



December 22, 2015

FOUNDATION INVESTIGATION AND DESIGN REPORT

**WATERMAIN RELOCATION
NORMAN BETHUNE AVENUE AND HIGHWAY 404 S-E/W RAMP EXTENSION
FROM HIGHWAY 7 TO NORMAN BETHUNE AVENUE
YORK REGION TRANSPORTATION SERVICES, CONTRACT NO. T-14-53
CITY OF MARKHAM, ONTARIO**

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REPORT





Table of Contents

PART A – FOUNDATION INVESTIGATION REPORT

1.0 INTRODUCTION.....	1
2.0 SITE DESCRIPTION.....	1
3.0 INVESTIGATION PROCEDURES	1
4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS	3
4.1 Regional Geology	3
4.2 Subsurface Conditions.....	3
4.2.1 Topsoil	4
4.2.2 Fill	4
4.2.3 Clayey Silt to Silty Clay (Upper)	4
4.2.4 Silt and Sand to Sand	5
4.2.5 Gravelly Silty Sand to Gravelly Sand (Interlayer)	5
4.2.6 Sandy Silt to Silty Sand Till	6
4.2.7 Clayey Silt (Lower)	6
4.3 Groundwater Conditions	7
5.0 CLOSURE	8

PART B – FOUNDATION DESIGN REPORT

6.0 DISCUSSION OF PROPOSED WATERMAIN INSTALLATION	9
6.1 General.....	9
6.2 Watermain Alignment	9
6.3 Anticipated Ground Conditions	10
6.4 Monitoring Well Decommissioning.....	10
6.5 Obstructions	10
6.6 Watermain Installation by Trenchless Methods	11
6.6.1 Suitable Trenchless Methodologies	11
6.6.1.1 Jack-and-Bore	12
6.6.1.2 Horizontal Directional Drilling (HDD)	13
6.6.1.2.1 Hydraulic Fracture (“Frac-out”) Potential	14
6.6.1.3 Microtunnelling (MTBM).....	15
6.7 Temporary Excavations	16



FOUNDATION REPORT - WATERMAIN RELOCATION

6.7.1	Temporary Open Cut Trench Excavations	16
6.7.2	Supported Excavations	17
6.7.3	Pipe Bedding and Cover	18
6.7.4	Trench Backfill	19
6.7.5	Trench Plug.....	20
6.8	Groundwater Control	20
6.9	Settlement Monitoring Program – E-N Ramp	21
7.0	CLOSURE	23

REFERENCES

TABLES

Table 1	Evaluation of Trenchless Crossing Alternatives for Watermain Installation Highway 404 E-N Ramp, North of Highway 7
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DRAWINGS

Drawing 1	Borehole Locations Index Plan
Drawing 2	Borehole Locations and Soil Strata
Drawing 3	Instrumentation Plan and Details

APPENDIX A Record of Boreholes

Lists of Symbols and Abbreviations
Record of Boreholes GA-BR-03 and GA-WM-01 to GA-WM-08

APPENDIX B Laboratory Test Results

Table B1	Summary of Analytical Testing of Groundwater
Figure B1	Grain Size Distribution – Clayey Silt to Clayey Silt with Sand (Upper)
Figure B2	Plasticity Chart – Clayey Silt to Silty Clay (Upper)
Figure B3A	Grain Size Distribution – Silt and Sand
Figure B3B	Grain Size Distribution – Silty Sand to Sand
Figure B4	Grain Size Distribution – Sandy Clayey Silt (Layer)
Figure B5	Grain Size Distribution – Sandy Silt (Layer)
Figure B6	Plasticity Chart – Sandy Clayey Silt (Layer)
Figure B7	Plasticity Chart – Sandy Silt (Layer)
Figure B8	Grain Size Distribution – Gravelly Silty Sand (Interlayer)
Figure B9	Grain Size Distribution – Sandy Silt to Silty Sand Till
Figure B10	Plasticity Chart – Clayey Silt (Lower)

APPENDIX C Non-Standard Special Provision (NSSP)

Saturated Non-Cohesive Soils (Silt and Sand to Sand and Sandy Silt to Silt and Sand Till)
Obstructions
Dewatering

APPENDIX D Non-Standard Special Provision for Pipe Installation by Trenchless Method



PART A

FOUNDATION INVESTIGATION REPORT
WATERMAIN RELOCATION
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM on behalf of York Region to provide foundation engineering services in support of the design of the E-N Ramp, S-E/W Ramp extension and their associated structures, as well as a watermain relocation, at the northeast quadrant of the intersection of Highway 404 and Highway 7. This work is associated with the Midblock Crossing project in Markham, Ontario which was originally initiated by Coffey Geotechnics Inc. (Coffey).

This report addresses the watermain relocation. Separate reports address the foundation investigations for the E-N Ramp and S-E/W Ramp components of the project. The scope of work for foundation engineering services associated with the Midblock Crossing project is contained in Golder's proposal dated June 26, 2015.

The factual data, interpretations and recommendations contained in this report pertain to a specific project as described in the report and are not applicable to any other project or site location. If the project is modified in concept, location or elevation, or if the project is not initiated within eighteen months of the date of the report, Golder should be given an opportunity to confirm that the recommendations are still valid.

2.0 SITE DESCRIPTION

The site of the proposed watermain relocation at Highway 404 and Highway 7 is located east of Highway 404 and north of Highway 7 and extends from the intersection of Highway 7 and Allstate Parkway at the east end to Highway 404 at a connection to the existing watermain. The relocation alignment of the watermain runs from Allstate Parkway along the north side of Highway 7 and the future E-N Ramp and crosses under the E-N Ramp to tie into the existing watermain on the east side of Highway 404. The site is located partially on Seneca College Markham Campus partially on the City of Markham's property and partially on the Ministry of Transportation, Ontario (MTO) right-of-way.

The overall surface topography in the vicinity of the site is relatively flat with cut areas for the existing S-E/W Ramp extension, E-N Ramp and Highway 7. The area consists predominantly of commercial developments, an educational institution and a sports field on the Seneca College Markham Campus. The ground surface at the site ranges between approximately Elevations 195 m and 187 m.

3.0 INVESTIGATION PROCEDURES

A geotechnical field investigation was carried out by Golder along the length of the proposed watermain between September 9 and 25, 2015, during which time a total of nine boreholes (Boreholes GA-BR-03 and GA-WM-01 to GA-WM-08) were advanced. The locations of these boreholes are shown in plan on Drawings 1 and 2.

The borehole investigation was carried out using a track-mounted CME-75 drill rig and a track-mounted Acker Soil-Max drill rig supplied and operated by Lantech Drilling Service Inc. of Sharon, Ontario, as well as a CME-75 track-mounted drill rig supplied and operated by Geo-Environmental Drilling Inc., of Acton, Ontario. The boreholes were advanced through the overburden using 210 mm outside diameter hollow stem augers and mud rotary drilling techniques. Soil samples were generally obtained at intervals of depth of about 0.75 m and 1.5 m, using a 50 mm outside diameter split-spoon sampler driven by manual hammers in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586). The boreholes were advanced to depths ranging from about 6.6 m to 17.2 m below existing ground surface.



FOUNDATION REPORT - WATERMAIN RELOCATION

The groundwater conditions and water level in the open boreholes were observed during and immediately following the completion of drilling operations. Piezometers were installed in Boreholes GA-WM-02 and GA-WM-04 to GA-WM-07 to allow monitoring of the groundwater level. The piezometers consist of a 50 mm diameter PVC pipe, with a slotted screen sealed within the silt and sand to sand deposit or the sandy silt to silty sand till deposit. The borehole and annulus surrounding the piezometer pipe above the screen and sand pack were backfilled with bentonite pellets to the ground surface. The piezometer installation details and water level readings are noted on the Record of Boreholes in Appendix A. All other boreholes were backfilled upon completion of drilling in accordance with Ontario Regulation 903 (as amended).

Samples of groundwater were collected from select wells after completion of the field investigation, using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters. The results of the analytical testing are provided in Table B1 in Appendix B.

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

The proposed borehole locations and the ground surface elevations were surveyed and staked by J.D. Barnes Limited (J.D. Barnes), a professional surveying company, and the as-drilled borehole locations were surveyed by Golder relative to the staked locations. The borehole locations provided on the Records of Boreholes and shown on Drawings 1 and 2 are given using UTM NAD 83 northing and easting coordinates, and the ground surface elevations are referenced to Geodetic datum. The borehole locations, including MTM NAD 83 coordinates, ground surface elevations and drilled depths are summarized below.

Borehole Number	Location in UTM NAD 83 (MTM NAD 83)		Ground Surface Elevation	Borehole Depth
	Northing	Easting		
GA-BR-03	4856328.0 m (4856501.2 m)	631066.7 m (315302.2 m)	190.7 m	14.2 m
GA-WM-01	4856357.2 m (4856524.3 m)	631401.5 m (315637.5 m)	187.4 m	6.6 m
GA-WM-02	4856330.0 m (4856498.5 m)	631328.2 m (315563.7 m)	186.7 m	8.1 m
GA-WM-03	4856319.8 m (4856489.6 m)	631251.3 m (315486.6 m)	188.8 m	8.1 m
GA-WM-04	4856304.4 m (4856474.8 m)	631219.3 m (315454.3 m)	188.5 m	11.1 m



FOUNDATION REPORT - WATERMAIN RELOCATION

Borehole Number	Location in UTM NAD 83 (MTM NAD 83)		Ground Surface Elevation	Borehole Depth
	Northing	Easting		
GA-WM-05	4856299.3 m (4856470.9 m)	631156.0 m (315390.9 m)	190.1 m	12.7 m
GA-WM-06	4856308.3 m (4856480.8 m)	631109.3 m (315344.4 m)	190.5 m	12.7 m
GA-WM-07	4856334.9 m (4856508.5 m)	631040.5 m (315276.1 m)	191.6 m	15.7 m
GA-WM-08	4856314.1 m (4856488.9 m)	630974.9 m (315210.1 m)	194.6 m	17.2 m

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The site at the intersection of Highway 404 and Highway 7 is located within the Peel Plain physiographic region, as delineated in *The Physiography of Southern Ontario*¹. The Peel Plain physiographic region covers the central portions of the Regional Municipalities of York, Peel and Halton. The general topography of this region consists of level to gently rolling terrain, sloping down gradually southward toward Lake Ontario. A surficial till sheet, which generally follows the surface topography, is present throughout much of this area. The till typically consists of clayey silt to silty clay, with occasional sand to silt zones. Shallow, localized deposits of loose sand and silt and/or soft clay can overlie this uppermost till sheet, and these represent relatively recent deposits, formed in small glacial meltwater ponds scattered throughout the Peel Plain and concentrated near river valleys. The recent sand, silt and clay and uppermost till deposits in this area overlie and are interbedded with stratified deposits of sand, silt and clay.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes, together with the results of in situ and laboratory testing, are presented on the Record of Borehole sheets and laboratory test summary figures provided in Appendices A and B, respectively. The interpreted stratigraphic profile is shown on Drawing 2.

The results of the in situ field tests (i.e. SPT 'N'-values) carried out during the subsurface investigation as presented on the Record of Borehole sheets and in Section 4.2 are uncorrected. According to the Canadian Foundation Engineering Manual (*CFEM*, 2006), the energy delivered to the drill rod varies with the hammer release system, hammer type, anvil and operator characteristics.

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



FOUNDATION REPORT - WATERMAIN RELOCATION

The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile are inferred from observations of drilling progress and non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

In general, the subsurface conditions at the site consist of a surficial layer of topsoil or clayey silt fill, underlain by an upper deposit of sandy clayey silt to silty clay, which in turn is underlain by a silt and sand to sand deposit. The native silt and sand to sand deposit is underlain by a sandy silt to silty sand till deposit or a lower deposit of clayey silt, which extends to the borehole termination depth.

A detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Topsoil

An approximately 100 mm to 200 mm thick layer of topsoil was encountered at ground surface in Boreholes GA-BR-03 and GA-WM-04 to GA-WM-08.

4.2.2 Fill

Fill consisting of sandy clayey silt was encountered at ground surface in Boreholes GA-WM-01 to GA-WM-03. The top of the fill deposit ranges from Elevation 188.8 m and 186.7 m and the thickness of the deposit ranges from 0.8 m to 1.4 m.

A SPT 'N'-value measured within the fill deposit is 9 blows per 0.3 m of penetration, suggesting a stiff consistency.

The natural water content measured on a sample of the cohesive fill is about 16 per cent.

4.2.3 Clayey Silt to Silty Clay (Upper)

An upper cohesive deposit comprised of clayey silt trace to some sand to with sand, and silty clay was encountered underlying the topsoil in Boreholes GA-BR-03 and GA-WM-04 to GA-WM-08 and underlying the fill in Boreholes GA-WM-01 to GA-WM-03. A 150 mm thick layer of sand and 80 mm thick layer of silty sand layer was encountered a depth of 1.7 m and 4.0 m in Boreholes GW-WM-04 and GA-WM-06, respectively. The top of the cohesive deposit ranges from Elevation 194.5 m to 185.9 m and the thickness of the deposit vary between 2.0 m and 3.8 m.

In general, the SPT 'N'-values measured within the cohesive deposit range from 17 blows per 0.3 m of penetration to 50 blows per 0.15 m of penetration, suggesting a very stiff to hard consistency. A SPT 'N'-value of 5 blows per 0.3 m of penetration was measured in Borehole GA-WM-08, suggesting a firm consistency.

The natural water content measured on samples of clayey silt to silty clay ranges from about 11 per cent to 25 per cent.

The results of grain size distribution tests completed on three samples of the upper cohesive deposit are shown on Figure B1 in Appendix B.



FOUNDATION REPORT - WATERMAIN RELOCATION

Atterberg limits test carried out on five samples of the upper cohesive deposit measured liquid limits ranging between about 20 per cent and 41 per cent and plastic limits ranging between about 13 per cent and 19 per cent, corresponding to plastic indices ranging between about 8 per cent and 22 per cent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure B2 in Appendix B and indicate that the material of the cohesive deposit is classified as clayey silt of low plasticity to silt clay of intermediate plasticity. The result of an Atterberg limits test carried out a sample of the sandy silt seam from Borehole GA-WM-06 indicates that the fines material is non-plastic.

4.2.4 Silt and Sand to Sand

A non-cohesive deposit comprised of silt and sand, silt and sand to silty sand, and silt and sand to sand was encountered underlying the upper clayey silt to silty clay deposit at all borehole locations, except Borehole GA-WM-03. A 10 cm thick layer of sandy clayey silt and a 150 mm thick layer of silt was encountered a depth of 3.1 m and 9.1 m in Boreholes GA-WM-07 and GW-WM-08, respectively. The presence of cobbles was inferred by auger grinding within the deposit in Boreholes GA-WM-05, GA-WM-06 and GA-WM-08. The top of the silt and sand to sand deposit ranges from Elevation 191.7 m and 183.9 m and the thickness of the deposit vary from about 0.4 m to 14.3 m upon termination of boreholes.

The SPT 'N'-values measured within the silt and sand to sand deposit range from 16 blows per 0.3 m of penetration to 101 blows per 0.15 m of penetration, indicating a compact to very dense relative density.

The natural water content measured on samples of the non-cohesive deposit ranges from about 6 per cent to 26 per cent.

The results of grain size distribution tests completed on ten samples of the silt and sand to sand deposit are shown on Figures B3A and B3B in Appendix B. The results of grain size distribution tests completed on one sample of a sandy clayey silt layer and one sample of a sandy silt layer within the silt and sand to sand deposit are shown on Figure B4 and B5 in Appendix B.

The results of Atterberg limits test carried out on six samples of the non-cohesive deposit indicate that the deposit is non-plastic. An Atterberg limits test carried out on a sample from the sandy clayey silt layer from Borehole GA-WM-07 measured a liquid limit of about 25 per cent, a plastic limit of about 13 per cent, corresponding to a plastic index of about 8 per cent. In addition, an Atterberg limits test carried out on a sample from a silt layer from Borehole GA-WM-08, measured a liquid limit of about 16 per cent and a plastic limit of about 13 per cent, corresponding to a plastic index of about 3 per cent. The results of the Atterberg limits tests on the sandy clayey silt and the silt layers are shown on the plasticity chart on Figures B6 and B7 in Appendix B, respectively.

4.2.5 Gravelly Silty Sand to Gravelly Sand (Interlayer)

An interlayer of gravelly silty sand to gravelly sand with inferred cobbles, was encountered within the silt and sand to sand deposit in Boreholes GA-BR-03 and GA-WM-07. A 23 cm thick silt layer was encountered within the gravelly sand portion of the deposit at a depth of 9.4 m in Borehole GA-WM-07. The top of the sand interlayer is at Elevation 184.3 m to 184.5 m and the thickness of the interlayer is about 0.9 m and 3.7 m in the respective boreholes.



FOUNDATION REPORT - WATERMAIN RELOCATION

The SPT 'N'-values measured within the gravelly silty sand to gravelly sand interlayer range from 54 blows per 0.3 m of penetration to 100 blows per 0.13 m of penetration, indicating a very dense relative density.

The natural water content measured on samples of the interlayer ranges from about 12 per cent to 20 per cent.

The result of a grain size distribution test completed on one sample of the interlayer is shown on Figure B8 in Appendix B. The result of an Atterberg limits test on one sample of the fines material of the gravelly silty sand interlayer indicates that the deposit is non-plastic.

4.2.6 Sandy Silt to Silty Sand Till

A deposit of till comprised of sandy silt, sandy silt to silty sand, and silt and sand, was encountered underlying the silt and sand to sand deposit in Boreholes GA-WM-01 to GA-WM-04 and within the silt and sand to sand deposit in Boreholes GA-WM-05. The presence of cobbles was inferred by auger grinding within the deposit in Boreholes GA-WM-04. The top of the till deposit ranges from Elevation 186.0 m to 183.0 m and the thickness of the deposit varies between about 1.5 m and 8 m where fully penetrated or to the termination depth of the boreholes.

The SPT 'N'-values measured within the till deposit range from 8 blows per 0.3 m of penetration to 190 blows per 0.26 m of penetration, indicating a compact to very dense relative density.

The natural water content measured on samples of the till deposit ranges from about 5 per cent to 18 per cent.

The results of grain size distribution tests completed on five samples of the till deposit are shown on Figure B9 in Appendix B.

The results of Atterberg limits tests carried out on three samples of the till deposit indicate that the deposit is non-plastic.

4.2.7 Clayey Silt (Lower)

A lower cohesive deposit comprised of clayey silt, trace sand and gravel was encountered underlying the silt and sand to sand deposit in Borehole GA- WM-05. The top of the cohesive deposit is at Elevation 180.6 m and the thickness of the deposit is 3.2 m to the termination depth of the borehole.

The SPT 'N'-values measured within the cohesive deposit are 99 blows and 101 blows per 0.3 m of penetration, suggesting a hard consistency.

The natural water content measured on a sample of clayey silt is about 14 per cent.

An Atterberg limits test carried out on one sample of the lower cohesive deposit measured a liquid limit of 28 per cent and a plastic limit of about 15 per cent, corresponding to a plastic index of about 13 per cent. The result of the Atterberg limits test is shown on the plasticity chart on Figure B10 in Appendix B and indicates that the material is classified as clayey silt of low plasticity.



FOUNDATION REPORT - WATERMAIN RELOCATION

4.3 Groundwater Conditions

In general, the overburden samples taken in the boreholes were moist to wet. The water level encountered during drilling and upon completion of drilling is between approximately Elevation 187.5 m and 181.7 m. However, the water level observed in the open boreholes during and/or on completion of drilling may not represent the longer-term, stabilized groundwater level at the site. Borehole GA-WM-01 was dry upon completion of drilling.

A standpipe piezometer was installed in each of Boreholes GA-WM-02 and GA-WM-04 to GA-WM-07 to allow monitoring of the groundwater level at the site. Details of the piezometer installation are shown on the Record of Borehole sheet in Appendix A and the groundwater level measured in the piezometer is summarized below.

Borehole	Depth to Water Level	Groundwater Elevation	Date of Measurement
GA-WM-02	2.7 m	184.0 m	September 11, 2015
	2.9 m	183.8 m	September 15, 2015
	2.9 m	183.8 m	October 13, 2015
GA-WM-04	Dry	--	September 11, 2015
	Dry	--	September 15, 2015
	Dry	--	October 13, 2015
GA-WM-05	4.6 m	185.5 m	September 11, 2015
	4.7 m	185.4 m	September 15, 2015
	4.6 m	185.5 m	October 13, 2015
GA-WM-06	5.0 m	185.5 m	September 10, 2015
	4.9 m	185.6 m	September 11, 2015
	4.9 m	185.6 m	September 15, 2015
	4.9 m	185.6 m	October 13, 2015
GA-WM-07	5.7 m	185.9 m	September 9, 2015
	5.8 m	185.8 m	September 11, 2015
	5.8 m	185.8 m	September 15, 2015
	5.2 m	186.4 m	October 13, 2015

The water level at the site is expected to fluctuate seasonally in response to changes in precipitation and snow melt, and is expected to be higher during the spring and periods of precipitation.



FOUNDATION REPORT - WATERMAIN RELOCATION

5.0 CLOSURE

Ms. Madison Kennedy, B.A.Sc., Messrs. Alex Szot, E.I.T. and Oleg Skorik, E.I.T., supervised the borehole investigation program. This report was prepared by Mr. Christopher Ng, P.Eng., a senior geotechnical engineer and Associate of Golder. Mr. Jorge M. A. Costa, P.Eng., a Principal of Golder and Designated MTO Foundations Contact, conducted an independent review of this report.

