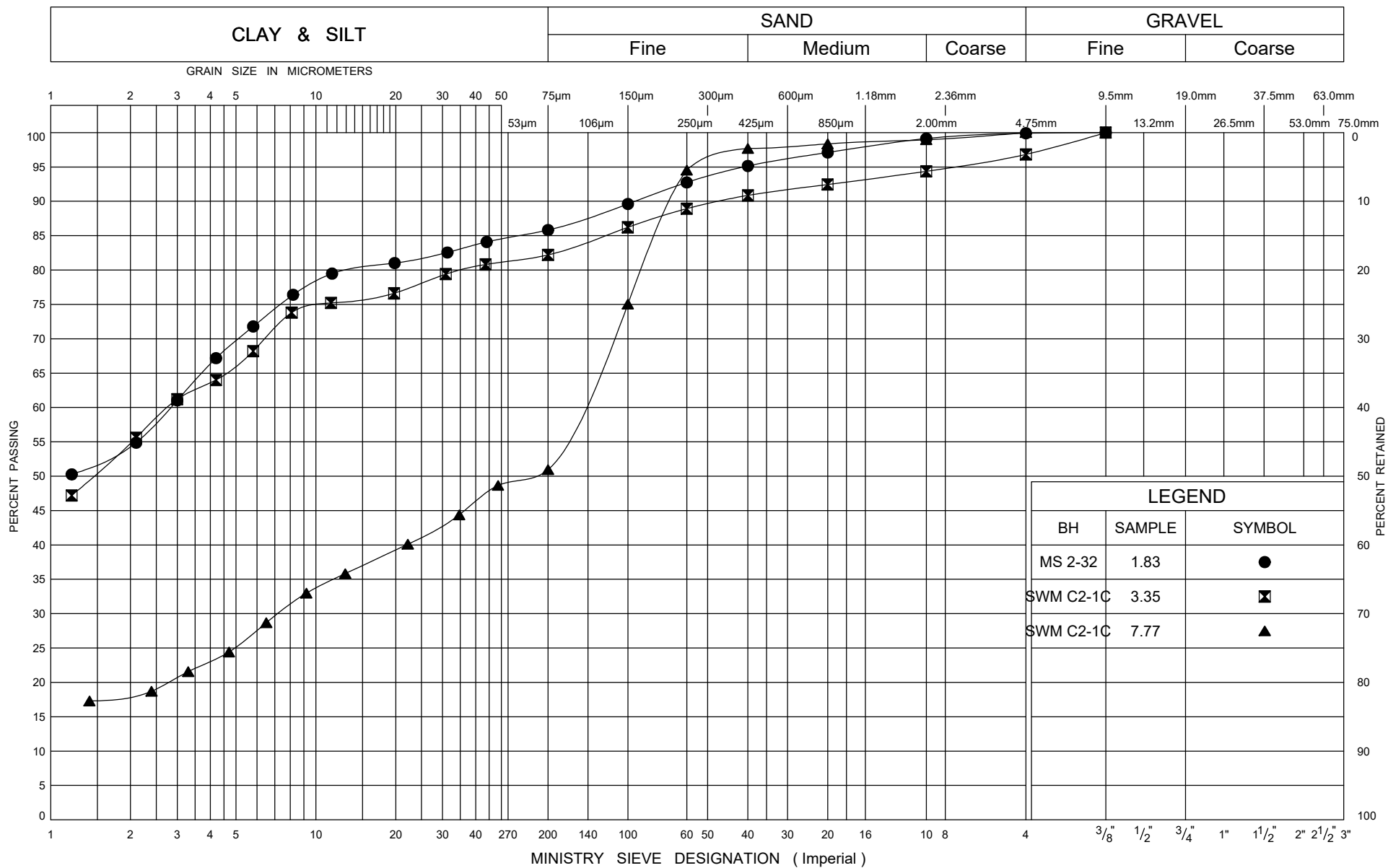
20
15
10
(%) STRAIN AT FAILURE

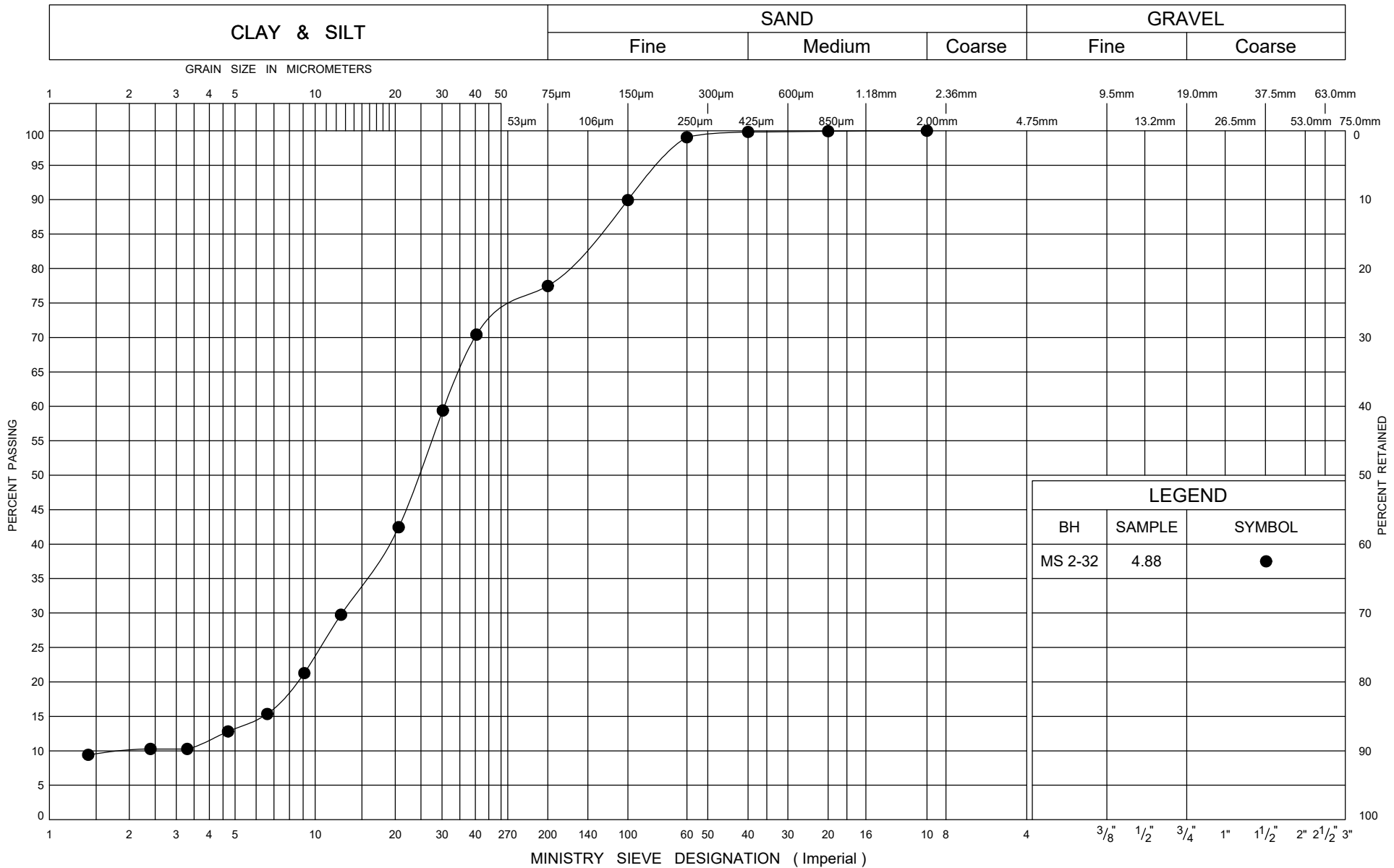
RECORD OF BOREHOLE No SWM C2-1C 2 OF 2 METRIC

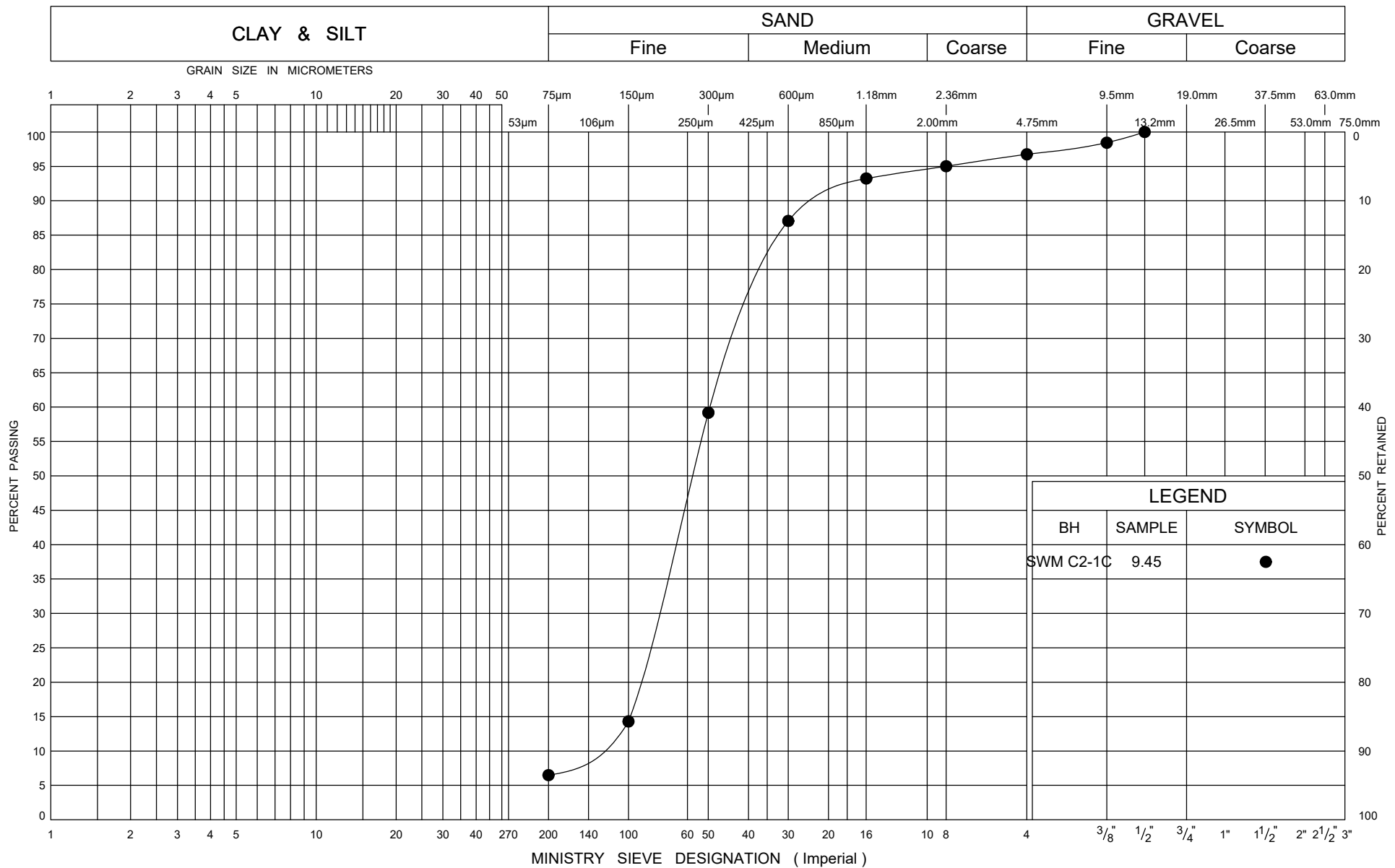
GWP# 2930-17-00 LOCATION N 4 857 314.9 E 314 942.1 ORIGINATED BY JNP
 HWY 404 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.09.24 - 2018.09.24 LATITUDE 43.855735 LONGITUDE -79.373842 CHECKED BY RD

