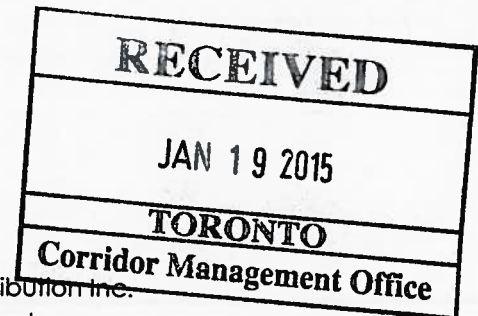


**Foundation Investigation and Design Report
GTA Project Detailed Engineering Design
Phase DOCUMENT NO.: 110901255.085
PROJECT NO.: 110901255**

Spread 3 – Crossing 3 (S3C3)
Highway 401
Mississauga, ON



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2015-01-12

**FOUNDATION INVESTIGATION AND DESIGN REPORT GTA PROJECT DETAILED ENGINEERING
DESIGN PHASE DOCUMENT NO.: 110901255.085 PROJECT NO.: 110901255**

2015-01-12

Revision History

Rev	Date	Description	Prepared By	Checked By	Approved By
A	August 8, 2014	Issued for Review	Khashayar Refahi	John J. Brisbois J.Brant Gill	Raymond Haché
0	October 10, 2014	Issued for Review	Khashayar Refahi	John J. Brisbois J.Brant Gill	Raymond Haché
1	October 21, 2014	Issued for Design	Khashayar Refahi	John J. Brisbois J.Brant Gill	Raymond Haché
2	January 12, 2015	Issued for Design	Khashayar Refahi	John J. Brisbois J.Brant Gill	Raymond Haché

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Introduction
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1.0 Introduction

Enbridge Gas Distribution Inc. (Enbridge) is planning to install approximately 50.7 kilometers of new steel pipe to upgrade the existing natural gas distribution system in the Greater Toronto Area (GTA).

The proposed new pipeline will reinforce the existing supply of natural gas to better serve both the current and future customer demand within the GTA. The proposed project is commonly referred to as the Enbridge GTA Project.

Stantec Consulting Ltd. (Stantec) was retained by Enbridge to complete a geotechnical and hydrogeological investigation at planned pipeline crossing locations and associated facility sites. The geotechnical and hydrogeological investigations were focused on identifying the subsurface and groundwater conditions for consideration in the design of the proposed pipeline crossings, and on identifying issues or concerns associated with the potential to adversely affect the environment during the construction process.

The work was completed in accordance with the revised proposal dated September 5, 2013, (Document No. ENI164.339) submitted to Enbridge and subsequent approval provided on September 18, 2013, in the form of a Work order.

This Foundation Investigation Report was prepared specifically for the proposed pipeline crossing of Highway 401. This crossing is designated as Spread 3 Crossing 3 (e.g. S3C3). The proposed construction methodology for this pipeline crossing is Horizontal Directional Drilling (HDD).

This report contains the factual results of the combined geotechnical and hydrogeological investigation, provides comments and recommendations for consideration in the design and construction of the proposed pipeline crossing, and includes comments pertaining to mitigation of potential adverse impacts associated with construction.

This report does not address any environmental aspects of the project such as the potential presence of environmental contamination, species at risk, surface water, or related topics.

The location of the required crossing is within lands designated to Highway 401. The Ontario Ministry of Transportation (MTO) is the designated regulatory authority for purposes of Public Transportation and Highway Improvements in this regard. Therefore, this Foundation Investigation Report has been prepared in accordance with the style and content of typical reports prepared for crossings of MTO infrastructure.

During initial consultation, the MTO has designated the 42 in. (1067 mm) diameter steel pipe crossing of Highway 401 as a crossing requiring the participation of a foundation engineering consultant registered in MTO's consultant acquisition system under High Complexity for Tunneling Specialty Services. Peto



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MacCallum Ltd. (Peto MacCallum) was subsequently retained by Stantec to review this report in this respect.

Limitations associated with this report and its contents are provided in the statement included in **Appendix A**.

2.0 Site Description and Geology

2.1 SITE LOCATION

The location of the planned crossing of Highway 401 is shown on Figure S3C3 in **Appendix B**.

The planned crossing is located approximately 230 m south of the interchange with the Highway 407 ETR, approximately 340 m west of Winston Churchill Boulevard, and approximately 150 m east of the termination (cul-de-sac) of 10th Line West.

For purposes of this report, the orientation of Highway 401 has been taken as east-west and the orientation of the alignment of the proposed pipeline crossing has been taken as north-south.

2.2 SITE DESCRIPTION

At the crossing location, Highway 401 is a 6-lane highway with a single lane for the on-ramp from southbound Winston Churchill Boulevard to the west bound lanes, and with two lanes (merging to one lane) for the off-ramp from east bound Highway 401 to Winston Churchill Boulevard. The highway has a center barrier and paved shoulders at the crossing location. The total width of the travel surface perpendicular to the alignment of the PPR is approximately 48 m and the width of the MTO lands at the crossing location is approximately 91 m.

Two photographs of the crossing location are included in **Appendix B** for reference.

The approaches to the pipeline crossing are within the existing Parkway Belt Utility Corridor on lands owned by Infrastructure Ontario (IO). The Parkway Utility Corridor presently accommodates various overhead and buried hydro power lines, including an existing NPS 36 (36 inch/914.4 millimeter outside diameter) Enbridge gas pipeline (EGD Vital Main), and an existing TransCanada Pipeline.

The Crossing Plan and Profile showing the preliminary horizontal and vertical alignments of the PPR at the Highway 401 crossing location was provided to Stantec for consideration in the preparation of this geotechnical report. The Plan and Profile drawing was dated September 16, 2014 and noted as "Issued For Construction".

The plan provided indicated that the EGD Vital Main is parallel to the proposed NPS 36 pipeline; the horizontal separation distance between the two pipelines is approximately 4.3 m. The site plan also indicated that the TransCanada Pipeline is parallel to the proposed NPS 36 pipeline; the horizontal



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separation distance between the two pipelines is approximately 9.6 m. The site plan and profile provided also indicated that the PPR for the NPS 36 pipeline crosses under a sewer pipe (600 mm diameter) that is located at the approximate median of Highway 401. The bottom of the sewer pipe is at a depth of approximately 2.6 m below grade (consistent with Elevation 205.8 m) at the crossing location. The vertical separation between the sewer pipe and the PPR is in the order of 12 m.

There are two rows of hydro towers on the east side of the alignment of the PPR and two rows of hydro poles on the west side of the alignment of the PPR. The closest hydro tower is located approximately 60 m east of the crossing location and the closest hydro pole is located approximately 10 m west of the crossing location.

Commercial and industrial developments exist to the east of the utility corridor and agricultural lands and industrial developments exist to the west of the utility corridor. There is a storm water management pond located immediately northwest of the crossing location, bounded by Highway 401 and Highway 407.

Lisgar Meadow Brook Tributary 4 crosses the alignment of the PPR approximately 45 m to the north of the Highway 401 crossing, and crosses Highway 401 approximately 50 m to the east of the Highway 401 crossing location.

The profile indicates that at the crossing location, Highway 401 is on an earth embankment approximately 2 m high. The embankment has an approximate slope of 3:1 (Horizontal:Vertical) on the north side of the highway and approximate slope of 6:1 (Horizontal:Vertical) on the south side of the highway. The elevation on the travel surface ranges from 208.4 m on the south side to 209.3 m on the north side of the highway. The bottom of the ditch on the shallow drainage ditch at the toe of the embankment on the south side of the highway is at Elevation 207.0 m. The ground surface topography beyond the ditch is at approximately Elevation 207.1 m and is relatively level. There is no ditch on the north side of the highway. The ground surface topography beyond the toe of the embankment on the north side of the highway is at approximately Elevation 207.3 m and is relatively level.

The ground surface cover on the lands on both sides of Highway 401 is generally comprised of a combination of rough grass and brush.

2.3 GEOLOGICAL DESCRIPTION

2.3.1 Background Review – Sources of Information

The resources and references considered in the preparation of this report are included in the list in Section 11.0 below.

With respect to the MOE Water Well online database and the OGS Borehole Record online database, while these sources of information are available to the public, they are provided without benefit of formal reliance, and as such, can only be used in the context of providing a general indication of the likely subsurface conditions to be encountered; the information should not be used for purposes of design and construction. In this respect, the information reviewed was considered solely in the development of the scope of the geotechnical investigation, as further reported herein.



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As a component of the Pull Forward Engineering (PFE) Design Phase for the project, Stantec advanced two (2) boreholes (denoted S3C3-1 and S3C3-4) at locations beyond the limits of the MTO designated lands. The information obtained in the boreholes was used to prepare a preliminary report, dated November 14, 2013, to facilitate and support the early stages of the design process. The two boreholes and all associated information have been used in the context of preparation of this report.

2.3.2 Overburden

The area of the crossing location is within the physiographic region identified as the Peel Plain by Chapman and Putnam (1984). The Peel Plain generally consists of glacial till soils, and is characterized as a level to undulating tract of clayey soils, covering approximately 800 square kilometers across central portions of the Regional Municipalities of York, Peel, and Halton. There is a gradual and relatively uniform downward slope towards Lake Ontario.

The Quaternary Geology of Southern Ontario Map 2556 indicates that the overburden in the region consists predominantly of soils having a silt to silty clay matrix, described as Halton Till.

A review of the MOE water well record database identified two (2) water wells within 450 m of the crossing. The water well record referenced the presence of clay, underlain by fine sand and gravel.

A review of the OGS database identified one (1) geotechnical borehole record within 400 m of the crossing. The record indicated that the overburden soils consisted of fine grained deposits of clay, silt, sand, and gravel.

2.3.3 Bedrock

Map 2544 indicates that the region is underlain by bedrock of either the Queenston Formation. For reference, the Queenston Formation consists of reddish shale often with layers of grey to green limestone.

The MOE water wells referenced above did not record the presence of bedrock within the maximum termination depth of approximately 20.4 m below grade.

The OGS borehole referenced above did not record the presence of bedrock within the termination depth of approximately 10.8 m below grade.

2.3.4 Groundwater

The MOE water well records referenced above indicated a static groundwater level at approximately 4.0 and 4.3 m below grade, translating to an approximate elevation of 204 m and 204.5 m, respectively.

The OGS geotechnical borehole record referenced above indicated a static groundwater level at a depth of 3.0 m below grade, translating to an approximate elevation of 208 m.



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2.4 EXISTING STRUCTURES

The location of the planned crossing is approximately 425 m west of the Winston Churchill Boulevard bridge over the Highway 401 and the associated on/off-ramps.

There is a culvert crossing located approximately 50 m to the east of the location of the proposed pipeline crossing.

Reference to the existing aboveground and underground utilities and services in proximity to the crossing location was provided above in Section 2.2.

3.0 Method of Investigation

3.1 DRILLING INVESTIGATION

The scope of the investigation was developed in consideration of the Guidelines For Foundation Engineering – Tunneling Specialty For Corridor Encroachment Permit Application, issued by the Ministry of Transportation, Pavement and Foundation Section. In the absence of specific requirements stipulating the number of monitoring wells, it was intended to install a single monitoring well in one of the boreholes advanced for the PFE phase of investigation. If unusual or variable conditions were encountered in the remaining boreholes, the installation of additional monitoring wells was to be considered.

For reference, consultation with MTO staff established the complexity rating for this specific undertaking as “High”.

The scope included advancement of five (5) boreholes for the crossing of Highway 401 with consideration the proposed installation method of Horizontal Directional Drilling (HDD). The borehole locations were established through discussions with the project team, with the project HDD consultant, J.D. Hair, with overview by the project pipeline consultant, Stantec's Calgary based Oil and Gas. The spacing between the boreholes was established to be less than 50 m, consistent with the requirements of the MTO Guidelines.

As referenced in the preceding sections of this report, the two boreholes (denoted S3C3-1 and S3C3-4) advanced for the PFE Design Phase have been incorporated herein. For the Detailed Engineering (DE) Phase of the investigation, 3 supplementary boreholes (denoted S3C3-2, S3C3-3, and S3C3-5) were advanced at locations within the limits of the MTO lands.

The locations of all five (5) boreholes are shown on Figure S3C3 in **Appendix B**.

For the PFE phase of investigation (boreholes S3C3-1 and S3C3-4) Stantec retained the services of a utility locate company, Underground Engineering Services (UES), to provide and maintain public utility locate clearances for the intended locations of these boreholes. UES also provided private utility locate services to identify any traceable underground utilities not identified by the public locates for the location of these boreholes.



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For the DE phase of investigation (boreholes S3C3-2, S3C3-3, and S3C3-5) Stantec obtained public utility locates clearances from various public utility companies for the intended locations of the boreholes. In addition, Stantec retained the services of a utility locate company, OnSite Locates, to provide private utility locate services to identify any traceable underground utilities not identified by the public locates for the location of these boreholes.

An Encroachment Permit was obtained from MTO for the purpose of advancing boreholes S3C3-2, S3C3-3 and S3C3-5 located within the boundaries of the Highway 401 corridor.

The PFE field investigation program was carried out during the period of September 26 and October 3, 2013. The DE field investigation program was carried out during the period of May 31 and June 5, 2014. The boreholes were advanced using a CME-75 track or truck mounted drill rig equipped with 200 mm hollow-stem augers. The boreholes were advanced to a depth in excess of the "3 tunnel diameters below invert" as required by the MTO Guidelines.

Stantec field personnel recorded the conditions encountered in the boreholes. Soil samples were recovered at regular intervals using a 50-mm (outside diameter) split-tube sampler by conducting Standard Penetration Tests (SPTs) in accordance with the procedures outlined in ASTM specification D1586-99. Semi-continuous sampling at an interval of 0.75 m (2.5 feet) was conducted through the full depth of the overburden encountered, exceeding the MTO Guidelines which require semi-continuous sampling to the proposed invert level of the pipe and a sampling interval of 1.5 m (5.0 feet) below the invert level. All soil samples recovered from the boreholes were placed in moisture-proof bags and returned to our laboratory for geotechnical classification with a number of samples being selected for geotechnical laboratory testing.

The upper zone of the bedrock was augered and sampled at regular intervals by conducting SPTs until auger refusal was achieved. Upon achieving auger refusal, the bedrock was cored using HQ-size (63-mm inside diameter) rock coring equipment in accordance with the procedures outlined in ASTM specification D2113. Stantec personnel recorded the total core recovery, solid core recovery, and Rock Quality Designations (RQD) in the field in accordance with the procedures outlined in ASTM specification D6032. All rock core samples recovered from the boreholes were placed in wooden rock core boxes for protection during transportation to our geotechnical and materials testing laboratory where the core was logged and classified, and samples selected for testing.

The use of water for rock coring precluded observation of the groundwater conditions on completion of the drilling process.

A single groundwater monitoring well was installed in borehole S3C3-4. The well included a 1.5 m long screen installed over a depth of approximately 13.7 m to 15.2 m below existing grade within the native silty clayey sand till stratum (further description of the soil and bedrock stratigraphy encountered in the boreholes is provided in subsequent sections of this report).

The hydrogeological fieldwork component of this investigation was carried out on October 1, 7, 11, and 15, 2013. The monitoring well was developed by purging the well dry six times, removing a total of 1.9 well



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volumes, or 52 L, of groundwater from the casing. The static groundwater level was recorded in the well on October 7 and February 25, 2013.

In-situ hydraulic testing was conducted in the well to determine the hydraulic conductivity of sandy silty clayey sand till present over the screened interval. The methodology consisted of completing a rising head test. The hydraulic conductivity of the surrounding formation was calculated using the commercial software AQTESOLV, and the analytical solution methods of Bouwer and Rice, and Hvorslev.

The remaining boreholes were backfilled with a mixture of granular bentonite and auger spoils to provide a low-permeability backfill, consistent with the requirements of the Ontario Ministry of the Environment (MOE) Regulation 903.

3.2 SURVEYING

The borehole locations were established in the field using handheld GPS equipment. The locations were marked with wooden stakes with unique borehole identifiers. The locations of the boreholes are shown on Figure S3C26 in **Appendix B**.

On completion of drilling, the borehole locations were surveyed by the project survey contractor, Sexton McKay/J.D. Barnes Ltd., who provided borehole elevations referenced to geodetic datum for use in this report. The approximate locations of the boreholes, including UTM Zone 17 northing and easting coordinates and respective ground surface elevations referenced to geodetic datum are provided in Table 3-1 below and are shown on Figure S3C3 in **Appendix B**. The elevations are considered accurate to less than 0.1 m and the horizontal coordinates accurate to less than 0.5 m, meeting the requirements of the MTO Guidelines.