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PART B

FOUNDATION DESIGN REPORT
WATERMAIN RELOCATION
NORMAN BETHUNE AVENUE AND HIGHWAY 404 S-E/W RAMP
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6.0 DISCUSSION OF PROPOSED WATERMAIN INSTALLATION

6.1 General

The following discussion and recommendations are based on our understanding of the project and our interpretation of the factual data obtained from the current subsurface investigation. Where comments are made on construction, they are provided in order to highlight those aspects which could affect the design of the project, and for which special provisions or operational constraints may be required in the Contract Documents. Those planning and undertaking specific aspects of construction should make their own interpretation of the factual information provided, as it may affect equipment selection, proposed construction methods, scheduling and the like. Our professional services for this assignment address only the geotechnical (physical) aspects of the subsurface conditions at this site. Analytical testing was completed on samples of the ground water and are presented in Appendix B for reference only. Soil and groundwater management issues and investigation or evaluation of the environmental (chemical) nature of the soils, groundwater, and bedrock are outside of the scope of our work and are not discussed herein.

This project involves installation of a watermain along the north side of the proposed realigned E-N Ramp (and north of Highway 7) and beneath the Highway 404 E-N Ramp and S-E/W Ramp Extension, as shown on Drawings 1 and 2. The location and vertical alignment of the proposed watermain including other pertinent design features such as shafts are shown on Drawing 2. The design details for the watermain are outlined below.

6.2 Watermain Alignment

Based on drawings WM1 to WM4 provided by AECOM on December 15, 2015, it is understood that the watermain will consist of a 600 mm diameter concrete watermain pipe. Generally, the watermain pipe will be installed in a 1,200 mm reinforced concrete microtunnelling pipe, with the exception beneath the Highway 404 E-N Ramp, where the watermain pipe is proposed to be installed within a 1,200 mm diameter steel casing. It is understood that the watermain crossing beneath the S-E/W Ramp Extension is currently within York Region, however, this property is planned to be transferred to MTO in the future. Therefore, this portion of the watermain may also be required to be encased within a 1,200 mm diameter steel casing. In addition, the following details regarding the proposed watermain have been provided to Golder:

Proposed Installation Methods (by AECOM)	Approximate Watermain Station (STA)	Length	Pipe Invert Elevation	Soil Cover ²
Open Cut Excavation	0+000 to 0+021	21 m	182.9 m to 183.2 m	2.1 m
Microtunnelling ¹	0+021 to 0+405	384 m	183.3 m to 185.8 m ³	3.1 m to 6 m
Open Cut Excavation	0+405 to 0+420	15 m	185.8 m	4 m to 6 m

¹ This trenchless crossing extends beneath the Highway 404 E-N Ramp with shaft locations at approximately STA 0+353 and STA 0+405.

² The approximate soil cover depth is based on the existing ground surface in areas where grade raises and/or cuts are to be carried out. It is assumed that the installation of the watermain will be carried prior to any preloading/grade raises and/or grade lowering.

³ The invert elevation provided for the trenchless crossing beneath Highway 404 Ramp E-N Ramp includes the installation of 1.2 m steel casing.



6.3 Anticipated Ground Conditions

The subsurface conditions at the boreholes along the proposed watermain alignment through which the watermain will be installed, generally consist of a moist to wet, compact to very dense granular silt and sand to sand and sandy silt to silt and sand till deposits along most of its length. Along the eastern extent of the watermain profile between Boreholes GA-WM-01 and GA-WM-03, a moist, very stiff to hard clayey silt to silty clay deposit is present, in turn underlain by a thin layer of wet loose to compact silt and sand.

Generally, the groundwater level along the watermain profile will be at least 0.5 m to 1.5 m above the invert of the proposed watermain. Correlating the soil classifications with a modified version of Terzaghi's Tunnelman's classification (Heuer, 1974), the tunnelling conditions can be described as "fast ravelling" to "flowing" if encountered in an open tunnel heading. If supported and allowed to drain or dewatered, would behave as "fast to slow ravelling" or "running" ground, that corresponds to a stand up time on the order of a few minutes progressively degrading, with the face beginning to ravel, with the amount of ravelling accelerating with time until the material begins to flow. An NSSP alerting the Contractor to the condition that the silt and sand deposit is subject to ravelling and flowing is provided in Appendix C.

The dense/very dense relative density of the silt and sand to sand deposit (beneath the E-N Ramp) and the compact to dense sandy silt to silt and sand till deposit elsewhere as well as the potential for the presence of cobbles and boulders within the non-cohesive and till deposits, will present difficult conditions for the trenchless installation of the watermain. In addition, the Contractor should also expect to encounter saturated seams/layers of granular material which were noted below the clayey silt to silty clay deposit along the eastern portion of the alignment. An NSSP alerting the Contractor to the potential for encountering obstructions such as boulders and cobbles is provided in Appendix C.

6.4 Monitoring Well Decommissioning

Ontario Regulation (O.Reg.) 903, as amended, of the Ontario Water Resources Act requires that monitoring wells/piezometers are properly abandoned/decommissioned by qualified personnel. It is recommended that the decommissioning of the groundwater level monitoring piezometers be carried out as part of the construction activities at the site so that water level measurements can be taken immediately prior to construction. If requested, Golder could provide assistance to the owner in arranging for the decommissioning of the piezometers by a licensed water well drilling contractor.

6.5 Obstructions

Auger grinding was noted in the silt and sand to sand deposit during the drilling, and as such, these soils should be expected to contain cobbles and boulders. Further, the silt and sand to sand deposit is granular and saturated which could affect trenchless installation operations. Similar conditions should be expected within the sandy silt to silt and sand till deposit. The Contractor should be made aware of the potential presence of cobbles and/or boulders within the overburden soils as noted in the NSSP for Obstructions and the nature of the silt deposit in the NSSP for Saturated Non-cohesive Soils, both included in Appendix C. The borehole drilling method does not permit accurate measurement of the cobbles or boulders; nor can an estimate to be made of the quantity (overall volume) of these materials. Should this information be required during the design and tender processes, further investigation would be required to determine the percentage and dimensions of the



cobbles and boulders. For such an investigation, if warranted, it is recommended that test pits be the method of investigation for this purpose, with the limitation that conditions will vary between test pit locations.

6.6 Watermain Installation by Trenchless Methods

Ministry of Transportation Ontario (MTO) has developed a Non-Standard Special Provision (NSSP) for Pipe Installation by Trenchless Methods, which is considered applicable for the watermain installation by trenchless methods beneath the Highway 404 E-N Ramp from Highway 7. The NSSP, which is included in Appendix D, presents the requirements for the design, material types/quality, construction, quality control, and monitoring of the watermain pipe and trenchless installation work. Additionally, we recommend that Contractor pre-qualification be specified in the Tender section of the Contract Documents, to ensure that Contractors bidding for this work have the experience/capabilities in carrying out similar works and to determine and develop the most appropriate installation method of the watermain crossing.

The Contractor should be fully responsible for the selection of the trenchless technology which best fits the contract requirements and his equipment, experience and staff availability. All trenchless work should be carried out by an experienced specialist Contractor employing only qualified workers skilled in their trade under the direction of an experienced foreman. The Contractor's work plan should include a provision for grouting should the need arise. It is recommended that the geotechnical aspects of the Contractor's work plan for the trenchless undercrossing be reviewed by the foundations consultant office prior to construction.

In general, when crossing beneath highways or within the zone of influence of adjacent roadways, trenchless operations should be carried out continuously from the start until the installation is complete. Continuous operations assist with minimizing risks of equipment becoming jammed in the hole, hole convergence, deterioration of ground conditions and non-detection of critical problems which may occur while the work area is unattended. Continuous trenchless excavation operations are particularly critical for this site where the saturated silt and sand (including till) deposits will have very limited stand-up time and whose behaviour will degrade to flowing conditions if operations are stopped and groundwater pressures equilibrate.

The interpretation and recommendations provided are intended to provide the designers with information to assess and specify the tunnelling methodology and equipment. This report does not assess other aspects of the design of the trenchless installation methods (e.g. identifying the steel bore pipe type, jacking/ramming force, etc.). Furthermore, the installation of the watermain should be carried out in accordance with all applicable regulations/guidelines.

The tunnelling/excavation methods discussed herein are considered feasible for watermain installation, based upon the ground conditions encountered; however, the Contractor is not limited to the methods discussed herein and, regardless of the method selected, must consider the suitability of the specific equipment and techniques relative to the ground conditions at the site.

6.6.1 Suitable Trenchless Methodologies

It is noted that traditional open trench construction is not considered feasible for the crossing of the Highway 404 E-N Ramp, as significant disruptions to traffic flow along the ramp would occur if this construction method is used. Further, it is understood that open cut methods have been limited to tie-in connection locations. As such, trenchless methods are being considered for approximately 384 m of this project alignment. Several trenchless



FOUNDATION REPORT - WATERMAIN RELOCATION

installation methods were evaluated and three methods are considered geotechnically feasible for the watermain installation, including:

- Jack-and-Bore,
- Horizontal Directional Drilling (HDD); or,
- Microtunnelling (MT).

The methods, construction recommendations and limitations for Jack & Bore, horizontal directional drilling and microtunnelling are discussed in the following section. The alternative of installing the watermain liner by pipe ramming techniques under the E-W Ramp is not considered suitable due to the presence of very dense zones within the soil deposits. For the remainder of the watermain alignment a number of access pits would be required to shorten the length of pipe ramming sections. Trenchless construction methods include various advantages and disadvantages depending on soil conditions, depth of cover, vertical and horizontal alignment, length of pipe installation, cost, and availability of equipment, and carry varying levels of risk of successfully completing the installation. In accordance with MTO reporting requirements, the advantages, disadvantages, relative costs and risks related to the Highway 404 E-N Ramp crossing only are compared in Table 1. Table 1 may also be considered for the crossing beneath the future S-E/W Ramp Extension.

Further, it is our understanding from the AECOM drawings that the proposed watermain installation beneath the Highway 404 E-N Ramp will pass beneath an existing watermain with a clearance of approximately 1.9 m between crown level of the proposed tunnel and the invert level of the existing watermain. Information on bedding material of the existing watermain is not available at this time. Independent of the chosen trenchless installation methodology, it is recommended that at least one tunnel diameter (1.2 m) of native soil material be present between the invert level of the existing watermain and the proposed tunnel crown. The presence of granular bedding material under the existing watermain coupled with a thinner layer of native material cover between the existing watermain bedding and the proposed tunnel crown could result in running or flowing of the granular material into the face of tunnel excavation.

6.6.1.1 *Jack-and-Bore*

Jack-and-Bore involves forming a horizontal borehole through the ground from a drive shaft to an exit shaft by means of a rotating cutting head. The cutting head is attached to continuous-flight helical augers within a casing which transports spoils from the face to the drive shaft. The main advantage of this system is that with suitable soil conditions and good workmanship, minimal settlement generally occurs due to the simultaneous installation of the casing or carrier pipe. Ground settlement will occur if the hole is over-excavated by advancing the cutting head near to or ahead of the casing leading edge, or if flowing ground is encountered.

When using Jack-and-Bore, the installation accuracy is dependent on groundwater conditions, length of drive, casing stiffness, initial setup and guiding systems, operator skill and extent of obstructions in the ground. Accuracy can be improved through use of a "pilot tube" method whereby a small diameter direction drilled bore is initially advanced, with the auger jack and bore operation being guided by the pilot hole. An accuracy (horizontal and vertical) within 1 per cent of the length of bore can be achieved under ideal conditions. Cobbles and boulders are anticipated to be encountered within the silt and sand deposit, and if encountered in sufficient number or size, these may halt advancement or affect the line and grade of the bore. In addition, the silt and sand deposit is noted to be compact, generally dense, to very dense. To reduce the risk of being impeded by



FOUNDATION REPORT - WATERMAIN RELOCATION

the compactness of the soils and / or by the presence of a large boulder or cobble nest, a rock cutting head should be considered for this installation. A lubricant (such as bentonite slurry) will be needed to reduce jacking loads and minimize casing friction.

When ground settlement or ground losses due to flowing ground conditions are of concern during jack-and-bore operations, the casing should be advanced as far ahead of the augers as possible, such that the auger head is maintained at least 0.6 m (preferably 1 m) behind the leading edge of the casing, creating a plug of soil material. The plug of soil at the front of the casing, in front of the auger, must be maintained when advancing through the silt and sand deposit. Typical construction specifications for the installation of the watermain by the Jack-and-Bore method are given in the NSSP for "Pipe Installation by Trenchless Method" in Appendix D. In this case, however, the ground conditions will likely preclude the ability to advance the casing ahead of the auger flights and may require that the augers be advanced ahead of the casing to continue using the jack-and-bore approach. Attempting to run the augers ahead of the casing in this case, however, increases the potential for unacceptable ground losses and settlements.

Dewatering will be required at the entry and exit pit locations to prevent flooding. This requirement should be reviewed upon finalization of the vertical alignment. Dewatering recommendations are provided in Section 6.8 of this report.

6.6.1.2 *Horizontal Directional Drilling (HDD)*

The horizontal directional drilling method of pipe installation uses a small rotating and steerable drill bit launched from the ground surface (or near the surface) at a shallow angle to drill a pilot hole supported with drilling fluid. Once the pilot bore is complete, the drill head is replaced with a backreamer or expander of progressively larger diameter which enlarges the drill hole. Once the desired size is reached, the casing, or carrier pipe as the case may be, is attached to the reaming head and pulled through the bore. During drilling, reaming and pipe installation, the drilled hole is supported by drilling fluids (slurry) of controlled density and viscosity. The main advantage of this system is its adaptability to a wide range of drilling conditions through selection of compatible drilling fluids, downhole tools and equipment.

Installation of flexible, thin-walled steel pressure pipes for transmission of compressed gases is relatively common; however, thicker walled (and stiffer) pipes designed to resist external compressive loads are more difficult to advance and are less commonly installed using the HDD technique. If acceptable to the MTO, a thick-walled High Density Polyethylene (HDPE) pipe can serve as the casing for the watermain crossing the E-N Ramp (and the S-E/W Ramp Extension, if required). If steel is to be used, HDD may not be feasible for the E-N Ramp crossing portion of the proposed watermain installation.

Installation accuracy depends on the ground conditions, operator's skill and surveying system. This technology allows directional control of the bore, but the alignment control precision is generally less than that for microtunnelling systems.

HDD methods generally commence / end at near ground surface elevations within shallow pits which are utilized to store and supply drilling fluid. As such, dewatering typically is not required for this type of trenchless installation. However, as the watermain pipe will be required to be connected to the existing watermain (at STA 0+000 and STA 0+420), open excavations at/below the groundwater table will be required. For these open excavations at each end of the HDD alignment, dewatering will be required; further information in this regard is provided in Section 6.8.



FOUNDATION REPORT - WATERMAIN RELOCATION

As noted in previous sections of this report, cobbles and boulders are anticipated to be encountered within the site soils, and as such the selected equipment and methods must be capable of handling cobbles and boulders which have the potential to impede advancement of the HDD unit or cause deflection. Drilling pressures must be carefully monitored to prevent exceedance of the maximum allowable pressure within the bore annulus and “blow out” of drilling fluids to the ground surface. Reaming and pullback rates should be carefully controlled so that the annulus is properly prepared and cuttings are effectively mixed with the slurry. The selected equipment should have sufficient thrust to overcome the stresses associated with the compact to very dense ground conditions. Specifications for the installation of the watermain by HDD method are given in the NSSP for “Pipe Installation by Trenchless Method” in Appendix D.

6.6.1.2.1 Hydraulic Fracture (“Frac-out”) Potential

For assessment of the HDD installation, a number of issues must be considered, such as hydraulic fracture (typically referred to as “frac-out”), settlement reduction and surface stability. Latorre et al. (2002) provide some guidance related to the recommended minimum depth of cover for various pipe diameters as reproduced below.

Recommended Minimum Depth of Cover for Various Pipe Diameters (Latorre et al., 2002)

Diameter	Depth of Cover
50 mm (2 in.) to 150 mm (6 in.)	1.2 m (4 ft)
200 mm (8 in.) to 350 mm (14 in.)	1.8 m (6 ft)
375 mm (15 in.) to 600 mm (24 in.)	3.0 m (10 ft)
625 mm (25 in.) to 1,200 mm (48 in.)	4.5 m (15 ft)

As noted in Section 6.2 the proposed casing diameter for the watermain installation along the alignment and beneath the E-N Ramp is 1,200 mm (STA 0+353 to 0+405) and the watermain carrier pipe diameter is 600 mm. Based on Latorre et al. (2002), a proposed HDD installation for this watermain should have a cover depth of at least 4.5 m below the base of the ramp(s) and below ground surface at the time of installation.

Where ground surface varies, the ground elevation should be constant laterally for a distance from the alignment that extends from the invert of the pipe up and outward at a 2 horizontal to 1 vertical inclination.

The contractor’s techniques during drilling, equipment and proposed installation method may produce high downhole pressures. In this case, it may be necessary to include mitigation measures to further limit the potential for frac-out from occurring during drilling. One mitigation measure used for limiting the potential for frac-outs is installing pressure relief pits (or “burp holes”) on either side of the installation to dissipate high fluid pressures that may develop during drilling. The installation of pressure relief pits will also minimize the potential for “hydrolock”, which is a condition where circulation from the bore is lost due to cuttings inhibiting mud circulation which then allows pressure build-up ahead of the advancing pipe, creating a hydraulic cylinder in the ground.

Boreholes advanced as part of the geotechnical investigation were located in close proximity to the proposed watermain alignment and piezometers were installed in four of the boreholes. The HDD drill fluids will take the path of least resistance and may potentially migrate to the ground surface through the piezometer at these



FOUNDATION REPORT - WATERMAIN RELOCATION

borehole locations. Prior to installation of the watermain, all piezometers should be decommissioned / grouted in order to limit the potential for upward fluid migration. The remaining boreholes were sealed with bentonite; however, as the HDD drill fluids will take the path of least resistance, there is a potential for migration of the drill fluids through the softer backfill in the boreholes. In either event, visual monitoring of the borehole locations for signs of drill fluid migration at all borehole locations should be carried out on a regular basis during the HDD operations.

It is recommended that the contractor be required to have contingency/mitigation plans in place to control/reduce drill fluid pressures and to clean up any drill fluid in the event that drilling fluid migrates to the ground surface. For the duration of the HDD crossing, provision for full time monitoring should be included in the contract to ensure that if drill fluid migration occurs, it could be identified immediately.

6.6.1.3 *Microtunnelling (MTBM)*

Microtunnelling relies on a horizontal jacking force applied to a pipe to propel a remotely controlled micro-tunnel boring machine (MTBM) together with the pipe string through the ground. The final pipe is typically installed while the bore is being advanced.

Avoidance of overexcavation above or ahead of the pipe/casing must be minimized particularly within the saturated non-cohesive silt and sand to sand deposit at this site. Overcut should be minimized by selection of a casing diameter which is similar to that of the shield. If over excavation occurs, the annulus between the outside of the pipe and the ground should be immediately filled with bentonite slurry of an appropriate viscosity. The slurry should be appropriately formulated, using suitable additives if necessary for the anticipated ground conditions; for example, within the silt and sand to sand deposit the slurry should be sufficiently viscous to create a 'filter-cake' to support this non-cohesive material. A seal will be required to close the annular space between the wall of the entry/exit shaft and the shield and pipes to retain soil behind the temporary shoring and stop backflow of slurry into the pits.

Microtunnelling can be fully obstructed if sufficient numbers and sizes of cobbles and boulders are encountered, due to the lack of access to the face and the smaller diameter of the equipment precluding manual removal of obstructions from the face. As such, the selected cutting tools and methods should be compatible with the dense/very dense soils containing cobbles and boulders. Properly selected rock cutter discs should be used to cut the dense/very dense soils and break cobbles and boulders at the face into sufficiently smaller fragments to pass through the apertures in the face. Alternatively, depending on the particular MTBM configuration, slurry properties and advance rate, some MTBMs can incorporate a crushing head which can draw cobbles and boulders into the shield and crush them. However, large boulders or many cobbles can choke internal crushers such that the obstructions cannot be cleared or ingested by the machine and the alignment will have to be either abandoned or a rescue shaft advanced to free the MTBM and remove the obstructions. Construction specifications for the installation of the watermain by the use of a MTBM are given in the NSSP for "Pipe Installation by Trenchless Method" in Appendix D.

In the greater Toronto area, some trenchless contractors use "small boring units" and present this system as "micro-tunnelling". In general, the small boring units often consist of a rotating cutter head system that is temporarily welded to the lead end of a steel casing. The ground is cut using a variety of face tools (similar to MTBMs described above), but the spoil is transported to the surface using an auger system, much like conventional jack and bore systems. Face openings on the small boring units are typically much smaller than



the auger opening on conventional jack and bore systems and the risk of uncontrolled ingress of ground into the lead end of the casing is lower for this system as compared to jack and bore methods. These systems do not, however, provide consistent and positive support to the ground at all face openings with any slurry or cuttings, unlike the slurry-based MTBMs described above. Therefore, while the small boring units are more suitable and advantageous for cutting through stiff to hard cohesive glacial till and weathered rock materials, they should only be used only with caution if granular soils.