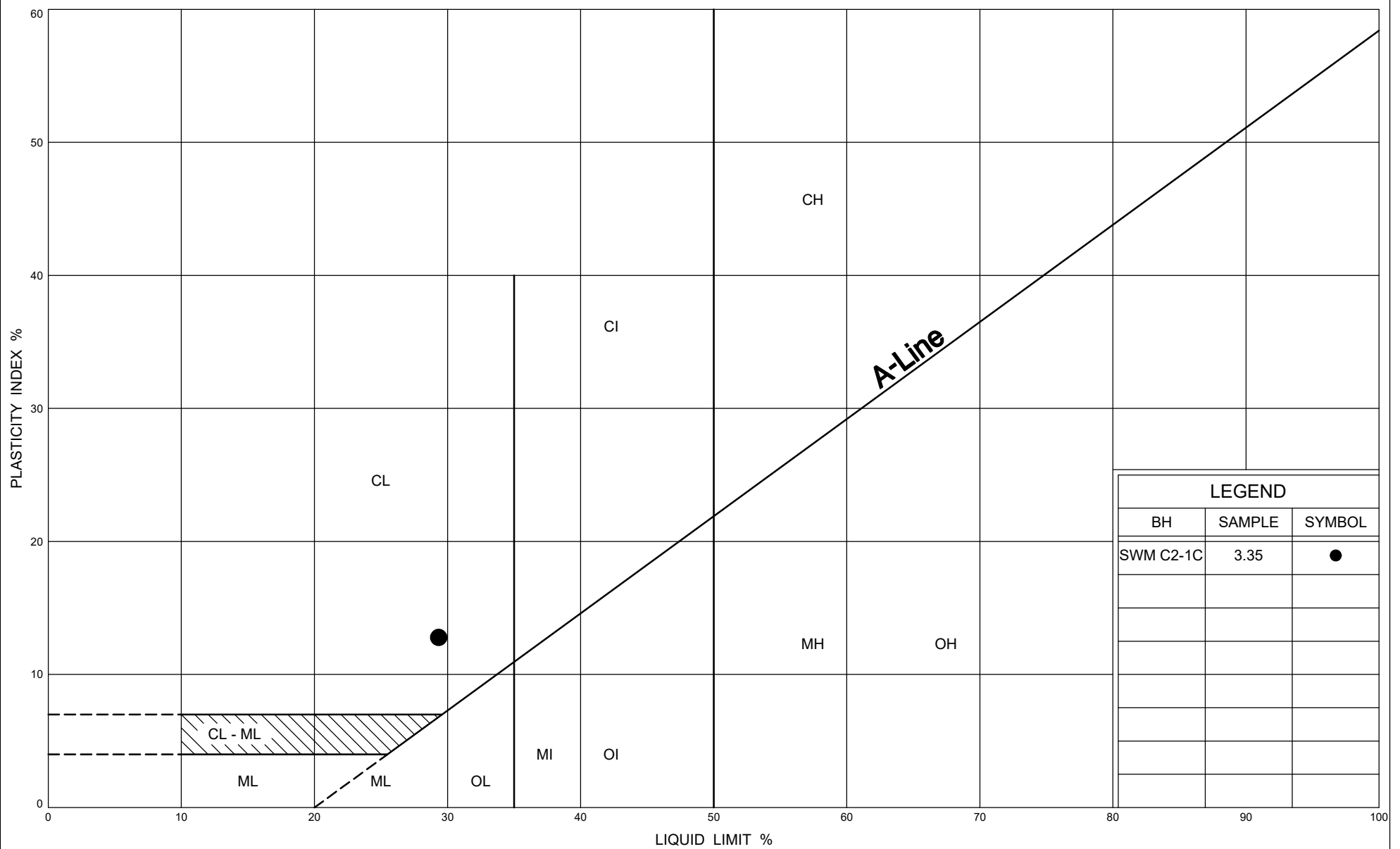
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
	Continued From Previous Page																
	Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2018.11.22 2.8 186.5																

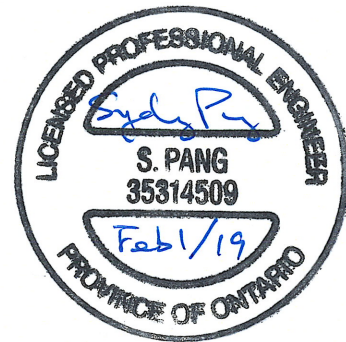
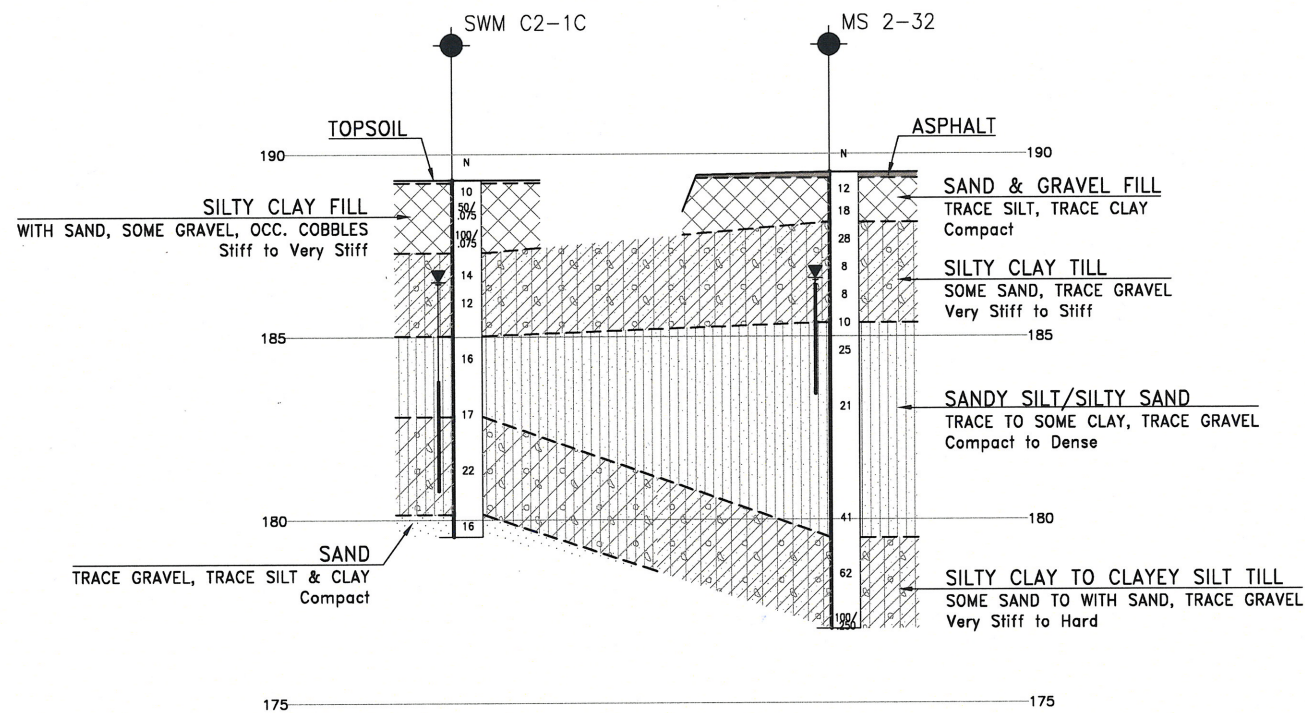
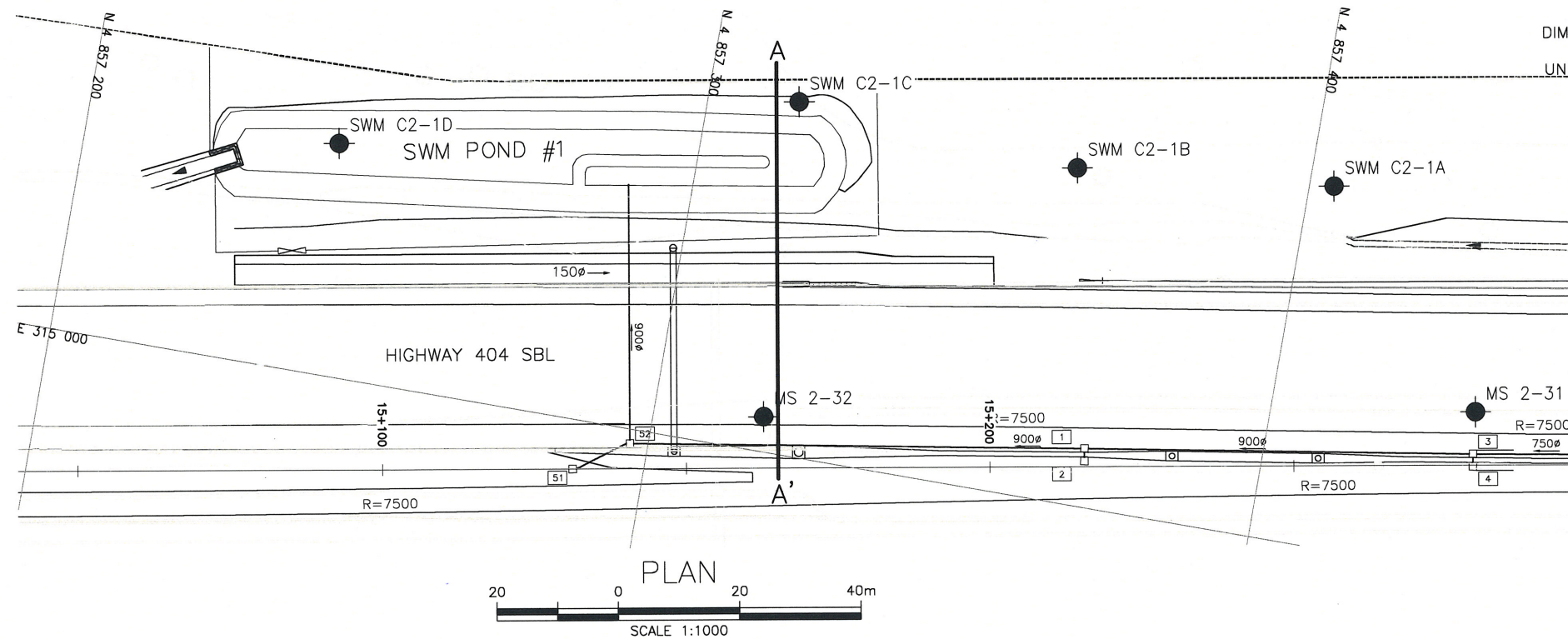
ONTMT452 MTO-15786.GPJ 2017TEMPLATE(MTO).GDT 2/1/19











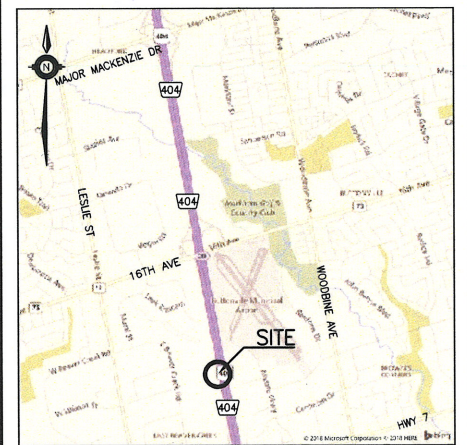
CONT No
GWP No 2930-17-00

HIGHWAY 404 WIDENING
SEWER LATERAL 52
STA 15+164
BOREHOLE LOCATIONS AND SOIL STRATA

wsp



THURBER ENGINEERING LTD.