Table 3-1 Borehole Location and Elevation Summary

Borehole		S3C3-1	S3C3-2	S3C3-3	S3C3-4	S3C3-5
Approximate Distance from the PPR		23 m east	16 m east	18 m west	20 m west	27 m east
Approximate Distance from Highway Centerline along the PPR		120 m south	55 m south	40 m north	190 m north	2 m south
UTM Zone 17	Easting	597420.2	597405.3	597357.5	597392.7	597361.8
	Northing	4827992.1	4828050.7	4828129.8	4828295.5	4828091.1
Ground Surface Elevation (m)		207.1	207.2	207.1	207.5	209.3
Depth Drilled (m)		35.3	30.7	30.5	35.1	31.0
End of Borehole Elevation (m)		171.8	176.5	176.7	172.4	178.3
Depth Augered (m)		12.6	14.3	15.0	17.3	16.1
Number of Soil Samples		21	20	20	25	22
Depth Cored (m)		22.7	16.4	15.7	17.8	14.8
Number of Coring Runs		13	11	10	11	10

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3.3 LABORATORY TESTING

All samples returned to our Markham geotechnical laboratory testing facility were subjected to visual examination by a Geotechnical Engineer.

Subsequent to a review of the field borehole records and the visual review of the samples obtained, the following scope of geotechnical laboratory testing was implemented:

Soil

- Atterberg Limits 24 samples
- Gradation Analysis 24 samples
- Moisture Content 91 samples

Bedrock Core

- Unconfined Compressive Strength (UCS) tests 47 (7 samples could not be tested)
- Unit Weight tests 47 (7 samples could not be tested)

The number of samples selected for testing was confirmed to meet the minimum laboratory testing requirements specified in the MTO Guidelines.

Results of the tests are shown in **Appendix D** and on the Borehole Record in **Appendix C**.

Samples remaining after testing will be placed in storage for a period of one year after the date of issue of the final report for this project. After the storage period, the samples will be discarded unless a request to the contrary is received from MTO.

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4.1 FRAME OF REFERENCE

The soils encountered in the boreholes and reported herein have been classified in accordance with the Unified Soil Classification System as defined in ASTM D2487 and D2488, with modifications consistent with the methods of the Ontario Ministry of Transportation (MTO). The modifications specifically include the removal of the descriptions “lean” and “fat” with reference to clay soils and include a “Medium” category with respect to plasticity.

4.2 OVERVIEW

In general, the overburden stratigraphy encountered in the boreholes consisted of:

- Organic ground surface cover and topsoil or asphalt (in one borehole only) at the ground surface; underlain by,
- Fill materials (in one borehole only); underlain by
- Firm to hard clay with sand (till); underlain by,
- Soft to hard sandy clay, sandy silty clay and sandy silty clay with gravel (till); underlain by,
- Very dense silty sand, silty clayey sand and silty clayey sand with gravel (only in two boreholes) (till).

Bedrock of the Queenston Formation was inferred to be present underlying the overburden in the boreholes, at depths ranging from 12.6 m to 17.3 m below grade.

The introduction of water into the boreholes during drilling precluded observation of free groundwater conditions in the open boreholes on completion of drilling. Static groundwater was recorded at a depth of 1.0 m below grade on October 7, 2013, and at 0.8 m below grade on February 25, 2014 in the single monitoring well installed at the site.

A stratigraphic section illustrating the soils and bedrock encountered in the boreholes is provided on Drawing No. 1 in **Appendix B**.

The subsurface conditions observed in the boreholes are presented in detail on the Borehole Records provided in **Appendix C**. An explanation of the symbols and terms used to describe the Borehole Records is also provided.

4.3 GROUND SURFACE COVER

4.3.1 Topsoil

Organic ground surface cover and topsoil was present at the locations of Boreholes S3C3-1 to S3C3-4. The topsoil was approximately 300 mm, 200 mm, 250 mm and 100 mm thick at the respective borehole locations.



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4.3.2 Asphalt

Asphalt pavement was present at the location of Borehole S3C3-4, drilled in the median of Highway 401. The asphalt was approximately 140 mm thick at the borehole location.

4.4 GRANULAR FILL

A layer of granular fill consisting of sand and gravel was encountered underlying the asphalt in Borehole S3C3-5. The granular fill was approximately 600 mm thick in the borehole.

An N-value of 29 was obtained from the single SPT in the granular fill material.

The result of the moisture content test conducted on the sample of the granular fill was approximately 5%.

4.5 FILL

A layer of fill material consisting of sandy silty clay was encountered underlying the granular fill in Borehole S3C3-5. The samples of the fill typically contained some gravel. The fill extended to approximately 3.0 m below grade in the borehole.

N-values ranging from 6 to 9 blow counts were obtained from the SPTs within the fill material.

Based on visual and textural examination, the fill was assessed as damp to moist. The results of the moisture content tests conducted on samples of the fill ranged from approximately 11% to 23%.

A Gradation test was completed on a sample of the fill. The test results are summarized in Table 4-1 below.

Table 4-1 Grain Size Distribution – Fill – Sandy Clay

Borehole	Sample	Depth (m)	Description	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
S3C3-5	SS3	1.8	Sandy clay Fill	14	22	38	26

The grain size distribution curves for the tests are shown on Figure 1 in **Appendix D**.

An Atterberg Limits test was also conducted on a portion of the sample referenced above. The results of the test are shown in Table 4-2 below.

Table 4-2 Atterberg Limits Test Results – Fill – Sandy Clay

Borehole	Sample	Depth (m)	Description	Liquid Limit	Plastic Limit	Plasticity Index
S3C3-5	SS3	1.8	Sandy clay Fill	28	16	12

The results of the Atterberg Limits tests are shown on Figure 2 in **Appendix D**.



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In accordance with the Unified Soil Classification System, the sample tested can be classified as Sandy Clay (CL).

4.6 CLAY WITH SAND TILL SOIL

A stratum of brown and grey clay with sand till soil was encountered underlying the topsoil or fill materials in all boreholes. This stratum is referred to as till based on the broad range in grain size present in the majority of the samples. The samples typically contained trace gravel. The occasional presence of cobbles and possible boulders was inferred within the clay with sand till in Borehole S3C3-1 based on auger grinding observed during drilling.

The stratum of clay with sand soil was approximately 4.3 m, 2.4 m, 5.9 m, 4.5 m and 6.1 m thick and extended to depths of approximately 4.6 m, 2.6 m, 6.1 m, 4.6 m and 9.1 m below grade in boreholes S3C3-1 through S3C3-5 respectively. The bottom elevation of the clay till ranged from 200.2 m to 204.6 m.

The consistency of the clay with sand till soil was assessed as firm to hard, based on the results of the SPT tests (N-values ranged from 9 to above 100 blows).

The moisture content of the samples tested ranged from approximately 11% to 23%.

Gradation tests were completed on six samples of the soil. The test results are summarized in Table 4-3 below.

Table 4-3 Grain Size Distribution – Clay with Sand Till Soil

Borehole	Sample	Depth (m)	Description	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
S3C3-1	SS4	2.6	CLAY (CL) with sand, TILL	5	21	44	30
S3C3-2	SS3	1.8	CLAY (CL) with sand, TILL	4	25	44	27
S3C3-3	SS2	1.1	CLAY (CL) with sand, TILL	1	17	49	33
S3C3-3	SS5	3.4	CLAY (CL) with sand, TILL	3	25	40	32
S3C3-4	SS3	1.8	CLAY (CL) with sand, TILL	2	17	45	36
S3C3-5	SS7	4.9	CLAY (CL) with sand, TILL	1	23	42	34

The grain size distribution curves for the tests are shown on Figures 3 and 4 in **Appendix D**.

The grain size distribution tests indicated that the gravel particles were limited to a maximum size less than 19 mm. It is noted however, that the internal (I.D.) diameter of the SPT sampler is 38 mm and hence the results may not reflect the entire gravel size fraction which extends to 75 mm diameter. The presence of cobbles (particles from 75 mm to 300 mm) and boulders (particles >300mm) are described separately from the gravel content.

Atterberg Limits tests were also conducted on portions of the samples referenced above. The results of the tests are shown in Table 4-4 below.



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Table 4-4 Atterberg Limits Test Results –Clay with Sand Till Soil

Borehole	Sample	Depth (m)	Description	Liquid Limit	Plastic Limit	Plasticity Index
S3C3-1	SS4	2.6	CLAY (CL) with sand, TILL	31	18	13
S3C3-2	SS3	1.8	CLAY (CL) with sand, TILL	28	19	9
S3C3-3	SS2	1.1	CLAY (CL) with sand, TILL	33	20	13
S3C3-3	SS5	3.4	CLAY (CL) with sand, TILL	29	18	11
S3C3-4	SS3	1.8	CLAY (CL) with sand, TILL	28	17	11
S3C3-5	SS7	4.9	CLAY (CL) with sand, TILL	30	17	13

The results of the Atterberg Limits tests are shown on Figure 5 in **Appendix D**.

In accordance with the Unified Soil Classification System, the samples tested can be classified as Clay with Sand (CL).

4.7 SANDY CLAY, SANDY SILTY CLAY AND SANDY SILTY CLAY WITH GRAVEL TILL SOIL

Strata of grey and reddish brown sandy clay, sandy silty clay and sandy silty clay with gravel till soils were encountered underlying the clay with sand soil in the boreholes. These strata are referred to as till soils based on the broad range in grain size present in the majority of the samples. These soils typically contained trace to some gravel.

The sandy silty clay was encountered in borehole S3C3-1 over a depth interval of 4.6 m to 12.7 m (thickness of 8 m), in borehole S3C3-2 over a depth interval of 2.6 m to 8.4 m (thickness of 5.8 m) [including a zone of sandy silty clay with gravel], and in borehole S3C3-4 over a depth interval of 9.9 m to 17.3 m (thickness of 7.4 m).

The sandy clay was encountered in borehole S3C3-2 over a depth interval of 10.4 m to 13.6 m (thickness of 3.2 m), in borehole S3C3-3 over a depth interval of 6.1 m to 9.2 m (thickness of 3.1 m), in borehole S3C3-4 over a depth interval of 4.6 m to 9.9 m (thickness of 5.3 m), and in borehole S3C3-5 over a depth interval of 9.1 m to 10.7 m (thickness of 1.6 m).

The consistency of the sandy clay to sandy silt clay (and sandy silty clay with gravel) soils was assessed as soft to hard, based on the results of the SPT tests conducted (N-values ranged from 3 to 134 blows).

The upper zone of the sandy clay to sandy silt clay soils typically varied from soft to stiff.

The lower portion of the sandy clay to sandy silty clay till soil encountered in Boreholes S3C3-1, S3C3-2 and S3C3-4 (reddish brown color) exhibited a hard consistency (i.e. virtual refusal of SPTs). Based on these conditions, these materials in the lower zone of the strata could be characterized as completely weathered shale and hence be part of the underlying Queenston Formation described below in Section 4.9. However, based specifically on the grain size distribution, coarse particle shape, and lack of rock



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structure, and for purposes of engineering design and construction, these materials were classified as till soils. The reddish brown and hard zone of the till soils was approximately 3.2 m, 5.9 m and 4.3 m thick and extended to depths of 12.6 m, 8.4 m and 13.1 m in the respective three boreholes.

The moisture content of the samples tested ranged from approximately 7% to 13%.

Gradation tests were completed on eleven samples of the soils. The test results are summarized in Table 4-5 below.

Table 4-5 Grain Size Distribution – Sandy Clay to Sandy Silty Clay Till Soil

Borehole	Sample	Depth (m)	Description	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
S3C3-1	SS8	5.6	Sandy silty CLAY (CL-ML), TILL	9	28	42	21
S3C3-1	SS11	7.9	Sandy silty CLAY (CL-ML), TILL	8	40	34	18
S3C3-1	SS12	8.7	Sandy silty CLAY (CL-ML), TILL	6	30	46	18
S3C3-2	SS5	3.4	Sandy silty CLAY (CL-ML) with gravel, TILL	2	32	42	24
S3C3-2	SS9	6.4	Sandy silty CLAY (CL-ML), TILL	7	32	39	22
S3C3-3	SS10	7.2	Sandy CLAY (CL), TILL	2	31	35	32
S3C3-4	SS7	4.9	Sandy CLAY (CL), TILL	12	25	38	25
S3C3-4	SS11	7.9	Sandy CLAY (CL), TILL	3	30	41	26
S3C3-4	SS22	16.1	Sandy silty CLAY (CL-ML), TILL	4	32	43	21
S3C3-5	SS13	9.4	Sandy CLAY (CL), TILL	3	28	39	30
S3C3-5	SS15	11.0	Sandy silty CLAY (CL-ML), TILL	8	42	39	11

The grain size distribution curves for the tests are shown on Figures 6 to 8 in **Appendix D**.

The grain size distribution tests indicated that the maximum size of the majority of the gravel particles was in the range of 9.5 mm to 12.5 mm, although there were several particles in the range of 12.5 mm to 19 mm. It is noted however, that the internal (I.D.) diameter of the SPT sampler is 38 mm and hence the results may not reflect the entire gravel size fraction which extends to 75 mm diameter. The presence of cobbles (particles from 75 mm to 300 mm) and boulders (particles >300mm) are described separately from the gravel content.

Atterberg Limits tests were also conducted on portions of the samples referenced above. The results of the tests are shown in Table 4-6 below.

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Table 4-6 Atterberg Limits Test Results - Sandy Clay to Sandy Silty Clay Till Soil

Borehole	Sample	Depth (m)	Description	Liquid Limit	Plastic Limit	Plasticity Index
S3C3-1	SS8	5.6	Sandy silty CLAY (CL-ML), TILL	23	16	7
S3C3-1	SS11	7.9	Sandy silty CLAY (CL-ML), TILL	22	15	7
S3C3-1	SS12	8.7	Sandy silty CLAY (CL-ML), TILL	19	13	6
S3C3-2	SS5	3.4	Sandy silty CLAY (CL-ML) with gravel, TILL	19	15	4
S3C3-2	SS9	6.4	Sandy silty CLAY (CL-ML), TILL	23	16	7
S3C3-3	SS10	7.2	Sandy CLAY (CL), TILL	25	17	8
S3C3-4	SS7	4.9	Sandy CLAY (CL), TILL	26	16	10
S3C3-4	SS11	7.9	Sandy CLAY (CL), TILL	24	15	9
S3C3-4	SS22	16.1	Sandy silty CLAY (CL-ML), TILL	21	15	6
S3C3-5	SS13	9.4	Sandy CLAY (CL), TILL	26	15	11
S3C3-5	SS15	11.0	Sandy silty CLAY (CL-ML), TILL	16	12	4

The results of the Atterberg Limits tests are shown on Figures 9 and 10 in **Appendix D**.

In accordance with the Unified Soil Classification System, the samples tested can be classified as Sandy Clay (CL), Sandy Silty Clay (CL-ML) and Sandy Silty Clay with Gravel (CL-ML).

4.8 SILTY SAND, SILTY CLAYEY SAND AND SILTY CLAYEY SAND WITH GRAVEL TILL SOIL

Strata of grey silty sand and reddish brown silty clayey sand and silty clayey sand with gravel till soils were encountered underlying the sandy silty clay till soil in Boreholes S3C3-3 and S3C3-5 and interbedded with the sandy silty clay and sandy clay in borehole S3C3-2. This deposit is referred to as till based on the broad range in grain size present in the majority of the samples. The silty sand and silty clayey sand till soil typically contained trace to some gravel and trace to some clay. The occasional presence of cobbles and possible boulders was inferred within this till soil based on auger grinding observed during drilling.

The silty sand and silty clayey sand soils were encountered over a depth interval of 9.1 m to 14.2 m in borehole S3C3-3 (thickness of 5.1 m) and over a depth interval of 12.9 m to 14.2 m in borehole S3C3-5 (thickness of 1.3 m). The silty clay sand soil was also encountered underlying the sandy silty clay and overlying the sandy clay in borehole S3C3-2 at a depth interval of 8.4 m to 10.4 m (thickness of 2 m).

The compactness condition of the till soils was assessed as compact to very dense based on the results of the SPT tests conducted (N-values ranged from 66 blows to virtual refusal).

The shallower portion of these soils (borehole S3C3-2) was typically compact to dense.

Similar to the comments provided in the previous section, the lower zone of the silty sand and silty clayey sand till soils in boreholes S3C3-3 and S3C3-5 (reddish brown color) were very dense (i.e. virtual refusal



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of SPTs). The materials in this zone could be characterized as completely weathered shale and part of the underlying Queenston Formation described below in Section 4.9. However, based specifically on grain size distribution, coarse particle shape, lack of observed rock structure in the samples, and for purposes of engineering design and construction, these materials were described as till soils.

The moisture content of the samples tested ranged from approximately 6% to 12%.