Similar to the other trenchless methods, entry and exit shafts are required for microtunnelling operations. Dewatering will be required at both pit locations to prevent flooding. This requirement should be reviewed upon finalization of the vertical alignment. Dewatering recommendations are provided in Section 6.8 of this report.

6.7 Temporary Excavations

6.7.1 Temporary Open Cut Trench Excavations

Temporary excavations below existing ground surface extending to depths on the order of 3 m to 4 m for the open cut trench portion and 6 m to 7 m for the tunnel shafts on each side of the E-N Ramp are anticipated to be required for the installation of the proposed watermain. The excavations are expected to be stable upon initial exposure; however, active external groundwater lowering will be required to maintain base stability and limit groundwater flow over the majority of the excavation lengths. If loose/disturbed soils are encountered at the base of the excavations (such as saturated lenses/layers of sandy soils), these materials should be subexcavated and replaced with engineered fill materials, or unshrinkable fill.

Depending on the trenchless method(s) chosen/adopted by the Contractor(s), entry and exit pits will likely be required as part of the watermain installation. Temporary excavations may be carried out using open cut methods. All excavation work should be carried out in accordance with the Occupational Health and Safety Act and Regulations (OHSA) and with local regulations. The fill materials are classified as Type 3 soils; the very stiff to hard cohesive soils and the compact to very dense silt and sand soils are classified as Type 2 soils. If dewatering is not in place, the silt and sand materials are classified as "Type 4" soils. For excavations through varying soil types, the soil with the highest number will be the soil that governs the side slope geometry. Conventional temporary type open cuts may be developed with side slopes not steeper than 1 horizontal to 1 vertical (1H:1V) in these materials above the groundwater level and 3H:1V for the silt and sand to sand deposit below the groundwater level given the fine gradation and ravelling potential for this soil. However, depending upon the construction procedures adopted by the contractor, actual groundwater seepage conditions, the success of the contractor's groundwater control methods and weather conditions at the time of construction, some flattening and/or blanketing of the slopes may be required. Care should be taken to direct surface water runoff away from the open excavations and all excavations should be carried out in accordance with the OHSA. Stockpiles of excavated material should be set back from the edge of the excavation by a distance at least equal to the excavation depth.

Where the side slopes of excavations are required to be steepened to limit the extent of the excavation, then some form of trench support will be required. Some trench excavations could be carried out using a vertically excavated, unsupported excavation (using a properly engineered prefabricated support system for personnel protection, certified by an experienced engineer); or by a supported excavation (discussed below) if conditions warrant in wet areas and/or in close proximity to adjacent underground services. It must be emphasized that a prefabricate support system (trench liner box) provides protection for construction personnel but does not provide any lateral support for adjacent excavation walls, underground services or existing structures. It is



FOUNDATION REPORT - WATERMAIN RELOCATION

imperative that underground services and existing structures adjacent to the trench excavations be accurately located prior to construction and adequate support provided where required. Steepened excavations should be left open for as short a duration as possible and completely backfilled at the end of each working day.

In addition, it would be prudent to carry out a “public digging” (i.e. test pitting) during the tender stage, to allow prospective bidders to assess the subsurface conditions and determine the type of groundwater control and shoring required, consistent with their equipment capabilities and the actual groundwater conditions at that time. The locations of the test pits should be determined in consultation with the geotechnical engineer.

6.7.2 Supported Excavations

Temporary excavation support (i.e., shoring) will be required in areas where sufficient space is not available to excavate the shafts or trenches using open cut methods and/or in other areas where existing facilities (i.e., ramps and Highway 7) require protection. It is considered that either a soldier pile and timber lagging system or continuous caisson wall would be suitable for the temporary excavation support based on the subsurface soil and groundwater conditions at this site. The temporary excavation support system should be designed and constructed in accordance with OPSS.MUNI 539 (Temporary Protection Systems). The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS.MUNI 539. Reference to OPSS.MUNI 539 should be made in the Contract Drawings.

The selection and design of the protection system will be the responsibility of the contractor.

The design of a braced soldier pile and lagging wall should be based on a rectangular earth pressure distribution as presented in NAVFAC DM 7.02 (1986) using the design parameters given below. Where the support to the wall is provided by anchors or rakers, the wall design should be based on a triangular earth pressure distribution using the design parameters given below. The raker/anchor support must be designed to accommodate the loads applied from pressures and surcharge pressures from area, line or point loads as well as the impact of sloping ground behind the system. Passive toe restraint to the soldier piles may be determined using a rectangular pressure distribution acting over an equivalent width equal to three times the diameter of the pile socket.

Soil Type	Coefficient of Earth Pressure			Angle of Friction (ϕ)	Unit Weight (γ)
	Active, K_a	At Rest, K_o	Passive, K_p		
New Granular Embankment Fill	0.3	0.4	3.5	34°	21 kN/m ³
Existing Firm to Very Stiff Clayey Silt Fill	0.4	0.5	2.8	28°	19 kN/m ³
Very Stiff to Hard Clayey Silt to Silty Clay	0.3	0.5	3.3	32°	18 kN/m ³



FOUNDATION REPORT - WATERMAIN RELOCATION

Soil Type	Coefficient of Earth Pressure			Angle of Friction (ϕ)	Unit Weight (γ)
	Active, K_a	At Rest, K_o	Passive, K_p		
Compact to Dense Sandy Silt to Sand	0.3	0.5	3.0	30°	19 kN/m ³
Compact to Dense Sandy Silt to Silt and Sand Till	0.3	0.5	3.0	30°	19 kN/m ³
Very Dense Silt and Sand	0.3	0.5	3.3	32°	19 kN/m ³
Very Dense Sand	0.3	0.4	3.5	34°	19 kN/m ³
Very Dense Gravelly Silt and Sand to Gravelly Sand	0.3	0.4	3.9	36°	21 kN/m ³
Hard Clayey Silt	0.3	0.4	3.5	34°	20 kN/m ³

The earth pressure coefficients noted above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are present, the coefficients should be adjusted accordingly.

The above pressure distributions are the minimum pressures for the ultimate stress condition. A stiffer design may be required than predicted by these distributions in order to maintain displacements within an acceptable range.

6.7.3 Pipe Bedding and Cover

The bedding for the watermain should be compatible with the type and class of pipe (as per manufacturer's requirements), the surrounding subsoil and anticipated loading conditions and should be designed (i.e. minimum bedding/cover thicknesses) in accordance with the applicable York Region standards. ASTM 2774 "Standard Practice for Underground Installation of Thermoplastic Pressure Piping" identifies five soil classes. ASTM Soil Class II generally meets an OPSS.MUNI 1010 Granular B material. The selected bedding, cover and backfill materials should be confirmed with the pipe manufacturer prior to construction and placement. If the watermain installation is to be carried out in wet trench conditions, York Regions standard (W-206) recommends a HL8 blend of crushed clear stone (surrounded by geotextile fabric if the groundwater table is above the trench bed) for the bedding material for PVC pipes. For this site, if crushed clear stone is used a complete, stitched non-woven geotextile surround should be provided, with the geotextile meeting the requirements of OPSS 1860 (Geotextiles) Class 2 material with a Filtration Opening Size (FOS) of not greater than 212 μ m.

Where granular bedding is deemed to be required (to be confirmed with the pipe manufacturer), it should consist of at least 200 mm of OPSS.MUNI 1010 (Aggregates) Granular 'A' (in accordance with W-206). From the springline to 300 mm above the obvert of the pipe, sand cover may be used. All bedding and cover materials should be placed in maximum 150 mm thick loose lifts and should be uniformly compacted to at least 98 percent of the material's Standard Proctor maximum dry density. Clear stone bedding material should not be used to stabilize the base. If applicable, bedding and cover material should conform to OPSS 401 (Trenching, Backfill and Compaction).



6.7.4 Trench Backfill

The excavated materials from the site will be variable, ranging from sandy/silty (non-cohesive) soils to clayey (cohesive) soils. The majority of the site subsoils from above the local water table are generally near their estimated optimum water contents for compaction and may be reused for trench backfill. The silt and sand to sand soils excavated from below the local water table are generally wet of their estimated optimum water contents for compaction and would likely require some drying prior to placement. In this regard, depending upon schedule and weather conditions, it may not be practical to effectively dry the excavated wet material in the field for reuse as trench backfill. The excavated materials at suitable water contents may be reused as trench backfill provided they are free of significant amounts of topsoil, organics or other deleterious material, and are placed and compacted as outlined below.

It should also be noted that due to the predominantly fine-grained, silty nature of the majority of the native subsoils, some difficulty would be expected in achieving adequate compaction during wet weather. All topsoil and organic materials should be wasted or used for landscaping purposes. All oversized cobbles and boulders (i.e. greater than 150mm in size) should be removed from the backfill.

It should also be noted that due to the silty nature of the predominant site soils, pore water pressure build-up may be encountered in the backfill material during compaction in wet conditions, resulting in some difficulty achieving adequate compaction and the potential for unstable subgrade conditions. As a result, even if the compaction requirements have been met, the subgrade strength in the trench backfill areas may not be adequate to support construction equipment loading, especially during wet weather or where backfill materials wet of optimum have been placed. In areas of future roads, the subgrade should be proof rolled and inspected by qualified geotechnical personnel prior to placing the subbase material, as required, consistent with the prevailing weather conditions and anticipated use by construction traffic.

All trench backfill, from the top of the cover material to subgrade elevation, should be placed in maximum 300 mm thick loose lifts and uniformly compacted to at least 98 percent of Standard Proctor maximum dry density.

An alternative bedding and backfill material, such as unshrinkable fill (U-fill), may be used, provided such materials are approved for use by the Region of York and the gradations of all fill materials are compatible with filter characteristics of the in-situ soils adjacent to the installation to prevent the migration of fines into the trench bedding and backfill.

Alternatively, if placement water contents at the time of construction are too high, or if there is a shortage of suitable in-situ material, then an approved imported material which meets the requirements for OPSS Select Subgrade Material (SSM) could be used. It should be placed in loose lift thicknesses as indicated above and uniformly compacted to at least 98 percent of standard Proctor maximum dry density. Backfilling operations during cold weather should avoid inclusions of frozen lumps of material, snow and ice.

Normal post-construction settlement of the compacted trench backfill should be anticipated, with the majority of such settlement taking place within about 6 months following the completion of trench backfilling operations. This settlement will be reflected at the ground surface and in pavement reconstruction areas, and may be compensated for where necessary by placing additional granular material prior to asphalt paving. However, since it is anticipated that the asphalt binder course will be placed shortly following the completion of trench backfilling operations, any settlement that may be reflected by subsidence of the surface of the binder asphalt should be



FOUNDATION REPORT - WATERMAIN RELOCATION

compensated for by placing an additional thickness of binder asphalt or by padding. In any event, it is recommended that the surface course asphalt should not be placed over the binder course asphalt (across the full road width) for at least 12 months. Post-construction settlement of the restored ground surface in any boulevard/ditch trench areas is also expected and should be topped-up and re-landscaped, as required.

6.7.5 Trench Plug

Where the watermain invert levels are located below the measured groundwater levels in cohesive soils (silty clay to clayey silt), impervious water-stops or cut-offs should be considered for constructed in the pipe trenches at regular intervals (every 100 m) according to OPSD 802.095 (Clay Seal for Pipe Trenches) or York Region Standard W-207. These should be constructed to reduce the potential for groundwater lowering in this area due to the “french drain” effect of the granular bedding and surround for the service pipes and to prevent the potential erosion and undermining of the pipe bedding and trench backfill materials in addition to preventing the trench from acting as a conduit. It is important that these barriers extend from trench wall to trench wall and that they fully penetrate the granular bedding to the trench bottom. The seal should be at least 1.5 m wide and could be constructed using silty clay or glacial till meeting the specifications in OPSS.MUNI 1205 (Clay Seal). These seals may be somewhat less effective in the relatively more permeable sandy deposits but should be used for the excavations made through the clayey deposits.

6.8 Groundwater Control

The open cut trench portion (tie-in connections) and entry and exit shafts/pits on each side of the E-N Ramp are anticipated to extend as deep as 3 m to 7 m below existing ground surface. Groundwater was measured in the piezometers in Boreholes GA-WM-02 and GM-WM-05 to GM-WM-07 at depths ranging from 2.7 m to 5.8 m below ground surface (Elevations 186.4 m to 183.8 m) on October 13, 2015. As such, it is anticipated that the groundwater level will be at least 0.8 m to 2.0 m above the proposed watermain invert within the open cut trench installation and/or pit excavation. Further, dewatering will be required to permit construction and facilitate operation of entry and exit shaft/pits for tunnelling activities (regardless of the trenchless method chosen) to limit the groundwater inflow into the shafts. Where excavations are carried out entirely within the clayey silt to silty clay and/or glacial till deposits and the groundwater level is near/at the invert depth, it may be possible to pump from properly filtered sumps located within the excavation (provided that the integrity of the excavation base can be maintained). However, the saturated granular silt and sand deposits should be dewatered using eductors, vacuum well points or the like; these should lower the groundwater level to at least 0.5 m below the level of the invert or base of the entry/exit pits prior to excavating. These requirements should be reviewed upon finalization of the vertical alignment.

A typical NSSP used by MTO for dewatering is provided in Appendix C. The contractor should be responsible for the selection and implementation of a suitable groundwater control/dewatering system; however, any groundwater control dewatering system proposed should be designed, installed and operated by an experienced specialist firm and licenced well technicians. The proposed groundwater control system should be reviewed by the geotechnical engineer to confirm that it meets the intention of this report.

Surficial water seepage into the excavations should be expected and will be heavier during periods of sustained precipitation. During these times, pumping from properly filtered sumps located at the base of the excavations may be required to provide additional groundwater control. Sumps should be maintained outside of the actual



FOUNDATION REPORT - WATERMAIN RELOCATION

excavation limits. Surface water runoff should be directed away from the excavations at all times. The contractor's proposed dewatering plan should be reviewed by the geotechnical engineer prior to construction.

For projects where removal of groundwater is greater than 50,000 L per day, a Permit to Take Water (PTTW) is required to be obtained from the Ministry of Environment. It is understood that a separate hydrogeological assessment is being carried out by AECOM who will confirm the dewatering thresholds and need for a PTTW. If dewatering is required (as per final excavation depths), a PTTW from the Ministry of Environment (MOE) may be required. Obtaining MOE approval for a PTTW can take up to several months; therefore, an allowance for this time should be included for in the overall planning process.

6.9 Settlement Monitoring Program – E-N Ramp

In accordance with the recommendations provided above and the anticipated dense to very dense relative density soil deposits encountered during the field investigation at the crossing of the E-N Ramp, significant settlement is not anticipated to occur from either the dewatering program or the trenchless installation crossing beneath the ramp, provided that appropriate construction methods are utilized during the installation process as required by the NSSP for "Pipe Installation by Trenchless Method". Nonetheless, even with careful workmanship, some post construction settlement may occur as a result of installation of the watermain. Therefore, as per the MTO Guidelines for Foundation Engineering-Tunnelling Specialty for Corridor Encroachment Permit Application (April 2008), it is recommended that provision for settlement monitoring should be made in the Contract Documents for monitoring the response of the highway ramp prior to, during and after the watermain installation to:

- Document the effects of the watermain installation on the overlying roadway ramp;
- Obtain prior warning of ground movements that could occur due to the construction methods and equipment or unforeseen ground conditions;
- Verify the contractor's compliance with the settlement limits imposed in the Contract; and
- Allow adjustments to be made to the watermain installation methods such that the settlement limits established are not exceeded.

The proposed monitoring program for the crossing of Highway 404 E-N Ramp is consistent with the "Appendix: Settlement Monitoring Guidelines -Tunneling" included in the above referenced Guideline and is summarized below:

- Shallow in-ground monitoring points should be installed between the shafts and along the unpaved portions of the tunnel alignment to depths of at least 1.2 m (i.e. below the depth of frost penetration).
- Surface monitoring points (reflectors) should be installed directly over the alignment along the centreline of the watermain where it crosses the existing E-N Ramp. The surface monitoring points should be installed on the pavement and paved shoulders within the limits of the highway ramp. The maximum spacing between such points should not exceed 5 m along the watermain alignment.
- Prior to the start of construction all monitoring points should be read a minimum of three times to provide a baseline.



FOUNDATION REPORT - WATERMAIN RELOCATION

- All monitoring points should be read and recorded a minimum of three times daily during the construction period (including work stoppages) and after construction for a period of at least two weeks, provided that further settlement has ceased.

Drawing 3 presents the monitoring point locations proposed to be installed as part of this settlement monitoring program. In addition, details and general specifications pertaining to the monitoring points are also presented on the drawing.

Monitoring of the instrumentation on this project will be constrained by the continuous and expected high traffic volume and the limited periods during which access to the highway can be obtained. The elevation of the top of the monitoring points would have to be read using conventional precision levelling equipment. By necessity, monitoring points on the road must be read remotely and the use of EDM equipment reading reflectors installed on the highway ramp is suggested. A specialist surveying firm should be retained to confirm the set-up and to carry out the monitoring during construction; their equipment and procedures must be capable of surveying the settlement point elevation to within ± 2 mm of the actual elevation.

All monitoring points should be read at least three times (on separate days) before the start of watermain installation to establish a pre-construction baseline. All points between the entry/exit shaft/pits as shown on Drawing 3 should be read every four hours over the duration of the watermain installation operations. The effectiveness of this monitoring method could be impacted by weather conditions if the work is undertaken during the winter months.

The following procedure should be followed if settlement levels of 10 mm (Review Level) and 15 mm (Alert Level) are reached:

- If the Review Level is reached the contractor would be required to provide a formal plan that states what is going to be done to ensure that the Alert Level is not reached.
- If the Alert Level is reached, the contractor shall stop drilling/tunnelling and MTO would have the authority to order that the contractor alter the drilling/tunnelling methods prior to continuing with the installation.

It is recommended that ground movement tolerances be established prior to start of construction based on the tolerance of existing utilities and surface structures to ground movement. The contractor should be required to submit method statements that demonstrate the means by which ground settlements will be controlled



7.0 CLOSURE

This Foundation Design Report was prepared by Ms. Shannon Palmer, P.Eng., a senior geotechnical engineer and Associate of Golder, and reviewed by Dr. Storer Boone, Ph.D., P.E., P.Eng., a senior geotechnical engineer and RAQS approved Tunneling Specialist; and Principal of Golder. Mr. Jorge M. A. Costa, P.Eng., a Principal of Golder and Designated MTO Foundations Contact, conducted an independent review of this report.

GOLDER ASSOCIATES LTD.



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Senior Geotechnical Engineer, Principal



Jorge M. A. Costa, P.Eng.
Designated MTO Foundations Contact, Principal

SLP/MCK/JMAC/SJB/mck

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FOUNDATION REPORT - WATERMAIN RELOCATION

REFERENCES

Canadian Geotechnical Society, 2006. *Canadian Foundation Engineering Manual*, 4th Edition. The Canadian Geotechnical Society, BiTech Publisher Ltd., British Columbia.

Chapman, L.J., and Putnam, D.F., 1984. *The Physiography of Southern Ontario*, 3rd Edition. Ontario Geological Survey, Special Volume 2. Ontario Ministry of Natural Resources.

Heuer, Ronald E. "Important Ground Parameters in Soft Ground Tunneling", Proceeding Specialty Conference on Subsurface Exploration for Underground Excavations and Heavy Construction, ASCE. NY, 1974.

Latorre et al. (2002). Guidelines for Installation of Utilities Beneath Corps of Engineers Levees Using Horizontal Directional Drilling, US Army Corps of Engineers, Engineer Research and Development Center, document ERD/GSL TR-02-9.

Unified Facilities Criteria, U.S. Navy. 1986. *NAVFAC Design Manual 7.02. Soil Mechanics, Foundation and Earth Structures*. Alexandria, Virginia.

ASTM International:

ASTM D1586	Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
ASTM D2774	Standard Practice for Underground Installation of Thermoplastic Pressure Piping

York Region:

York Region Standard W-206

York Region Standard W-207

Ontario Occupational Health and Safety Act:

Ontario Regulation 213 Construction Projects (as amended)

Ontario Provincial Standard Specifications (OPSS)

OPSS 401	Construction Specification for Trenching, Backfill, and Compacting
OPSS.MUNI 539	Construction Specifications for Temporary Protection Systems
OPSS.MUNI 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material
OPSS,MUNI 1205	Material Specification for Clay Seal
OPSS 1860	Material Specifications for Geotextiles



FOUNDATION REPORT - WATERMAIN RELOCATION

Ontario Provincial Standard Drawings (OPSD)

OPSD 802.095 Clay Seal for Pipe Trenches

Ontario Water Resources Act:

Ontario Regulation 903 Wells (as amended)



TABLES



FOUNDATION REPORT - WATERMAIN RELOCATION

**TABLE 1 – EVALUATION OF TRENCHLESS CROSSING ALTERNATIVES FOR WATERMAIN INSTALLATION HIGHWAY 404
E-N RAMP, NORTH OF HIGHWAY 7**

Installation Method	Feasibility	Advantages	Disadvantages	Relative Costs	Relative Risks
Jack-and-Bore Installation	Feasible	<ul style="list-style-type: none"> Widely used method. The line and grade can be maintained with moderate accuracy if the appropriate steering system is used. Equipment can be withdrawn and bore can be restarted at different location if obstructions are encountered. Reduced level of vibrations. 	<ul style="list-style-type: none"> Large work areas required for jacking pits. Obstructions (e.g. cobbles and boulders) may deflect and/or halt bore. Removal of augers and man entry would be required to remove boulders. Unstable water-bearing non-cohesive interlayers can go undetected until ground loss and settlement has occurred. Dense to very dense silt and sand to sand will make augering difficult. 	<ul style="list-style-type: none"> Relatively low cost. 	<ul style="list-style-type: none"> Risk of encountering refusal on obstructions. Obstructions can result in deflection of the casing resulting in misalignment of the watermain Potential for loss of ground into casing if saturated fine grained materials are present Potential need to excavate pits to remove obstructions
Horizontal Directional Drilling	Not Feasible (due to liner requirement)	<ul style="list-style-type: none"> Relatively small exit/entry shafts required. Dewatering not required. Method with greatest flexibility in altering/correcting borepath as drill string can be retracted and redrilled if obstructions cannot be cleared. Moderate control of line and grade 	<ul style="list-style-type: none"> Pilot hole steering may be imprecise and control of bore stability may be difficult within saturated non-cohesive material. Numerous passes of the drill string with increasing drillhead diameter required to achieve 1 m diameter bore Not capable of installing a steel liner, as required at this site. 	<ul style="list-style-type: none"> More expensive than jack-and-bore but less costly than microtunnelling. 	<ul style="list-style-type: none"> Low risk but still potential for loss of drilling fluid due to hydrofracturing of overlying very stiff to hard clayey stratum or encountering obstructions within the dense to very dense silt and sand to sand unit.