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
SWM C2-1A	189.8	4 857 404.0	314 940.7
SWM C2-1B	189.4	4 857 361.9	314 945.0
SWM C2-1C	189.3	4 857 314.9	314 942.1
SWM C2-1D	188.1	4 857 241.5	314 961.8
MS 2-31	189.4	4 857 433.4	314 973.3
MS 2-32	189.5	4 857 318.0	314 994.2

-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. 30M14-496

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	RPR	CHK SKP	CODE
DRAWN	AN	CHK RPR	SITE
LOAD	DATE	FEB 2019	
STRUCT	DWG	1	



Appendix B

Sewer Lateral 19 at Pond 2 – (Station 16+386) Boreholes MS2-20 and SWM C2-2C

- Record of Borehole Sheets
- Laboratory Test Results
- Drawings titled “Borehole Locations and Soil Strata”

RECORD OF BOREHOLE No MS 2-20

1 OF 2

METRIC

GWP# 2930-17-00 LOCATION N 4 858 520.8 E 314 799.0 ORIGINATED BY BL
 HWY 404 BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.07.09 - 2018.07.09 LATITUDE 43.866591 LONGITUDE -79.375600 CHECKED BY RD

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 (%)				
197.2	GROUND SURFACE							20	40	60	80	100						
0.0	ASPHALT (75mm)						197											
0.1	SAND and GRAVEL Compact Brown Moist (FILL)		1	SS	27									○				
196.1			2	SS	42		196							○				
1.1	Silty SAND, trace gravel, trace clay Dense													○				
195.7	Brown Wet (FILL)													○				
1.4	Silty CLAY, with sand, trace gravel Very Stiff to Hard Brown Moist (TILL)		3	SS	27		195							○				0 24 40 36
			4	SS	17									○				
			5	SS	32		194							○				
193.4																		
3.8	SAND and SILT, trace clay Compact Brown Wet		6	SS	12		193							○				0 66 31 3
							192											
							191							○				
			7	SS	20													
190.0							190							○				
7.2	Silty CLAY, with sand, trace gravel Hard Grey Moist to Wet (TILL)		8	SS	36		189											
							188							○				
			9	SS	36													

Continued Next Page


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

RECORD OF BOREHOLE No MS 2-20

2 OF 2

METRIC

GWP# 2930-17-00 LOCATION N 4 858 520.8 E 314 799.0 ORIGINATED BY BL
 HWY 404 BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.07.09 - 2018.07.09 LATITUDE 43.866591 LONGITUDE -79.375600 CHECKED BY RD

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 (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
	Continued From Previous Page							20	40	60	80	100								
	Silty CLAY , with sand, trace gravel Hard Grey Moist (TILL)		10	SS	46		187										2 31 38 29			
							186													
							185													
184.4			11	SS	50/ 0.125															
12.8	END OF BOREHOLE AT 12.8m. WATER LEVEL AT 4.6m DEPTH BEFORE BOREHOLE CAVING TO 4.3m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 3.0m, AUGER CUTTINGS TO 0.6m, BENTONITE HOLEPLUG TO 0.1m, THEN COLD PATCH ASPHALT TO SURFACE.																			

RECORD OF BOREHOLE No SWM C2-2C 1 OF 2 METRIC

GWP# 2930-17-00 LOCATION N 4 858 538.0 E 314 733.3 ORIGINATED BY JNP
 HWY 404 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.09.13 - 2018.09.13 LATITUDE 43.866747 LONGITUDE -79.376417 CHECKED BY RD

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											
197.6	GROUND SURFACE							20	40	60	80	100							
0.0	TOPSOIL: (175mm)																		
0.2	Sandy SILT , some clay, trace gravel Compact Brown Moist (TILL)		1	SS	12		197												
			2	SS	12		196												
195.8			3	SS	11		195												
1.8	Silty CLAY , some sand, trace gravel, occasional oxide stains Stiff to Very Stiff Brown Moist (TILL)		4	SS	21		194												
			5	SS	15		193												
			6	SS	15		192												
192.6							191												
5.0	SAND and SILT , trace clay Compact Grey Wet		7	SS	16		190												
							189												
190.1							188												
7.5	Silty CLAY , with sand, trace gravel Stiff to Very Stiff Grey Moist (TILL)		8	SS	13														
			9	SS	19														
187.8																			
9.8	END OF BOREHOLE AT 9.8m.																		

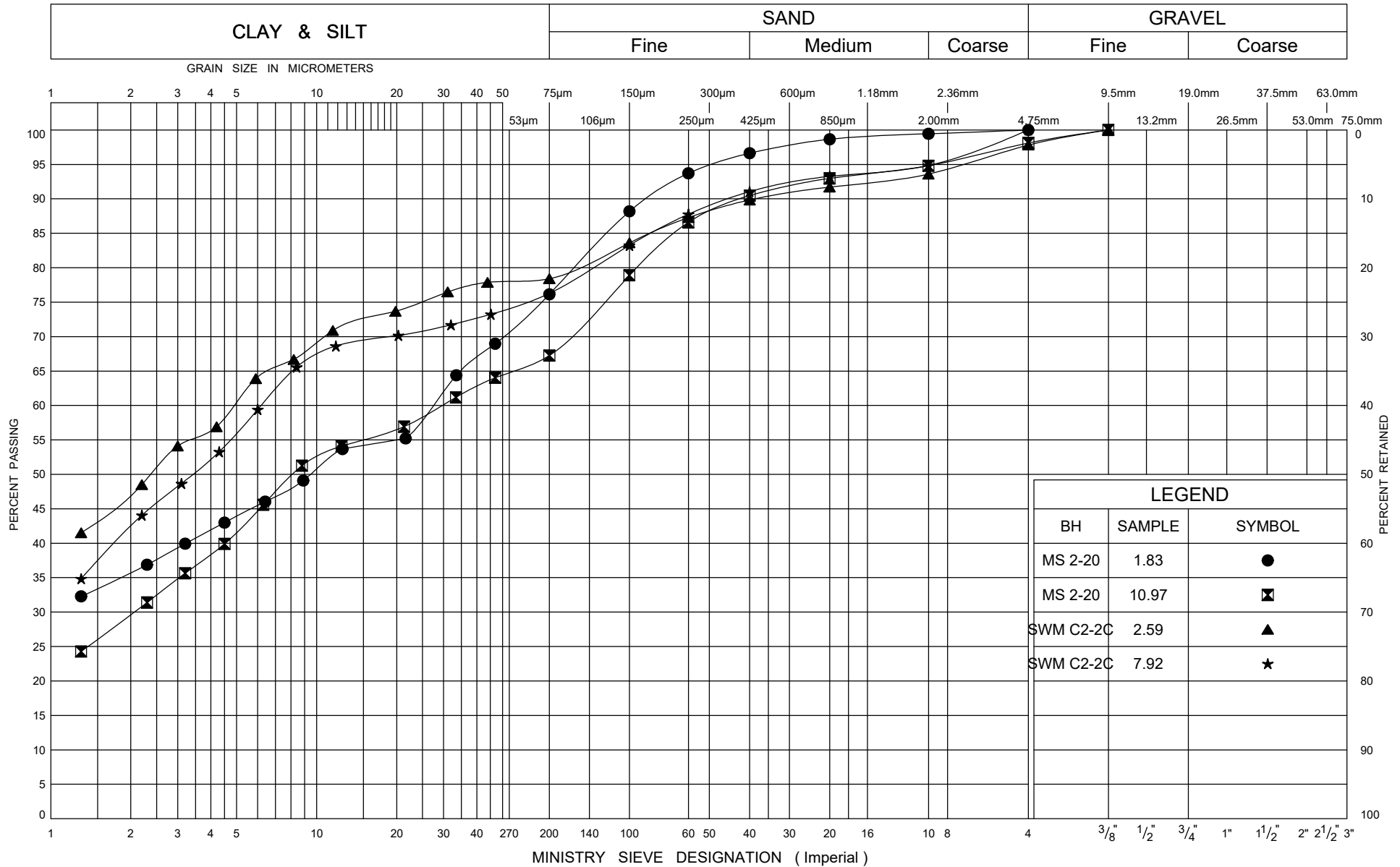
Continued Next Page

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

RECORD OF BOREHOLE No SWM C2-2C 2 OF 2 METRIC

GWP# 2930-17-00 LOCATION N 4 858 538.0 E 314 733.3 ORIGINATED BY JNP
 HWY 404 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.09.13 - 2018.09.13 LATITUDE 43.866747 LONGITUDE -79.376417 CHECKED BY RD

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			20	40	60	80	100					
	Continued From Previous Page																
	WATER LEVEL AT 5.6m UPON COMPLETION. Well installation consists of 25mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2018.09.13 5.6 192.0 2018.09.17 4.7 192.9 2018.11.22 3.2 194.4																