Grain size distribution tests were completed on three samples of the soil. The results of the tests are shown in Table 4-7 below.

Table 4-7 Grain Size Distribution – Silty Sand, Silty Clayey Sand and Silty Clayey Sand with Gravel Till Soil

Borehole	Sample	Depth (m)	Description	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
S3C3-3	SS13	9.4	Silty SAND (SM), TILL	4	54	34	8
S3C3-3	SS19	13.8	Silty clayey SAND (SC-SM), TILL	13	49	30	8
S3C3-5	SS18	13.2	Silty clayey SAND (SC-SM) with gravel, TILL	22	35	33	10

The grain size distribution curves are shown on Figure 11 in **Appendix D**.

The grain size distribution tests indicated that the maximum size of the gravel particles was in the range of 19 mm to 25 mm. It is noted however, that the internal (I.D.) diameter of the SPT sampler is 38 mm and hence the results may not reflect the entire gravel size fraction which extends to 75 mm diameter. The presence of cobbles (particles from 75 mm to 300 mm) and boulders (particles >300mm) are described separately from the gravel content.

Atterberg Limits tests were attempted on all three samples referenced above. The results of the tests are shown in Table 4-8 below.

Table 4-8 Atterberg Limits - Silty Clayey Sand and Silty Clayey Sand with Gravel Till Soil

Borehole	Sample	Depth (m)	Description	Liquid Limit	Plastic Limit	Plasticity Index
S3C3-3	SS19	13.8	Silty clayey SAND (SC-SM), TILL	19	14	5
S3C3-5	SS18	13.2	Silty clayey SAND (SC-SM) with gravel, TILL	16	12	4

The test on Sample SS13 from Borehole S3C3-3 indicated this sample was non-plastic. The results of the remaining two Atterberg Limits tests are shown on Figure 12 in **Appendix D**.

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In accordance with the Unified Soil Classification System, the samples tested can be classified as Silty Sand (SM), Silty Clayey Sand (Sc-SM) and Silty Clayey Sand with Gravel (SC-SM).

4.9 BEDROCK

4.9.1 Bedrock Frame of Reference

There is typically a zone of weathering at the contact between the bedrock of the Queenston Formation and the overlying overburden. The Ontario Ministry of Transportation and Communication Document RR229, Evaluation of Shale for Construction Projects, includes a typical weathering profile of low durability shale, reproduced from Skempton, Davis, and Chandler. The profile differentiates the shale into three grades of weathering and four zones as described below in Table 4-10.

Table 4-9 Typical Weathering Profile of Low Durability Shale

	Zone	Description	Notes
Fully Weathered	IVb	soil like matrix only	indistinguishable from glacial drift deposits, slightly clayey, may be fissured
Partially Weathered	Iva	soil like matrix with occasional pellets of shale less than 3 mm diameter	little or no trace of rock structure, although matrix may contain relic fissures
	III	soil like matrix with frequent angular shale particles up to 25 mm diameter	moisture content of matrix greater than the shale particles
	II	angular blocks of unweathered shale with virtually no matrix separated by weaker chemically weathered but intact shale	spheroidal chemical weathering of shale pieces emanating from relic joints and fissures, and bedding planes
Unweathered	I	Shale	regular fissuring

A summary of the physical properties of the Queenston Formation bedrock was provided in the Ontario Ministry of Transportation and Communication publication RR229 – Evaluation of Shales for Construction Projects - An Ontario Shale Rating System, dated March 1983. Extracts of the physical properties are presented below in Table 4-11 for reference.

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Table 4-10 Typical Physical Properties for the Queenston Formation

	Unconfined Compressive Strength	Young's Modulus	Poisson's Ratio
	(MPa)	(GPa)	
Average	8.7	0.90	0.32
Range	7.2 to 9.6	0.7 to 1.0	0.28 to 0.35

4.9.2 Inferred Bedrock

Bedrock (and inferred bedrock) was encountered in all boreholes. The boreholes were augered and sampled to depths of approximately 15.5 m, 14.3 m, 15.0 m, 18.7 m and 16.1 m respectively.

The lower portion of the stratigraphy augered in the boreholes was inferred to consist of highly to completely weathered shale bedrock (Queenston Formation) based on the limited penetration (virtual refusal) of the SPTs, a review of the limited samples obtained from the SPTs, and consideration of the conditions encountered underlying this zone. The depths and geodetic elevations of the inferred highly to completely weathered shale bedrock are shown in Table 4-9.

Table 4-11 Inferred Highly to Completely Weathered Shale Bedrock

Borehole	S3C3-1	S3C3-2	S3C3-3	S3C3-4	S3C3-5
Depth (m)	12.6 - 15.5	13.5 - 14.3	14.2 - 15.0	17.3 - 18.7	14.2 - 16.1
Geodetic Elevation (m)	194.5 - 191.6	193.7 - 192.9	193.0 - 192.1	190.2 - 188.8	195.1 - 193.2
Thickness (m)	2.9	0.8	0.9	1.4	2.1

Consistent with the frame of reference provided in the preceding section, the inferred bedrock would be considered representative of Zone IVb exhibiting a soil like matrix practically indistinguishable from the overlying glacial drift deposits.

4.9.3 Bedrock Field Coring and Laboratory Testing

Coring of the bedrock was conducted in all the boreholes. The bedrock cored consisted of shale with limestone interbedding. Based on the reddish-brown colour of the rock core, it was interpreted that the bedrock was from the Queenston Formation.

The bedrock formation encountered, depths of the coring and corresponding elevations, and total core recovery (TCR), solid core recovery (SCR) and rock quality designation (RQD) are shown in Table 4-12 below. The RQD refers to the total length of pieces of sound core which are 100 mm or greater in length in a core run, expressed as a percentage of the total length of that core run. Sound pieces of rock are those pieces separated by natural fractures or bedding, and not machine induced or artificial breaks.

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Table 4-12 Summary of Bedrock Coring Operations

Borehole No.	Rock	Depth (mbgs)	Geodetic Elevation (m)	TCR (%)	SCR (%)	RQD (%)
S3C3-1	Reddish brown to greyish green shale with grey limestone interbedding (Queenston Formation), moderately weathered to un-weathered	15.5 - 35.3	191.6 - 171.8	95 to 100	84 to 100	65 to 100
S3C3-2	Reddish brown to greyish green shale with grey limestone interbedding (Queenston Formation), moderately to slightly weathered	14.3 - 30.7	192.9 - 176.5	95 to 100	65 to 100	55 to 100
S3C3-3	Reddish brown to greyish green shale with grey limestone interbedding (Queenston Formation), moderately to slightly weathered	15.0 - 30.7	192.1 - 176.7	100	87 to 100	80 to 97
S3C3-4	Reddish brown to greyish green shale with grey limestone interbedding (Queenston Formation), moderately weathered to un-weathered	18.7 - 35.1	188.8 - 172.4	94 to 100	62 to 99	53 to 99
S3C3-5	Reddish brown to greyish green shale with grey limestone interbedding (Queenston Formation), moderately to slightly weathered	16.1 - 31.0	193.2 - 178.3	75 to 100	77 to 100	33 to 100

The description of the core obtained from the boreholes is shown in the table above. The bedding planes were typically oriented at less than 20° from the horizontal.

The RQD of the rock core recovered in Borehole S3C3-1 varied between 65% and 100%. Based on the RQD range indicated, the rock obtained from Borehole S3C3-1 is classified as fair to excellent in quality. The majority of the rock core in this borehole was characterized as moderately weathered to un-weathered.

The RQD of the rock core recovered in Borehole S3C3-2 varied between 55% and 100%. Based on the RQD range indicated, the rock obtained from Borehole S3C3-1 is classified as fair to excellent in quality. The majority of the rock core in this borehole was characterized as moderately to slightly weathered.

The RQD of the rock core recovered in Borehole S3C3-3 varied between 80% and 97%. Based on the RQD range indicated, the rock obtained from Borehole S3C3-1 is classified as good to excellent in quality. The majority of the rock core in this borehole was characterized as moderately to slightly weathered.



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The RQD of the rock core recovered in S3C3-4 varied between 53% and 99%. Based on the RQD range indicated, the rock obtained from Borehole S3C3-4 is classified as fair to excellent in quality. The majority of the rock core in this borehole was characterized as moderately weathered to un-weathered.

The RQD of the rock core recovered in Borehole S3C3-5 varied between 33% and 100%. Based on the RQD range indicated, the rock obtained from Borehole S3C3-5 is classified as poor to excellent in quality. The majority of the rock core in this borehole was characterized as moderately to slightly weathered.

Forty seven (47) samples of the rock core obtained from the boreholes were selected for testing to determine the Unconfined Compressive Strength (UCS) and unit weight. The bulk of the shale rock obtained from the core runs was not suitable for testing. As a result, the samples tested were typically comprised of limestone. The results of the tests are shown in Table 4-13 below.

Table 4-13 Results of Unconfined Compressive Strength and Unit Weight Tests on Samples of Rock Core

Borehole No.	Formation	Majority Rock Type	Median Depth (mbgs)	Median Geodetic Elevation (m)	Unit Weight (kg/m ³)	UCS (MPa)
S3C3-1	Queenston Formation	Reddish Brown and Greyish Green Shale with Grey Limestone Interbedding, moderately weathered to un-weathered	15.7	191.4	2553	21.7
			18.0	189.1	2576	41.0
			23.4	183.7	2510	20.0
			25.0	182.1	2513	8.5
			27.2	179.9	2588	51.0
			28.1	179	2497	39.3
			29.2	177.9	2564	13.4
			31.4	175.7	2564	38.1
			33	174.1	2592	34.5
S3C3-2	Queenston Formation	Reddish Brown and Greyish Green Shale with Grey Limestone Interbedding, moderately weathered to un-weathered	15.4	191.8	2586	37.7
			17.1	190.1	2593	36.1
			17.6	189.6	2616	32.6
			19.0	188.2	2614	42.8
			20.6	186.6	2600	32.0
			24.0	183.2	2617	26.2
			26.0	181.2	2621	33.4
			28.3	178.9	2613	43.2
			29.3	177.9	2619	36.2
			29.8	177.4	2617	37.6

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Borehole No.	Formation	Majority Rock Type	Median Depth (mbgs)	Median Geodetic Elevation (m)	Unit Weight (kg/m ³)	USC (MPa)
S3C3-3	Queenston Formation	Reddish Brown and Greyish Green Shale with Grey Limestone Interbedding, moderately weathered to un-weathered	15.5	191.7	2593	33.7
			17.3	189.9	2608	27.1
			19.5	187.7	NR	
			21.1	186.1	2611	44.7
			22.8	184.4	2602	35.5
			23.6	183.6	NR	
			25.3	181.9	2593	27.1
			26.4	181.9	2614	33.1
			28.5	178.7	NR	
			29.8	177.4	NR	
S3C3-4	Queenston Formation	Reddish Brown and Greyish Green Shale with Grey Limestone Interbedding, moderately weathered to un-weathered	19.4	188.0	2485	3.8
			21.1	186.3	2595	21.3
			24.2	183.2	2572	23.5
			25.0	182.4	2565	22.4
			30.0	177.4	2603	47.0
			32.7	174.7	2593	41.8
			34.0	173.4	2588	48.6
			34.7	172.7	2550	34.6
S3C3-5	Queenston Formation	Reddish Brown and Greyish Green Shale with Grey Limestone Interbedding, moderately weathered to un-weathered	16.5	192.7	NR	
			17.6	191.7	2590	54.1
			18.8	190.5	NR	
			20.2	189.1	NR	
			22.8	186.5	2604	55.1
			24.7	184.6	2623	39.0
			26.0	183.3	2607	44.8
			27.7	181.6	2583	42.9
			29.6	179.7	2600	25.8
			30.9	174.7	2617	34.8

Notes:

NR No Result: The sample fractured during preparation and was not suitable for testing.

As a result, the unconfined compressive strength test results reported should not be considered generally representative of the "mass" of the bedrock. The literature reference discussed in the preceding section provides an indication of the general range in the strength of the shale bedrock, representing the predominant rock type in the Queenston Formation.



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4.10 GROUNDWATER

Water was used for the rock coring procedure and as a result, observations of the presence of free groundwater in the open boreholes could not be obtained on completion of drilling.

The static groundwater level was recorded in monitoring well MW S3C3-4 at depths of approximately 1.0 m and 0.8 m below existing grade on October 7, 2013 and February 25, 2014, respectively.

The monitoring well was screened across a depth of 13.7 m to 15.2 m in the underlying sandy silty clay till soils. The groundwater level measured indicates the presence of a hydrostatic head in the sandy silty clay till soils. The hydrostatic head is above the contact surface with the overlying clay with sand till soils, but is not above the ground surface level (i.e. flowing artesian conditions were not recorded).

The rising head permeability test conducted in S3C3-4 yielded a hydraulic conductivity of 7.0×10^{-8} m/s (7.0×10^{-6} cm/s) for the sandy silty clay till soil present over the screened interval.

The details of the installation for the groundwater monitoring well, and the respective static groundwater level measured, are shown on the Borehole Record included in **Appendix C**.

5.0 Miscellaneous

The field work was carried out under the supervision of Mr. Mazin Jarjis, C.E.T. and Mr. Robert Stroebel, C.E.T., under the direction of Maged Abdel-Mesih, P.Eng., Geotechnical Engineer.

The drill rigs were supplied and operated by Terex Drilling Solutions of Goodwood, Ontario and Geo-Environmental Drilling Ltd., of Milton, Ontario.

Geotechnical laboratory testing was carried out at the Stantec geotechnical and construction materials testing facility in Markham.

This geotechnical component of the report was prepared by Mr. Khashayar Refahi, P.Eng.. The hydrogeological analysis for the report was completed by Ms. Hagit Blumenthal, M.A.Sc.

The report was reviewed by Mr. J. Brant Gill, H.B.Sc., P.Geo., Mr. John J. Brisbois, M.Sc.Eng., P. Eng., and by Mr. Raymond Haché, M.Sc., P.Eng., MTO Designated Principal Contact.



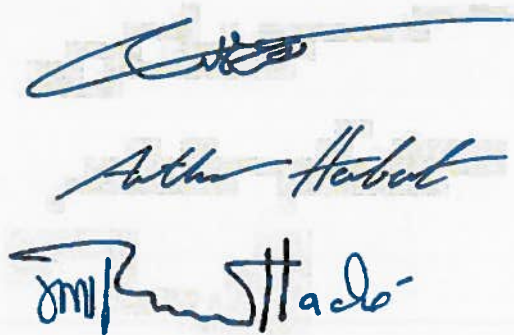
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Closure
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6.0 Closure

A subsurface investigation is a limited sampling of a site. The subsurface conditions described herein are based on information obtained at specific borehole locations. Conditions between and beyond the borehole locations must be expected to vary beyond that described herein.

Should any conditions be encountered at the site, which differ from those at the borehole locations as described herein, we request that we be notified immediately in order to assess the additional information and revise the content and recommendations in this report, as required.



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FOUNDATION DESIGN REPORT

FOR

Spread 3 – Crossing 3 (S3C3)
Highway 401
Mississauga, ON

7.0 Discussion

7.1 PROJECT DESCRIPTION & BACKGROUND

7.1.1 Overall Project

The planned pipeline consists of a total of 50.7 km and is comprised of four sections, referred to as Spreads. The 4 spreads are described as follows.

Spread 1 consists of approximately 7.6 kilometers of NPS 36 (36 inch/ 914.4 millimeter outside diameter) steel pipe. The preferred pipeline route (PPR) for Spread 1 begins at Sheppard Avenue (between Pharmacy Road and Warden Avenue) and follows the Buttonville Corridor (a designated utility corridor), terminating at the Buttonville Meter Station located south of Highway 407 between Rodick Road and Warden Avenue.

Spread 2 consists of approximately 15.7 kilometers of NPS 36 (36 inch/914.4 millimeter outside diameter) steel pipe. The PPR for Spread 2 begins at the Buttonville Meter Station (see above) and follows the northern link of the Parkway Belt utility corridor, terminating at the existing Enbridge Keele/CNR Gate Station located west of Keele Street, north of Steeles Avenue and south of Highway 407.

Spread 3 consists of approximately 27.4 kilometers of NPS 42 (42 inch/ 1067 millimeter outside diameter) steel pipe. The PPR for Spread 3 begins at the proposed Albion Station to be located west of Highway 427 and south of Steeles Avenue, and follows the northern link of the Parkway Belt utility corridor, extending west to the proposed Parkway West Station to be located west of Highway 407 and south of Derry Road

Spread 4 consists of approximately 430 m of NPS 36 (36 inch/914.4 millimeter outside diameter) steel pipe. The PPR for Spread 4 begins at the proposed Parkway West Gate Station to be located east of Eighth Line and west of Highway 407; the PPR will extend east to the proposed Parkway Cons Bypass Regulator Station to be located west of Highway 407 and south of Derry Road East.