FOUNDATION REPORT - WATERMAIN RELOCATION

**TABLE 1 – EVALUATION OF TRENCHLESS CROSSING ALTERNATIVES FOR WATERMAIN INSTALLATION HIGHWAY 404
E-N RAMP, NORTH OF HIGHWAY 7**

Installation Method	Feasibility	Advantages	Disadvantages	Relative Costs	Relative Risks
Microtunnelling (MTBM)	Feasible	<ul style="list-style-type: none"> Continuous support to excavation face is provided. Does not require groundwater lowering. Final pipe can be installed while bore is being advanced. More accurate than HDD and jack-and-bore methods. For hard and very dense soils, cobbles and boulders (of limited size) can often be cut and penetrated provided appropriate disc cutter face tools are utilized. 	<ul style="list-style-type: none"> Large work areas required for jacking pits. Will require a machine capable of crushing boulders. Greater cost for muck handling and disposal. Advance of MTBM may be halted by large numbers of cobbles or large boulders; only method of removing obstruction may be shaft excavated from surface. Lack of readily available machines. Relatively expensive – high mobilization costs for short crossings. 	<ul style="list-style-type: none"> Most expensive method. 	<ul style="list-style-type: none"> Low to moderate risk for watermain installation provided appropriate equipment and slurry properties are selected and controlled. Potential schedule delay in obtaining a suitable MTBM.
Pipe Ramming	Not Feasible	<ul style="list-style-type: none"> Better suited for penetrating through cobbles and boulders than Jack-and-Bore (depending on size and strength of obstructions). Continuous casing installation. Where conditions warrant, spoil can be removed once the exit pit is reached minimizing subsidence and overcut 	<ul style="list-style-type: none"> Large work area required for ramming pit. Large obstructions/ boulders can result in deflection or refusal. Potential for heave at ground surface. Potential for settlement of near surface fills due to vibration. Removal of spoil may be required after advancing the pipe partway due to the weight of and drag on the pipe. Dense to very dense non-cohesive soils will make ramming difficult and subsequent augering of spoil from inside the pipe. Would require groundwater lowering – likely affecting a large area. 	<ul style="list-style-type: none"> Least expensive – likely less than Jack-and-Bore 	<ul style="list-style-type: none"> High risk of affecting performance of the roadway due to vibrations. Cobbles and boulders can hinder/stop penetration requiring hand mining or open excavation to remove obstructions. Misalignment of tunnel may occur if large obstructions are encountered and this cannot be corrected. Significant jacking/ramming forces would be required due to the dense/very dense nature of the overburden and the proposed length of the pipe.

Prepared By: SLP

Reviewed By: SB

Checked By: JMAC



DRAWINGS



-	-	-	-	-	-
NO.	DATE	BY	REVISION		
Geocres No. 30M14-424					
HWY. 404		PROJECT NO. 1533525		DIST. ,	
SUBM'D. MCK		CHKD. MCK		DATE: Oct. 2015	
DRAWN: JFC		CHKD. CN		APPD. JMAC	
				DWG. 1	

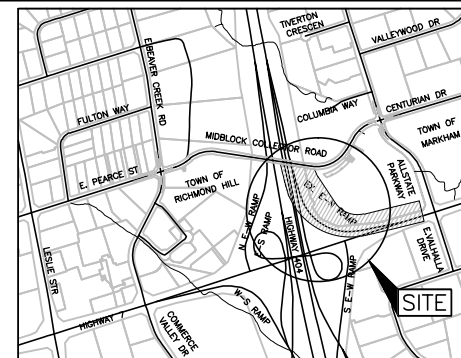
METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.



HIGHWAY 7 TO HIGHWAY 404
WATERMAIN RELOCATION
BOREHOLE LOCATIONS AND
SOIL STRATA

SHEET



KEY PLAN

NOT TO SCALE

LEGEND

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

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
GA-BR-03	190.7	4856328.0	631066.7
GA-WM-01	187.4	4856357.2	631401.5
GA-WM-02	186.7	4856330.0	631328.2
GA-WM-03	188.8	4856319.8	631251.3
GA-WM-04	188.5	4856304.4	631219.3
GA-WM-05	190.1	4856299.3	631156.0
GA-WM-06	190.5	4856308.3	631109.3
GA-WM-07	191.6	4856334.9	631040.5
GA-WM-08	194.6	4856314.1	630974.9

NOTES

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

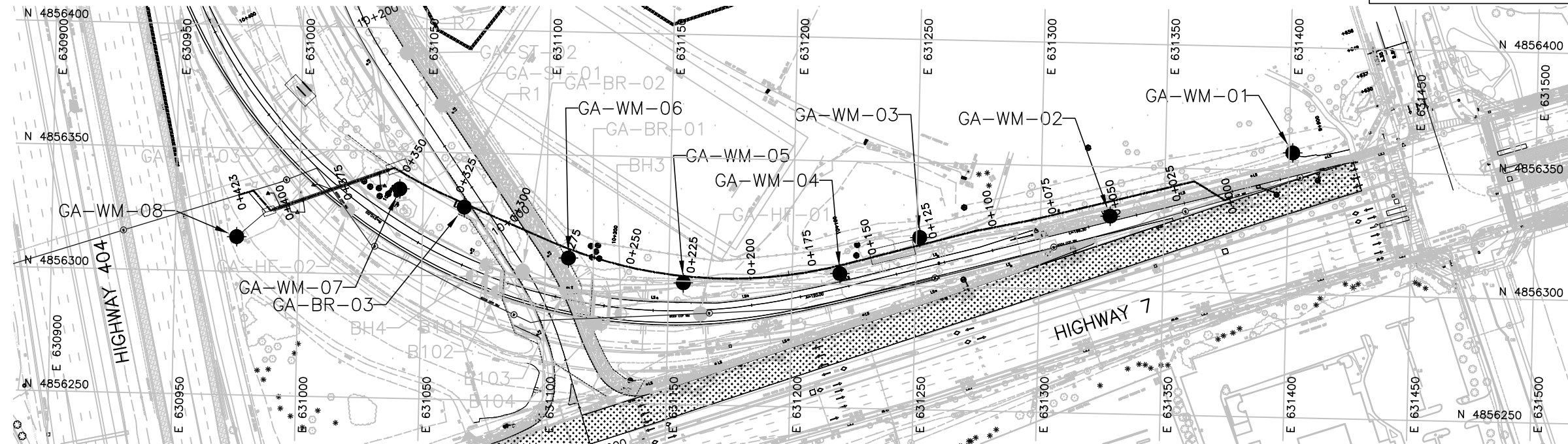
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCES

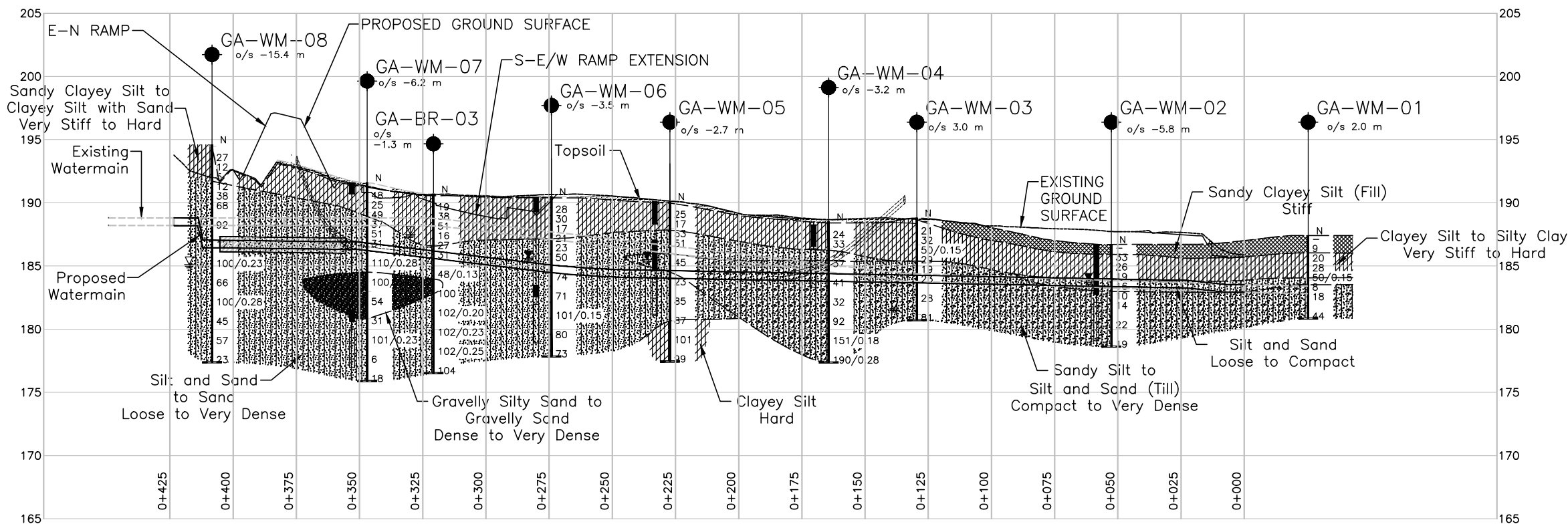
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NO.	DATE	BY	REVISION
Geocres No. 30M14-424			
HWY. 404			PROJECT NO. 1533525
SUBM'D. MCK	CHKD. MCK	DATE: Nov. 2015	DIST.
DRAWN: JFC	CHKD. CN	APPD. JMAC	SITE:
			DWG. 2



PLAN SCALE

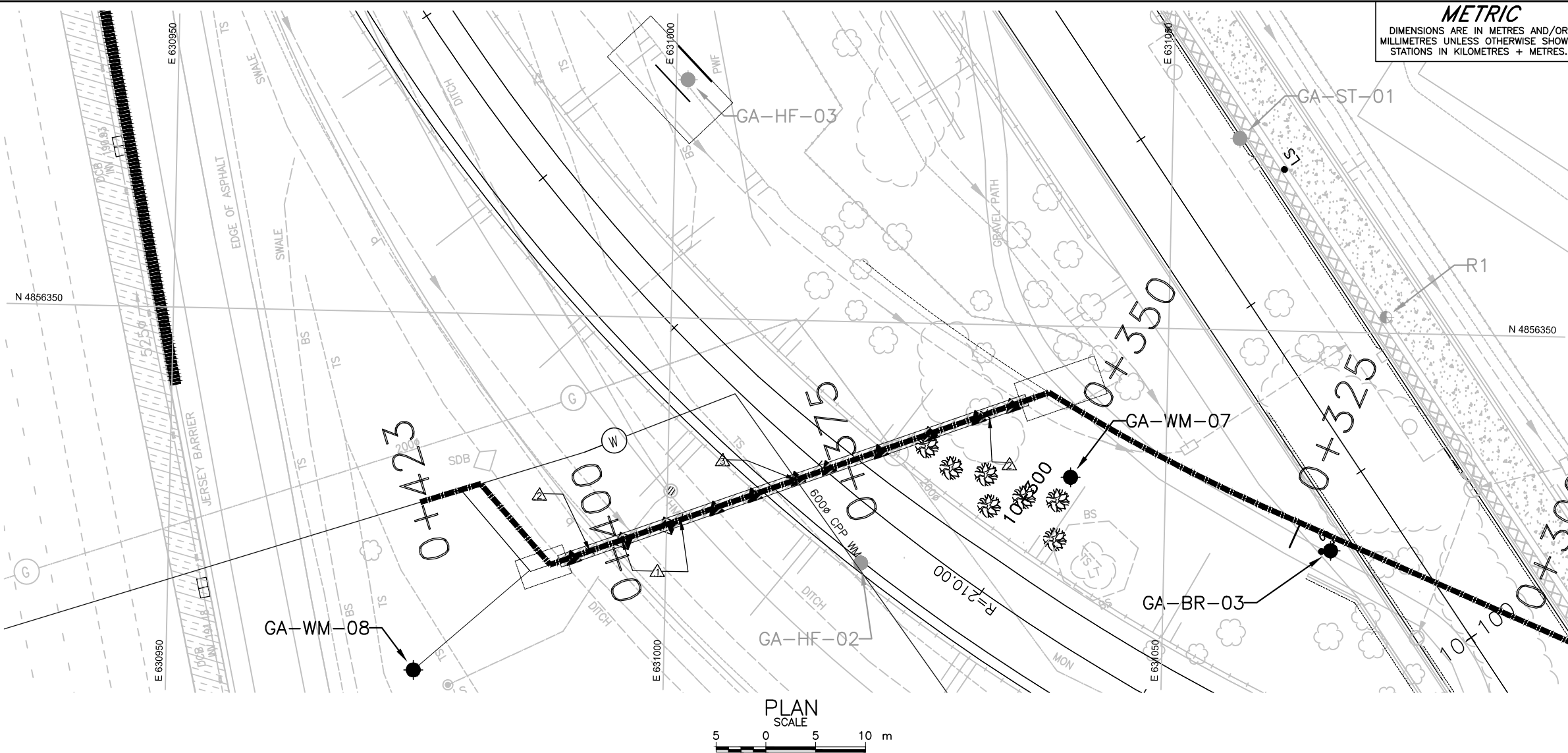
20 0 20 40 m



A-A PROFILE OF WATERMAIN

HORIZONTAL SCALE 20 0 20 40 m
VERTICAL SCALE 4 0 4 8 m

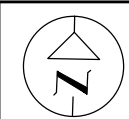




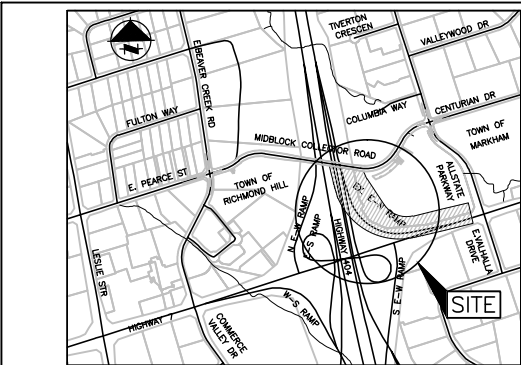
METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.

HIGHWAY 404 E-N RAMP
WATERMAIN RELOCATION
INSTRUMENTATION PLAN AND
DETAILS



SHEET



KEY PLAN
NOT TO SCALE



LEGEND

- Borehole – Current Investigation
- Surface Monitoring Point
- In-ground Monitoring Point (1.2 m depth)

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
GA-BR-03	190.7	4856328.0	631066.7
GA-WM-07	191.6	4856334.9	631040.5
GA-WM-08	194.6	4856314.1	630974.9

NOTES

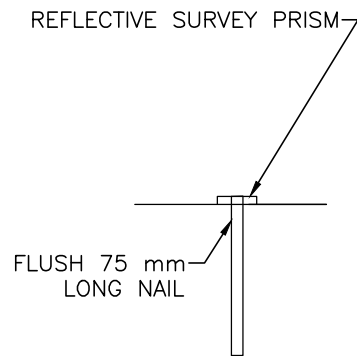
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The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

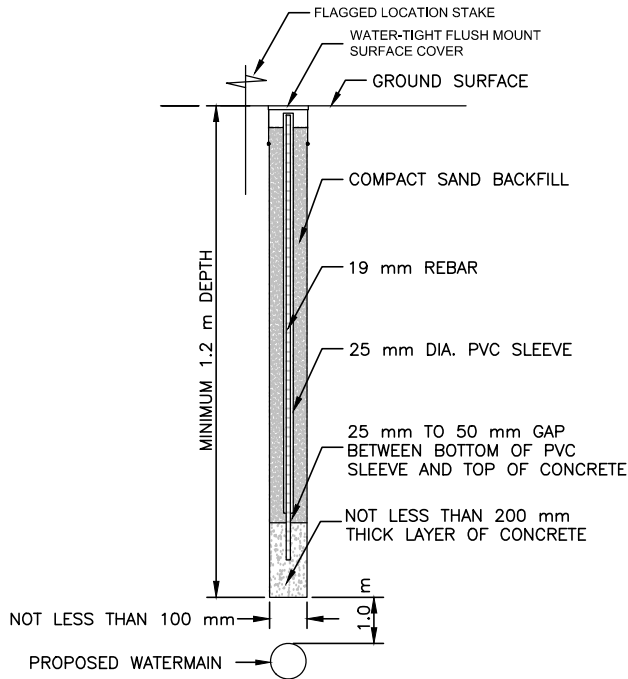
REFERENCES

Base plans provided in digital format by AECOM, drawing file nos. Bgd-2015.dwg, Mdbk_Ramp_Pln.dwg, Ramp_Aln.dwg, Ramp_Pln.dwg, received October 13, 2015 and WM-PROFILE-.dwg, received November 9, 2015.

NO.	DATE	BY	REVISION
Geocres No. 30M14-424			
HWY. 404		PROJECT NO. 1533525	
SUBM'D. MCK		CHKD. SLP	DATE: Oct. 2015
DRAWN: JFC		CHKD. CN	APPD. JMAC
		DIST. .	
		SITE: .	
		DWG. 3	



SURFACE MONITORING
POINT INSTALLATION DETAIL
N.T.S.



IN-GROUND MONITORING
POINT INSTALLATION DETAIL
N.T.S.

NOTES:

- THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH GOLDER ASSOCIATES LTD. DRAFT REPORT NO. 1533525-3, DATED OCTOBER 30, 2015.
- ALL MONITORING LOCATIONS SHOULD BE CONSIDERED APPROXIMATE AND MUST BE CONFIRMED IN THE FIELD PRIOR TO INSTALLATION AND CONSTRUCTION.
- THE CONTRACTOR SHALL RETAIN A SURVEYOR REGISTERED IN ONTARIO FOR ESTABLISHING AND SURVEYING THE MONITORING POINTS FOR THE DURATION OF CONSTRUCTION OF THIS CROSSING.
- ALL MONITORING EQUIPMENT SHALL BE INSTALLED AT LEAST 7 DAYS PRIOR TO ANY EXCAVATION OR TUNNELING TAKING PLACE AT THE CROSSING.
- SURFACE MONITORING POINTS SHALL BE A STANDARD NAIL WITH A SURVEYING PRISM ATTACHED TO IT.
- THE CONTRACTOR SHALL ESTABLISH 3 TEMPORARY BENCHMARKS OUTSIDE THE AREA OF CONSTRUCTION FOR THE CROSSING. THE CONTRACTOR SHALL SUBMIT THE PROPOSED BENCHMARK LOCATIONS TO THE ENGINEER FOR APPROVAL PRIOR TO CONSTRUCTION. ALL MONITOR POINTS SHALL BE COORDINATED TO A TOLERANCE OF 10mm AND THE ELEVATIONS SHALL BE DETERMINED TO A TOLERANCE OF NOT MORE THAN 2mm. AN ELEVATED PLATFORM MAY BE REQUIRED TO READ ALL MONITORING POINTS.
- DURING ANY CONSTRUCTION ACTIVITY AND WORK STOPPAGES (SUCH AS DURING NON-OPERATION PERIOD (OFF-SHIFT) OR WEEKENDS), ALL POINTS SHALL BE SURVEYED A MINIMUM OF 3 TIMES PER DAY.
- DURING MONITORING, IF SETTLEMENTS REACH THE "REVIEW LEVEL" OF 10mm, THE CONTRACTOR SHALL PROVIDE A FORMAL PLAN TO ENSURE FURTHER SETTLEMENTS DO NOT OCCUR. IF SETTLEMENTS REACH THE "ALERT LEVEL" OF 15mm, THE CONTRACTOR SHALL SUSPEND TRENCHLESS OPERATION AND THE OWNER WILL HAVE THE AUTHORITY TO ORDER THE CONTRACTOR TO MAKE THE FACE SECURE AND SUSPEND ALL TUNNELLING UNTIL AN APPROVED MITIGATIVE SOLUTION IS DEVELOPED.
- AFTER CONSTRUCTION HAS BEEN COMPLETED, THE CONTRACTOR SHALL SURVEY THE MONITORING POINTS ONCE PER DAY FOR 10 DAYS, THEN ONCE EVERY 3 DAYS FOR 15 DAYS AND THEN ONCE PER EVERY 10 DAY PERIOD FOR THE FOLLOWING 30 DAYS OR UNTIL DATA INDICATES THAT ALL MOVEMENTS HAVE ESSENTIALLY CEASED.
- WITHIN 2 HOURS OF COMPLETION OF ANY MEASUREMENT A COPY OF PRELIMINARY RESULTS SHALL BE MADE AVAILABLE TO THE ENGINEER AND FINALIZED RESULTS SHALL BE PROVIDED WITHIN 24 HOURS OF COMPLETION OF THE SURVEY.
- THE CONTRACTOR SHALL MAKE ALL ARRANGEMENTS FOR TRAFFIC SAFETY PRECAUTIONS AS REQUIRED BY THE MTO.
- REMOVE ALL MONITORING POINTS ON COMPLETION OF SURVEY AS PER ITEM No. 9 ABOVE, SUBJECT TO APPROVAL FROM THE ENGINEER.