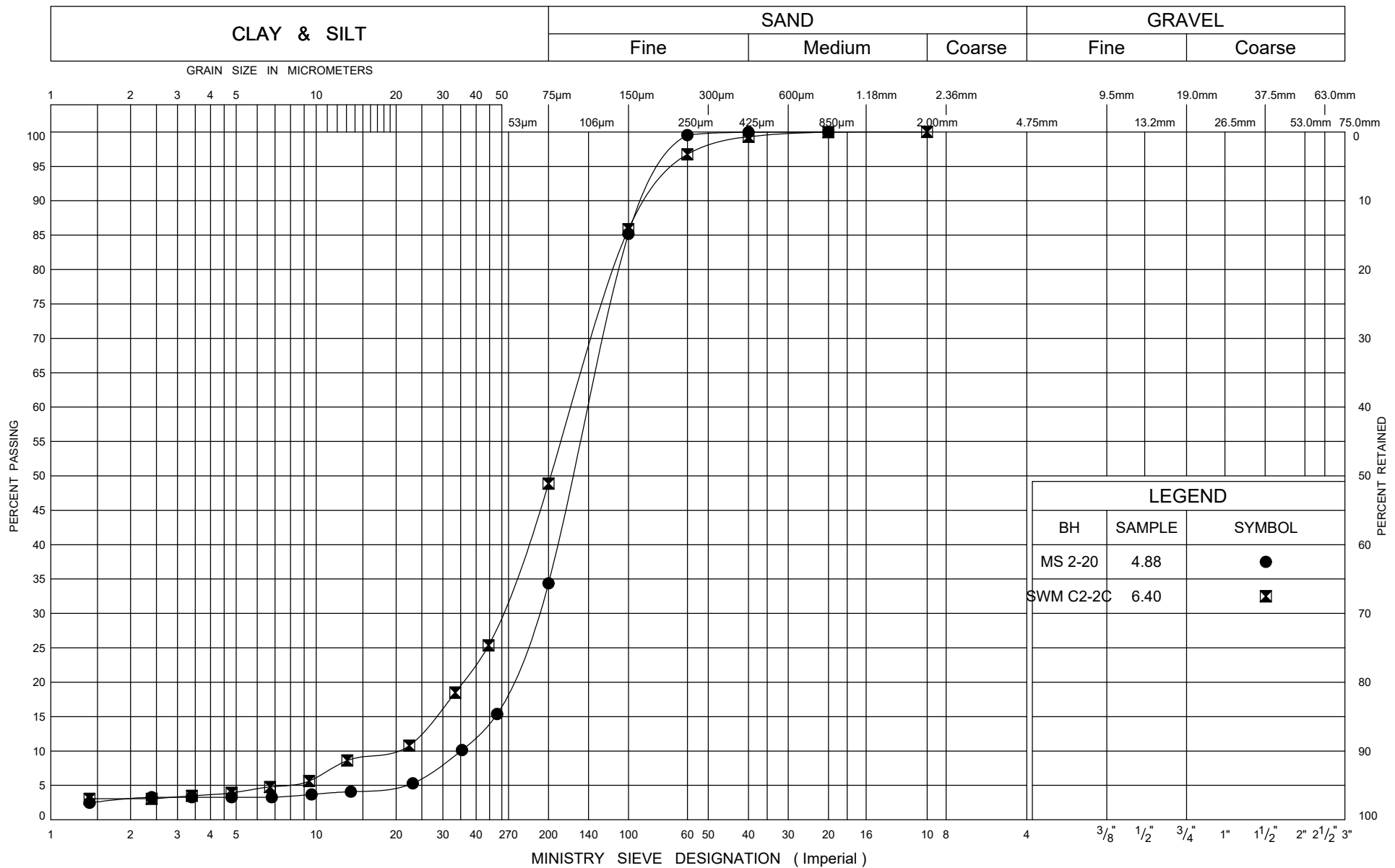
Ministry of
Transportation

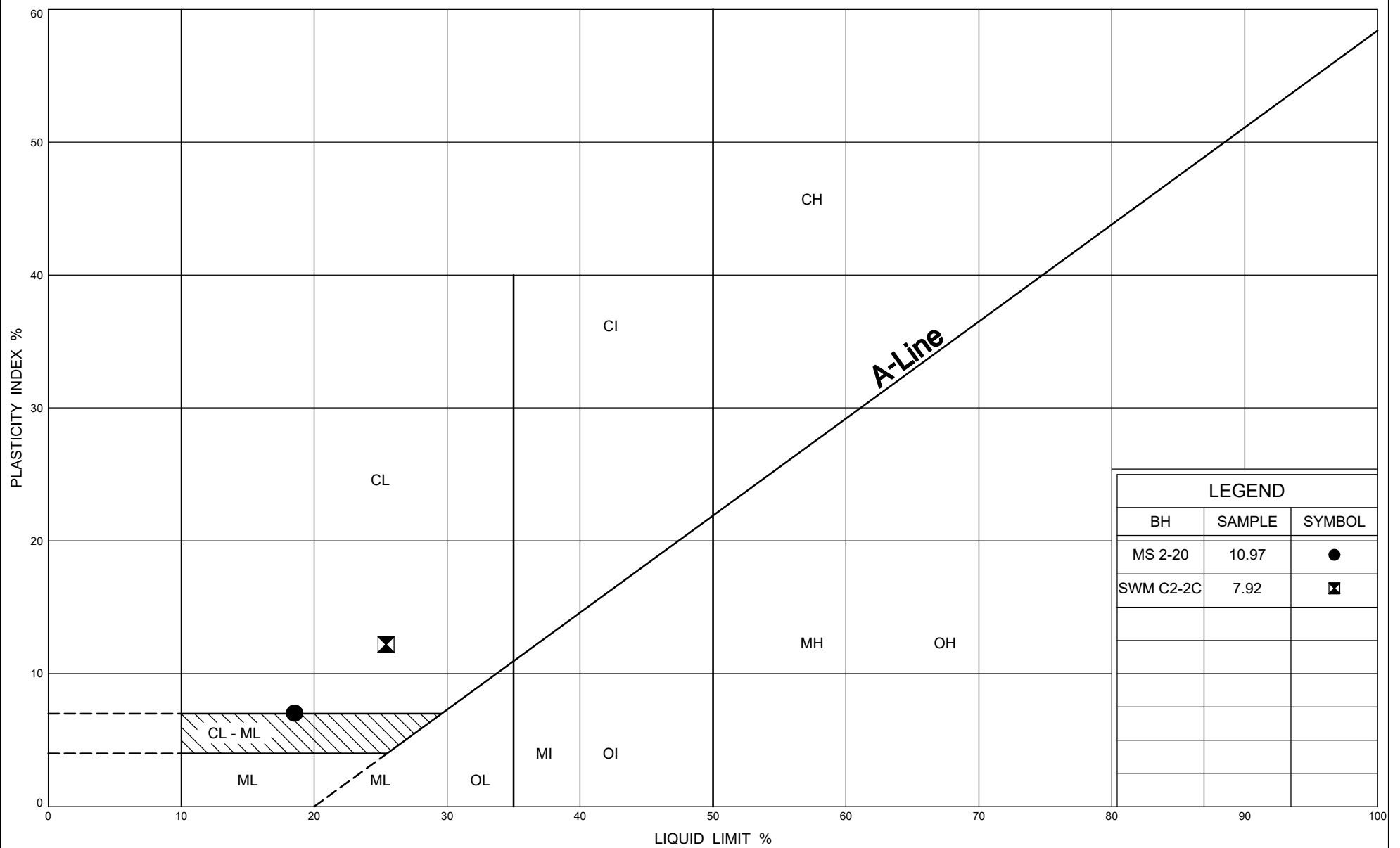
GRAIN SIZE DISTRIBUTION

Silty CLAY TILL

FIG No B1

G W P 2930-17-00





Ministry of
Transportation

PLASTICITY CHART

Silty CLAY TILL

FIG No B3

G W P 2930-17-00

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

CONT No
GWP No 2930-17-00

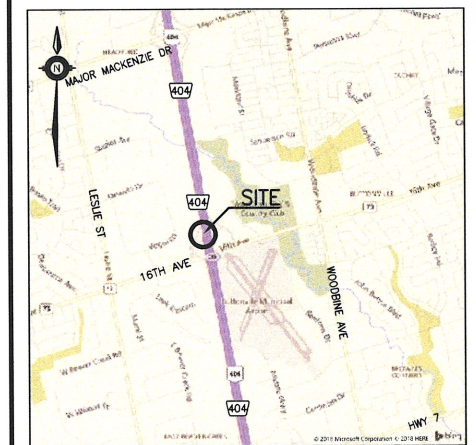


HIGHWAY 404 WIDENING
SEWER LATERAL 19
STA 16+386
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET








THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

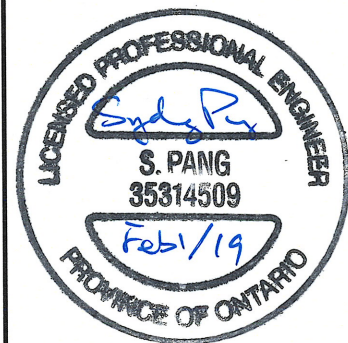
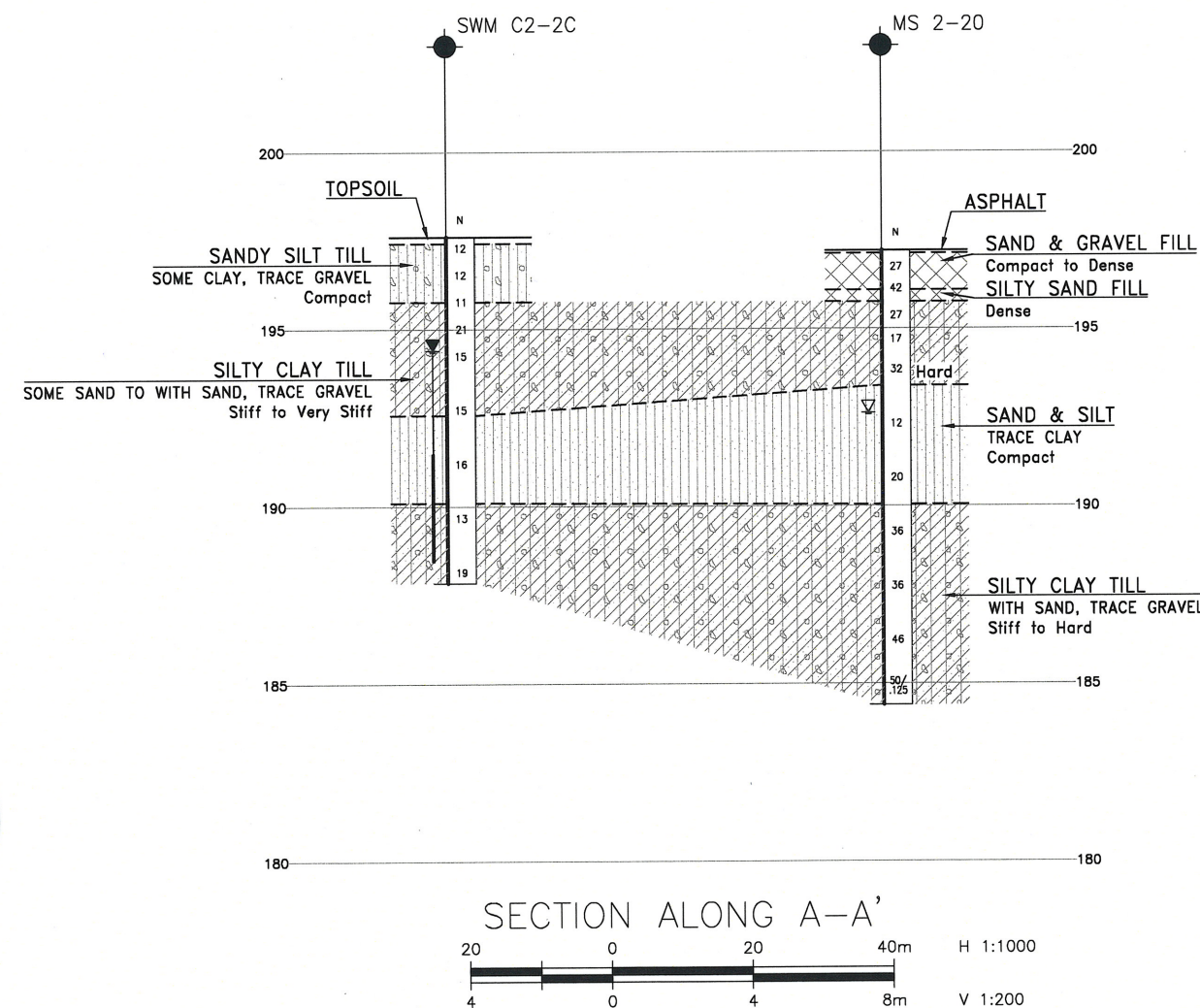
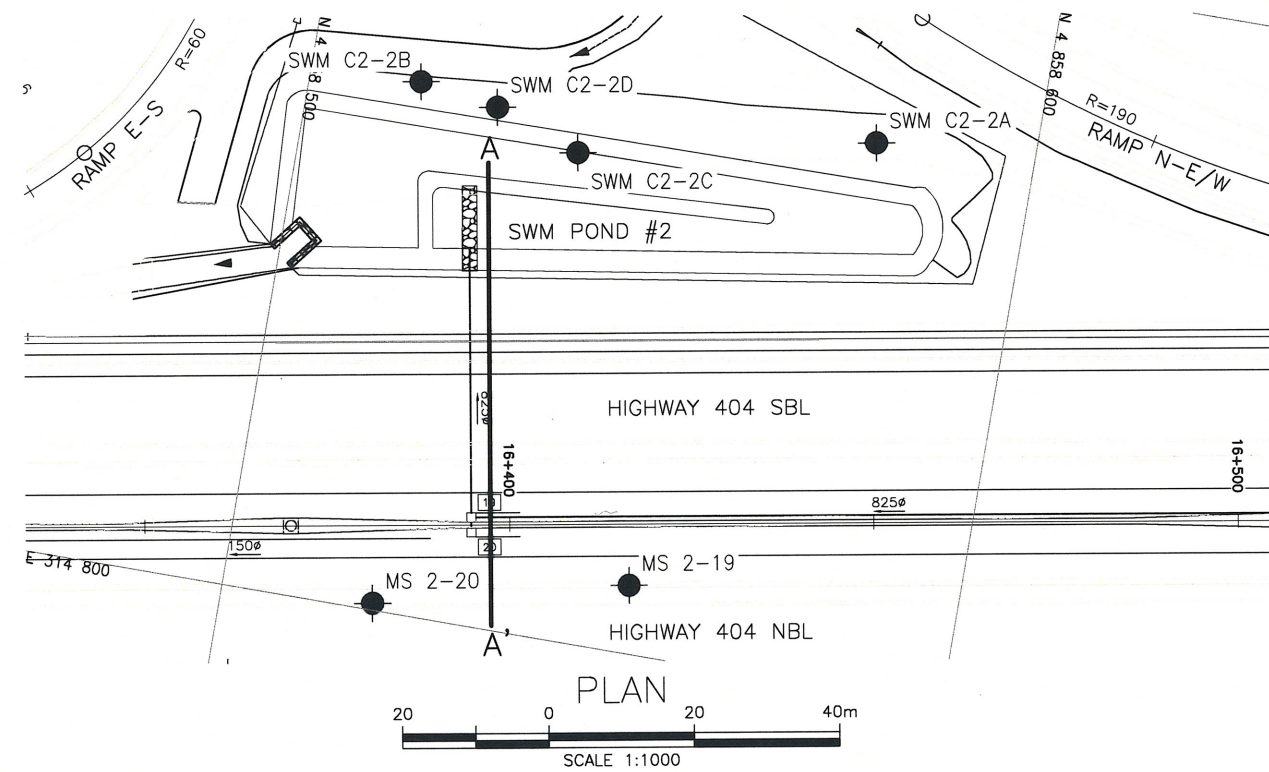
	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
SWM C2-2A	198.5	4 858 578.2	314 725.0
SWM C2-2B	199.4	4 858 515.2	314 727.3
SWM C2-2C	197.6	4 858 538.0	314 733.3
SWM C2-2D	197.3	4 858 526.1	314 729.0
MS 2-19	197.3	4 858 555.0	314 790.6
MS 2-20	197.2	4 858 520.8	314 799.0

-NOTES-

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

GEOCRES No. 30M14-496

[illegible]



Appendix C

Sewer Lateral 33 at Pond 3 - (Station 17+423) Boreholes MS2-08 and SWM C2-3C

- Record of Borehole Sheets
- Laboratory Test Results
- Drawings titled "Borehole Locations and Soil Strata"

RECORD OF BOREHOLE No MS 2-08

1 OF 1

METRIC

GWP# 2930-17-00 LOCATION N 4 859 526.4 E 314 617.2 ORIGINATED BY BL
 HWY 404 BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.07.19 - 2018.07.19 LATITUDE 43.875645 LONGITUDE -79.377843 CHECKED BY RD

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 (%)				
204.2	GROUND SURFACE							20	40	60	80	100					
0.0	ASPHALT (200mm)																
0.2	SAND and GRAVEL, trace silt, trace clay Dense Brown Moist (FILL)		1	SS	35		204										
203.5																	
0.8	Silty CLAY, with sand, trace gravel Hard to Very Stiff Brown Moist (TILL)		2	SS	36		203										
			3	SS	20		202										0 33 48 19
			4	SS	37		201										
			5	SS	23		200										
			6	SS	19		199										
198.6																	
5.6																	
	Stiff		7	SS	14		198										4 31 33 32
197.1																	
7.2							197										
			8	SS	22												
196.0																	
8.2	END OF BOREHOLE AT 8.2m. BOREHOLE OPEN AND WATER LEVEL AT 7.3 DEPTH UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 7.0m, AUGER CUTTINGS TO 0.8m, BENTONITE HOLEPLUG TO 0.2m, THEN COLD PATCH ASPHALT TO SURFACE.																