7.1.2 Highway 401 Crossing (S3C3)

7.1.2.1 Alignment

This investigation report is focused on the required crossing of Highway 401, referred to as crossing S3C3.



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Horizontal Directional Drilling (HDD) is the proposed method of construction for the pipeline at this crossing.

The Crossing Plan and Profile drawing used in the preparation of this geotechnical report illustrated the preliminary horizontal and vertical alignments of the PPR at the crossing location. The Plan and Profile drawing was titled "KP 4+598.5, NPS 42 GTA Project, Parkway West to Albion Road, Highway 401 – HDD Crossing Method", labelled "Issued For Construction" and dated July 18, 2014. The drawing indicated that the installation will consist of a NPS 42 (42 inch/1067 millimeter outside diameter) steel pipe with a wall thickness of 25.4 mm. The pipe is specified as CSA Z245.1, GR. 483, CAT II, M5C.

For reference, Design Basis Memorandum (DBM), Document No. 110901255.027, Revision 0, dated February 13, 2104, indicates the normal depth of cover for the pipeline at road crossings is intended to be approximately 1.5 m to 2.5 m below the ditch, a minimum of 0.6 m below the deepest utility crossing, and at least 1 m below the sewer line, and would be subject to municipal requirements.

It is understood that the HDD design will incorporate a minimum vertical clearance of 5 m between existing utilities/services and the HDD PPR to mitigate against the adverse effects of settlement, heave, or inadvertent return of drilling fluids potentially resulting from the HDD construction operations. In cases where the services/utilities are considered unusually sensitive to disturbance, additional separation clearance will be considered in the design.

The horizontal separation clearance between any existing utilities/services and the PPR is dictated to a large extent by constraints associated with establishing the overall alignment. It is anticipated that the majority of concerns with respect to the horizontal separation clearance and the PPR will be near the endpoints of the PPR, where the HDD is shallow and existing utilities/services installed by conventional cut and cover methods may be at a similar elevation. To protect existing utilities/services in such areas from damage as a result of HDD operations, it is recommended that the existing utilities/services be located and marked in the field prior to commencement of construction. It is understood that the design drawings reference this requirement. Exposure of said utilities/services to provide visual confirmation of location can also be considered to confirm that adequate separation is maintained.

Based on the Plan and Profile referenced above the key dimensions and elevations of the proposed drill/bore path pipeline installation with the use of Horizontal Directional Drilling (HDD) method are as follows:

• Horizontal Drill Length	378 m
• True Length	379 m
• Arc Radius	1280 m
• Ground Surface Elevation – Entry Point (north side of Highway 401)	207.4 m
• Ground Surface Elevation – Exit Point (south side of Highway 401)	207.5 m
• Ground Surface Elevation – Top of Asphalt Highway 401	208.5 m (lowest level)
• Median Pipe - Lowest Elevation (beneath Highway 401)	193.5 m
• Minimum Depth of Top of Pipe below Asphalt (Highway 401)	14.0 m (south edge)



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The drawing indicates that the entry pit is located approximately 145 m beyond the toe of the embankment on the north side of the highway and the exit pit is located 165 m beyond the toe of the embankment on the south side of the highway.

Based on the depths and elevations referenced above the top of pipe will be approximately 14 m to 15 m below the travel surface of the Highway, approximately 12 m below the ditch on the south side of the Highway, approximately 14 m below the median. These depths meet the requirements of the DBM document referenced above.

The PPR alignment is approximately 11.8 m below the deepest utility (i.e. the 600 mm Sewer). This depth/vertical separation with the HDD alignment meets the requirements of the DBM Document as referenced above and the HDD designer's considerations as referenced above.

A spread sheet including coordinates and elevations of the existing vital main, titled "Pipeline Tally, Enbridge Gas distribution, NPS36 GEMINI Anomaly Inspection", prepared by Baker Hughes, dated June 10, 2013 was provided to Stantec for information. Within the length of the proposed HDD installation, the existing vital main (located approximately 4.3 m west of the PPR) is at the following elevations:

- Proposed Entry Point Elevation 204.2 m
- Proposed Exit Point Elevation 204.5 m
- Beneath Highway 401 Elevation 203.1 m (lowest point)

A comparison of the elevations referenced above with the proposed HDD alignment indicates that the lowest point of the HDD alignment (beneath Highway 401) is approximately 9.6 m below the existing vital main. However, within approximately 20 m of the endpoints (entry and exit points) of the HDD alignment, the HDD drill path and the existing vital main are at a similar elevation (i.e. in the order of 204 m). In this respect, the comments provided above with respect to identifying, marking, and confirming the existing utilities/services in proximity to the endpoints of the HDD alignment would apply in all respects.

With reference to the Guidelines For Foundation Engineering issued by the MTO, and considering a tunnel diameter $> 1 \text{ m}$ & $\leq 2 \text{ m}$, the **Complexity Rating for Tunneling Specialty Services (Table 1 in the Guidelines)** for this crossing is High.

7.1.2.2 Design Guidelines & References

The report titled "HDD Design Report, Revision 2, Enbridge GTA Project, dated June 27, 2014 prepared by J.D. Hair and Associates, Inc. (J.D. Hair) was provided by Enbridge to Stantec for information.

The HDD design is based on the subsurface conditions encountered in the PFE Phase of this geotechnical investigation supplemented by the conditions encountered in the DE Phase of this geotechnical investigation.



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It is understood that the HDD design considers the following guidelines:

- Appendix A of the US Army Corps of Engineers (USACE) publication titled "Recommended Guidelines for Installation of Pipelines beneath Levees using Horizontal Directional Drilling"
- "Installation of Pipelines by Horizontal Directional Drilling", An Engineering Design Guide (Arlington, VA: Pipeline Research Council International, Inc., 2008), 26-36.

The following guideline is also recommended by J.D. Hair for the protection of underground facilities.

- "Guidelines for Preventing Underground Facility Damage as a Result of Horizontal Directional Drilling", prepared by J.D. Hair, authored by Jeff Puckett, May 2011.

7.1.2.3 Conceptual Construction Schedule Overview

The HDD design report referenced above estimated the HDD construction duration for the proposed crossing of Highway 401 based on a 12 hours shift per day as follows:

- | | |
|--|-----------|
| • Pilot Hole Duration | 3.8 days |
| • Pre-reaming and Pullback | 12 days |
| • Total Duration (without margin for risk) | 15.9 days |

7.2 SOIL SUMMARY AND STRATIGRAPHIC MODEL

Table H-1 in **Appendix H** includes values for geotechnical parameters, specific to the subsurface stratigraphy encountered in each and every borehole. The information included in the table is intended for use by the HDD designers in the analysis and design of the HDD and the assessment of the potential for hydrofracture to occur.

The geotechnical parameters were developed using empirical methods, based on a number of literature references and standards that specifically included the Canadian Foundation Engineering Manual (4th Edition, 2006) and Foundation Analysis and Design (Bowles et al, 5th Edition, 1997). For general consideration, the friction angles are inferred to be below "peak" values and the Young's Modulus values are considered to be representative of un-drained or "short term" conditions. The strength values for the bedrock were developed based on the Hoek-Brown Failure Criterion for Tunneling Applications.

The design should also consider the static groundwater level which was recorded at a minimum depth of 0.8 m below the existing grade, corresponding to Elevation 206.7 m, in S3C3-4. The monitoring well was screened in the sandy silty clay till soil overlain by the sandy clay and clay with sand till soils. The conditions described indicate the presence of a hydrostatic head in the underlying sandy silty clay till soils.

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7.3 SEISMIC DESIGN CONSIDERATIONS

7.3.1 Seismic Site Class

The following is provided for general reference if and as required in the design process.

The seismic site class determination is based on the soil conditions in the upper 30 m of the stratigraphy. For the purposes of this report, the weighted average N-value method and Su method for cohesive soils have been used to assess the Seismic Site Classification for this project location, consistent with the second and third methods stated in the National Building Code (2010).

The boreholes for the current investigation were advanced to a maximum depth of 35.3 m below existing grade. The maximum depth provided the data to the 30 m depth necessary for interpretation of the Seismic Site Classification as referenced above.

The following stratigraphic profile and respective N_{60} values (Borehole S3C3-5) were considered for purposes of assessing the Seismic Site Classification:

Table 7-1 Parameters for Seismic Site Classification

Depth	Soil	N_{60} Value	Su (kPa)
0 to 0.8	Sand and gravel, Fill	29	N/A
0.8 m to 3 m	Sandy silty clay, Fill	7	25
3.0 m to 10.7 m	Firm to Hard Clay with Sand and Sandy Clay, Till	10	50
10.7 m to 13.1 m	Very Stiff to Hard Sandy Silty Clay, Till	42	150
13.1 m to 14.2 m	Very Dense Silty Clayey Sand with Gravel, Till	100	N/A
14.2 m to 30 m	Shale Bedrock	100	N/A
Average		21	48

Based on the profile described above, a weighted average N_{60} value of 21 for the upper 30 m of the stratigraphy and a weighted average Su value of 48 for the cohesive soils in the upper 30 m of the stratigraphy were calculated. Therefore, in accordance with Table 4.1.8.4.A of the National Building Code (2010), Seismic Site Class 'D' can be used for design.

7.3.1 NBC Seismic Hazard Calculation Data Sheet

A copy of the NBC Seismic Hazard Calculation Data sheet is provided in **Appendix G** for reference.

For reference, Table A3.1.1 of the Canadian Highway Bridge Design code (CHBDC) indicates that the Zonal Acceleration Ratio for the Municipality of Mississauga is 0.05.

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7.3.2 Liquefaction Potential

Liquefaction of soils is not considered a concern for this project as the soils encountered in the boreholes were characterized as either hard or dense to very dense and there is a very low Zonal Acceleration Ratio applicable for the area.

8.0 Trenchless Technology Installation

8.1 HORIZONTAL DIRECTIONAL DRILLING

Horizontal Directional Drilling (HDD) is the proposed method of construction for the pipeline at this crossing.

It is understood that development of a contingency approach for the planned installation at this crossing is in progress at the time of preparation of this report.

8.1.1 Horizontal Directional Drilling (HDD) Technique

The HDD process as presented in the literature reference Guidelines for Preventing Underground Facility Damage as a Result of Horizontal Direction Drilling, developed by J.D. Hair and Associates, dated March 2012 is comprised of a three stage process; pilot hole, pre-reaming, and pullback as described below. For additional reference, a section describing the use of drilling mud is provided.

8.1.2 Pilot Hole

The pilot hole begins when the bit enters the ground at the entry point located directly in front of the rig. As the bit is advanced away from the rig, individual joints of drill pipe are added behind it in succession creating a continuous string of drill pipe in the hole.

In soft soils, progress is typically achieved using a high-velocity stream of drilling fluid to erode the soil ahead of the bit. This is referred to as jetting. In harder soils and rock, mechanical cutting action is required. This is provided by a hydraulically driven mud motor which allows for continuous rotation of the bit.

As the pilot hole is drilled, its actual path is monitored using either a transmitter or a steering tool positioned as close as possible to the bit. Directional control is achieved using a non-rotating drill string with an asymmetrical leading edge. The asymmetry of the leading edge creates a steering bias while the non-rotating aspect of the drill string allows the steering bias to be held in a specific position while drilling. If a change in direction is required, the drill string is rolled so the direction of bias is the same as the desired change in direction. The drill string may also be continuously rotated where directional control is not required. On large rig installations, leading edge asymmetry is typically accomplished with a bent sub or a bent motor housing located directly behind the bit. Leading edge asymmetry on small rig installations is typically accomplished using a slant-faced bit.



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Pilot hole drilling continues until the bit punches out at the exit point on the opposite end of the crossing, at which point the pilot hole is complete.

8.1.3 Pre-Reaming

Enlargement of the pilot hole is typically accomplished by conducting one or more pre-reaming passes until the desired hole size has been achieved. The number of passes that are required is dependent upon the diameter of the facility being installed and the properties of the subsurface materials along the drilled path.

For a typical pre-reaming pass, a reaming tool attached to the drill string at the exit point is rotated and drawn back to the drilling rig, thus enlarging the hole. Drill pipe is typically added behind the reamer as it progresses toward the rig so that a full string of pipe is maintained in the hole at all times.

It is also possible to ream away from the drilling rig, in which case a reamer fitted into the drill string at the rig is rotated and advanced away from the drilling rig. Push reaming refers to advancing the reamer away from the drilling rig using only the drilling rig's thrust. Push reaming is generally considered to be poor practice as it increases the potential for a drill pipe failure. The preferred method is to pull the reaming tool through the bore from the exit point while the reamer is rotated by the drilling rig; this process has the benefit of maintaining tension on the reamer throughout the reaming operations.

8.1.4 Drilling Mud

Typically a drilling mud is injected into the bore during the cutting and reaming process to stabilize the hole and remove soil cuttings.

The drilling mud typically consists of a clay or polymer material; the most common clay used being a sodium montmorillonite (referred to as bentonite). The drilling mud must have sufficient gel strength to keep the cuttings suspended for transport, to form a filter cake on the boring wall that contains the water within the drilling fluid, and to provide lubrication between the pipe and the boring wall on pullback.

The drilling muds used are often described as thixotropic and thus thicken when left undisturbed after pullback. However, unless cementitious agents are added, the thickened mud provides little to no side-support for the pipe.

8.1.5 Pullback

Prior to commencing pullback operations, the pipeline to be installed is typically assembled to its full length on the side of the crossing opposite the drilling rig. This prefabricated segment is referred to as the pull section. Once the hole has been enlarged to its final diameter, the facility is installed in the reamed hole by attaching the pull section behind a reaming assembly at the exit point, then pulling both the reaming assembly and pull section through the hole to the drilling rig.



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A swivel is placed between the pull section and the reaming assembly to minimize the amount of torsion that is transmitted to the pipeline being installed.

The pull section is typically supported as it proceeds into the hole using some combination of roller stands and pipe handling equipment to minimize the tensile load and prevent damage to the pipeline.

8.1.6 Anticipated Stratigraphy along the HDD Path

Consistent with the comments provided herein, it is anticipated that the HDD will be conducted at a depth in which the top of pipe is approximately 14.0 m below the road surface.

Given the depths and corresponding elevations referenced, Table 8-1 below provides an indication of the strata anticipated to be present at the installation depth of the pipeline, with due consideration for the conditions encountered in the boreholes advanced for this investigation.

Table 8-1 Anticipated Stratigraphy for the HDD Crossing

Borehole¹	Approximate Pipeline Elevation at Borehole Location (m)	Soil Strata Anticipated at the Proposed Pipeline Installation Level
S3C3-1	200.0 – 199.0 ^{2,3}	Stiff to Very Stiff Sandy Silty Clay, Till
S3C3-2	195.3 – 194.2 ^{2,3}	Hard Sandy Clay, Till
S3C3-5	194.1 – 193.0 ^{2,3}	Inferred Completely to Highly Weathered Shale Bedrock
S3C3-3	194.4 – 193.3 ^{2,3}	Very Dense Silty Clayey Sand, Till over Inferred Completely to Highly Weathered Shale Bedrock
S3C3-4	205.5 – 206.5 ^{2,3}	Stiff to Very Stiff Clay with Sand, Till

Notes:

- 1 The order of the boreholes as shown is arranged from the entry pit to the exit pit
- 2 The alignment referenced in the table was provided on the HDD Plan and Profile provided for use in preparation of this geotechnical report.
- 3 The elevations provided in the table refer to the top of pipe and bottom of pipe respectively, at the borehole locations.

The HDD installation is anticipated to be below the static groundwater level taken as 206.7 m based on the maximum level recorded in the monitoring well installed for the geotechnical investigation described herein.

The subsurface soil profile is shown in Drawing No. 1 in **Appendix B** for reference. As previously stated, the conditions between and beyond the borehole locations must be assumed to vary, both horizontally and vertically. The soil profile is therefore considered for conceptual illustration only.

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8.1.7 Suitability of Preferred Approach

The following bullets provide a brief overview of the feasibility of a HDD approach for this project.