APPENDIX A

Record of Boreholes



LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

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

* Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
C_v	coefficient of consolidation (vertical direction)
C_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan \delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes: 1
2

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



LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d :

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

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

III. SOIL DESCRIPTION

(a) Non-Cohesive Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils Consistency

	c_u, s_u	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

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

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

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand



PROJECT	1533525	RECORD OF BOREHOLE		No GA-BR-03	SHEET 1 OF 2	METRIC
W.P.		LOCATION	N 4856328.0 ;E 631066.7		ORIGINATED BY	MCK
DIST	HWY	BOREHOLE TYPE	108 mm I.D. Hollow Stem Power Augers / 98 mm Open Hole Mud Rotary/Tricone		COMPILED BY	JM
DATUM	Geodetic	DATE	September 11, 2015		CHECKED BY	CN

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

PROJECT <u>1533525</u>	RECORD OF BOREHOLE No GA-BR-03	SHEET 2 OF 2	METRIC
W.P. _____	LOCATION <u>N 4856328.0 ; E 631066.7</u>	ORIGINATED BY <u>MCK</u>	
DIST _____ HWY _____	BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Power Augers / 98 mm Open Hole Mud Rotary/Tricone</u>	COMPILED BY <u>JM</u>	
DATUM <u>Geodectic</u>	DATE <u>September 11, 2015</u>	CHECKED BY <u>CN</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					w _p	w	w _L							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED														
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100		10	20	30						
	NOTE: 1. Water level in open borehole measured at a depth of 3.2 m below ground surface (Elev. 187.5 m), upon completion of drilling.																					

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PROJECT 1533525		RECORD OF BOREHOLE No GA-WM-01				SHEET 1 OF 1		METRIC									
W.P. _____		LOCATION N 4856357.2 ; E 631401.5				ORIGINATED BY AJS											
DIST _____ HWY _____		BOREHOLE TYPE 108 mm I.D. Hollow Stem Power Augers				COMPILED BY JM											
DATUM Geodectic		DATE September 9, 2015				CHECKED BY CN											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
187.4	GROUND SURFACE																
0.0	Sandy clayey silt, some gravel to gravelly (FILL) Stiff Brown Dry		1	AS	-												
186.0			2	SS	9												
1.4	CLAYEY SILT, trace to some sand to sandy, trace rootlets to 2.0 m Very stiff to hard Brown Moist		3	SS	20												
			4	SS	28												
			5	SS	50/0.15												
183.9	- Auger grinding at a depth of 3.2 m																
183.5	SILT and SAND Brown to grey Wet		6A	SS	8												
3.9	SILT and SAND, some clay, trace gravel (TILL) Loose to dense Grey Wet		6B														
			7	SS	18												
			8	SS	44												
180.8	END OF BOREHOLE																
6.6	NOTES: 1. Open borehole dry, upon completion of drilling.																

PROJECT		1533525		RECORD OF BOREHOLE No GA-WM-02				SHEET 1 OF 1		METRIC																		
W.P.				LOCATION		N 4856330.0 ; E 631328.2		ORIGINATED BY		AJS																		
DIST		HWY		BOREHOLE TYPE		108 mm I.D. Hollow Stem Power Augers		COMPILED BY		JM																		
DATUM		Geodetic		DATE		September 9, 2015		CHECKED BY		CN																		
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 (%)										
186.7 0.0	GROUND SURFACE Sandy clayey silt, rootlets (FILL) Brown Dry		1	AS	-																							
185.9 0.8	CLAYEY SILT, some sand to sandy Very stiff to hard Brown Moist		2	SS	33																							
			3	SS	26																							
			4	SS	19																							
183.8 2.9	SILT and SAND, some gravel, trace clay Compact Brown Wet		5	SS	16																							
183.0 3.7	SILT and SAND, trace to some gravel, trace to some clay (TILL) Compact Grey Moist		6	SS	10																							
			7	SS	14																							
			8	SS	22																							
			9	SS	19																							
178.6 8.1	END OF BOREHOLE																											
NOTE: 1. Water level measurements in piezometer: <table style="margin-left: 40px;"> <tr> <th>Date</th> <th>Depth (m)</th> <th>Elev. (m)</th> </tr> <tr> <td>09/11/15</td> <td>2.7</td> <td>184.0</td> </tr> <tr> <td>09/15/15</td> <td>2.9</td> <td>183.8</td> </tr> <tr> <td>10/13/15</td> <td>2.9</td> <td>183.8</td> </tr> </table>																	Date	Depth (m)	Elev. (m)	09/11/15	2.7	184.0	09/15/15	2.9	183.8	10/13/15	2.9	183.8
Date	Depth (m)	Elev. (m)																										
09/11/15	2.7	184.0																										
09/15/15	2.9	183.8																										
10/13/15	2.9	183.8																										

PROJECT 1533525		RECORD OF BOREHOLE No GA-WM-03				SHEET 1 OF 1		METRIC						
W.P. _____		LOCATION N 4856319.8 ; E 631251.3				ORIGINATED BY AJS								
DIST _____ HWY _____		BOREHOLE TYPE 108 mm I.D. Hollow Stem Power Augers				COMPILED BY JM								
DATUM Geodectic		DATE September 9, 2015				CHECKED BY CN								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
188.8	GROUND SURFACE													
0.0	Sandy clayey silt, trace to some gravel (FILL) Brown Dry		1	AS	-									
188.0	CLAYEY SILT, some sand, some gravel Very stiff to hard Brown Moist		2	SS	21									
0.8	- Auger grinding at a depth of 2.6 m		3	SS	32									
			4	SS	50/0.15									
185.4	SILT and SAND, trace to some clay, trace to some gravel (TILL) Compact to very dense Grey Moist to wet		5A 5B 5C	SS	29									
3.4	- 15 cm silt layer encountered at a depth of 3.2 m		6	SS	19									
			7	SS	23									
			8	SS	28									
			9	SS	81									
180.7	- 5 cm silty clay pocket encountered at a depth of 7.9 m END OF BOREHOLE													
8.1	NOTES: 1. Water level in open borehole at a depth of 7.2 m below ground surface (Elev. 181.6 m), measured upon completion of drilling.													

PROJECT 1533525		RECORD OF BOREHOLE No GA-WM-04				SHEET 1 OF 1		METRIC				
W.P. _____		LOCATION N 4856304.4 ; E 631219.3				ORIGINATED BY OS						
DIST _____ HWY _____		BOREHOLE TYPE 108 mm I.D. Hollow Stem Power Augers				COMPILED BY JM						
DATUM Geodetic		DATE September 10, 2015				CHECKED BY CN						
SOIL PROFILE			SAMPLES			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	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa				WATER CONTENT (%)
188.5	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	10 20 30		
0.0	TOPSOIL											
	CLAYEY SILT, some sand, trace wood fragments, rootlets Very stiff Brown Moist		1	SS	24							
187.1												
1.4	CLAYEY SILT, trace sand Hard Grey Moist		2A 2B	SS	33							
186.4												
2.1	- 15 cm sand layer at a depth of 1.7 m		3	SS	24							
	SILT and SAND, trace gravel, trace clay Compact Brown Wet		4	SS	37							
185.4												
3.1	Sandy SILT to Silty SAND, some gravel to gravelly, trace to some clay, inferred cobbles at a depth of 9.5 m and 11.1 m (TILL) Dense to very dense Grey Moist		5	SS	41							
			6	SS	32							
			7	SS	92							
			8	SS	151/0.18							
			9	SS	190/0.28							
177.4	END OF BOREHOLE											
11.1	NOTE: 1. Water level measurements in piezometer: Date Depth (m) Elev. (m) 09/11/15 Dry - 09/15/15 Dry - 10/13/15 Dry - 2. Well installed 1.0 m west of GA-WM-04.											

PROJECT		RECORD OF BOREHOLE				No GA-WM-05		SHEET 1 OF 2		METRIC			
W.P. _____		LOCATION				N 4856299.3 ; E 631156.0		ORIGINATED BY		OS			
DIST _____ HWY _____		BOREHOLE TYPE				108 mm I.D. Hollow Stem Power Augers		COMPILED BY		JM			
DATUM Geodetic		DATE				September 10 and 11, 2015		CHECKED BY		CN			
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _p W W _L	WATER CONTENT (%)		
190.1	GROUND SURFACE												
0.0	TOPSOIL												
0.1	SILTY CLAY, some sand, trace organics, rootlets Very stiff Brown Moist		1	SS	25							41	
			2	SS	17								
188.0													
2.1	SILT and SAND, some gravel Very dense Light brown Moist to dry - Auger grinding at a depth of 2.4 m		3	SS	53								
			4	SS	51								0 53 41 6
186.0													
4.1	Sandy SILT, some gravel, trace clay (TILL) Dense Grey Moist to wet - Auger grinding at a depth of 5.5 m		5	SS	45								
184.5													
5.6	SILT and SAND, trace to some clay Compact to very dense Brown to grey Wet		6	SS	23								
			7	SS	85								0 52 45 3
			8A										
180.6			8B	SS	87								
9.5	CLAYEY SILT, trace sand, trace gravel Hard Grey Moist												
			9	SS	101								
			10	SS	99								
177.4													
12.7	END OF BOREHOLE												

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

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PROJECT <u>1533525</u>	RECORD OF BOREHOLE No GA-WM-05	SHEET 2 OF 2	METRIC
W.P. _____	LOCATION <u>N 4856299.3 ; E 631156.0</u>	ORIGINATED BY <u>OS</u>	
DIST _____ HWY _____	BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Power Augers</u>	COMPILED BY <u>JM</u>	
DATUM <u>Geodetic</u>	DATE <u>September 10 and 11, 2015</u>	CHECKED BY <u>CN</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _P	W	W _L		
--- CONTINUED FROM PREVIOUS PAGE ---																	
NOTES: 1. Water level measurements in piezometer Date Depth (m) Elev. (m) 09/11/15 4.6 185.5 09/15/15 4.7 185.4 10/13/15 4.6 185.5 2. Well installed 1.0 m west of GA-WM-05.																	

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PROJECT		1533525		RECORD OF BOREHOLE No GA-WM-06				SHEET 1 OF 1		METRIC																		
W.P.				LOCATION		N 4856308.3 ; E 631109.3		ORIGINATED BY		MCK																		
DIST		HWY		BOREHOLE TYPE		108 mm I.D. Hollow Stem Power Augers		COMPILED BY		JM																		
DATUM		Geodetic		DATE		September 10, 2015		CHECKED BY		CN																		
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)															
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _p W W _L	WATER CONTENT (%)			10 20 30														
190.5	GROUND SURFACE																											
0.9	TOPSOIL																											
	CLAYEY SILT, trace to some sand, trace to some gravel Very stiff Brown Moist		1	SS	28																							
			2	SS	30																							
	- 8 cm sandy silt layer encountered at a depth of 4.0 m		3A	SS	17																							
			3B	SS																								
187.4			4	SS	21																							
3.1	SILT and SAND to SAND, trace clay, trace to some silt, trace gravel to gravelly, inferred cobbles at depths of 3.8 m, 5.3 m and 8.5 m to Compact to very dense Brown to grey Dry to wet		5A	SS	23																							
			5B	SS																								
	- 6 cm clayey silt layer encountered at a depth of 4.0 m		6	SS	50																							
			7	SS	74																							
			8	SS	71																							
			9	SS	101/0.15																							
			10A	SS	80																							
			10B	SS																								
			11A	SS	73																							
177.8			11B	SS																								
12.7	END OF BOREHOLE																											
NOTE: 1. Water level measurements in piezometer: <table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th>Date</th> <th>Depth (m)</th> <th>Elev. (m)</th> </tr> </thead> <tbody> <tr> <td>09/10/15</td> <td>5.0</td> <td>185.5</td> </tr> <tr> <td>09/11/15</td> <td>4.9</td> <td>185.6</td> </tr> <tr> <td>09/15/15</td> <td>4.9</td> <td>185.6</td> </tr> <tr> <td>10/13/15</td> <td>4.9</td> <td>185.6</td> </tr> </tbody> </table>														Date	Depth (m)	Elev. (m)	09/10/15	5.0	185.5	09/11/15	4.9	185.6	09/15/15	4.9	185.6	10/13/15	4.9	185.6
Date	Depth (m)	Elev. (m)																										
09/10/15	5.0	185.5																										
09/11/15	4.9	185.6																										
09/15/15	4.9	185.6																										
10/13/15	4.9	185.6																										

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PROJECT 1533525		RECORD OF BOREHOLE No GA-WM-07		SHEET 1 OF 2		METRIC	
W.P. _____		LOCATION N 4856334.9 ;E 631040.5		ORIGINATED BY		MCK	
DIST _____ HWY _____		BOREHOLE TYPE 108 mm I.D. Hollow Stem Power Augers		COMPILED BY		JM	
DATUM Geodectic		DATE September 9, 2015		CHECKED BY		CN	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		SHEAR STRENGTH kPa								WATER CONTENT (%)		
							20 40 60 80 100										
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED										
191.6	GROUND SURFACE																
0.0	TOPSOIL																
0.2	CLAYEY SILT, some sand, trace to some gravel Very stiff to hard Brown Moist		1	SS	48												
	- 10 cm sand seam encountered at a depth of 1.8 m		2	SS	25												
189.2			3A	SS	49												
2.4	SILT and SAND to SAND, trace to some silt, trace clay, trace gravel Dense to very dense Brown to grey Moist to wet - 10 cm sandy clayey silt layer encountered at a depth of 3.1 m		4A 4B	SS	37												
			5	SS	51												
			6	SS	31												
			7	SS	110/0.28												
184.5			8	SS	100/0.13												
7.1	Gravelly Silty SAND to Gravelly SAND, some silt, trace clay Dense to very dense Brown to grey Wet		9A 9B	SS	54												
	- 23 cm silt layer encountered at a depth of 9.4 m																
180.8			10A 10B	SS	31												
10.8	SAND, some silt, trace to some gravel, trace clay Loose to very dense Grey Wet		11	SS	101/0.23												
	- 5 cm gravelly sand layer encountered at a depth of 12.5 m		12	SS	6												

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

○ 3% STRAIN AT FAILURE

PROJECT 1533525		RECORD OF BOREHOLE No GA-WM-07 SHEET 2 OF 2				METRIC																							
W.P. _____		LOCATION N 4856334.9 ; E 631040.5		ORIGINATED BY MCK																									
DIST _____ HWY _____		BOREHOLE TYPE 108 mm I.D. Hollow Stem Power Augers		COMPILED BY JM																									
DATUM Geodectic		DATE September 9, 2015		CHECKED BY CN																									
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)													
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)												
	--- CONTINUED FROM PREVIOUS PAGE ---						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					10 20 30				GR SA SI CL													
175.9			13	SS	18																								
15.7	END OF BOREHOLE NOTES: 1. Water level measurements in piezometer: <table border="1" style="margin: 5px 0;"> <thead> <tr> <th>Date</th> <th>Depth (m)</th> <th>Elev. (m)</th> </tr> </thead> <tbody> <tr> <td>09/09/15</td> <td>5.7</td> <td>185.9</td> </tr> <tr> <td>09/11/15</td> <td>5.8</td> <td>185.8</td> </tr> <tr> <td>09/15/15</td> <td>5.8</td> <td>185.8</td> </tr> <tr> <td>10/13/15</td> <td>5.2</td> <td>186.4</td> </tr> </tbody> </table> 2. Hole caved to a depth of 10.5 m upon completion of drilling.	Date	Depth (m)	Elev. (m)	09/09/15	5.7	185.9	09/11/15	5.8	185.8	09/15/15	5.8	185.8	10/13/15	5.2	186.4													
Date	Depth (m)	Elev. (m)																											
09/09/15	5.7	185.9																											
09/11/15	5.8	185.8																											
09/15/15	5.8	185.8																											
10/13/15	5.2	186.4																											



PROJECT 1533525		RECORD OF BOREHOLE No GA-WM-08		SHEET 1 OF 2		METRIC	
W.P.		LOCATION N 4856314.1 ; E 630974.9		ORIGINATED BY		MCK	
DIST HWY		BOREHOLE TYPE 108 mm I.D. Hollow Stem Power Augers		COMPILED BY		JM	
DATUM Geodectic		DATE September 25, 2015		CHECKED BY		CN	

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

○ 3% STRAIN AT FAILURE

PROJECT 1533525		RECORD OF BOREHOLE No GA-WM-08				SHEET 2 OF 2		METRIC									
W.P. _____		LOCATION N 4856314.1 ; E 630974.9				ORIGINATED BY MCK											
DIST _____ HWY _____		BOREHOLE TYPE 108 mm I.D. Hollow Stem Power Augers				COMPILED BY JM											
DATUM Geodectic		DATE September 25, 2015				CHECKED BY CN											
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)
	--- CONTINUED FROM PREVIOUS PAGE ---						20	40	60	80	100						
			13	SS	57												
177.4	SILT and SAND to Silty SAND, trace clay, trace gravel Compact to very dense Brown to grey Dry to wet																
17.2	END OF BOREHOLE		14	SS	23												
	NOTE: 1. Water level in open borehole measured at a depth of 9.5 m below ground surface (Elev. 185.1 m) upon completion of drilling.																



APPENDIX B

Laboratory Test Results



FOUNDATION REPORT - WATERMAIN RELOCATION

TABLE B1 – SUMMARY OF ANALYTICAL TESTING OF GROUNDWATER

Borehole Number	Parameter (Units / Detection Limit)				
	Dissolved Chloride (mg/L / 0.5)	Dissolved Sulfate (mg/L / 0.5)	Conductivity (uS/cm / 2)	Resistivity (ohm-cm)	pH
GA-WM-02	230 / 0.5	72.6 / 0.5	1330 / 2	752	7.85
GA-WM-06	143 / 0.5	59.2 / 0.5	1190 / 2	840	7.88
GA-WM-07	1310 / 2	132 / 2	4470 / 2	224	7.71

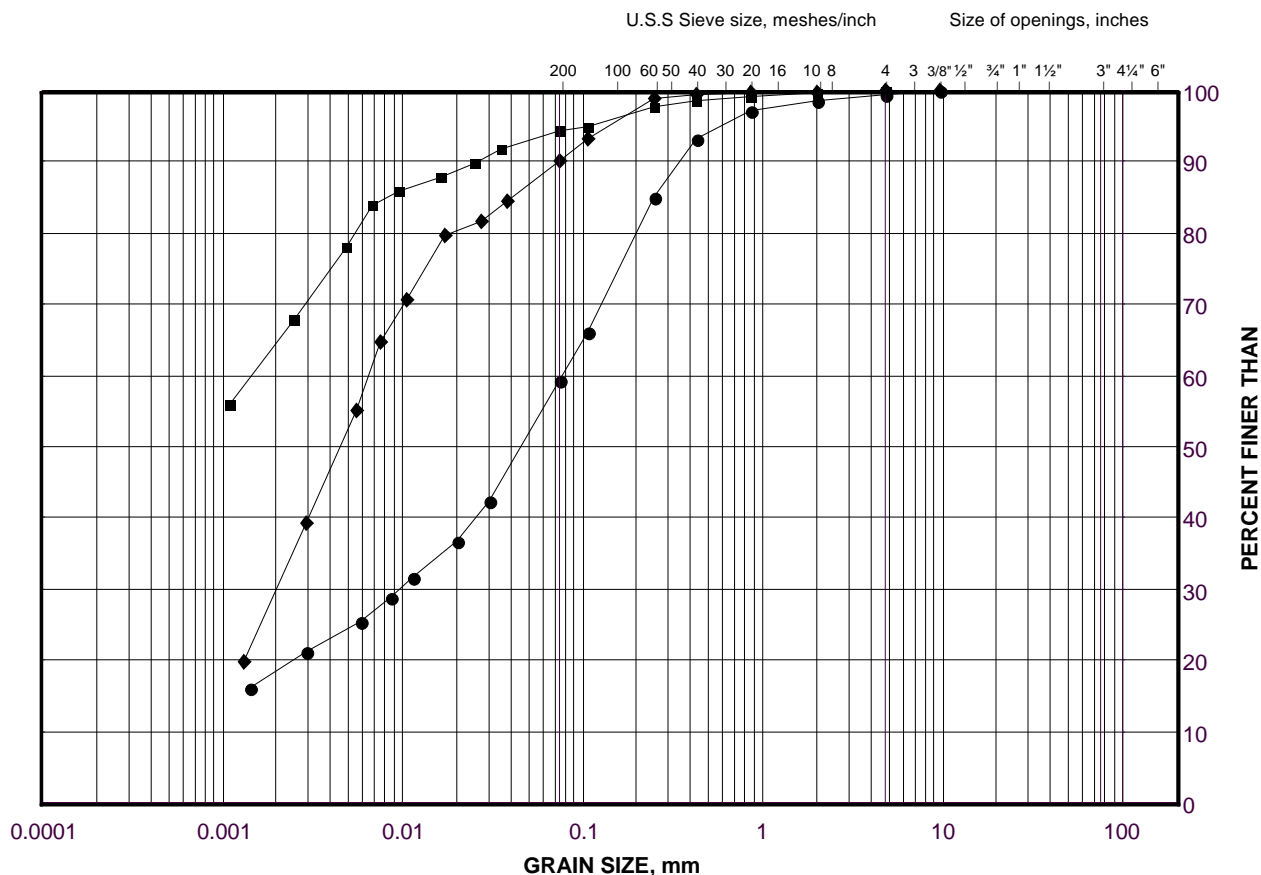
Notes: 1. Samples obtained October 13, 2015.
2. Analytical testing carried out by Agat Laboratories.