ONTMT452 MTO-15786.GPJ 2017TEMPLATE(MTO).GDT 2/1/19

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

RECORD OF BOREHOLE No SWM C2-3C

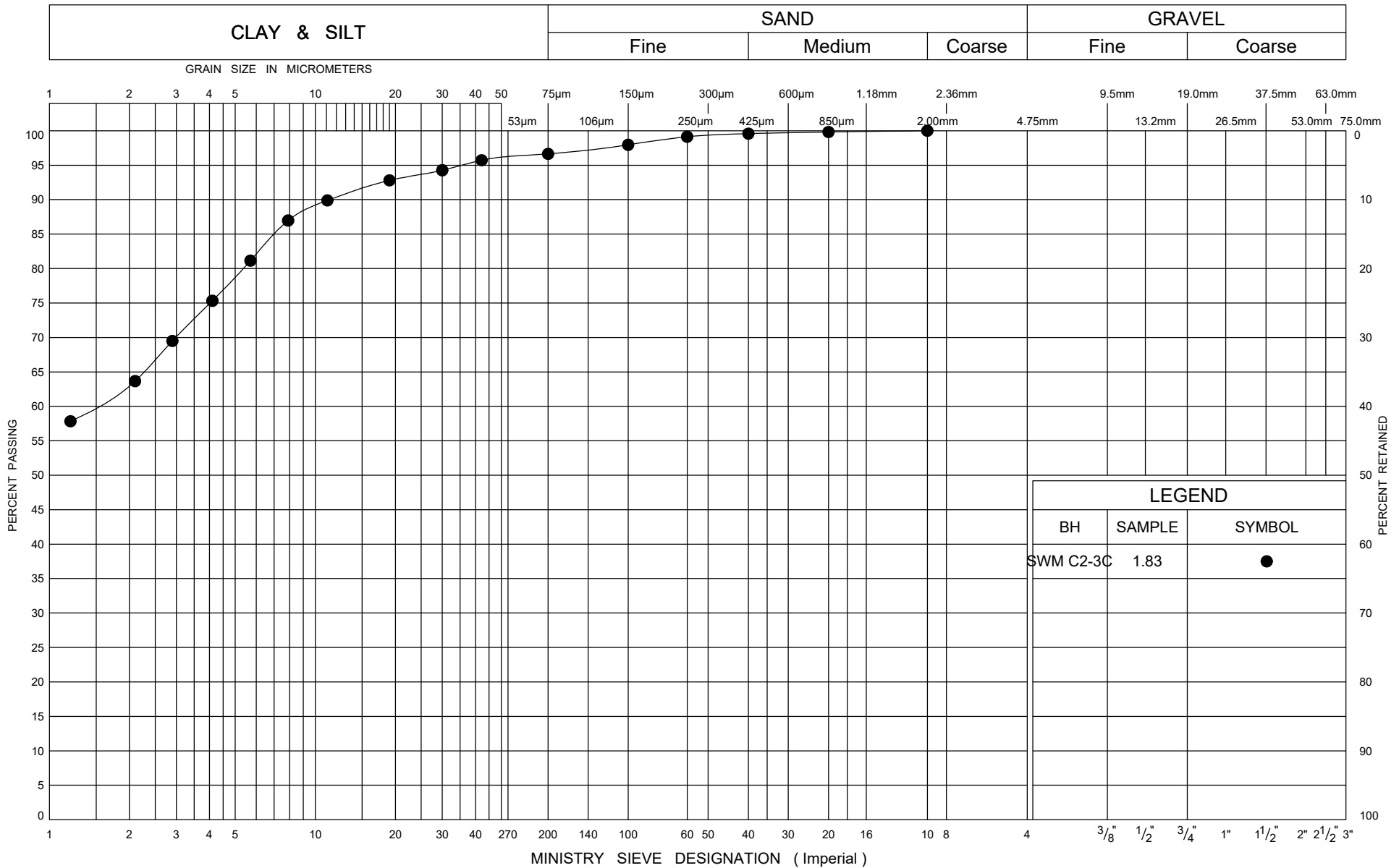
1 OF 1

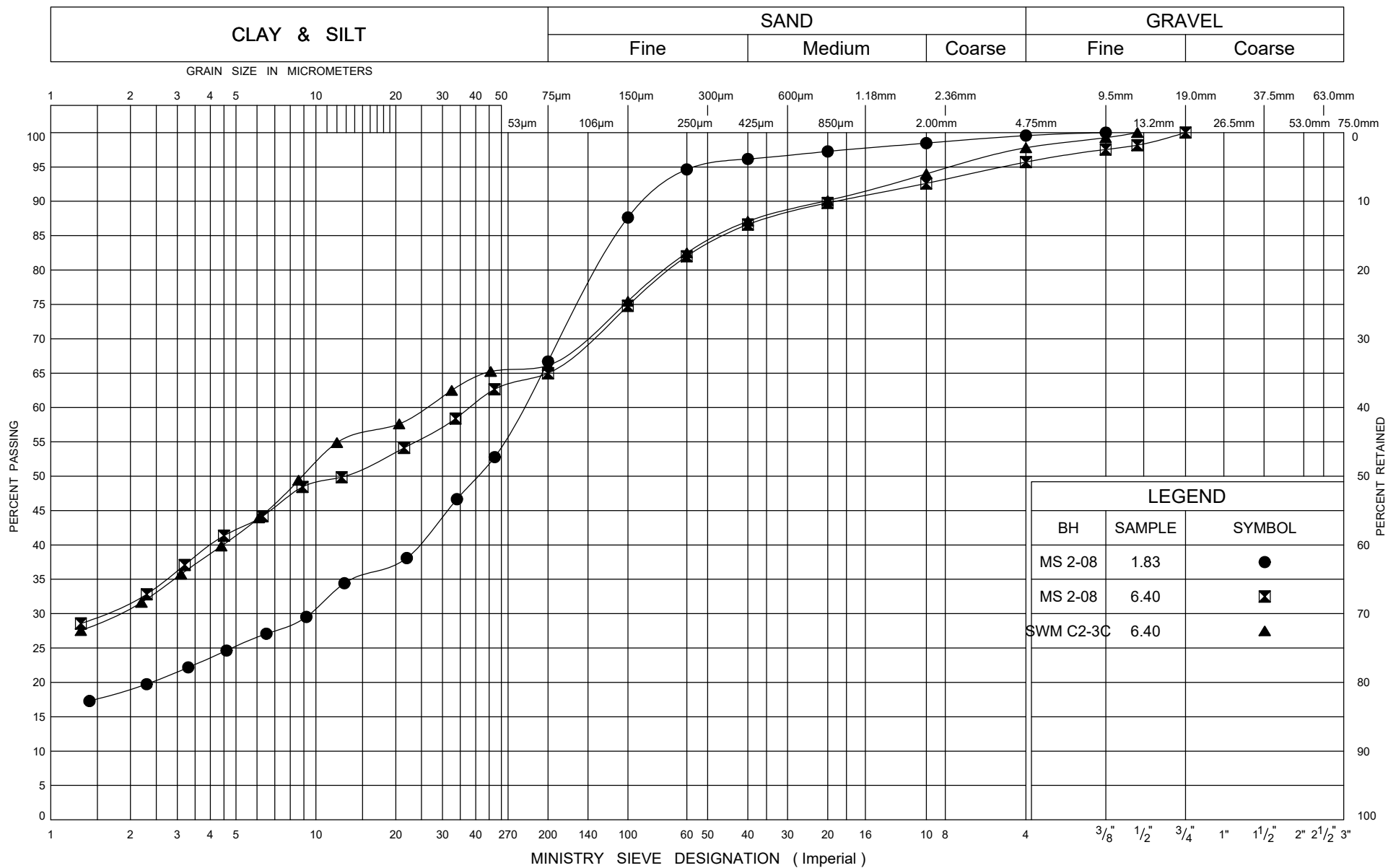
METRIC

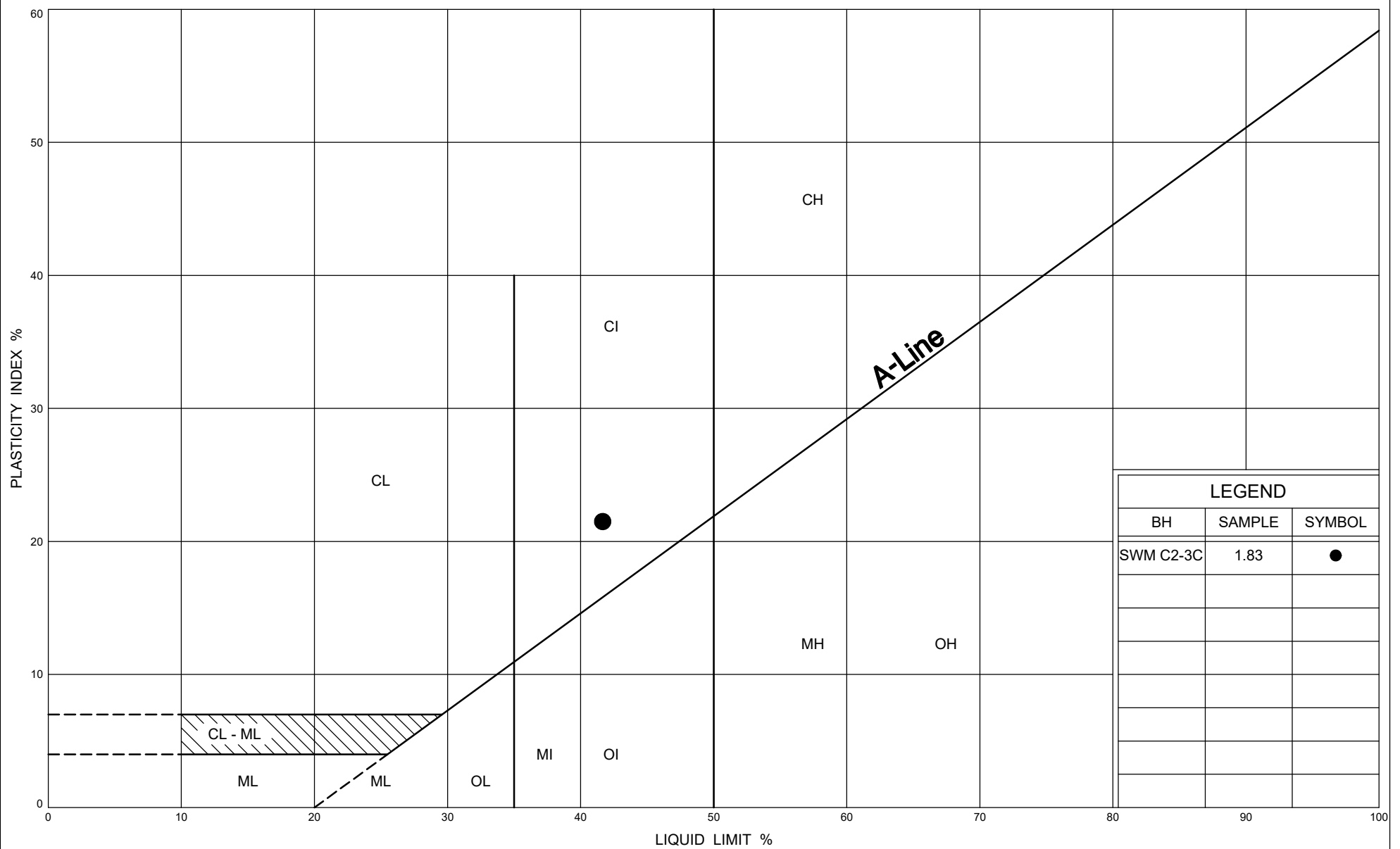
GWP# 2930-17-00 LOCATION N 4 859 521.0 E 314 581.1 ORIGINATED BY KK
 HWY 404 BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.10.21 - 2018.10.21 LATITUDE 43.875597 LONGITUDE -79.378293 CHECKED BY RD