- The work requires a crossing of the MTO Right-of-Way (Highway 401). Open cut excavation in the MTO Right-of-Way is not permitted, necessitating the adoption of a trenchless technology approach.
- There is no existing infrastructure (bridges, overpasses, or similar) in immediate proximity to the crossing location. The closest hydro infrastructure is the hydro pole located 10 m to the west of the crossing alignment.
- The construction methodology associated with the HDD will serve to mitigate against potential disruption of the Highway 401.
- The site has sufficient space for a HDD installation.
- HDD installation in the stiff to very stiff clay with sand, stiff to hard sandy clay and very dense silty clayey sand till soils encountered in the boreholes at a depth consistent with the planned alignment of the PPR is not anticipated to pose unusual or undue problems. The occasional presence of cobbles and boulders inferred within these soils may deflect or block the drill/bore path. The specialty contractor's design and construction methodology will need to consider the presence of these materials.
- The completely to highly weathered shale bedrock was encountered in Boreholes S3C3-2 and S3C3-3, and S3C3-5 at or immediately below depths consistent with the alignment of the PPR. The variation in properties between the till soils and the completely to highly weathered shale (and the potential presence of harder rock layers and/or clay seams in the shale) can cause skipping of the drill bit. Flattening the PPR or reducing the depth a very modest amount may mitigate against this potential. Regardless, the specialty contractor's design and construction methodology will need to consider the presence of these materials.

Based on the statements provided above, the HDD method of construction is considered a feasible method of construction for the crossing of Highway 401, referred to as crossing S3C3.

8.1.8 Constraints and Limitations of HDD Method of Construction

The following are potential constraints and limitations associated with the HDD:

- Based on the conditions encountered in the boreholes, the entry/exit pits and/or the tie-in pits will be excavated in the clay with sand till soil. Excavation in these soils should be relatively straightforward using medium to large size excavation equipment, though the presence of cobbles and boulders should not be ruled out.
- At shallow depth, the overlying lithostatic pressure is reduced. Where the lithostatic pressure is minimal, the fluid pressure generated at the cutting face of the HDD rig may be sufficient to cause inadvertent release of drilling fluid to the ground surface. The design plan requires that existing services (such as the sewer, vital main, and TransCanada Pipeline) be identified, marked and monitored during construction to mitigate against potential disturbance or damage as a result of the HDD operations.



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- At increasing depth, an inadvertent loss or return of drilling fluid can occur via an “open pathway” such as provided by existing fractures, fissures, continuous voids, seams of coarse materials, or at the interface of buried structures or similar preferential pathways. This is considered unlikely given the typically massive nature of the glacial till soil deposits present and the absence of observations of any vertical fissures, fractures, or similar pathways in the numerous samples obtained from the boreholes, and the absence of any deeper utilities/services. The inadvertent return of drilling fluid may also occur due to spikes in the annular operating pressure associated with temporary blockage or collapse of the HDD drill hole. Given the vertical clearance of approximately 12 m between the HDD drill path and the sewer (and assumed similar vertical separation distances between the HDD drill path and the existing vital main and TranCanada Pipeline) and the head loss anticipated for the inadvertent return drilling mud over the 12 m elevation change, the potential to impact the existing services is considered minimal.
- Till deposits can contain sand seams or lenses. The presence of seams or lenses, particularly containing very loose granular soils, can cause steering difficulties and/or inadvertent loss of drilling fluids during the HDD installation.
- The completely to highly weathered shale bedrock was encountered at a depth consistent with the alignment of the PPR in Borehole S3C3-5. Where the drill bit penetrates the contact between the overburden soils and the underlying bedrock, skipping of the drill bit can occur.
- The variation within the completely to highly weathered shale and the potential presence of harder shale/limestone beds, and clay seams can cause skipping of the drill bit.
- The Queenston formation is known to possess high residual horizontal stresses. The resulting phenomenon is often referred to as “rock squeeze” and can adversely impact infrastructure installed in the rock. The design includes an over-drill of 150 mm which should be sufficient to address any rock squeeze that may occur.
- The bore will extend below the static groundwater table, measured at a minimum depth below grade of 0.8 m (corresponding to Elevation 206.7 m). The groundwater level measured in the monitoring well confirmed the presence of a hydrostatic head in the underlying sandy silty clay till soil. It is likely that this condition also exists in the silty sand and silty clayey sand soils as well and the weathered zone of the underlying shale bedrock.
- The design and construction of the HDD must consider the potential presence of cobbles and/or boulders in the drill/bore path. The presence of cobbles and/or boulders is typical within the Halton Till soils. Oversize materials may tend to deflect or block the drill/bore path. If the bit deflects off a boulder resulting in an exceedance of the specified pilot hole tolerances, the contractor will back-up and re-drill until the alignment is within acceptable limits. Similarly, if the drill hole should be obstructed by a boulder, the contractor will back-up and attempt to re-drill around the boulder.
- The potential for disturbance to occur along the drill path (the drill hole to become larger than the design hole diameter due to loss of ground into the hole) is considered minimal, given the predominant soil type encountered in the boreholes (i.e. stiff to very stiff clay with sand, stiff to hard sandy clay and very dense silty clayey sand till soils). Some localized soil collapse may occur along the HDD path where sand seams or lenses, and cobbles or boulders are present in the till.
- The potential for ground surface movements (i.e. settlement or heave) in the area of Highway 401 is considered minimal, given the predominant soil type encountered in the boreholes (i.e. stiff to very stiff clay with sand, stiff to hard sandy clay and very dense silty clayey sand till soils) and the presence



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of approximately 14 m to 15 m of soil cover over the top of the drill/bore path. In addition, the design calls for an annular mud pressure of similar magnitude as the total soil pressure confining the drill hole and as a result, no distortion or displacement in the area immediately overlying the drill path (or at a higher elevation) is anticipated.

The implementation of a settlement monitoring program in accordance with the MTO Guidelines will serve to identify and mitigate against any potential disturbance or damage at the ground surface.

Consistent with the commentary provided above, Table 8-2 below provides a summary of the strata encountered in the boreholes with specific reference to the constraints and limitations identified that are considered to pose a possible risk to the HDD installation.

Table 8-2 Table of Strata and Conditions Posing Potential Risk to the HDD Installation

Strata	Approximate Elevation Range in Boreholes (m)					Constraints
	S3C3-1	S3C3-2	S3C3-3	S3C3-4	S3C3-5	
Clay with sand, Till	205.3 and 203.3	207.0 and 204.6	206.9 and 201.1	207.4 and 202.9	206.3 and 200.2	- Gravel content: more than 1% to 5% ² - Inferred presence of cobbles and possible boulders ¹
Sandy Clay, Sandy Silty Clay, and Sandy Silty Clay with Gravel, Till	202.6 and 194.5	204.6 and 198.8	201.1 and 198.0	202.9 and 190.2	200.2 and 196.4	- Gravel content: more than 2% to 15% ² - Inferred presence of cobbles and possible boulders ¹
Silty Sand, Silty Clayey Sand, and Silty Clayey Sand with Gravel, Till	N/A	N/A	198.0 and 193.0	N/A	196.4 and 195.1	- Gravel content: more than 2% to 15% ² - Inferred presence of cobbles and possible boulders ¹
Completely to Highly Weathered Shale (Soil-like)	194.5 and 191.6	193.7 and 193.2	193.0 and 192.1	190.2 and 188.8	195.1 m and 193.7	Completely to highly weathered Shale
N/A	206.7	206.7	206.7	206.7	206.7	Static Groundwater Level (confined overburden and underlying weathered bedrock is considered to be under hydrostatic pressure)

Notes:

- ¹ Based on the conditions encountered in the boreholes and the general nature of Halton till deposits, the presence of cobbles and boulders should be anticipated in these strata
- ² The percentile range provided for gravel content is based on the results of lab testing on samples obtained by the SPT samplers. The diameter of the SPT sampler is 38 mm, and as a result the range provided does not reflect all the gravel-size (i.e. up to 75 mm diameter) and larger particles (cobbles and boulders) that may be present in the soil.

N/A - Not Applicable

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Considering the ground surface topography along the length of the HDD alignment as shown on the Site Profile referenced in Section 2.2, there is no obvious indication of concerns with respect to potential slope instability for the proposed locations of the entry/exit points or for the required tie-in pits.

Although the PPR is intended to cross under Highway 401, the exit and entry pits are in excess of 100 m from the highway corridor and as such there is no perceived adverse implication anticipated in this respect.

8.2 RECOMMENDATIONS

8.2.1 Non Standard Special Provision & HDD Execution Plan

An edited copy of the "Pipe Installation by Trenchless Method, Non Standard Special Provision (NSSP), dated February 2009 is included in **Appendix G** for reference. The edited version of the NSSP as attached is intended to:

- Indicate the MTO's expectations to the designers of what is required to be addressed and included in the designer; and,
- To understand the benchmark upon which the contract documents will be reviewed from a geotechnical perspective.

The contractor should prepare and provide a comprehensive HDD execution plan addressing the requirements of the edited NSSP, as attached, and the following, in advance of undertaking the work.

- Surface water management across the area of the construction site;
- HDD entry and exit pit installation and dewatering;
- Navigation and monitoring of pilot hole tolerances;
- Reaming including steering around boulders or other obstacles;
- Environmental management including mud management, monitoring drilling fluids and response to inadvertent returns;
- Drill continuance and or contingency plans; and,

Pullback operations including addition of pullback sections and resumption or suspension of pullback operations (for welding or if stuck).

8.2.2 Monitoring

The MTO Guidelines for Foundation Engineering – Tunneling Specialty For Corridor Encroachment Permit Application includes an appendix titled "Settlement Monitoring Guidelines – Tunneling". The appendix addresses the requirements for a settlement monitoring program to prevent damage to existing utilities and highway structures along the tunnel alignment.

In the NSSP referenced in the preceding section, Section 7.06 titled Instrumentation Monitoring also addresses the requirements for a settlement monitoring program in this respect.



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In general, the monitoring program provides for completion of a pre-condition survey of the existing pavement, installation of a number of surface settlement markers and in-ground settlement monitoring points, collection of settlement monitoring data, assessment of the settlement monitoring data including comparison to prescribed trigger levels, and distribution of results of the monitoring including notification if the trigger level(s) are exceeded and recommended corrective and/or preventive measures as warranted if movements are recorded.

Additional comments regarding the settlement monitoring program is provided in Section 9.3 below.

It is also recommended that monitoring be conducted for the hydro pole(s) located in proximity to the alignment of the HDD.

9.0 Construction Considerations

9.1 SITE PREPARATION

Given the existing conditions observed at the locations of the planned entry and exit points, it is anticipated that site preparation activities will be limited to localized stripping, and preparation of access/egress and layover areas for stockpiling/ponding of construction materials.

Reference is given to OPSS 201, OPSS 503 and OPSS 565 for Specifications associated with site preparation and related activities.

9.2 DEWATERING & UNWATERING

Groundwater level was measured at a minimum depth of 0.8 m below grade (corresponding to Elevation 206.7 m) in the monitoring well. This level was associated with the presence of the hydrostatic head in the underlying sandy silty clay soils.

Given the generally fine-grained nature of the overlying clay with sand till soils, it is unlikely that dewatering (considered herein as pumping of groundwater to depressurize or lower the groundwater table in advance of construction) will be required for excavations in the order of 1.5 m deep, typical of that required for the HDD entry and exit pits and/or the pipeline tie-in pits.

Excavations to the depth indicated will encounter the clay with sand till soil. Given the firm to hard consistency inferred from the boreholes and the fine grain nature of this soil, infiltration and seepage into the open excavations should be very limited. In this respect, low to moderate seepage and infiltration should be anticipated in the open excavations.

Handling and controlling the anticipated groundwater seepage and infiltration into excavations to a depth in the order of 1.5 m below grade should be manageable using sump pits and contractor's pumps. If precipitation occurs during construction and/or sand and gravel (or similar) lenses, zones, or seams are



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encountered in the prevailing native soils exposed in the excavations, higher volumes of groundwater infiltration should be anticipated and more extensive unwatering system may be required.

Deeper excavations than that described above are not anticipated to be required in the context of the proposed construction methodology and associated requirements. Should any excavations penetrate the more "granular" soils described herein as a combination of silty clayey sand and silty sand, moderate to high seepage may be encountered and hydrostatic head present in these soils could lead to piping and boiling of the base of the excavation. Dewatering (depressurizing) of these underlying water bearing till soils would likely be required to facilitate deeper excavation.

The design of any dewatering system would need to address the extent of dewatering required, the depth of intended excavation, and the soil and groundwater conditions that prevail at the intended excavation location at the time of the excavation.

Any unwatering/dewatering program should contain a communication protocol with the regulatory agencies and the public, short term containment, sampling and analysis, permitting, disposal, and reporting requirements.

The preceding comments are intended for general reference and information only. The Contractor is solely responsible for the design and implementation of any required unwatering and/or dewatering, including requirements for withdrawal, handling, treatment, and discharge. It should be noted that consistent with the current Ontario Ministry of the Environment regulations, a Permit to Take Water is required for volumes in excess of 50,000 L/day.

Further details with respect to dewatering can be found in OPSS 517 and OPSS 518. For purposes of these specifications, unwatering applications are inferred to be included in the definition of dewatering (reference Clause 518.03 Definitions) in this regard.

Given the comments provided above the limited unwatering requirement described (in conjunction with the location of the required entry/exit and tie-in pits) is not anticipated to have a negative impact on the existing infrastructure (e.g. the hydro pole to the north of the alignment, buried utilities under or in proximity to the road, or the road embankment and pavement structure).

9.3 SETTLEMENT MONITORING PROGRAM

9.3.1 Overview

Typically, the most common type of distress for trenchless technology applications is settlement caused by loss of ground around the tunnel. For HDD installation, heave of the ground surface and or inadvertent drilling fluid returns are also possible.

The NSSP titled Pipe Installation By Trenchless Method includes recommendations for monitoring and the criteria for assessment of roadway subsidence/heave that are applicable for MTO highways. The



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comments in the following sections are intended for general reference only. The NSSP should be referred to for additional details with respect to the scope and execution of the required monitoring program.

A detailed monitoring plan will be prepared in advance of construction. The plan will include a drawing illustrating the locations of the required settlement monitoring markers and points, appropriate trigger levels, standards for survey, notification list and required schedule for distribution of results of monitoring, and outline of likely mitigation measures as may be required for implementation if movements are detected via the monitoring program.

9.3.2 Condition Survey

A condition survey of each lane of the existing pavement should be carried out prior to the commencement of construction. The results of the survey are documented for the purpose of establishing the scope of required restoration, if necessary. The survey is carried out by an approved pavement engineer qualified to inspect highways.

The condition survey is typically completed in conjunction with the installation of the surface settlement markers (described further below) on the road surface.

Interim surveys are conducted if movement is detected.

A final condition survey is undertaken subsequent to completion of the trenchless technology installation.

9.3.3 Settlement Markers and Settlement Monitoring Points

A system of surface markers and in-ground monitoring points is established in advance of the track bore installation. A high-precision survey of the monitoring points is conducted. Specific to this undertaking, the following scope of monitoring is recommended:

- Three sets of readings per day for two consecutive days are to be obtained prior to construction to establish "base-line" data.
- Three to five sets of readings per day are to be obtained each day of construction, presuming that movements remain within the anticipated/tolerable limits. If movements are recorded, the frequency of monitoring is adjusted consistent with consultation with the MTO.
- A minimum of three readings per day during non-operational periods (e.g. off-shift, weekends)
- Weekly readings are to be obtained after completion of the HDD installation for a period of 1 month (or as directed by the MTO if movements are observed/recorded during the construction period).

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9.3.4 Criteria For Assessment

The criteria provide for an alert level and a review level with respect to the magnitude of movement recorded. These are described as follows:

- **Review Level** – A movement of 10 mm relative to established baseline readings. If the review level is exceeded, the Contractor is advised accordingly and changes to the installation method, rate/progress of installation or sequence of construction, are implemented to mitigate further ground displacement.
- **Alert Level** – A movement of 15 mm relative to the established baseline readings. If this level is exceeded, the Contractor is required to cease construction operations and execute pre-planned measures to secure the site, to mitigate further displacement, to assure public safety, and to maintain traffic flow on the road.

9.3.5 Communication and Reporting

A detailed communication and notification plan is also required in conjunction with the monitoring plan such that all parties (including the MTO) are kept informed and advised promptly of the results of the monitoring.

9.4 EXCAVATION

Temporary excavations must be carried out in accordance with the latest edition of the Occupational Health & Safety Act & Regulations (OH&S Act). Given that the entry and exit pits for the HDD are anticipated to be quite shallow, it is presumed that these excavations will be conducted via open cut. The following comments with respect to the soils types and classification for purposes of adhering to the OH&S Act are provided in this respect. It is noted that if temporary shoring is installed within the MTO property for any aspect of the project, the temporary shoring must be removed on completion of construction.

The sand and gravel and sandy silty clay fill materials (above groundwater level) should be classified as Type 3 soils. The maximum excavation side slope for a Type 3 soil is 1:1 (Horizontal: Vertical) in accordance with the OH&S Act.

The native firm to hard clay with sand till soils should be classified as Type 3 soils. The maximum excavation side slope for a Type 3 soil is 1:1 (Horizontal: Vertical) in accordance with the OH&S Act.