Prepared by: MCK
Checked by: CN

GRAIN SIZE DISTRIBUTION

Clayey Silt to Clayey Silt with Sand (Upper)
Watermain

FIGURE B1



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

LEGEND

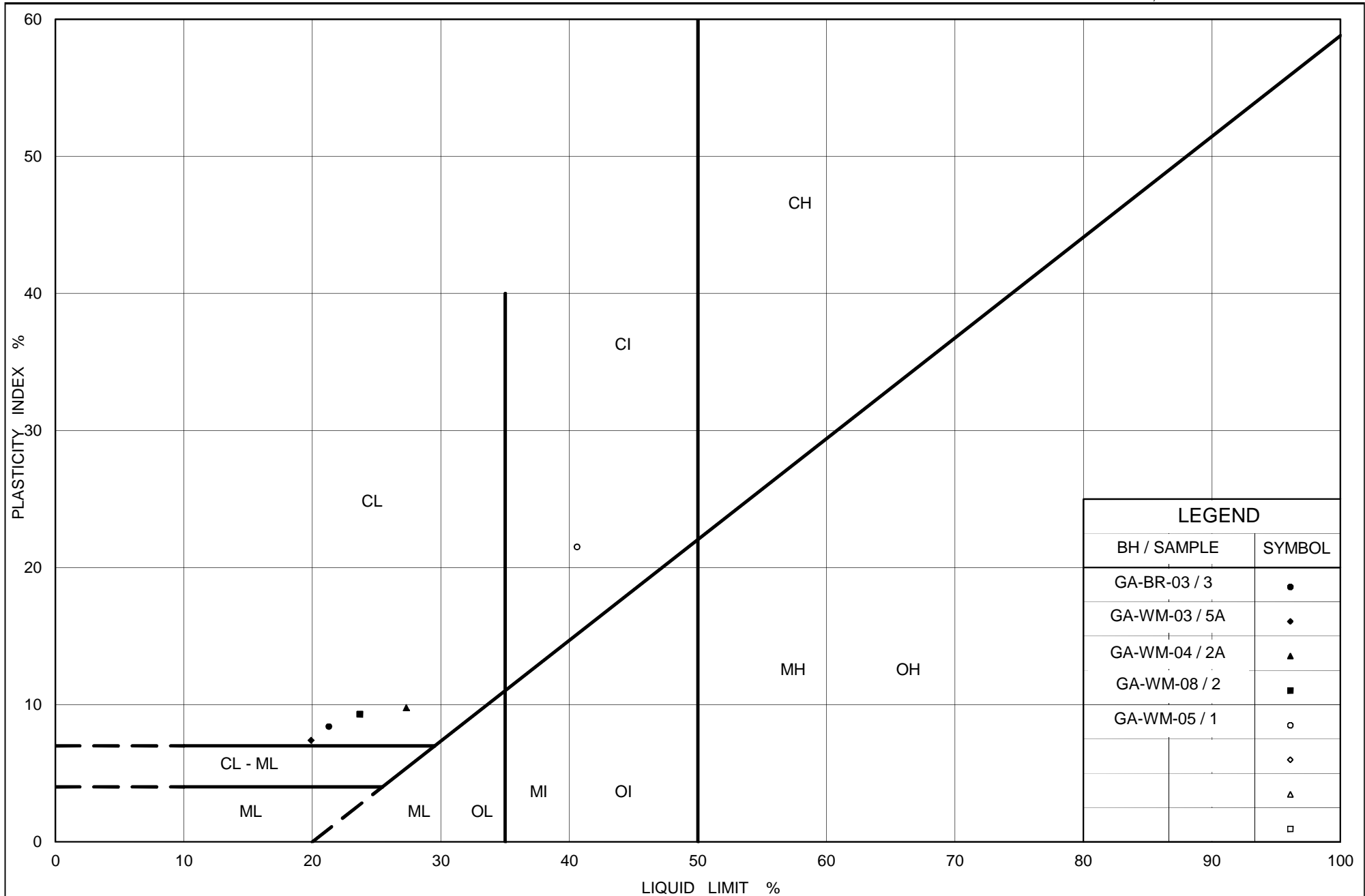
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	GA-WM-08	2	192.9
■	GA-WM-01	3	185.7
◆	GA-BR-03	4B	187.4

Project Number: 1533525

Checked By: CN

Golder Associates

Date: 22-Dec-15



Ministry of Transportation

Ontario

PLASTICITY CHART Clayey Silt to Silty Clay (Upper) Watermain

Figure No. B2

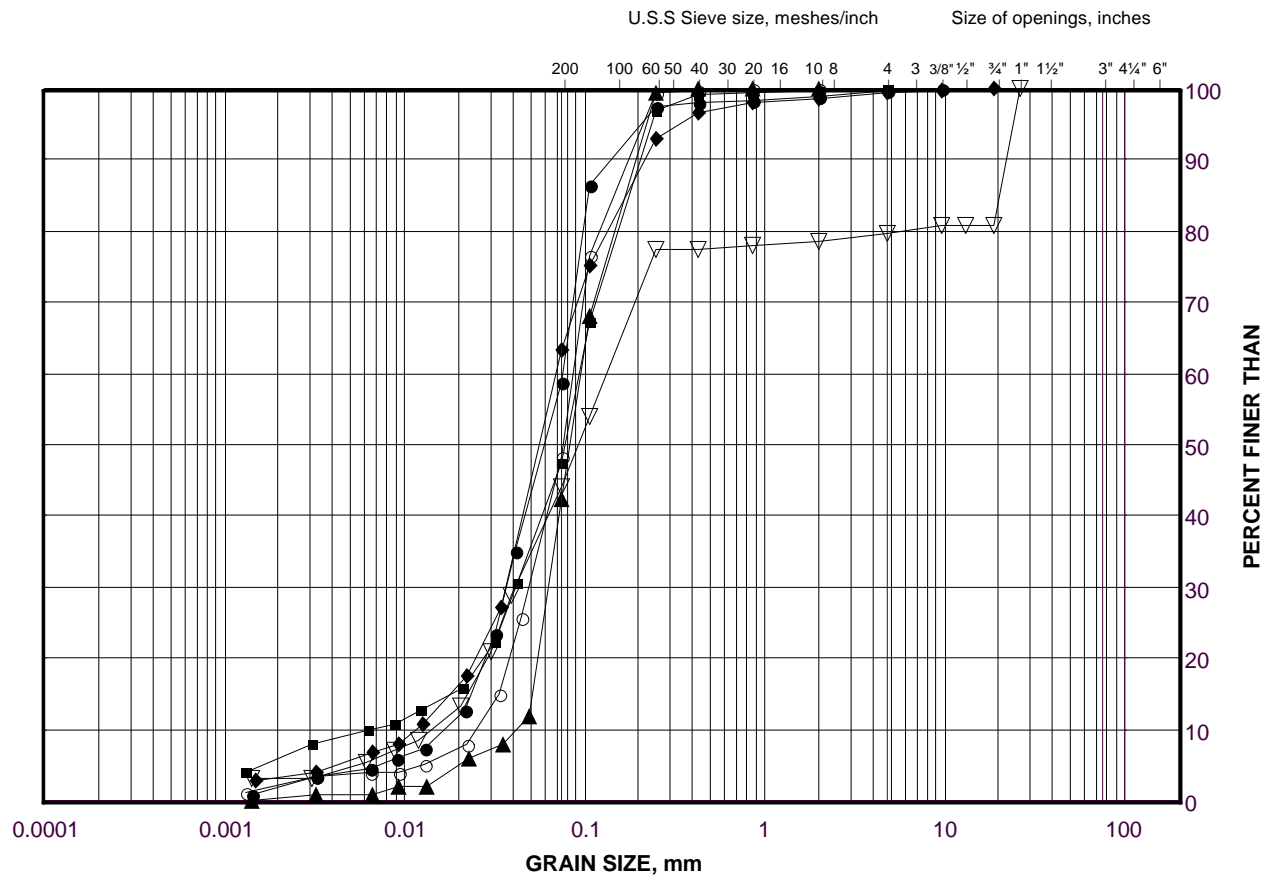
Project No. 1533525

Checked By: CN

GRAIN SIZE DISTRIBUTION

Silt and Sand
Watermain

FIGURE B3A



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	GA-WM-04	3	186.0
■	GA-WM-05	4	186.8
◆	GA-WM-08	6	189.8
▲	GA-BR-03	6	185.9
▽	GA-WM-06	7	184.2
○	GA-WM-05	7	182.2

Project Number: 1533525

Checked By: CN

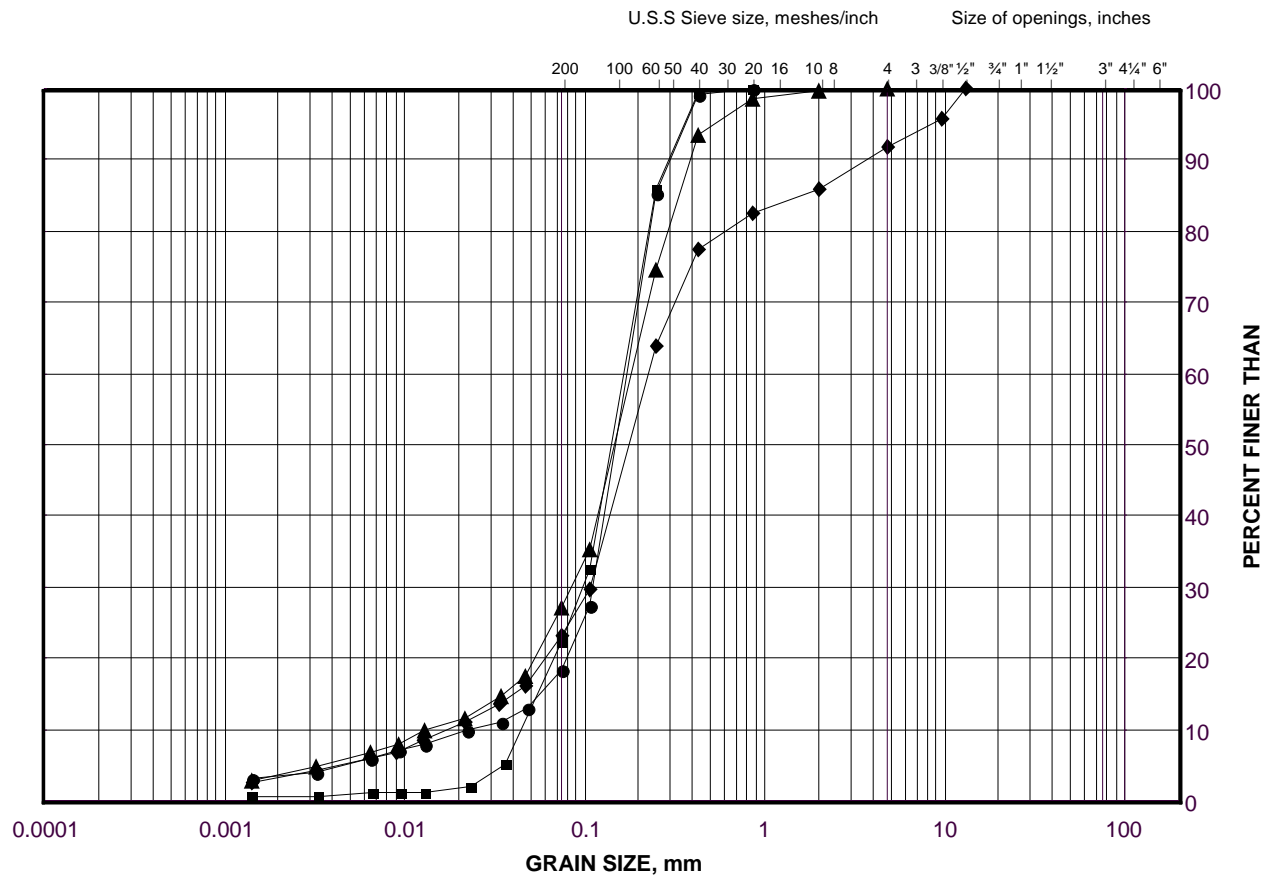
Golder Associates

Date: 18-Oct-15

GRAIN SIZE DISTRIBUTION

Silty Sand to Sand
Watermain

FIGURE B3B



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	GA-WM-06	11B	177.9
■	GA-WM-08	12	180.7
◆	GA-WM-07	12	177.6
▲	GA-BR-03	8	182.8

Project Number: 1533525

Checked By: CN

Golder Associates

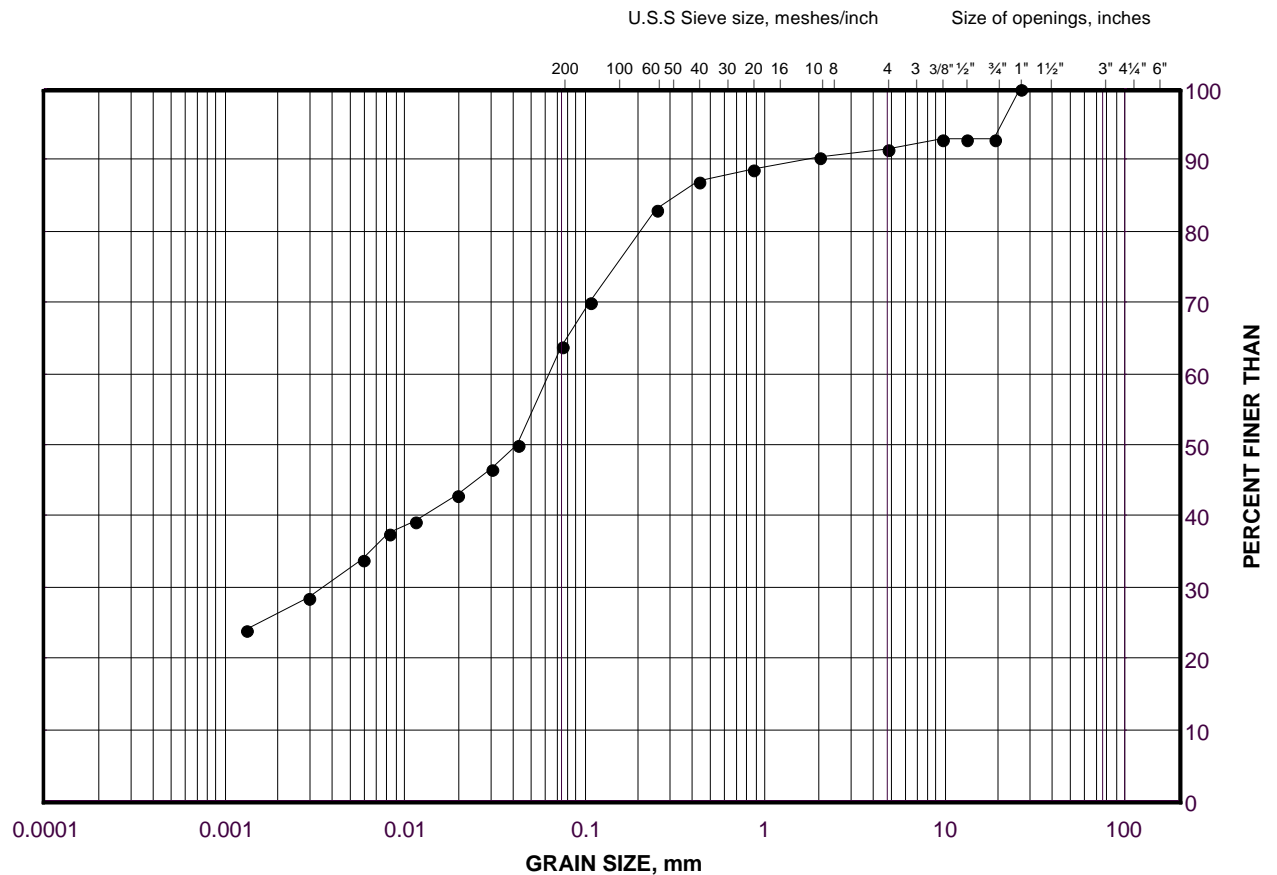
Date: 18-Oct-15

GRAIN SIZE DISTRIBUTION

Sandy Clayey Silt (Layer)

Watermain

FIGURE B4



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	GA-WM-07	4A	188.5

Project Number: 1533525

Checked By: CN

Golder Associates

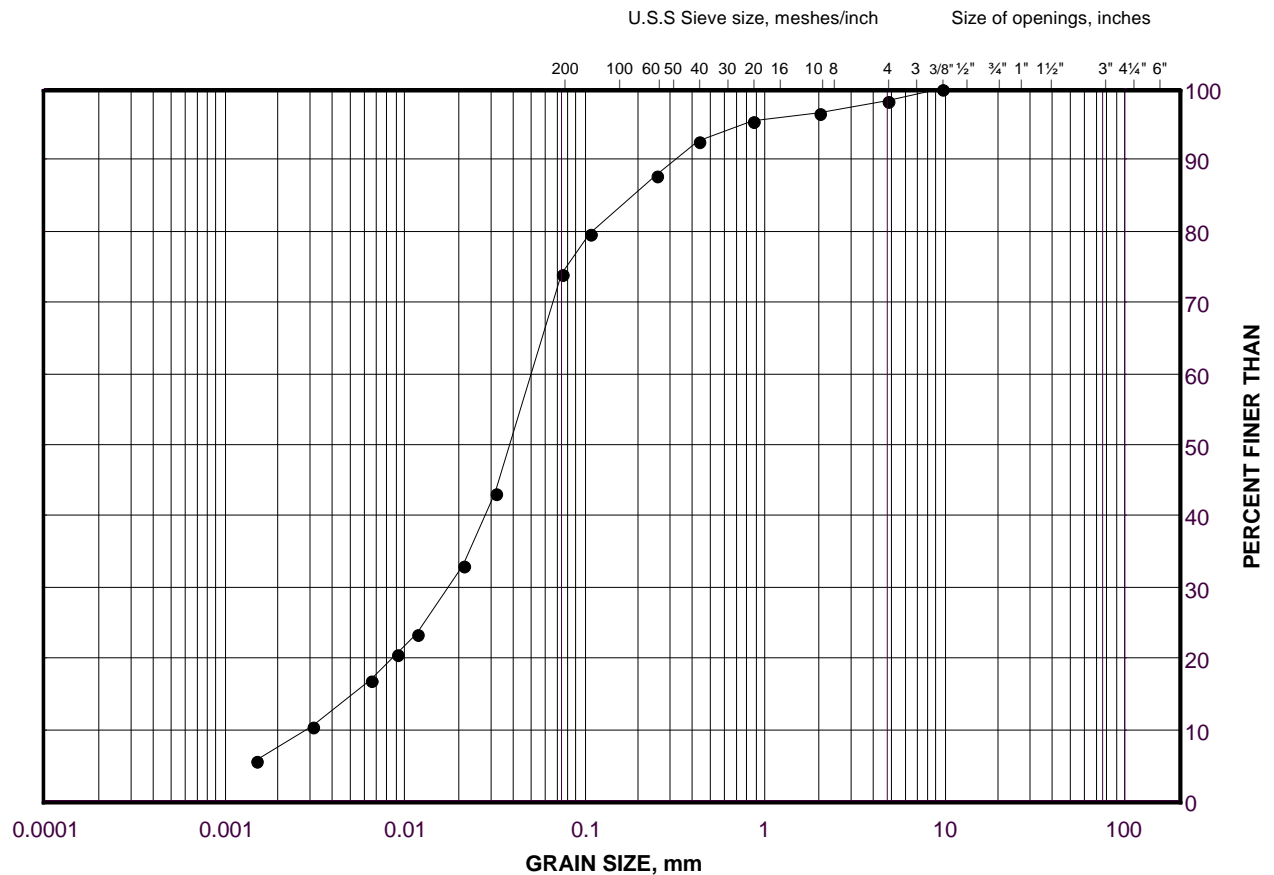
Date: 18-Oct-15

GRAIN SIZE DISTRIBUTION

Sandy Silt (Layer)