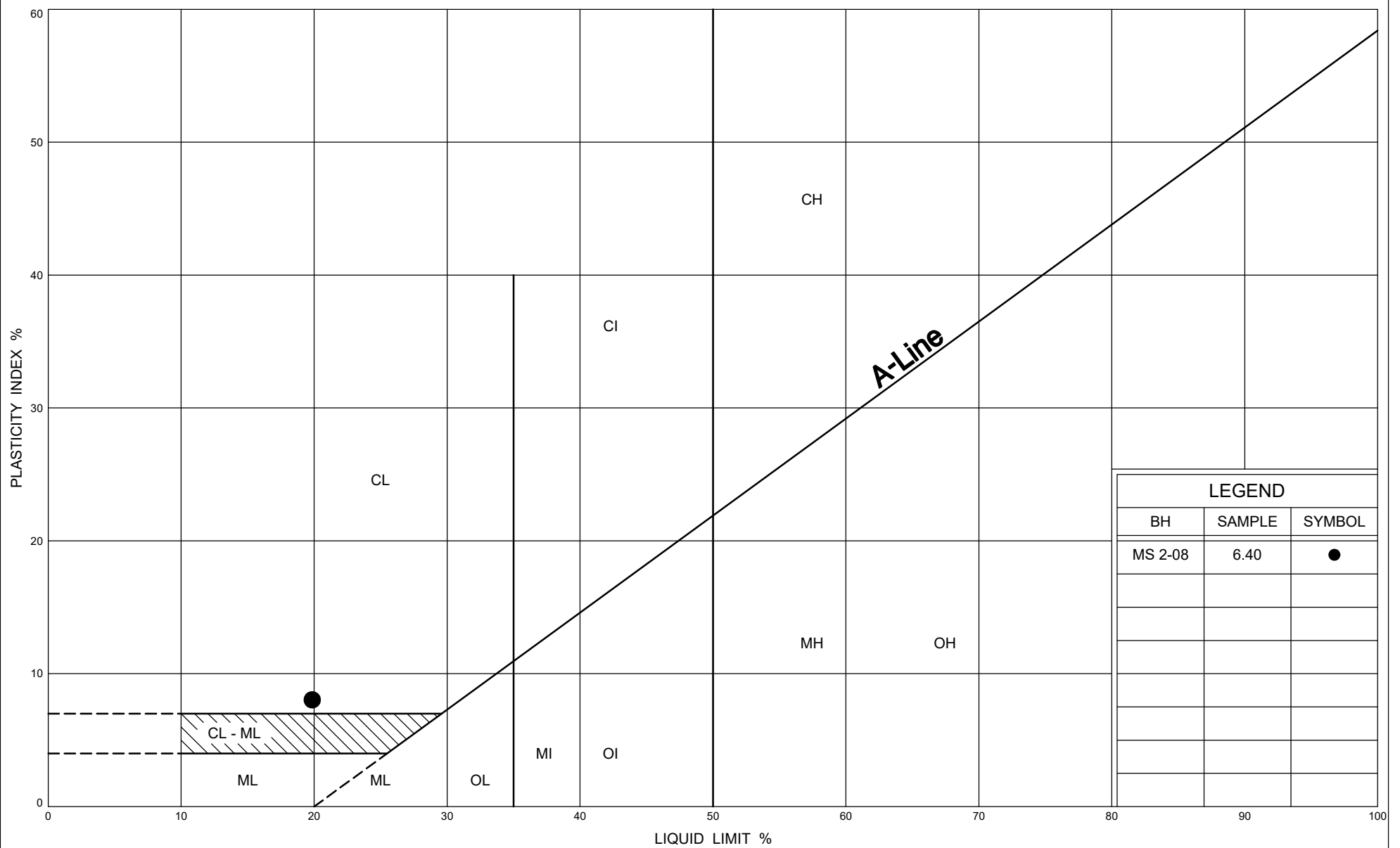
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
204.2	GROUND SURFACE							20	40	60	80	100		
0.0	ASPHALT (150mm)						204							
0.2	SAND and GRAVEL, trace silt, trace gravel Compact		1	SS	23									
203.4	Brown Moist (FILL)		2	SS	12									
0.8	Silty CLAY, trace sand, trace gravel, occasional organics and rootlets						203							
202.8	Stiff Brown Moist (FILL)		3	SS	5									
1.4	Silty CLAY, trace sand Firm to Very Stiff						202							
	Brown Moist		4	SS	20									
							201							
			5	SS	18									
200.1														
4.1	SAND and SILT, trace gravel Dense Brown Moist		6	SS	37		200							
							199							
198.6	Silty CLAY, with sand, trace gravel Hard Grey Moist (TILL)		7	SS	42		198							
5.6							197							
196.4			8	SS	100/									
7.8	END OF BOREHOLE AT 7.8m. BOREHOLE OPEN AND DRY UPON COMPLETION. Well installation consists of 50mm diameter Schedule 40 PVC pipe with a 3.1m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2018.11.22 7.5 196.7				0.075									

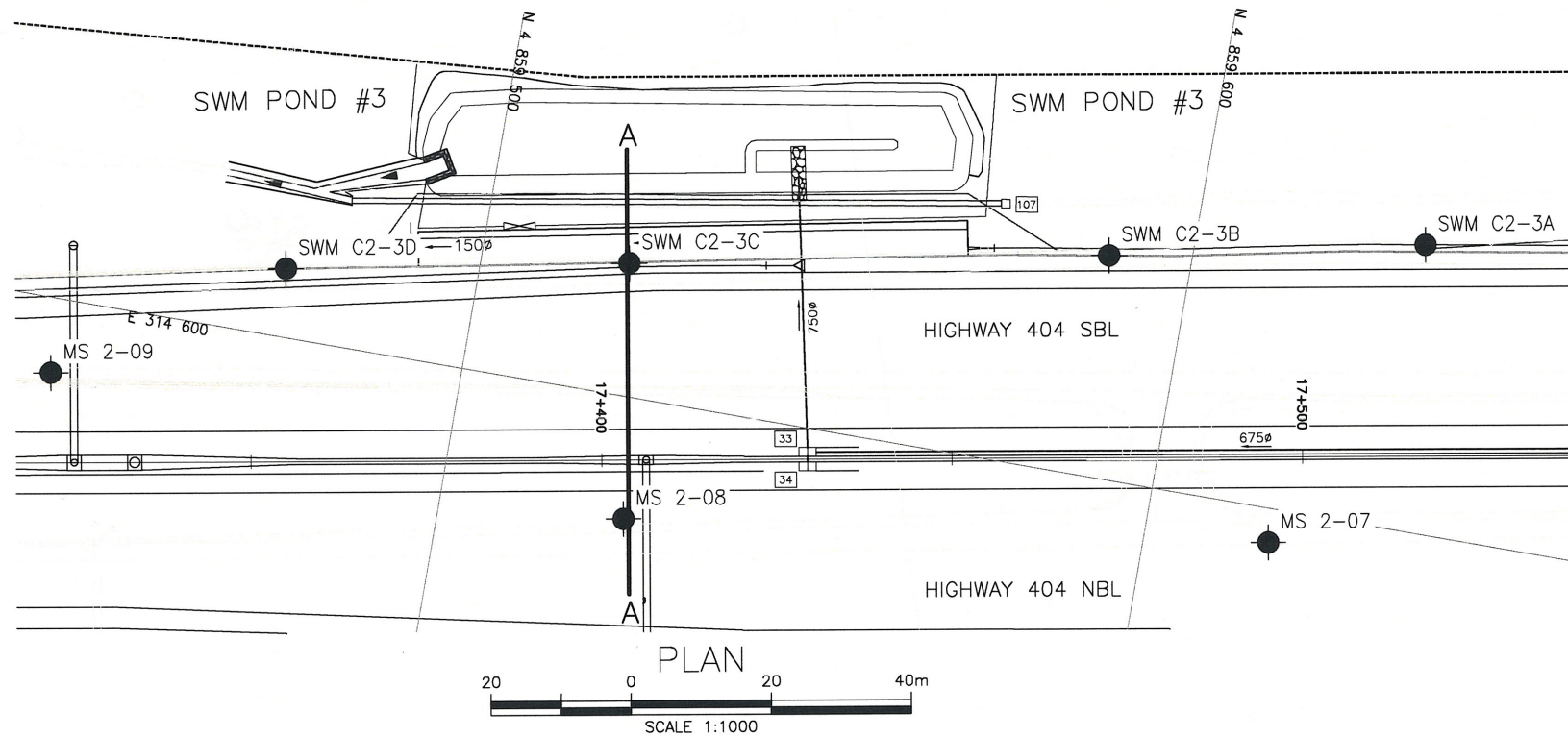
+³, ×³: Numbers refer to Sensitivity 20 15 10 5 (%) STRAIN AT FAILURE











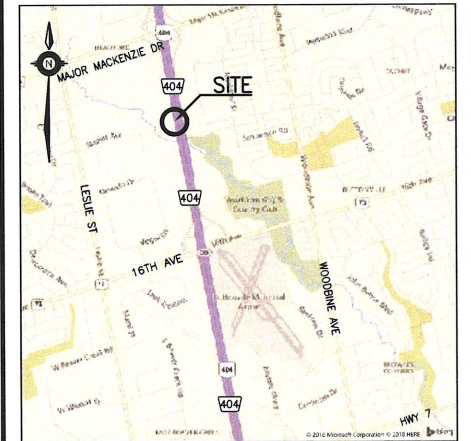
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
GWP No 2930-17-00

HIGHWAY 404 WIDENING
SEWER LATERAL 33
STA 17+423
BOREHOLE LOCATIONS AND SOIL STRATA



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

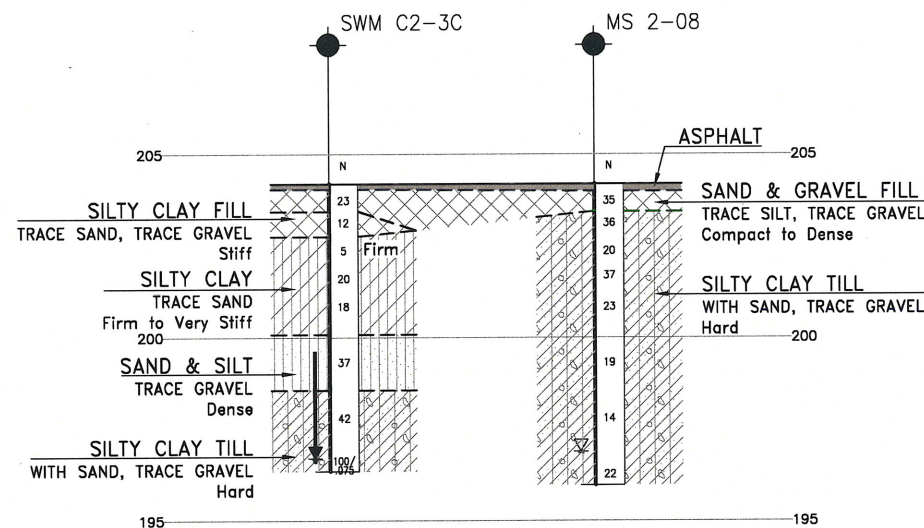
	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60' Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
SWM C2-3A	204.6	4 859 632.5	314 559.1
SWM C2-3B	204.5	4 859 588.3	314 568.3
SWM C2-3C	204.2	4 859 521.0	314 581.1
SWM C2-3D	203.9	4 859 472.9	314 590.2
MS 2-07	204.9	4 859 617.6	314 604.8
MS 2-08	204.2	4 859 526.4	314 617.2
MS 2-09	204.0	4 859 442.5	314 610.6

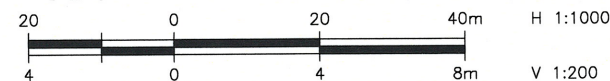
-NOTES-

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

GEOCREs No. 30M14-496



SECTION ALONG A-A'



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	RPR	CHK SKP	CODE
DRAWN	AN	CHK RPR	SITE
LOAD	STRUCT	DWG	3
DATE	FEB 2019		



Appendix D

Analytical Laboratory Test Results



FINAL REPORT

CA14030-OCT18 R1

15786

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 Rocio Reyna

Telephone 905-829-8666 x 263

Facsimile

Email rreyna@thurber.ca

Project 15786

Order Number

Samples Soil (3)

LABORATORY DETAILS

Project Specialist Rob Irwin B.Sc., C.Chem

Laboratory SGS Canada Inc.