The native sandy clay, sandy silty clay, silty sand and silty clayey sand till soils are water-bearing (reference the presence of a hydrostatic head as discussed in the preceding sections of this report) and must be classified as Type 4 soil. The maximum excavation side slope for a Type 4 soil is 3:1 (Horizontal:Vertical) in accordance with the OH&S Act.

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The presence of cobbles and boulders was inferred from the grinding of the augers during drilling. The presence of cobbles and boulders should therefore be anticipated in the excavations for the entry/exit and tie-in pits.

Excavation side slopes should be protected from exposure to precipitation and associated ground surface runoff and should be inspected regularly for signs of instability. If localized instability is noted during excavation or if wet conditions are encountered, the side slopes should be flattened as required to maintain safe working conditions.

If open-cut excavations extending to a depth in excess of 1.2 m are contemplated, but space is restricted such that the side slope cannot be safely cut back in accordance with the OHSA regulation, or sloughing and cave-in are encountered in the excavations, temporary shoring must be provided in accordance with the OHSA.

9.5 BACKFILLING

On completion of the trenchless installation, the excavations will be backfilled.

The excavations and any adjacent disturbed areas should be restored to an equivalent (or better) condition than existed prior to the commencement of construction.

Reference is given to OPSS 514 with respect to requirements for trenching, backfilling, and compacting for the entry and exit pits and the tie-in pits.

9.6 ESTIMATES OF HYDRAULIC CONDUCTIVITY

For reference, the results of the grain size distribution tests (and Unified Soil Classifications) completed on the predominant soil strata encountered in the boreholes has been compared to the grain size curves and soil types referenced in Supplementary Standard SB-6 of the 2006 Ontario Building Code (OBC). The OBC has been used as a guideline to estimate the likely range in the coefficient of permeability of the soils encountered in the investigation. It is noted that the industry typically refers to "hydraulic conductivity" rather than "coefficient of permeability" in this respect. The terms are often considered interchangeable, but for purposes of this report the values provided are in the form of "length/time" (cm/sec) and are therefore considered strictly applicable to "hydraulic conductivity", and hence "hydraulic conductivity" is used herein.

Based on the comparison conducted, the following values are provided:

- | | |
|---|---------------------------------------|
| ● Clay with Sand (CL) | 10^{-6} cm/sec or less |
| ● Sandy Silty Clay (CL-ML) and Sandy Clay (CL) | 10^{-5} to 10^{-6} cm/sec or less |
| ● Silty Sand (SM) and Silty Clayey Sand (SC-SM) | 10^{-3} to 10^{-5} cm/sec |

The OBC states, in part, that "it must be emphasized that, particularly for fine grained soils, there is no consistent relationship [between coefficient of permeability and soils of various types] due to the many



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factors involved". Such factors as structure, mineralogy, density (compactness or consistency), plasticity, and organic content of the soil can have a large influence on the hydraulic conductivity; variations in excess of an "order of magnitude" are common place in this respect. In addition, the OBC does not differentiate between soils of "till" or "non-till" origin.

Values for the hydraulic conductivity of the fill materials are not available as the inherent variability of fill materials does not provide for consistent and representative values or range in values.

The results of the field hydraulic conductivity test conducted in S3C3-4 yielded a hydraulic conductivity of 7.0×10^{-6} cm/s for the reddish brown hard sandy silty clay till. This value falls within the overall range provided in the OBC for the combination of the sandy silty clay (CL-ML) soil referenced above.

10.0 Specifications

Table 10-1 provides a summary of a number of specifications that are referenced in this report.

Table 10-1 Specifications Referenced in This Geotechnical Report

Document	Title
NPSS	Pipe Installation By Trenchless Method
OPSS 201	Construction Specification for Clearing, Close Cut Clearing, Grubbing, and Removal of Surface and Piled Boulders
OPSS 503	Construction Specification for Site Preparation for Pipelines, Utilities, and Associated Structures
OPSS 514	Construction Specifications for Trenching, Backfilling, and Compacting
OPSS 517	Construction Specification for Dewatering of Pipeline, Utility and Associated Structure Excavation
OPSS 518	Construction Specifications for Control of Water from Dewatering Operations
OPSS 538	Construction Specification for Shoring and Bracing
OPSS 539	Construction Specification for Temporary Protection Systems
OPSS 565	Construction Specification for the Protection of Trees

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11.0 References

In addition to the specifications referenced in the table in the previous section, the following references also apply to the preparation of this report.

ASTM 4.08. Standard D1586-99: Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils.

MTO LS-701 ASTM Standard D2216 - 10: Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by

MTO LS-703/704 ASTM Standard D4318 - 10: Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

MTO LS-702. ASTM Standard D422 - 63(2007): Standard Test Method for Particle-Size Analysis of Soils

ASTM 4.08. Standard D2487-00: Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System).

Canadian Geotechnical Society. Canadian Foundation Engineering Manual, 4th Edition. Richmond: BiTech Publisher Ltd, 2006.

Chapman, L.J., and Putnam, D.F. The physiography of southern Ontario; Ontario Geological Survey, Special Volume 2. Toronto: Ontario Research Foundation, Ontario Geological Survey, 1984.

Ministry of Labour. Occupational Health & Safety Act & Regulations Consolidated Edition. Carswell, 2013.

Ministry of Transportation. Ontario Provincial Standards for Roads and Municipal Services. Downsview, Ontario: Ministry of Transportation, 1998.

Ministry of Northern Development. The Quaternary Geology of Ontario, Southern Sheet, Map 2556, by Ministry of Northern Development and Mines (1991);

Ministry of Northern Development. The Bedrock Geology of Ontario, Southern Sheet, Map 2544, by Ministry of Northern Development and Mines (1991);

Ontario Geological Survey. Quaternary Geology Toronto and Surrounding Area Southern Ontario, Preliminary Map P. 2204, by Ontario Geological Survey (1980);

Ontario Ministry of the Environment (MOE) Water Well Record database; and,

Ontario Geological Survey (OGS) Borehole Record database.



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12.0 Closure

A soil investigation is a limited sampling of a site. The conclusions given herein are based on information gathered at the specific borehole locations. Should any conditions at the site be encountered which differ from those at the borehole locations, we request that we be notified immediately in order to assess the additional information and its effects on the above recommendations.

We trust the information presented herein meets your present requirements. Should you have any questions or require additional information, please do not hesitate to contact us.


This geotechnical component of the report was prepared by Mr. Khashayar Refahi, P.Eng. and Mr. John J. Brisbois, M. Sc. Eng., P.Eng., and reviewed by Mr. J. Brant Gill, H.B.Sc., P.Geo. and approved by Mr. Raymond Haché, M.Sc., P.Eng., MTO Designated Principal Contact.

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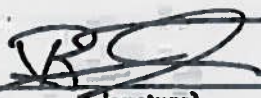
Sign-Off Sheet
2015-01-12

13.0 Sign-Off Sheet

Prepared by 
(signature)
Khashayar Refahi

Prepared by 
(signature)
John J. Brisbois



Reviewed by 
(signature)
J. Brant Gill



Approved by 
(signature)
Raymond Haché



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Appendix A
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Appendix A

A.1 STATEMENT OF GENERAL CONDITIONS



STATEMENT OF GENERAL CONDITIONS

USE OF THIS REPORT: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec Consulting Ltd and the Client. Any use which a third party makes of this report is the responsibility of such third party.

BASIS OF THE REPORT: The information, opinions, and/or recommendations made in this report are in accordance with Stantec Consulting Ltd's present understanding of the site specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed site specific project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Stantec Consulting Ltd is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

STANDARD OF CARE: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

INTERPRETATION OF SITE CONDITIONS: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec Consulting Ltd at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behavior. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

VARYING OR UNEXPECTED CONDITIONS: Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Stantec Consulting Ltd must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Stantec Consulting Ltd will not be responsible to any party for damages incurred as a result of failing to notify Stantec Consulting Ltd that differing site or sub-surface conditions are present upon becoming aware of such conditions.

PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec Consulting Ltd, sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Stantec Consulting Ltd cannot be responsible for site work carried out without being present.

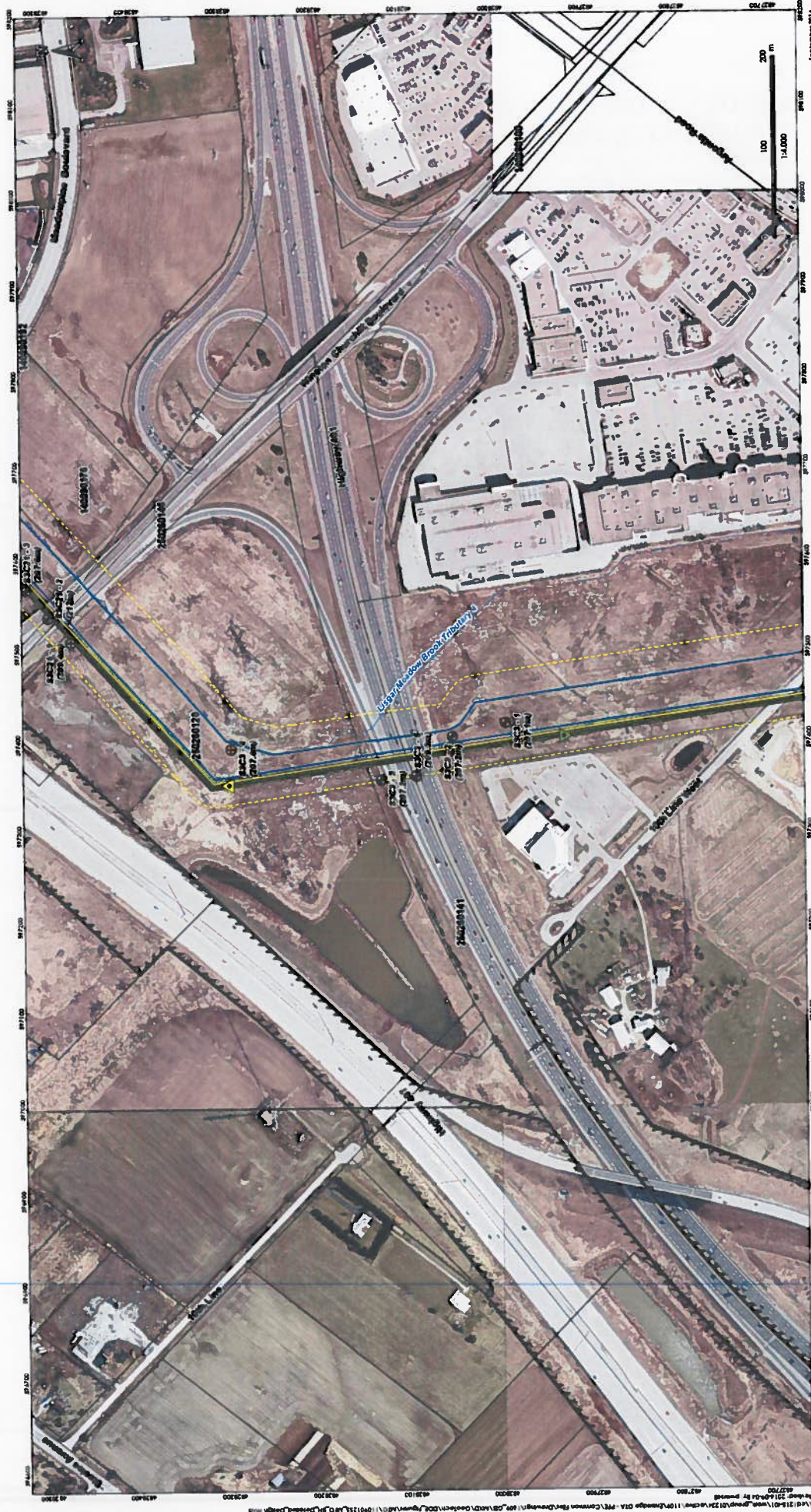
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Appendix B

- B.1 FIGURE S3C26 – BOREHOLE LOCATION PLAN**
- B.2 DRAWING NO. 1 – BOREHOLE LOCATION PLAN AND SOIL STRATA**
- B.3 SITE PHOTOS**





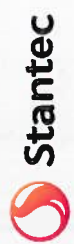
Client/Project
 Enbridge Gas Distribution Inc.
 Geotechnical - Hydrogeological Investigation
 GTA Project - Detailed Engineering (DE) Phase
 Figure No. **SC3**
Borehole Locations
Highway 401
(HDD)



Borehole ID	Easting	Northing
SC3 - 1	597420	482792
SC3 - 2	597405	482805
SC3 - 3	597358	4828130
SC3 - 4	597393	4828295
SC3 - 5	597382	4828071

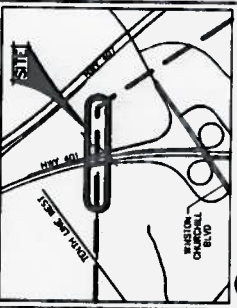
- Enbridge GTA Route 3 (Proposed)
- 50D Vital Main (Existing)
- TransCanada Pipeline (Existing)
- NES Regulated Area
- Watercourse
- Property Parcel
- Unit of Highway 407 ETR Lands

- Borehole (PFE, 2013)
- Borehole (DE, 2014)
- Borehole with Monitoring Well (PFE, 2013)
- Borehole with Monitoring Well (DE, 2014)
- Ground Surface Elevation (metres A.S.L.)
- HDD Entry Point
- HDD Exit Point



Notes
 1. Coordinate System: NAD 1983 UTM Zone 17N
 2. Base features produced under license with the Ontario Ministry of Natural Resources & Queen's Printer for Ontario, 2014.
 3. Cartography © First Base Solutions, 2014.
 Imagery © 2013.

PROJECT No 110901255
ENBRIDGE
GTA PROJECT
HIGHWAY 401
MISSISSAUGA, ONTARIO
BOREHOLE LOCATIONS & SOIL STRATA



LEGEND

- Borehole
- Borehole with Monitoring Well
- Borehole (0.3m (51d Pen Test, 475 V/Down)
- WT Measured June 2014
- (18.9 m WEST) Offset from CL of Preferred Pipeline Route