Watermain

FIGURE B5



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

LEGEND

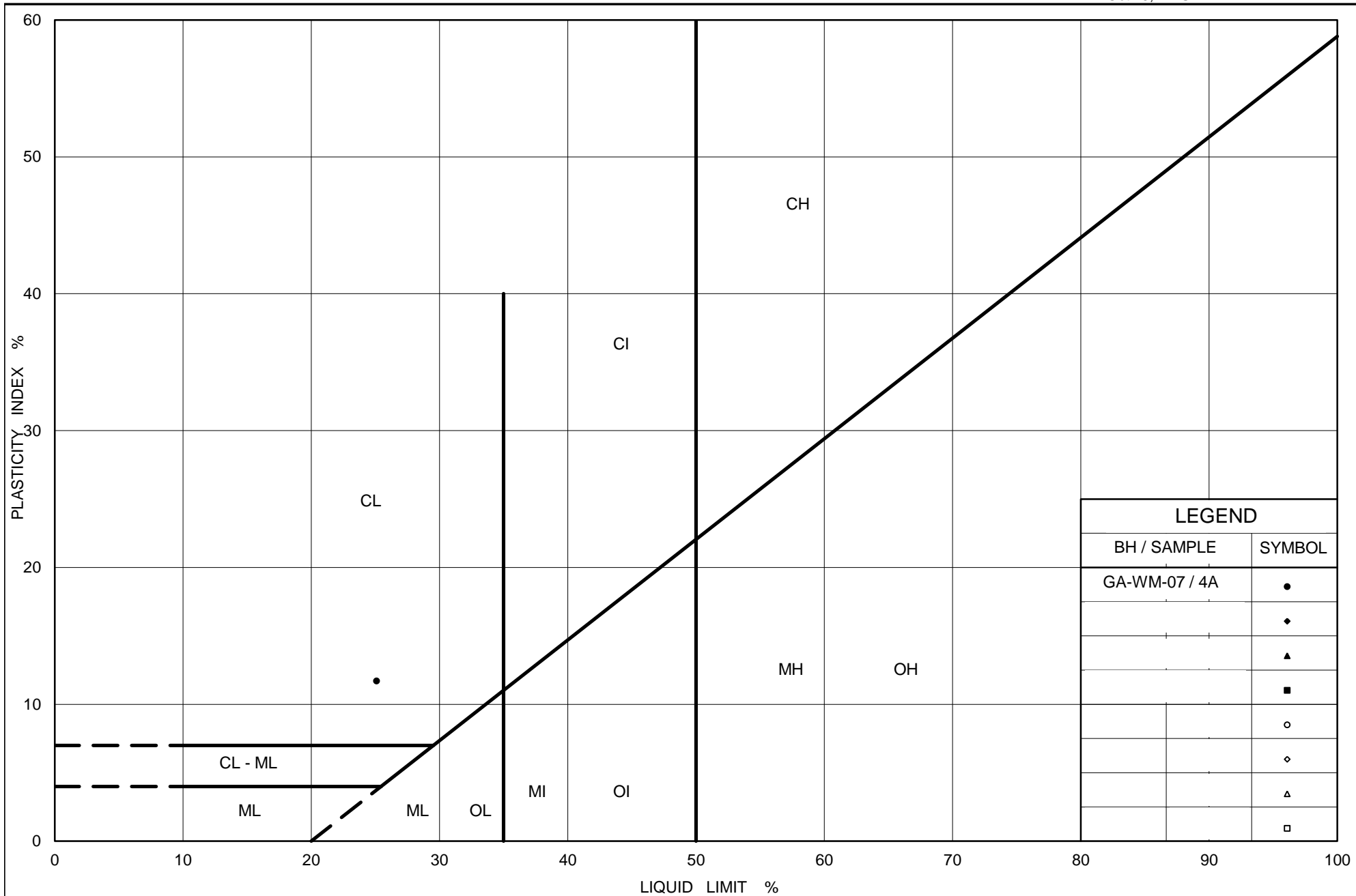
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	GA-WM-08	8B	186.7

Project Number: 1533525

Checked By: CN

Golder Associates

Date: 18-Oct-15



Ministry of Transportation

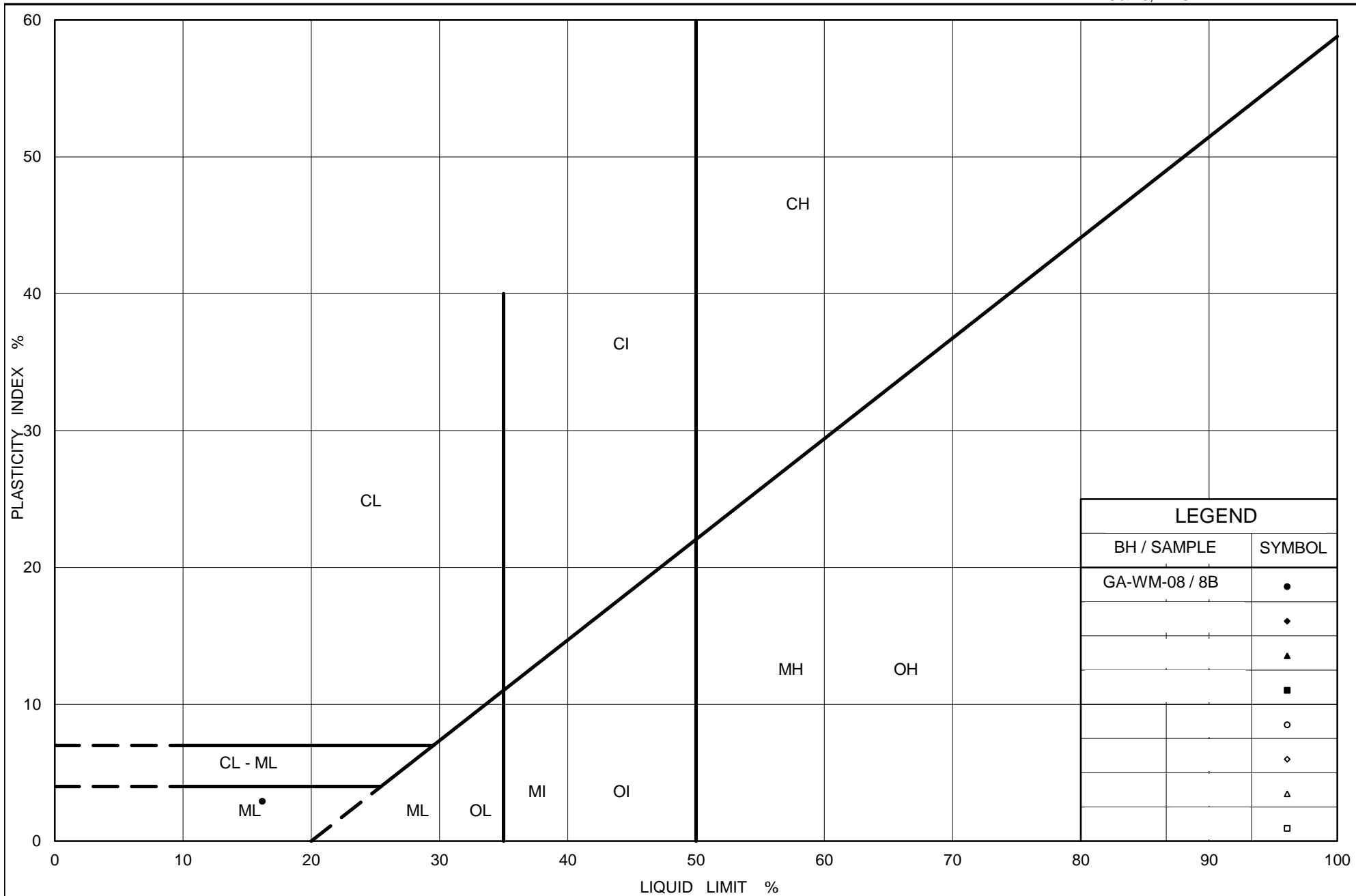
Ontario

PLASTICITY CHART **Sandy Clayey Silt (Layer)** **Watermain**

Figure No. B6

Project No. 1533525

Checked By: CN



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PLASTICITY CHART Sandy Silt (Layer) Watermain

Figure No. B7

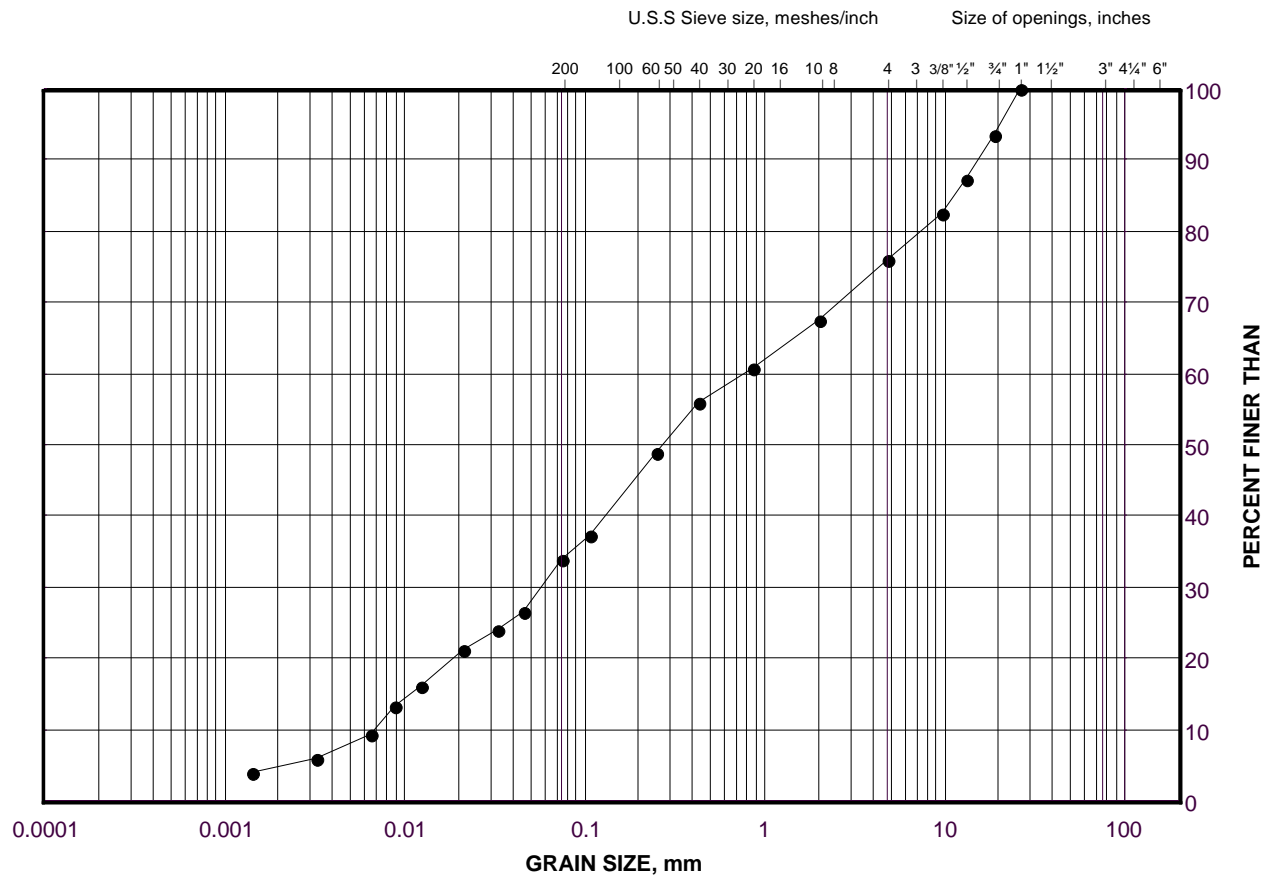
Project No. 1533525

Checked By: CN

GRAIN SIZE DISTRIBUTION

Gravelly Silty Sand (Interlayer)
Watermain

FIGURE B8



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	GA-WM-07	8	183.8

Project Number: 1533525

Checked By: CN

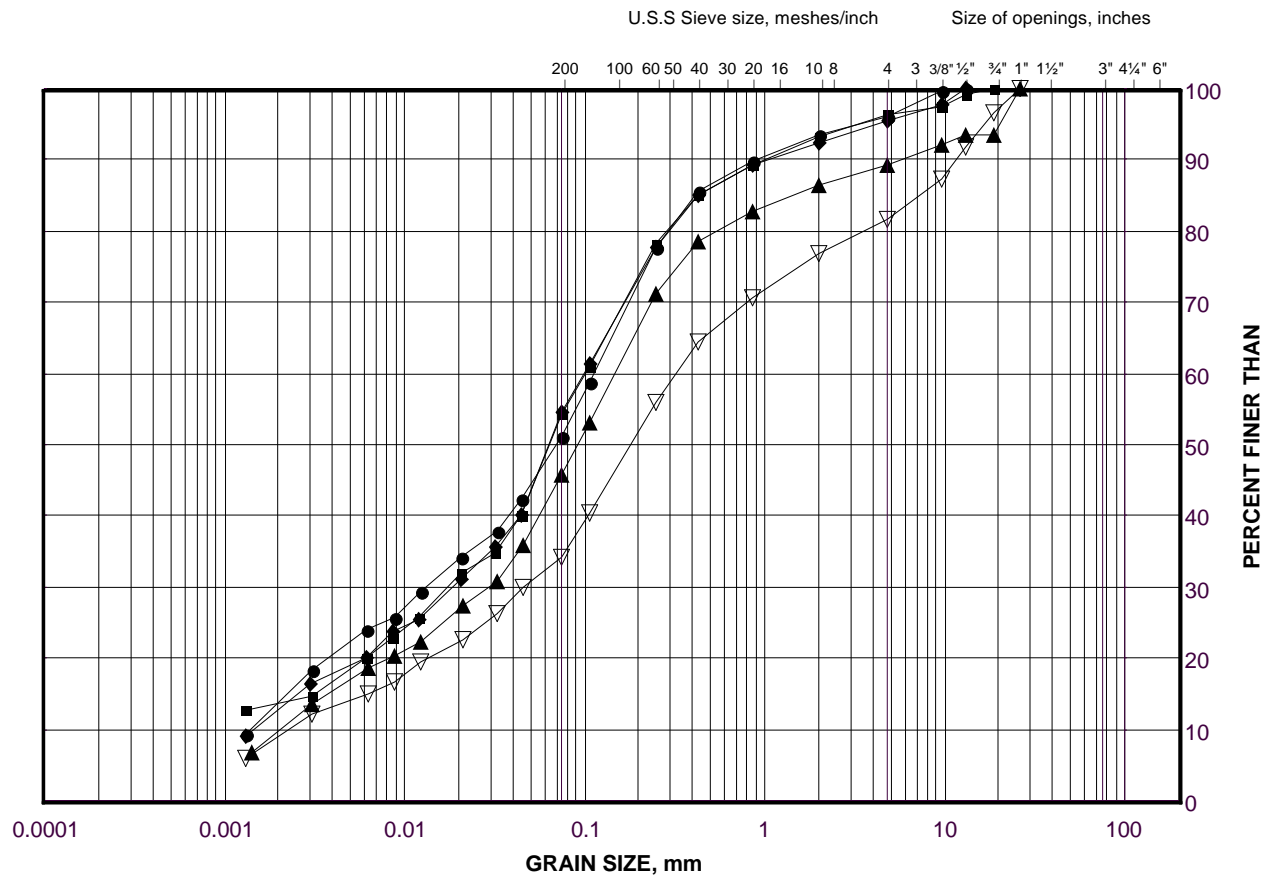
Golder Associates

Date: 22-Dec-15

GRAIN SIZE DISTRIBUTION

Sandy Silt to Silty Sand Till
Watermain

FIGURE B9



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

LEGEND

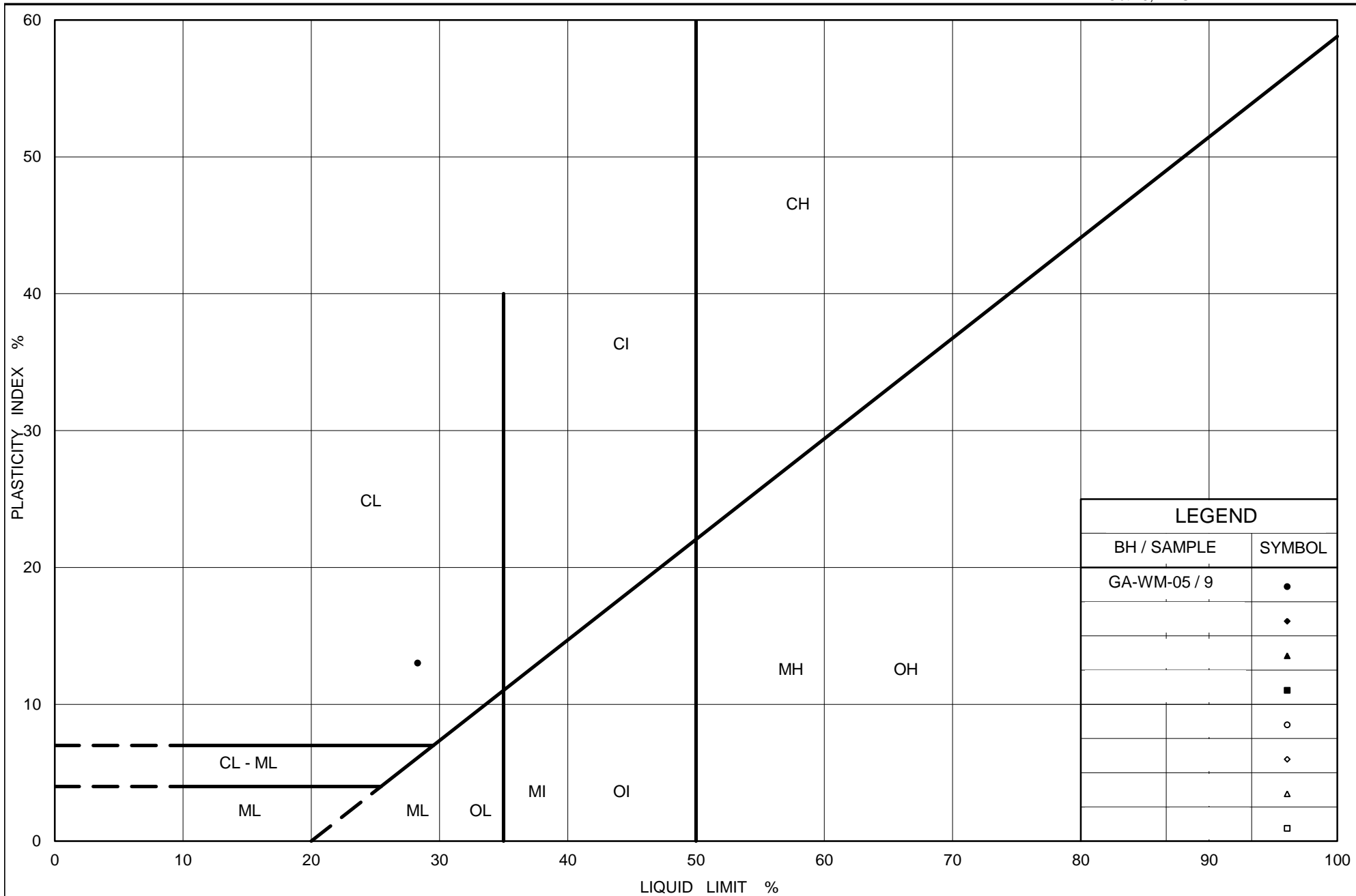
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	GA-WM-02	6	182.7
■	GA-WM-01	7	182.6
◆	GA-WM-03	7	184.0
▲	GA-WM-02	8	180.4
▽	GA-WM-04	9	177.6

Project Number: 1533525

Checked By: CN

Golder Associates

Date: 19-Oct-15



Ministry of Transportation

Ontario

PLASTICITY CHART Clayey Silt (Lower) Watermain

Figure No. B10

Project No. 1533525

Checked By: CN



APPENDIX C

Non-Standard Special Provision (NSSP)

SATURATED NON-COHESIVE SOILS (SILT AND SAND TO SAND AND SANDY SILT TO SILT AND SAND TILL) – Item No.

Non-Standard Special Provision

SCOPE

The contractor shall be alerted that the saturated non-cohesive silt and sand to sand deposit and the sandy silt to silt and sand till deposit encountered in the boreholes may be subject to flowing and raveling during the trenchless operations. Where these deposits are encountered, appropriate construction procedures and equipment will be required to minimize ground loss during the trenchless operations.

OBSTRUCTIONS – Item No.

Non-Standard Special Provision

The Contractor is alerted that for the Trenchless Installation of the watermain liner along the section of the alignment through the silt and sand to sand deposit and the sandy silt to silt and sand till deposit, the presence of cobbles and boulders should be expected and appropriate equipment and methods must be employed to remove such obstructions.

Consideration of the presence of these obstructions must be made in selection of appropriate equipment and procedures for sub-excavation and installation of the temporary shoring for the entry/exit shafts/pits, and roadway protection systems if required, as well as for the advancement of the watermain by a trenchless method chosen by the Contractor.

BASIS OF PAYMENT

Payment at the contract price for the above tender item shall be full compensation for all labour, equipment and materials required to do the work.

DEWATERING – Item No.

Special Provision

SCOPE

The work under this item includes the design, installation, operation, maintenance and removal of temporary dewatering systems to facilitate the watermain installation. Entry/exit shafts/pits for the watermain installation by a Trenchless Method will require excavation below the groundwater level. Non-cohesive soils below the groundwater table will be subjected to conditions of unbalanced hydrostatic head and can slough, boil, ravel and cave in during temporary excavation work.