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

Telephone 2361

Facsimile 705-652-6365

Email

SGS Reference CA14030-OCT18

Received 10/01/2018

Approved 10/09/2018

Report Number CA14030-OCT18 R1

Date Reported 10/09/2018

COMMENTS

Temperature of Sample upon Receipt: 9 degrees C

Cooling Agent Present:No

Custody Seal Present:No

Chain of Custody Number:

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

Rob Irwin B.Sc., C.Chem





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Legend..... 7

Annexes..... 8-9



FINAL REPORT

CA14030-OCT18 R1

Client: Thurber Engineering Ltd.

Project: 15786

Project Manager: Rocío Reyna

Samplers: N/a

PACKAGE: - Corrosivity Index (SOIL)

Sample Number	5	6	7
Sample Name	MS2-08 SS2	MS2-32 SS4	MS2-20 SS4
Sample Matrix	Soil	Soil	Soil
Sample Date	19/07/2018	19/08/2018	19/07/2018

Parameter	Units	RL		Result	Result	Result
Corrosivity Index						
Corrosivity Index	none	1		5	10	3
Soil Redox Potential	mV	-		253	260	252
Sulphide	%	0.02		< 0.02	< 0.02	< 0.02
pH	pH Units	0.05		9.43	8.23	8.54
Resistivity (calculated)	ohms.cm	-9999		2240	1450	3410

PACKAGE: - General Chemistry (SOIL)

Sample Number	5	6	7
Sample Name	MS2-08 SS2	MS2-32 SS4	MS2-20 SS4
Sample Matrix	Soil	Soil	Soil
Sample Date	19/07/2018	19/08/2018	19/07/2018

Parameter	Units	RL		Result	Result	Result
General Chemistry						
Conductivity	uS/cm	2		447	688	293

PACKAGE: - Metals and Inorganics (SOIL)

Sample Number	5	6	7
Sample Name	MS2-08 SS2	MS2-32 SS4	MS2-20 SS4
Sample Matrix	Soil	Soil	Soil
Sample Date	19/07/2018	19/08/2018	19/07/2018

Parameter	Units	RL		Result	Result	Result
Metals and Inorganics						
Moisture Content	%	0.1		11.2	23.2	17.2
Sulphate	µg/g	0.4		37	160	43



FINAL REPORT

CA14030-OCT18 R1

Client: Thurber Engineering Ltd.

Project: 15786

Project Manager: Rocío Reyna

Samplers: N/a

PACKAGE: - Other (ORP) (SOIL)

Sample Number	5	6	7
Sample Name	MS2-08 SS2	MS2-32 SS4	MS2-20 SS4
Sample Matrix	Soil	Soil	Soil
Sample Date	19/07/2018	19/08/2018	19/07/2018

Parameter	Units	RL		Result	Result	Result
Other (ORP)						
Chloride	µg/g	0.4		250	880	190



FINAL REPORT

CA14030-OCT18 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	DIO0060-OCT18	µg/g	0.4	<0.4	3	20	97	80	120	105	75	125
Sulphate	DIO0060-OCT18	µg/g	0.4	<0.4	14	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	ECS0006-OCT18	%	0.02	<0.02	ND	20	104	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	EWL0043-OCT18	uS/cm	2	< 0.002	2	10	100	90	110	NA		



QC SUMMARY

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	EWL0043-OCT18	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 --



SGS Environmental Services

Request for Laboratory Services and CHAIN OF CUSTODY

Q

No:

Page ____ of ____

- Lakefield: 185 Concession St., Lakefield, ON K0L 2H0 Phone: 705-652-2000 Toll Free: 877-747-7658 Fax: 705-652-6365
- London: 657 Consortium Court, London, ON, N6E 2S8 Phone: 519-672-4500 Toll Free: 877-848-8060 Fax: 519-672-0361 Web: www.ca.sgs.com

Laboratory Information Section - Lab use only

LAB LIMS #: CA14030-0018

Received By: Stephanie Barbieric

Received Date (mm/dd/yyyy): 10/01/18 (mm/dd/yyyy)

Custody Seal Present: ☐ YES ☒ NO

Received Time: 1:30 pm

Cooling Agent Present: ☐ YES ☒ NO

Temperature Upon Receipt (°C): 10.4°C, 11.3°C, 10.8°C 9x3

REPORT INFORMATION

Company: Thulber Env. Ltd.

Contact: Rocio Palomera Reyna

Address: 103-010 Windsor Park Dr

City: Oakville, ON L6H 5E7

Phone: 905-829-8666 x260

Fax: 1

Email: Treyna@thulber.ca

INVOICE INFORMATION

☐ (same as Report Information)

Company:

Contact:

Address:

Phone:

Email:

PROJECT INFORMATION

Quotation #:

Project #: 15786

P.O. #:

Site Location/ID:

TURNAROUND TIME (TAT) REQUIRED

☒ Regular TAT (5-7 days)

TAT's are quoted in business days (exclude statutory holidays & weekends). Samples received after 3pm or on weekends: TAT begins the next business day

RUSH TAT (Additional Charges May Apply) ☐ 1 Day ☐ 2 Days ☐ 3-4 Days

PLEASE CONFIRM RUSH FEASIBILITY WITH SGS REPRESENTATIVE PRIOR TO SUBMISSION

Specify Due Date:

Rush Confirmation ID:

DRINKING WATER SAMPLES (POTABLE WATER FOR HUMAN CONSUMPTION) MUST BE

SUBMITTED WITH SGS DRINKING WATER CHAIN OF CUSTODY

REGULATIONS

Regulation 153 (2011):

☐ Table 1 ☐ Res/Park ☐ Soil Texture:☐ Table 2 ☐ Ind/Com ☐ Coarse☐ Table 3 ☐ Agri/Other ☐ Medium☐ Table ☐ Fine

Other Regulations:

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

Sewer By-Law:

☐ Sanitary☐ Storm

Municipality:

ANALYSIS REQUESTED

COMMENTS:
Field Filtered (F)
Preserved (P)RECORD OF SITE CONDITION (RSC) ☐ YES ☐ NO

SAMPLE IDENTIFICATION

DATE SAMPLED

TIME SAMPLED

OF BOTTLES

MATRIX

PHC F1-F4 BTEX

O.Reg153 Metals (ICP & hydride metals)

☐ Hg ☐ B-HWS ☐ Cr(VI)

O.Reg 153 VOCs

Corrosivity

✓

✓

✓

Observations/Comments/Special Instructions

Sampled By (NAME):

Signature:

Date: 28/09/2018

(mm/dd/yy)

Pink Copy - Client

Relinquished by (NAME):

Signature:

Date: 28/09/2018

(mm/dd/yy)

Yellow & White Copy - SGS

Revision #: 1.0

Date of Issue: 01 June, 2014



SAMPLE INTEGRITY REPORT

Project Number: 15786

ONTARIO REGULATION 153/04

SGS Sample ID CA14030-00118

Date / Time Sampled July, Aug

Client Sample ID see CoC

ALL

Sample Submission General Sample Integrity Violations

- Temperature >10 C upon receipt if not sampled same day
No evidence of cooling trend initiated if sampled same day
Chain of Custody not submitted
Chain of Custody incomplete
Chain of Custody not signed / dated
Chain of Custody not a current version
Bottles / Samples listed on CoC but not received
Bottles / Samples received but not listed on the CoC
Sample container received empty

☐
☐
☐
☐
☐
☐
☐
☐
☐

Sample Specific Sample Integrity Violations

- Sample received past hold time
Incorrect preservation (including no preservation where required)
Headspace present in VOC vial (aqueous)
Sample(s) received frozen
Bottle(s) broken or damaged in transport
Discrepancy between sample label and chain of custody
Analysis requirements absent / unclear
Missing or incorrect sample label(s)
Inappropriate sample container used
Insufficient number of bottles received
Limited sample volume
Insufficient sample volume
Sample contains multiple phases

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
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<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Sediment Log

- Groundwater samples contain visible sediment / particulate
Groundwater contains greater than 1cm of sediment / particulate matter in bottle

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Additional Comments/Remarks:

No issues upon receipt



Initials:



Appendix E

Trenchless Methods Comparison



Table E1 - Trenchless Methods Comparison

Trenchless Method	Advantages	Disadvantages	Relative Risks and Cost Effectiveness
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 	<p>HIGH RISK (sands and silts)</p> <p>MEDIUM RISK (clayey silt / silty clay)</p> <ul style="list-style-type: none"> • Cost effective if used for clayey soils and no oversized obstructions are encountered.
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 	<p>MEDIUM RISK</p> <ul style="list-style-type: none"> • Cost effective if no oversized obstructions are encountered.
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 	<p>MEDIUM RISK</p> <ul style="list-style-type: none"> • Cost effective if multiple trenchless installations are completed for the same contract.



Appendix F

List of Special Provisions and Suggested Wording for NSSP



1. List of Special Provisions Referenced in this Report

- OPSS.PROV 539

2. Suggested Text for NSSP on Trenchless Installation.

The Contractor's attention is drawn to the following:

- The fill materials and glacial till deposits may contain cobbles and boulders. In particular, fill inherently has a variable composition and may contain large boulders at this site. The Contractor must select a methodology that can adapt to varying composition and behaviour of the fill, and must be equipped to dislodge, remove and otherwise handle such obstructions at the tunnel face should it be required.
- The Contractor shall maintain at all times the soil cover above the crown of the casing at a minimum two (2) times the casing diameter.
- The pipe installation will largely be carried out through cohesive stiff to hard silty clay/silty clay till, The Contractor's equipment must be capable of advancing the pipes through the cohesive deposit.
- It must be noted that native water-bearing sands and silts were encountered below the upper silty clay till. Even though it is not anticipated, should sands and silts be encountered at the tunnel face, loss of ground due to sloughing or caving can occur in the borings. The Contractor's methodology must include means of handling potential sloughing of these soils and water seepage at the tunnel face.



Appendix G

Instrumentation and Monitoring Program



INSTRUMENTATION AND MONITORING PROGRAM
PROPOSED SEWER LATERAL CROSSINGS OF HIGHWAY 404
FROM HIGHWAY 407 TO MAJOR MACKENZIE DRIVE

- Item No.

Special Provision

1 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 culvert alignment and in array. Each array consists of a group of instruments installed approximately perpendicular to the culvert alignment.

1.2 Purpose

The purpose of these instruments is to monitor settlements during installation of the sewer laterals.

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 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 Drawing 15786-G1 for schematic instrument locations.

1.8 Subsurface Conditions

- The subsurface conditions at the site are described in Thurber's Report titled: "Foundation Investigation Report, Sewer Laterals, Highway 404 HOV Lane Expansion and Rehabilitation, Contract 2, From Highway 407 to Major Mackenzie Drive, Markham, Ontario, G.W.P. 2930-02-00", by Thurber Engineering Ltd., Reference No. 15786, dated December 2018.

2 INSTALLATION

2.1 Generals

There are thirty (30) surface monitoring points (SMP) and three (3) settlement rods (SR) to be installed at this site as shown on Drawing 15786-G1.

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 or at the toes of highway embankments along the proposed culvert centreline.