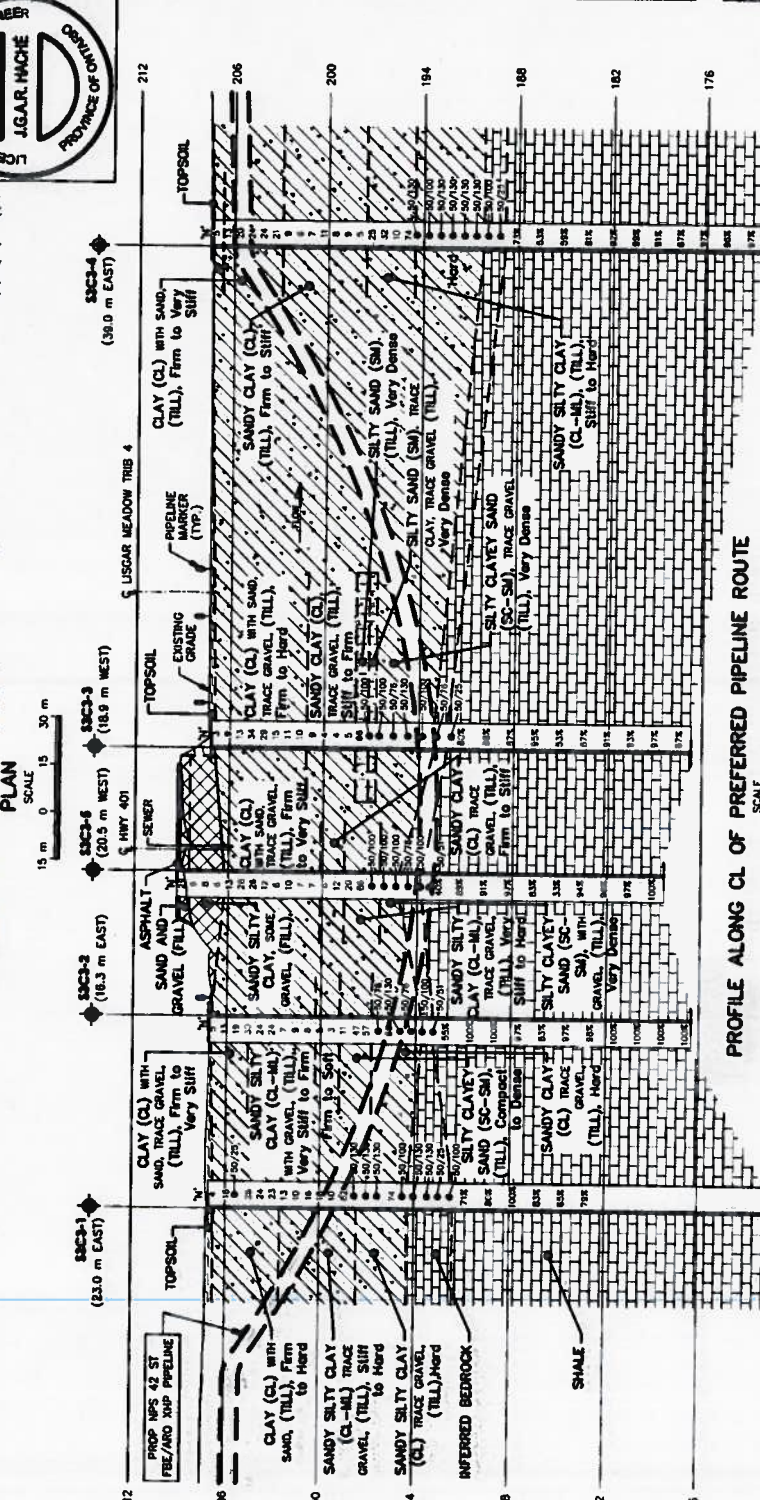
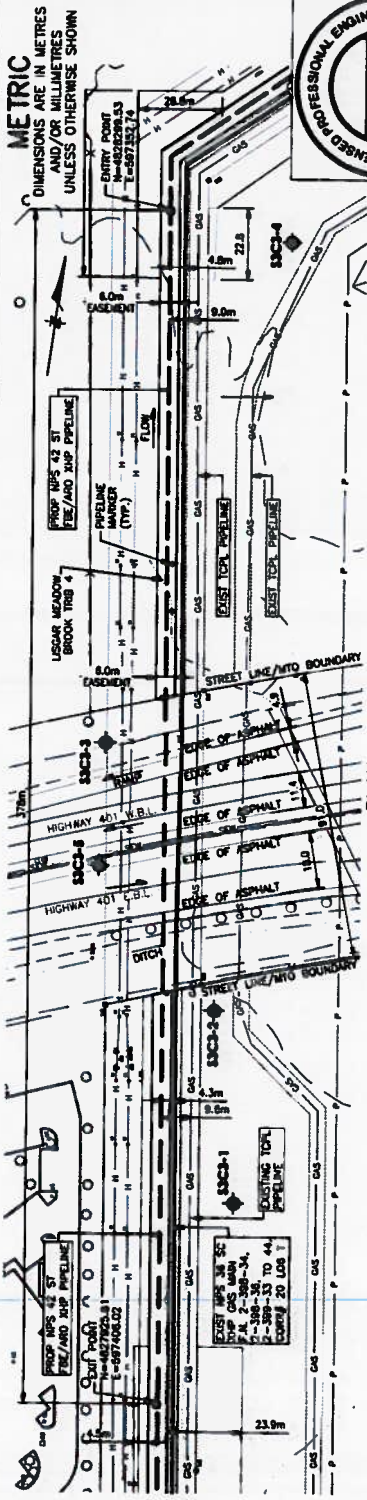
No	ELEV	UTM ZONE 17	NORTH	EAST
SBC3-1	207.1	7 827 982	597 420	
SBC3-2	207.2	7 828 051	597 425	
SBC3-3	207.2	7 828 050	597 356	
SBC3-4	207.2	7 828 051	597 356	
SBC3-5	209.3	7 828 081	597 362	

NOTES

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

This drawing is for subsurface information only. It is not to be used for design or construction purposes. The profile does not duplicate of the utilities and services shown on the plan. The presence of utilities and services within the proposed horizontal alignment and vertical clearance are not shown. The profile is discussed in the geotechnical report.

DATE: 2014-10-13
BY: J. H. H. / A.
CHECKED: J. H. H. / A.
DATE: 2014-10-13
BY: J. H. H. / A.
CHECKED: J. H. H. / A.



PROFILE ALONG CL OF PREFERRED PIPELINE ROUTE

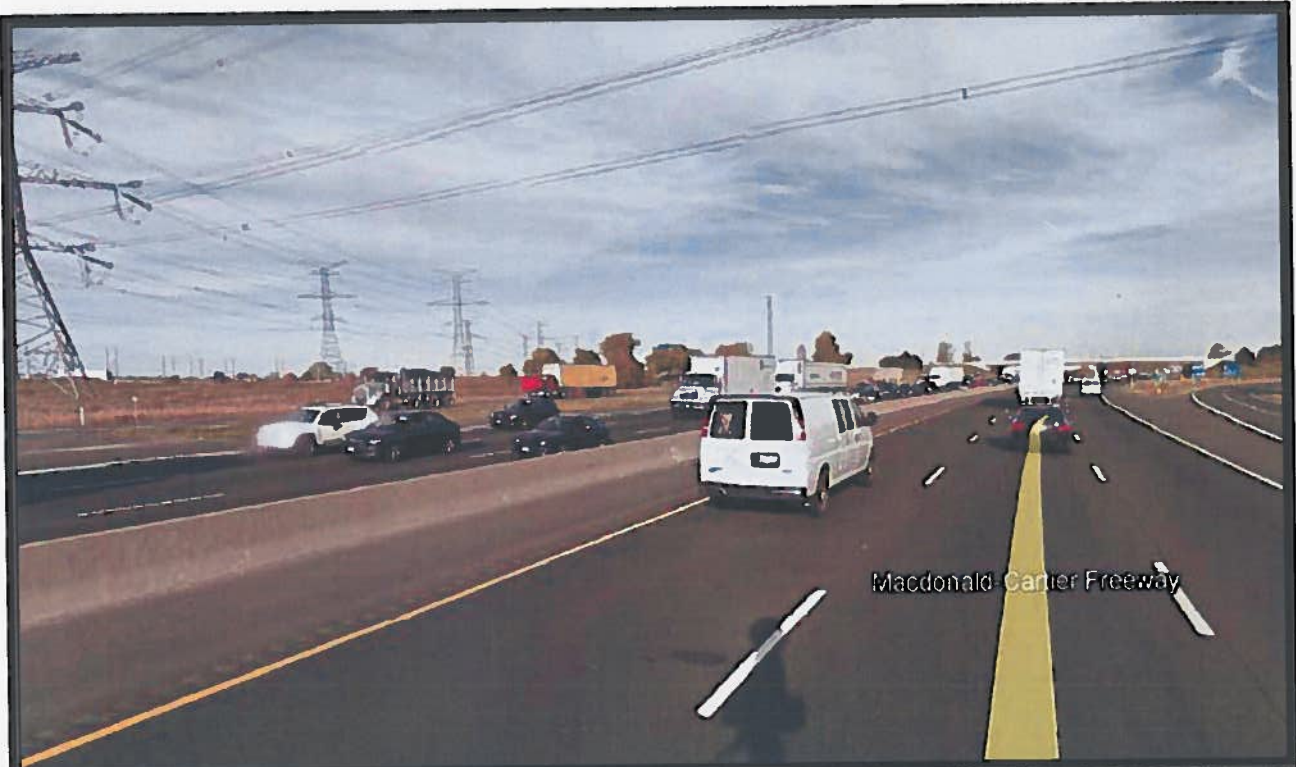


Photo 1: Location of proposed HDD crossing of Highway 401. Photo by Google Earth, October 2012. Middle lane of east bound lanes.



Photo 2: Location of proposed HDD crossing of Highway 401. Photo by Google Earth, October 2012. Right lane of west bound lanes looking west on Highway 401.

**FOUNDATION INVESTIGATION AND DESIGN REPORT GTA PROJECT DETAILED
ENGINEERING DESIGN PHASE DOCUMENT NO.: 110901255.085 PROJECT NO.: 110901255**

Appendix C
2015-01-12

Appendix C

C.1 SYMBOLS AND TERMS USED ON BOREHOLE RECORDS

C.2 BOREHOLE RECORDS

C.3 MONITORING WELL RECORD



SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

SOIL DESCRIPTION

Terminology describing common soil genesis:

Rootmat	- vegetation, roots and moss with organic matter and topsoil typically forming a mattress at the ground surface
Topsoil	- mixture of soil and humus capable of supporting vegetative growth
Peat	- mixture of visible and invisible fragments of decayed organic matter
Till	- unstratified glacial deposit which may range from clay to boulders
Fill	- material below the surface identified as placed by humans (excluding buried services)

Terminology describing soil structure:

Desiccated	- having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.
Fissured	- having cracks, and hence a blocky structure
Varved	- composed of regular alternating layers of silt and clay
Stratified	- composed of alternating successions of different soil types, e.g. silt and sand
Layer	- > 75 mm in thickness
Seam	- 2 mm to 75 mm in thickness
Parting	- < 2 mm in thickness

Terminology describing soil types:

The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488) which excludes particles larger than 75 mm. For particles larger than 75 mm, and for defining percent clay fraction in hydrometer results, definitions proposed by Canadian Foundation Engineering Manual, 4th Edition are used. The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris):

Terminology describing materials outside the USCS, (e.g. particles larger than 75 mm, visible organic matter, and construction debris) is based upon the proportion of these materials present:

Trace, or occasional	Less than 10%
Some	10-20%
Frequent	> 20%

Terminology describing compactness of cohesionless soils:

The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test (SPT) N-Value - also known as N-Index. The SPT N-Value is described further on page 3. A relationship between compactness condition and N-Value is shown in the following table.

Compactness Condition	SPT N-Value
Very Loose	<4
Loose	4-10
Compact	10-30
Dense	30-50
Very Dense	>50

Terminology describing consistency of cohesive soils:

The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests. Consistency may be crudely estimated from SPT N-Value based on the correlation shown in the following table (Terzaghi and Peck, 1967). The correlation to SPT N-Value is used with caution as it is only very approximate.

Consistency	Undrained Shear Strength		Approximate SPT N-Value
	kips/sq.ft.	kPa	
Very Soft	<0.25	<12.5	<2
Soft	0.25 - 0.5	12.5 - 25	2-4
Firm	0.5 - 1.0	25 - 50	4-8
Stiff	1.0 - 2.0	50 - 100	8-15
Very Stiff	2.0 - 4.0	100 - 200	15-30
Hard	>4.0	>200	>30

ROCK DESCRIPTION

Except where specified below, terminology for describing rock is as defined by the International Society for Rock Mechanics (ISRM) 2007 publication "The Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006"

Terminology describing rock quality:

RQD	Rock Mass Quality
0-25	Very Poor Quality
25-50	Poor Quality
50-75	Fair Quality
75-90	Good Quality
90-100	Excellent Quality

Alternate (Colloquial) Rock Mass Quality	
Very Severely Fractured	Crushed
Severely Fractured	Shattered or Very Blocky
Fractured	Blocky
Moderately Jointed	Sound
Intact	Very Sound

RQD (Rock Quality Designation) denotes the percentage of intact and sound rock retrieved from a borehole of any orientation. All pieces of intact and sound rock core equal to or greater than 100 mm (4 in.) long are summed and divided by the total length of the core run. RQD is determined in accordance with ASTM D6032.

SCR (Solid Core Recovery) denotes the percentage of solid core (cylindrical) retrieved from a borehole of any orientation. All pieces of solid (cylindrical) core are summed and divided by the total length of the core run (it excludes all portions of core pieces that are not fully cylindrical as well as crushed or rubble zones).

Fracture Index (FI) is defined as the number of naturally occurring fractures within a given length of core. The Fracture Index is reported as a simple count of natural occurring fractures.

Terminology describing rock with respect to discontinuity and bedding spacing:

Spacing (mm)	Discontinuities	Bedding
>6000	Extremely Wide	-
2000-6000	Very Wide	Very Thick
600-2000	Wide	Thick
200-600	Moderate	Medium
60-200	Close	Thin
20-60	Very Close	Very Thin
<20	Extremely Close	Laminated
<6	-	Thinly Laminated

Terminology describing rock strength:

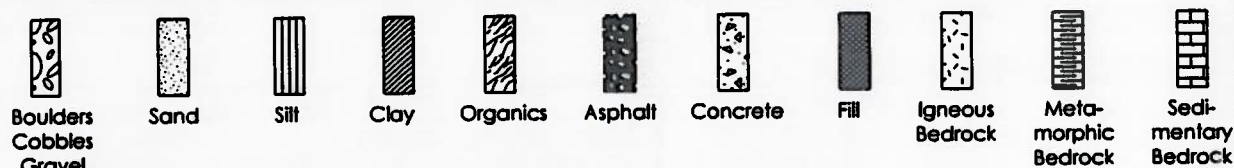
Strength Classification	Grade	Unconfined Compressive Strength (MPa)
Extremely Weak	R0	<1
Very Weak	R1	1 - 5
Weak	R2	5 - 25
Medium Strong	R3	25 - 50
Strong	R4	50 - 100
Very Strong	R5	100 - 250
Extremely Strong	R6	>250

Terminology describing rock weathering:

Term	Symbol	Description
Fresh	W1	No visible signs of rock weathering. Slight discoloration along major discontinuities
Slightly	W2	Discoloration indicates weathering of rock on discontinuity surfaces. All the rock material may be discolored.
Moderately	W3	Less than half the rock is decomposed and/or disintegrated into soil.
Highly	W4	More than half the rock is decomposed and/or disintegrated into soil.
Completely	W5	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.
Residual Soil	W6	All the rock converted to soil. Structure and fabric destroyed.

STRATA PLOT

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



SAMPLE TYPE

SS	Split spoon sample (obtained by performing the Standard Penetration Test)
ST	Shelby tube or thin wall tube
DP	Direct-Push sample (small diameter tube sampler hydraulically advanced)
PS	Piston sample
BS	Bulk sample
HQ, NQ, BQ, etc.	Rock core samples obtained with the use of standard size diamond coring bits.

WATER LEVEL MEASUREMENT



measured in standpipe, piezometer, or well



inferred

RECOVERY

For soil samples, the recovery is recorded as the length of the soil sample recovered. For rock core, recovery is defined as the total cumulative length of all core recovered in the core barrel divided by the length drilled and is recorded as a percentage on a per run basis.

N-VALUE

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 140 pound (63.5 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (300 mm) into the soil. In accordance with ASTM D1586, the N-Value equals the sum of the number of blows (N) required to drive the sampler over the interval of 6 to 18 in. (150 to 450 mm). However, when a 24 in. (610 mm) sampler is used, the number of blows (N) required to drive the sampler over the interval of 12 to 24 in. (300 to 610 mm) may be reported if this value is lower. For split spoon samples where insufficient penetration was achieved and N-Values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50/75). Some design methods make use of N-values corrected for various factors such as overburden pressure, energy ratio, borehole diameter, etc. No corrections have been applied to the N-values presented on the log.

DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to 'A' size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone one foot (300 mm) into the soil. The DCPT is used as a probe to assess soil variability.