REFERENCES

- OPSS 517 Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
- OPSS 518 Construction Specification for Control of Water from Dewatering Operations

SUBMISSION AND DESIGN REQUIREMENTS

Written details for the proposed dewatering system shall be submitted to the Contract Administrator for information purposes a minimum of ten business days prior to commencing dewatering operations. The Contractor shall reference borehole records included in the Contract Documents as a guide in determining requirements.

CONSTRUCTION

Dewatering System

The Contractor is responsible for the design, installation, operation and maintenance of an adequate dewatering system to lower the groundwater level to at least 0.6 m below the founding level for the shaft/pits to allow excavation in dry conditions and for construction of the watermain depending on the installation method chosen and adopted by the Contractor.

Operation

A continuous dewatering operation shall be provided to facilitate the installation of the watermain at all times during the work. All components of the dewatering system shall be maintained in an effective, functioning and stable condition at all times during the work. Notwithstanding the above, the work shall be completed in accordance with the environmental and operational constraints specified elsewhere in the Contract.

Restoration

All equipment and materials placed shall be removed from the right-of-way upon the completion of the work and all areas disturbed as part of this work shall be restored to their preconstruction conditions, unless specified otherwise.

BASIS OF PAYMENT

Payment at the contract price for the above tender item shall be full compensation for all labour, equipment and material to do the work.



APPENDIX D

Non-Standard Special Provision for Pipe Installation by Trenchless Method

PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Special Provision

1. SCOPE

This specification covers the general requirements for the installation of pipes by trenchless methods, including Jack & Bore, Pipe Ramming, Directional Drilling, and Tunnelling. The Contractor shall determine the most appropriate method of installation for each of the crossing locations.

This specification shall supersede OPSS 415 (Construction Specification for Pipeline Installation by Tunneling), OPSS 416 (Construction Specification for Pipeline and Utility Installation by Jacking and Boring) and OPSS 450 (Construction Specification for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling).

2. REFERENCES

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

Ontario Provincial Standard Specifications, General

OPSS 180	Management and Disposal of Excess Materials
----------	---

Ontario Provincial Standard Specifications, Construction

OPSS 401	Trenching, Backfilling, and Compacting
OPSS 404	Support Systems
OPSS 491	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 517	Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS.PROV 539	Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

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

American Society for Testing and Materials (ASTM) International Standards

ASTM A252-93	Welding and Seamless Steel Pipe Piles
ASTM D2657-03	Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings
ASTM D3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
ASTM F894	Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

Canadian Standards Association Standards:

CSA B182.6	Profile Polyethylene Sewer Pipe and Fittings.
CAN/CSA A5-93	Portland Cement
CSA W59	Welded Steel Construction (Metal Arc Welding)

3. DEFINITIONS

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

Auger Jack & Bore: a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead and rotating a cutter head, followed by removal of material from inside the bore by using an auger.

Backreamer: a cutting head suitably designed for the subsurface conditions that is attached to the end of a drill string to enlarge the pilot bore during a pullback operation.

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

Design Engineer: means the Engineer retained by the Contractor who produces the original design and working drawings. The design engineer shall be licensed to practice in the Province of Ontario.

Design Checking Engineer: means the Engineer retained by the Contractor who checks the original design and working drawings. The design checking engineer shall be licensed to practice in the Province of Ontario.

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

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

Drilling Fluid Fracture or Frac Out: a condition where the drilling fluid’s pressure in the bore is sufficient to overcome the in situ confining stress, thereby fracturing the soil and/or rock materials and allowing the drilling fluids to migrate to the surface at an unplanned location.

Engineer: a Professional Engineer licensed by the Professional Engineers of Ontario to practice in the Province of Ontario.

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

Environmentally Sensitive Area (ESA): areas adjacent to construction that are off limits to the Contractor as specified elsewhere in the Contract.

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

Grouting: injection of grout into voids.

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

Directional Drilling (DD): directional boring or guided boring.

HDPE: high density polyethylene.

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

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

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

Pipe Jacking: a method for installing steel casing or concrete pipe in the subsurface utilizing hydraulically operated jacks of adequate number and capacity to ensure smooth and uniform advancement without overstressing the liner/pipe.

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

Primary Liner (Support): system installed prior to or concurrent with excavation, to maintain stability of an excavation and to support earth or rock and any structure utilities or other facilities in or on the supported earth or rock mass, until the excavation is completed.

Product: pipe culverts, pipe sewers, watermain pipe and sanitary pipe.

Pullback: that part of the DD method in which the drill string is pulled back through the bore path to the entry point.

Quality Verification Engineer (QVE): an Engineer who has a minimum of five (5) years experience in the field of pipe installation using trenchless methods or alternatively has demonstrated expertise by providing satisfactory quality verification services for the work at a minimum of two (2) projects of similar scope to the contract. The Quality Verification Engineer shall be retained by the Contractor to certify that the work is in general conformance with the contract documents and to issue Certificate(s) of Conformance.

Reaming: a process for pulling a tool attached to the end of the drill string through the bore path to enlarge the bore and mix the cuttings with the drilling fluid. This typically includes multiple passes.

Rock: natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a size equivalent to 0.3 m in diameter or greater.

Secondary Liner: concrete pipe, HDPE pipe or un-reinforced cast-in-place concrete, installed subsequent to tunnel excavation.

Shaft: vertically sided excavation used as entry and/or exit points from which the trenchless method is initiated or directed for the installation of product.

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

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

Soil: all materials except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials; includes rock fragments having an equivalent size less than 0.3 m in diameter.

Trenchless Installation: an underground method of constructing a passage open at both ends that involves installing a pipe. For the purpose of this specification, the pipe may be installed by any of the various methods defined herein such as Auger Jack & Boring, Pipe Jacking, Pipe Ramming, Directional Drilling, or using a tunnelling machine or hand mining methods.

Tunnelling: An underground method of constructing a passage using a tunnel boring machine (TBM), a microtunnel boring machine (MTBM) or hand mining using a shield to support the opening.

4. DESIGN AND SUBMISSION REQUIREMENTS

4.01 General

The Contractor's documentation, submission requirements and installation methods shall specifically consider and address the subsurface conditions at each pipe crossing as identified in the Foundation Investigation Report or elsewhere in the Contract Documents.

4.02 Working Drawings

Three copies of stamped working drawings for portal or shaft construction, primary liner, excavation, secondary lining, dewatering and groundwater control and grouting shall be submitted to the Contract Administrator (CA) at least one week prior to the commencement of the work for information purposes. All submissions shall bear the seal and signature of the Design Engineer and Design Checking Engineer. The Contractor shall have a copy of the stamped working drawings at the site during construction.

As a minimum, working drawings/details pertaining to the tunnel design and construction shall include the following (as appropriate):

a) Plans, Elevations and Details:

- A work plan outlining the materials, procedures, methods and schedule to be used to execute the work;
- A list of personnel, including backup personnel, and their qualifications and experience;
- A safety plan including the company safety manual and emergency procedures;
- The work area layout;
- An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail;
- A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan detailing emergency procedures in the event that the fluid management plan fails;

- Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations; and
- Excavated materials disposal plan.

b) Design Criteria:

- Primary liner design details, if applicable;
- Design assumption and material data when materials other than those specified are proposed for use; and
- Drill path design, details of alignment and alignment control, maximum curvature and reaming stages.

c) Materials:

- Certification from the manufacturer that the product furnished on the contract meets the specifications cited in the manufacturer's product specification and that the materials supplied are suitable for the application; and
- Material mixture for filling voids and installation procedures.

d) Upstream/Downstream Portal Installation Procedure:

- The access shaft or entry/exit pit details designed and stamped/signed by the Design Engineer, as applicable; and
- Face support and other temporary support details, if applicable.

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

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

f) Excavation and Dewatering:

- Ground control/dewatering details, as applicable, describing the proposed method for control, handling, treatment, and disposal of water.

g) Monitoring Method:

- The methods to be employed to monitor and maintain the alignment of the installation.

4.03 Site Survey

Prior to commencing the work, the Contractor shall, at each pipe location, lay-out the alignment and install settlement monitoring points.

4.04 Certificate of Conformance

The Contractor shall submit details of the sequence and method of construction to the Quality Verification Engineer for review, prepared and stamped by the Design Engineer. The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer a minimum of one week prior to commencement of work under this item. The Certificate shall state that the construction procedures are in conformance with the requirements and specifications of the contract documents.

The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer upon completion of each of the following operations and prior to

commencement of each subsequent operation for each pipe installation:

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

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

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

The Design Engineer will not be permitted to carry out the work of the Quality Verification Engineer.

5. MATERIALS

5.01 Product

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

5.02 Concrete

Concrete shall be according to OPSS.PROV 1350. The concrete strength shall be as specified in the Contractor's design submission.

5.03 Concrete Reinforcement

Steel reinforcing for concrete work shall be according to OPSS.PROV 1440.

5.04 Timber

Timber shall be sound, straight, and free from cracks, shakes and large or loose knots.

5.05 Grout

The Contractor shall submit the proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces. Purging grout shall consist of a mixture of one part Portland cement conforming to the requirements of CAN/CSA A5-93 and two parts mortar sand conforming to OPSS.PROV 1004 wetted with only sufficient water to make the mixture plastic.

5.06 Auger Jack & Bore Materials

5.06.01 Pipe Materials

Steel pipe shall conform with ASTM A252-93 welded joints suitable for jacking operations. The Contractor shall select pipe class for pipe jacking.

Concrete pipe as per OPSS.PROV 1820.

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

5.07 Pipe Ramming Materials

5.07.01 Pipe Materials

Steel pipe shall conform with ASTM A 252-93 welded joints.

New steel casing when specified shall be smooth wall carbon steel pipe according to ASTM A252-93 Grade 2.

Used steel casing can be used provided that the steel casing can resist the applicable static and dynamic loadings.

Pipe wall thickness shall be determined by the Contractor based on static and dynamic loads from traffic loading and anticipated ramming forces for selected pipe and driven pipe lengths. The wall thickness shall be increased as required to ensure the casing is not damaged during handling and installation. The pipe minimum wall thickness shall be as per Table 1 of OPSS 1802.

Pipe segments shall be determined by the Contractor.

Steel pipe joints shall be pressure fit type or welded.

All steel casing pipe shall be square cut.

Steel casing pipe shall have roundness such that the difference between the major and minor outside diameters shall not exceed 1% of the specified nominal outside diameter or 6 mm, whichever is less.

Steel casing pipe shall have a minimum allowable straightness of 1.5 mm maximum per metre of length.

5.07.02 Mill Certificates

For permanent casing, the Contractor shall submit to the Contract Administrator at the time of delivery one copy of the mill certificate, indicating that the steel meets the requirements for the appropriate standards for casings.

Where mill test certificates originate from a mill outside Canada or the United States of America the Contractor shall have the information on the mill certificate verified by testing by a Canadian laboratory. The laboratory shall be accredited by a Canadian National Accreditation Body to comply with the requirements of ISO/IEC Guide 25 for the specific tests or type of tests required by the material standard specified on the mill test certificate. The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date and the signature of an authorized officer of the Canadian testing laboratory.

5.08 Directional Drilling Materials

5.08.01 Drilling Fluids

The drilling fluids shall be mixed according to the manufacturer's recommendations and be appropriate for the anticipated subsurface conditions.

5.08.02 Pipe Materials

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

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

The Contractor shall determine the required dimensional ratio (DR) of the HDPE pipe to support all subsurface conditions and hydrostatic pressures, and to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

The Contractor's submission shall demonstrate, in conjunction with the manufacturer's specifications, that the heat resistance of the pipe material is sufficient to tolerate without damage the heat of hydration generated by grout curing.

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

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

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

5.09 Tunnelling Materials

5.09.01 Primary Liner

Tunnelling methods will require installation of a primary liner. The primary liner shall be designed by the Contractor and the design/drawings shall be stamped/signed by the Design Engineer. The design shall be submitted to the Contract Administrator as specified herein.

5.09.02 Secondary Liner

Concrete or High Density Polyethylene Pipe shall be used according to the following requirements.

5.09.02.01 Concrete Pipe

Concrete pipe as per OPSS.PROV 1820 shall be used. The Contractor shall select the pipe class to withstand grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

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

5.09.02.02 High Density Polyethylene (HDPE)

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

The requirements for fittings shall be according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

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

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

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

6. EQUIPMENT

6.01 Auger Jack & Bore Equipment

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

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

6.02 Pipe Ramming Equipment

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

The pipe ramming hammer(s) shall be capable of driving the pipe casing from the drive pit through the existing subsurface conditions at the site.

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

6.03 Directional Drilling Equipment

6.03.01 General

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

6.03.02 Drilling Rig

The directional drilling rig shall:

- consist of a leak free hydraulically powered boring system to rotate, push, and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head;
- contain a guidance system to accurately guide boring operations;
- be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation; and
- be grounded during all operations unless otherwise specified by the drilling rig manufacturer.

6.03.03 Drill Head

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

6.03.04 Guidance System

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

6.03.05 Drilling Fluid Mixing System

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

6.03.06 Drilling Fluid Delivery System

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

6.04 Tunnelling Equipment

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

Specific details of the manner in which rock or boulders will be broken and removed from the tunnel face shall be submitted to the Contract Administrator information purposes. Use of rock fracturing chemicals shall only be considered subject to a field demonstration satisfactory to the Ministry prior to its use.

Use of explosives is prohibited.

7. CONSTRUCTION

7.01 General

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

Administrator for information purposes prior to commencing the work and shall be subject to the limitations presented in the following subsections.

7.01.01 Layout, Alignment and Depth Control

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

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

The Contractor shall calibrate tracking and locating equipment at the beginning of each work day, and shall monitor and record the alignment and depth readings provided by the tracking system at every 5 m in normal conditions and every 2 m where precise alignment control is necessary;

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

All excavations shall be carried out in accordance with the Occupational Health and Safety Act (OHSA) of Ontario.

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

7.01.02 Construction Shafts

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

Shafts shall be maintained in a drained condition.

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

7.01.03 Protection Systems

The construction of all protection systems shall be according to OPSS.PROV 539. Where the stability, safety, or function of an existing roadway, watercourse, other works, proposed works or ESA’s may be impaired due to the method of operation, protection shall be provided. Protection may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works.

7.01.04 Settlement or Heave

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

7.01.05 Stability of Excavation

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

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

7.01.06 Preservation and Protection of Existing Facilities

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

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

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

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer's handling and storage recommendations shall be followed.

7.01.08 Trenching, Backfilling and Compacting

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

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

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

7.01.10 Dewatering

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

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

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

Should water enter the excavation in amounts that could adversely affect the performance of the work or

could cause loss of ground, the Contractor shall take immediate steps to control the inflow.

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

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Boulders

The Contractor is alerted that cobbles and boulders should be anticipated in the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

7.01.12 Record Keeping

Verification record requirements of the alignment and depth of the installation shall be as specified in the Contract Documents. A copy of the verification records shall be given to the Contract Administrator at the completion of the installation.

7.01.13 Testing

Testing of the product installation shall consist of verifying the specified grade between the two ends of the pipe and passing of water from the inlet end of the pipe to the outlet end to confirm gravity flow conditions.

7.01.14 Management and Disposal of Excess Material

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

7.01.15 Site Restoration

Site restoration shall be according to OPSS 492.

7.01.16 Supervision

A qualified individual, who is experienced in the pipe installation by trenchless methods shall supervise the work at all times.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

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

- Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.
- A suitably padded jacking head or collar shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.

- Selection of the excavation method and jacking equipment shall take into consideration the conditions at each pipe crossing.

7.02.02 Pipe Installation

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

During the jacking of the liner the space between the liner and the wall of the excavation shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavation shall be filled with grout.

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

7.03 Pipe Ramming Installation

For pipe ramming installation the following requirements apply:

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

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

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

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

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

7.04 Directional Drilling Installation

7.04.01 General

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

7.04.02 Site Preparation

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

7.04.03 Pilot Bore

The pilot bore shall be drilled along the bore path in accordance with the grade, alignment, and tolerances as

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

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

In the event that a drilling fluid fracture, inadvertent returns, or loss of circulation occurs during pilot bore drilling operations, the Contract Administrator shall be advised of the event and action shall be taken in accordance with the Contractor's submitted contingency plan.

At the entry and exit points, there is potential for ravelling of the existing soil, fill and or weathered rock areas along the alignment. This is conventionally addressed by the use of drilling fluid. However, casing may be required. The Contractor's methods shall take into consideration the potential need to install sections of casing to manage ravelling at or near ground surface.

If a drill hole beneath the highway must be abandoned, the hole shall be backfilled with grout or bentonite to prevent future subsidence.

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

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

7.04.04 Drilling Fluid Fracture (Frac-Out)

In order to reduce the potential for hydraulic fracturing of the hole during directional drilling, a minimum depth of cover of 5m is normally maintained between the pipe and the ground surface. Sections of the pipe close to the exit pit with less than 5m cover shall be cased. The Contractor shall ensure that drilling fluid pressures are properly set and controlled to prevent frac-out, for the depth of cover available between the bottom of the pavement structure (bottom of the subbase material) and the top of the bore.

Since fluid loss normally occurs in fault zones, fracture zones, or seams of coarse material, fluid migration does not always gravitate to the surface, thus making detection difficult. Once a fluid loss is detected, the Contractor shall halt operations immediately and conduct a detailed examination of the drill path and implement measures to mitigate fluid loss. If no surface migration is evident, resume operation while paying particular attention to fluid monitoring.

In the event of a fluid migration to the surface occurring, the Contractor shall halt all operations immediately, isolate the migration site, and recover fluids. Once the fracture is controlled, continue drilling operations with the operator paying particular attention to the fracture points

7.04.05 Reaming

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

7.04.06 Product Installation

7.04.06.0 General

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

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

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

Product shall be allowed to recover before connections to new or existing facility are made. Product recovery time shall be according to manufacturers recommendations.

7.04.06.02 Pullback and Grouting

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

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

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

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

The space between the pipe and the excavation walls shall be filled with grout.

7.05 Tunnelling Installation

7.05.01 General

The method of tunnelling shall be selected by the Contractor and shall be submitted to the Contract Administrator prior to commencement of the work for information purposes.

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

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

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

The Contractor shall advance the ventilation system as a regular part of the normal excavation cycle.

The Contractor shall provide lighting in accordance with OSHA requirements for the entire length of the tunnel.

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

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

In the event that excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation. The Contractor shall then evaluate methods of construction and revise as necessary to ensure the safe continuation of the work.

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

7.05.01 Tunnelling Method

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

7.05.02 Primary Liner (Support System)

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

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

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

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

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

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

All voids between the primary lining and the surface of the excavation shall be filled with cement grout. If an unexpanded liner is used, the space outside the liner plates shall be grouted at least daily.

7.05.03 Secondary Liner

7.05.03.01 Placing of Grout

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

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

7.06 Instrumentation Monitoring

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

Surface settlement markers for monitoring ground stability shall be installed at the pavement/ground surface level on the shoulder, side slope and pavement at not greater than 5 m intervals along the tunnel alignment and as an array of three in-ground (1.5 m depth) measurement points on the shoulder of the highway perpendicular to the alignment. The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within ± 1 mm of the actual elevation.

Surface settlement markers shall be hardened steel markers treated or coated to resist corrosion, with an exposed convex head having a minimum diameter of 12 mm and similar to surveyor's PK nails. Markers shall be rigidly affixed so as not to move relative to the surface to which it is attached. Traffic shall be managed by the contractor using short-term lane closures in accordance with the Ontario Traffic Manual (OTM).

In general, settlement monitoring points shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe, set to a depth of 1.5 m below ground surface. The assembly shall be placed in a drill hole and backfilled with uniform sand.

The Contractor shall install all surface settlement instruments a minimum of one week prior to the start of works.

The surface settlement instruments shall be clearly labelled for easy identification.

The Contractor shall submit to the Contract Administrator a site plan showing the locations of the monitoring points, a geodetic survey of the settlement monitoring points including station, offset and elevation recorded at the following time intervals:

- Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);
- Once per shift during tunnelling operations period; and
- Weekly after completion of the work for one month, or until such time at which all parties agree that further movement has stopped.

All readings shall be submitted to the Contract Administrative for information purposes on a weekly basis. Each report shall include all survey data collected in tabular and graphical format as plots of time versus settlement in comparison to survey data collected prior to commencement of the work.

7.07 Criteria for Assessment of Roadway Subsidence/Heave

Based on the monitoring of ground movement as specified in Subsections 4.02 and 7.06, the following represents trigger levels that define magnitude of movement and corresponding action:

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

The Contractor shall avoid damaging instrumentation during construction. Instrumentation that is damaged as a result of the Contractor's operation shall be repaired or replaced by the Contractor within one business day. The costs for replacement/repair shall be borne by the Contractor.

At the completion of the job, the Contractor shall abandon all instrumentations installed during the course of the Work.

9. MEASUREMENT FOR PAYMENT

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

10. BASIS OF PAYMENT

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

Payment for the rigid or flexible pipe conduits installed inside the pipe liners shall be paid separately under the appropriate tender items.

Where a protection system is made necessary because of the Contractor's operations (e.g. choice of trenchless

installation method), the cost shall be included in this item and shall be full compensation for all labour, equipment and materials required to carry out the work including subsequently removing the temporary protection system and performing any necessary restoration work.

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

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

Payment for removal of boulders/obstructions greater than an equivalent 0.3 m in diameter shall be on a time and materials basis. The Contractor shall inform the Contract Administrator when boulders/obstructions are encountered and prior to removal to allow for proper and accurate tracking of time and material charges.

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