The number of monitoring points that will be installed at the culvert replacement are shown in the table below:

Sewer Lateral I.D.	Pipe Diameter (mm)	Trenchless Length (m)	Number of Monitoring Points	
			SMP	SR
52 (Pond 1)	900	42	10	1
19 (Pond 2)	825	36	10	1
33 (Pond 3)	750	39	10	1

The array with three instruments will consist of the following:

- One (1) instrument installed at the proposed sewer lateral centreline
- One (1) instrument installed at 2 m north of the proposed sewer lateral
- One (1) instrument installed at 2 m south of the proposed sewer lateral.



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 culvert 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 15786-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 culvert alignment. The settlement readings shall assist in assessing the culvert 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 15786-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 MONITORING PROGRAM

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 Contractor 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 Hwy 404 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 replacement twin culverts.

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 culvert installation	Once	1
During trenchless installation	A minimum of three (3) sets of readings be taken daily for all instruments located above a sewer lateral being installed, 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 trenchless installation	After the end of installation of each sewer lateral, all instruments located above the culvert shall be read weekly for the first month.	4

(*) Baseline Readings: Instrument elevation readings taken prior to culvert 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. culvert 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 culvert 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 culvert 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 movements or other surface distress occurs.

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

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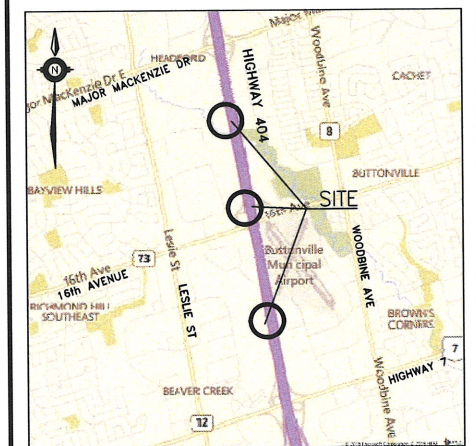
HIGHWAY 404 WIDENING HWY 407 TO MAJOR MACKENZIE DR. SEWER LATERALS 52, 19 & 33 INSTRUMENTATION & MONITORING PROGRAM
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THURBER ENGINEERING LTD.



KEYPLAN

LEGEND



Surface Monitoring Point (SMP)
Settlement Rod (SR)
Proposed Sewer Lateral

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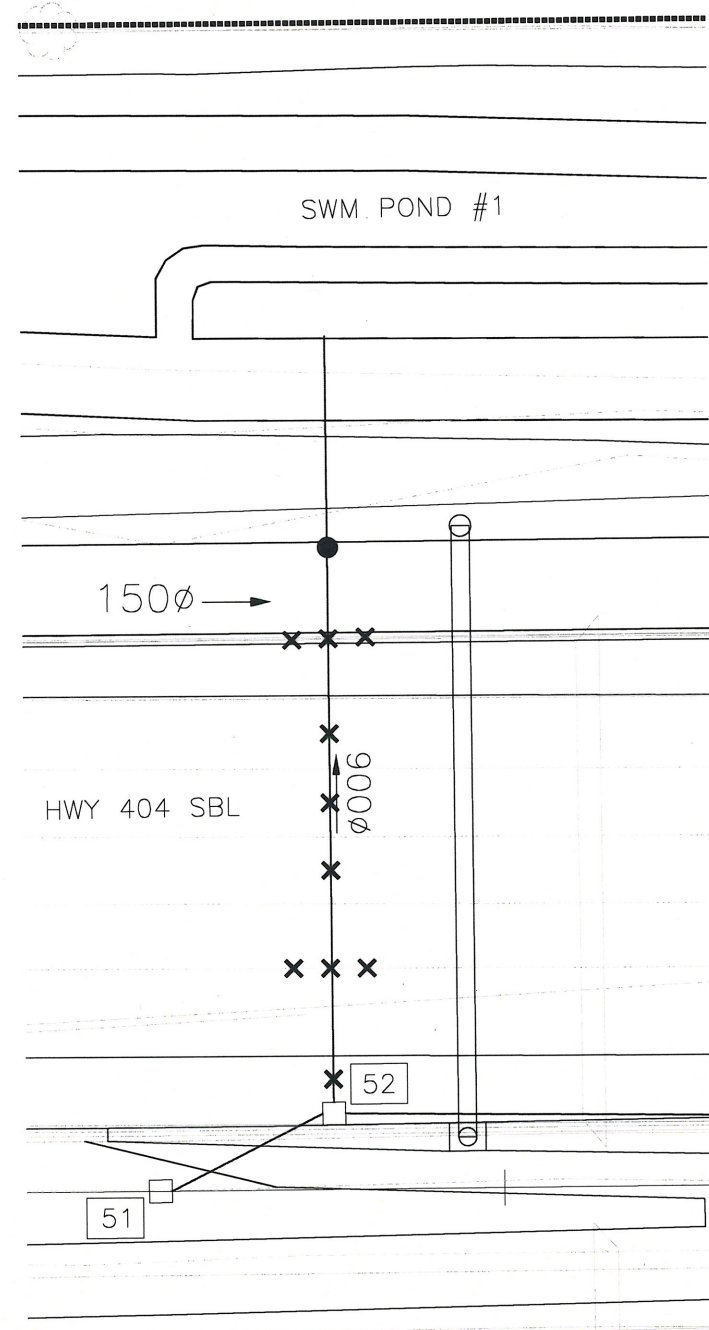
-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

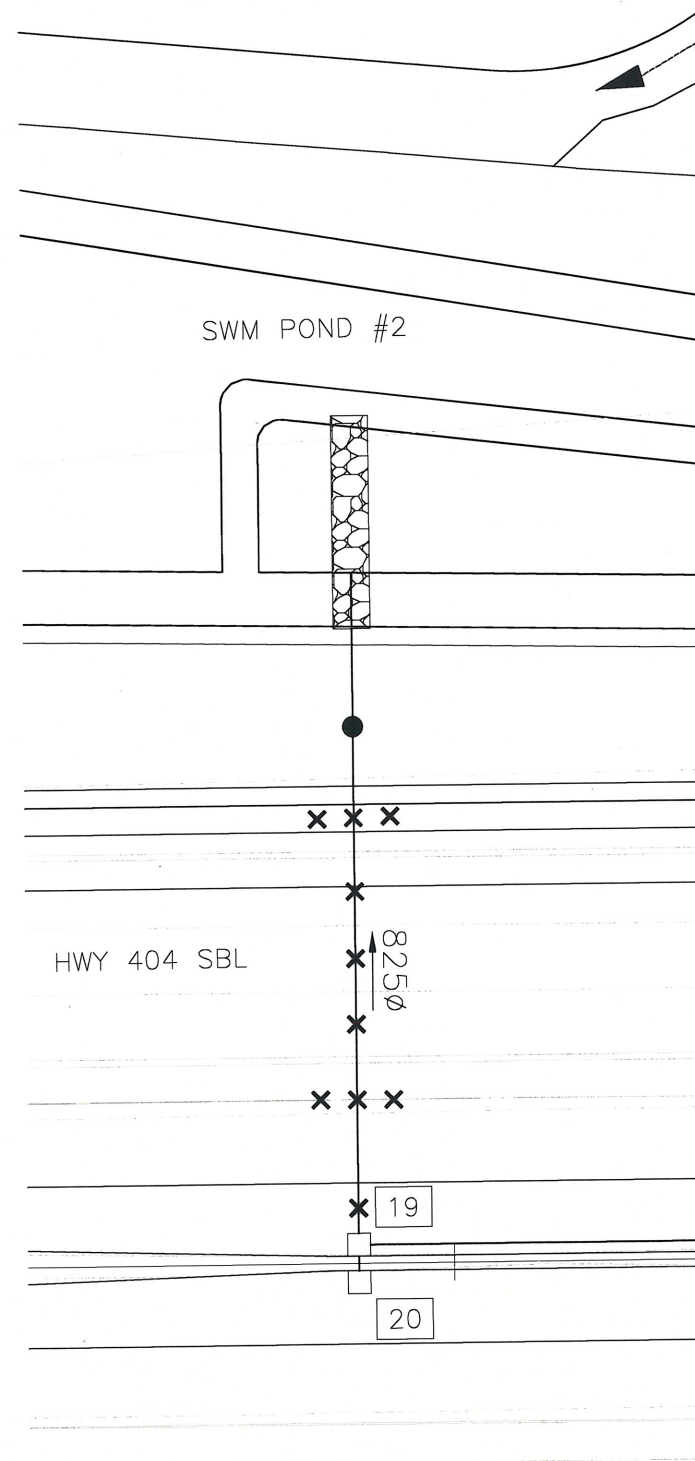
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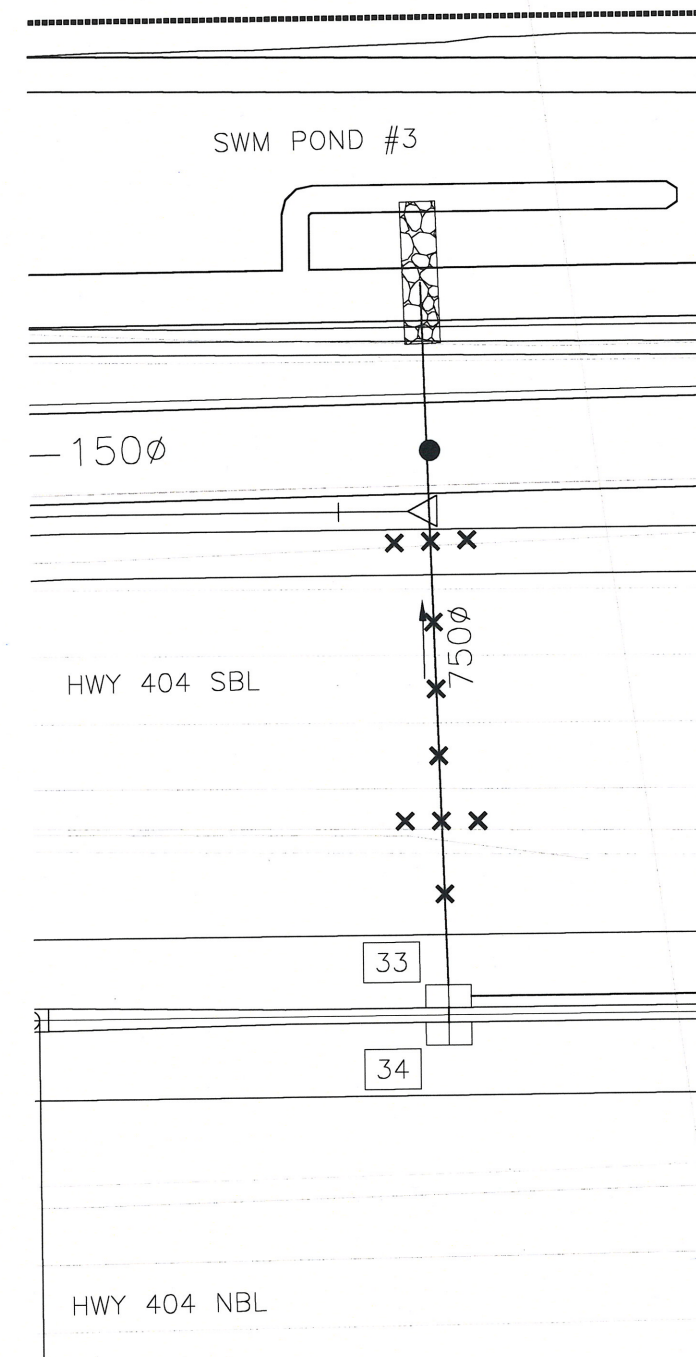
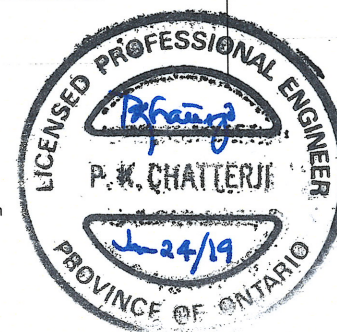
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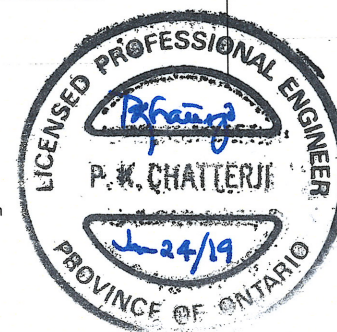
SEWER LATERAL 52



SEWER LATERAL 19



SEWER LATERAL 33



PLAN

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