OTHER TESTS

S	Sieve analysis
H	Hydrometer analysis
k	Laboratory permeability
y	Unit weight
G _s	Specific gravity of soil particles
CD	Consolidated drained triaxial
CU	Consolidated undrained triaxial with pore pressure measurements
UU	Unconsolidated undrained triaxial
DS	Direct Shear
C	Consolidation
Q _u	Unconfined compression
I _p	Point Load Index (I _p on Borehole Record equals I _p (50) in which the index is corrected to a reference diameter of 50 mm)

	Single packer permeability test; test interval from depth shown to bottom of borehole
	Double packer permeability test; test interval as indicated
	Falling head permeability test using casing
	Falling head permeability test using well point or piezometer



RECORD OF BOREHOLE No S3C3-1

1 OF 4

METRIC

PROJECT # 110901255

PROJECT Enbridge GTA Project - DE Phase

W.P. NA

LOCATION S3C3 Highway 401

N: 4 827 992 E: 597 420 ORIGINATED BY MJarvis

DIST NA HWY 401

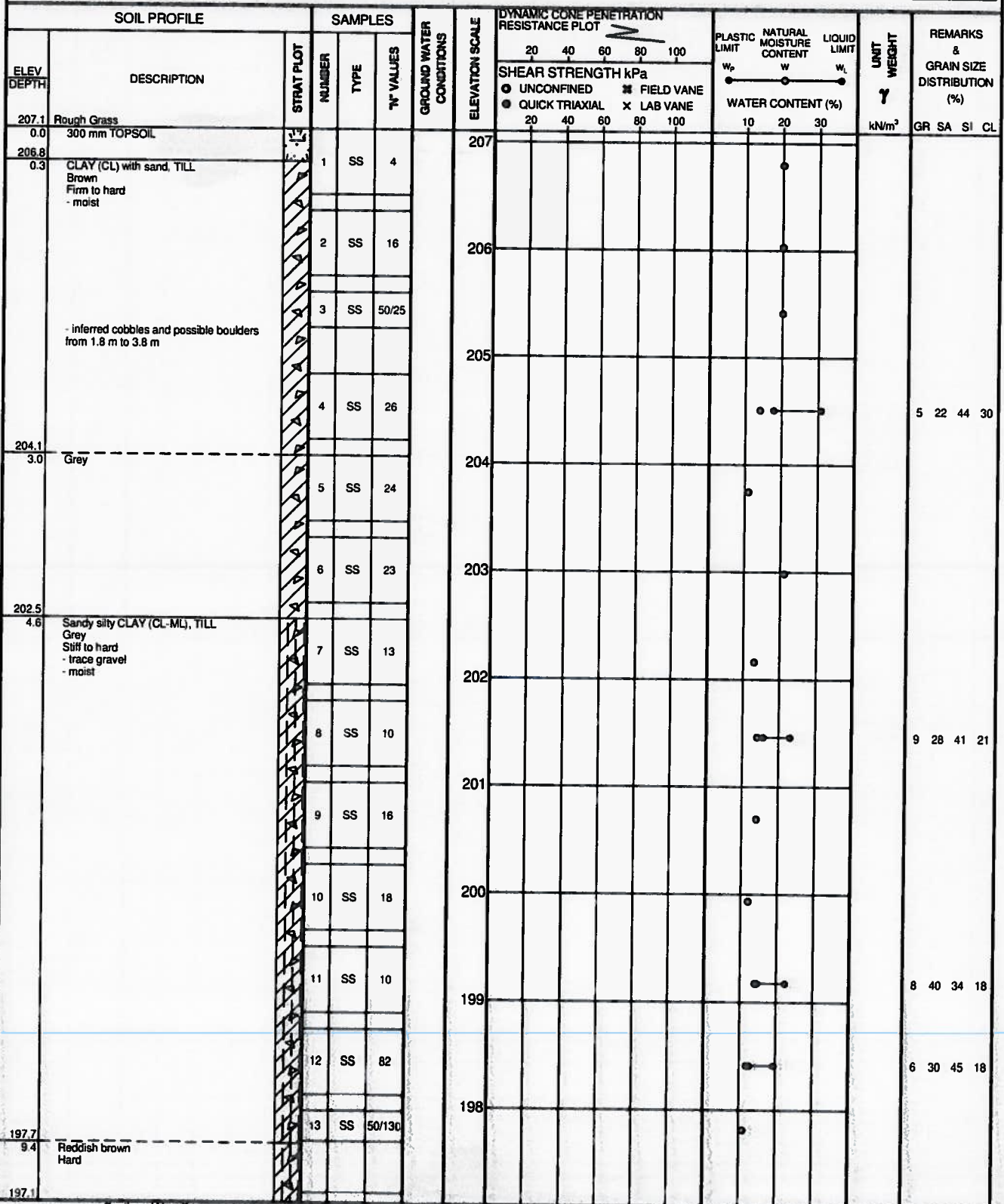
BOREHOLE TYPE CME, Hollow Stem Auger

COMPILED BY KRefahi

DATUM Geodetic

DATE October 3, 2013

CHECKED BY RHache



Continued Next Page

x³ x³ Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC S3C3-MTO.GPJ STANTEC MARKHAM.GDT 1/12/15



RECORD OF BOREHOLE No S3C3-1

2 OF 4

METRIC

PROJECT # 110901255 PROJECT Enbridge GTA Project - DE Phase
W.P. NA LOCATION S3C3 Highway 401 N: 4 827 992 E: 597 420 ORIGINATED BY MJanis
DIST NA HWY 401 BOREHOLE TYPE CME, Hollow Stem Auger COMPILED BY KRefahi
DATUM Geodetic DATE October 3, 2013 CHECKED BY RHache

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					
							20 40 60 80 100						
							20 40 60 80 100						

STN13-ONTARIO MTO STANTEC S3C3-MTO.GPJ STANTEC MARKHAM.GDT 1/12/15

Continued Next Page

x 3 x 3

Numbers refer to
Sensitivity

3% STRAIN AT FAILURE

PROJECT # 110901255

PROJECT Enbridge GTA Project - DE Phase

W.P. NA

LOCATION S3C3 Highway 401

N: 4 827 992 E: 597 420 ORIGINATED BY MJarjis

DIST NA HWY 401

BOREHOLE TYPE CME, Hollow Stem Auger

COMPILED BY KRafah

DATUM Geodetic

DATE October 3, 2013

CHECKED BY RHache

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	20	40						60	80	100	WATER CONTENT (%)	GR	SA	SI	CL
							SHEAR STRENGTH kPa															
							● UNCONFINED	⊠ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE												
20.0	Fair to excellent quality, reddish brown and greyish green SHALE with very thinly to thinly laminated limestone interbedding (Queenston Formation) - moderately weathered to unweathered - very close to close joint spacing - flat bedding oriented less than 20 deg. from horizontal - occasional clay soil layers up to 30 mm thick		4	HQ		187										TCR=95% SCR=91% RQD=83%						
						186																
	- 150 mm clay soil layer at 22.1 m below existing grade		5	HQ		185										TCR=100% SCR=84% RQD=65%						
						184																
			6	HQ		183										TCR=97% SCR=80% RQD=79%						
						182																
			7	HQ		181										TCR=100% SCR=97% RQD=88%						
						180										TCR=96% SCR=95% RQD=95%						
						179																
			9	HQ		178										TCR=100% SCR=100% RQD=100%						

STN13-ONTARIO MTO STANTEC S3C3-MTO.QPJ STANTEC MARKHAM.GDT 1/12/15

177.1

Continued Next Page

✕³, ×³ Numbers refer to Sensitivity

③ 3% STRAIN AT FAILURE

PROJECT # 110901255

PROJECT Enbridge GTA Project - DE Phase

W.P. NA

LOCATION S3C3 Highway 401

N: 4 827 992 E: 597 420 ORIGINATED BY MJarjis

DIST NA HWY 401

BOREHOLE TYPE CME, Hollow Stem Auger

COMPILED BY KRefahi

DATUM Geodetic

DATE October 3, 2013

CHECKED BY RHache

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE LIQUID LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
								20	40	60	80	100			20	40	60	80	100	10	20	30																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										

STN13-ONTARIO MTO STANTEC S3C3-MTO.GPJ STANTEC MARKHAM.GDT 1/12/15

✕³ ✕³ Numbers refer to Sensitivity

3% STRAIN AT FAILURE



RECORD OF BOREHOLE No S3C3-2

1 OF 4

METRIC

PROJECT # 110901255

PROJECT Enbridge GTA Project - DE Phase

W.P. NA

LOCATION S3C3 Highway 401

N: 4 828 051 E: 597 405

ORIGINATED BY JZhou

DIST NA HWY 401

BOREHOLE TYPE CME, Hollow Stem Augers

COMPILED BY KRefahi

DATUM Geodetic

DATE June 5, 2014

CHECKED BY RHache

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						
207.2	Rough Grass							20 40 60 80 100						
0.0	200 mm TOPSOIL							20 40 60 80 100						
207.0														
0.2	CLAY with sand (CL), TILL Brown Firm to very stiff - trace gravel - moist		1	SS	5		207							
			2	SS	13		206							
			3	SS	19		205							4 25 44 27
204.6			4	SS	30		204							
2.6	Sandy silty CLAY (CL-ML) to sandy silty CLAY (CL-ML) with gravel, TILL Brown Very stiff to firm - moist		5	SS	24		203							15 30 41 14
			6	SS	24		202							
			7	SS	7		201							
			8	SS	9		200							
			9	SS	8		199							7 32 39 22
200.3			10	SS	5		198							
6.9	Grey Firm to soft - wet		11	SS	3									
			12	SS	11									
198.8			13	SS	47									8 62 21 9
8.4	Silty clayey SAND (SC-SM), TILL Grey compact to dense - trace gravel - wet													

STN13-ONTARIO MTO STANTEC S3C3-MTO.GPJ STANTEC MARKHAM.GDT 1/12/15

Continued Next Page

x³ x³ Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE



RECORD OF BOREHOLE No S3C3-2

2 OF 4

METRIC

PROJECT # 110901255

PROJECT Enbridge GTA Project - DE Phase

W.P. NA

LOCATION S3C3 Highway 401

N: 4 829 051 E: 597 405 ORIGINATED BY JZhou

DIST NA HWY 401

BOREHOLE TYPE CME, Hollow Stem Augers

COMPILED BY KRefahi

DATUM Geodetic

DATE June 5, 2014

CHECKED BY RHache

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
								20 40 60 80 100							
								● UNCONFINED ✕ FIELD VANE							
								● QUICK TRIAXIAL ✕ LAB VANE							
								20 40 60 80 100	20 40 60 80 100	20 40 60 80 100					
198.8			14	SS	57		197								
10.4	Sandy CLAY (CL), TILL Reddish brown Hard - trace gravel - moist		15	SS	50/76		196								
			16	SS	66		195								
			17	SS	50/130		194								
			18	SS	50/76		193								
193.6			19	SS	50/100		192								
13.6	Inferred BEDROCK (Queenston Formation) Reddish brown - completely to highly weathered shale (soil-like consistency)		20	SS	50/51		191								
192.9			1	HQ			190								
14.3	SHALE with very thinly to thinly laminated limestone interbedding (Queenston Formation) Reddish brown and grey Fair to excellent quality - moderately to slightly weathered - very close to close joint spacing - flat bedding oriented less than 20 deg. from horizontal		2	HQ			189								
			3	HQ			188								
			4	HQ											
187.2															

Continued Next Page

x³ x³Numbers refer to
Sensitivity○^{3%}

STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC S3C3-MTO.GPJ STANTEC MARKHAM.GDT 1/12/15

PROJECT # 110901255

PROJECT Enbridge GTA Project - DE Phase

W.P. NA

LOCATION S3C3 Highway 401

N: 4 828 051 E: 597 405 ORIGINATED BY JZhou

DIST NA HWY 401

BOREHOLE TYPE CME, Hollow Stem Augers

COMPILED BY KRefahi

DATUM Geodetic

DATE June 5, 2014

CHECKED BY RHache

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20 40 60 80 100					
20.0	SHALE with very thinly to thinly laminated limestone interbedding (Queenston Formation) Reddish brown and grey Good to excellent quality - slightly weathered - very close to moderate joint spacing - flat bedding oriented less than 20 deg. from horizontal		5	HQ		187							TCR=97% SCR=92% RQD=83%
			6	HQ		185							TCR=97% SCR=97% RQD=97%
			7	HQ		183							TCR=98% SCR=98% RQD=98%
			8	HQ		182							TCR=100% SCR=100% RQD=100%
			9	HQ		180							TCR=100% SCR=100% RQD=100%
			10	HQ		179							TCR=100% SCR=100% RQD=100%
						178							

177.2

Continued Next Page

3 x 3 Numbers refer to Sensitivity

● 3% STRAIN AT FAILURE



RECORD OF BOREHOLE No S3C3-2

4 OF 4

METRIC

PROJECT # 110901255

PROJECT Enbridge GTA Project - DE Phase

W.P. NA

LOCATION S3C3 Highway 401

N: 4 828 051 E: 597 405 ORIGINATED BY JZhou

DIST NA HWY 401

BOREHOLE TYPE CME, Hollow Stem Augers

COMPILED BY KRefahi

DATUM Geodetic

DATE June 5, 2014

CHECKED BY RHache

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
							20	40	60	80	100					
							20	40	60	80	100					
30.0	SHALE with very thin to thin laminated limestone interbedding (Queenston Formation) Reddish brown and grey Excellent quality - slightly weathered - moderate joint spacing - flat bedding oriented less than 20 deg. from horizontal END OF BOREHOLE at approximately 30.7 m below existing grade. Groundwater level not recorded due to the introduction of water for rock coring.		11	HQ		177										TCR=100% SCR=100% ROD=100%
176.5																
30.7																

STN3-ONTARIO MTO STANTEC S3C3-MTO.GPJ STANTEC MARKHAM.GDT 1/12/15

x³ x³ Numbers refer to Sensitivity○³ STRAIN AT FAILURE

**Stantec****RECORD OF BOREHOLE No S3C3-3**

1 OF 4

METRIC

PROJECT # 110901255

PROJECT Enbridge GTA Project - DE Phase

W.P. NA

LOCATION S3C3 Highway 401

N: 4 828 130 E: 597 350

ORIGINATED BY RSroebel

DIST NA HWY 401

BOREHOLE TYPE CME, Hollow Stem Augers

COMPILED BY KRefahi

DATUM Geodetic

DATE June 5, 2014

CHECKED BY RHache

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	W _u VALUES			20 40 60 80 100	20 40 60 80 100					
207.2	Rough Grass													
0.0	250 mm TOPSOIL													
206.9														
0.3	CLAY (CL) with sand, TILL Brown Firm to hard - trace gravel - damp to moist		1	SS	3		207							
			2	SS	9		206							1 17 49 33
			3	SS	13		205							
			4	SS	34		204							
			5	SS	29		203							3 25 40 32
203.4			6	SS	15		202							
3.8	Grey		7	SS	11		201							
			8	SS	10		200							2 31 35 32
201.1			9	SS	9		199							
6.1	Sandy CLAY (CL), TILL Grey Stiff to firm - trace gravel - moist		10	SS	4		198							Non-Plastic
			11	SS	4									4 54 34 8
	- wet		12	SS	5									
198.1			13	SS	66									
9.1	Silty SAND (SM), TILL Grey Very dense													
197.2														

Continued Next Page

x³ x³Numbers refer to
Sensitivity

○ 3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC S3C3-MTO.GPJ STANTEC MARKHAM.GDT 1/12/15



RECORD OF BOREHOLE No S3C3-3

2 OF 4

METRIC

PROJECT # 110901255

PROJECT Enbridge GTA Project - DE Phase

W.P. NA

LOCATION S3C3 Highway 401

N: 4 828 130 E: 597 358

ORIGINATED BY RStroebel

DIST NA HWY 401

BOREHOLE TYPE CME, Hollow Stem Augers

COMPILED BY KRefahi

DATUM Geodetic

DATE June 5, 2014

CHECKED BY RHache

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	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100					
10.0	Silty SAND (SM), TILL Grey Very dense - trace clay - trace gravel - moist		14	SS	100/100								
196.8													
10.4	Silty clayey SAND (SC-SM), TILL Reddish brown Very dense - trace gravel - moist to damp - inferred cobbles and boulders from 11.0 m to 13.0 m		15	SS	100/100								
			16	SS	100/75								
			17	SS	100/125								
			18	SS	100/100								
			19	SS	100/75								
193.0													13 49 30 8
14.2	Inferred BEDROCK (Queenston Formation) Reddish brown - completely to highly weathered shale (soil-like consistency)		20	SS	100/25								
192.2													
15.0	SHALE with very thinly to thinly laminated limestone interbedding (Queenston Formation) Reddish brown and grey Good quality - moderately to slightly weathered - very close to close joint spacing - flat bedding oriented less than 20 deg. from horizontal		1	HQ									TCR=100% SCR=94% RQD=80%
			2	HQ									TCR=100% SCR=92% RQD=88%
			3	HQ									TCR=100% SCR=100% RQD=87%
187.2													

STN13-ONTARIO MTO STANTEC S3C3-MTO.GPJ STANTEC MARKHAM.GDT 1/12/15

Continued Next Page

x³ x³Numbers refer to
Sensitivity

○ 3% STRAIN AT FAILURE



RECORD OF BOREHOLE No S3C3-3

3 OF 4

METRIC

PROJECT # 110901255

PROJECT

Enbridge GTA Project - DE Phase

W.P. NA

LOCATION

S3C3 Highway 401

N: 4 828 130 E: 597 358

ORIGINATED BY RStroebe

DIST NA

HWY 401

BOREHOLE TYPE CME, Hollow Stem Augers

COMPILED BY KRefahi

DATUM Geodetic

DATE

June 5, 2014

CHECKED BY RHache

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			20	40	60	80	100		
							SHEAR STRENGTH kPa						
							● UNCONFINED ✖ FIELD VANE						
							● QUICK TRIAXIAL ✖ LAB VANE						
							20	40	60	80	100		
							PLASTIC NATURAL LIQUID						
							LIMIT MOISTURE LIMIT						
							W _p W W _L						
							WATER CONTENT (%)						
							10	20	30				
20.0	SHALE with very thin to thin laminated limestone interbedding (Queenston Formation) Reddish brown and grey Fair to excellent quality - moderately to slightly weathered - very close to close joint spacing - flat bedding oriented less than 20 deg. from horizontal		4	HQ		187							TCR=100% SCR=100% RQD=95%
			5	HQ		186							TCR=95% SCR=87% RQD=53%
			6	HQ		184							TCR=100% SCR=96% RQD=87%
			7	HQ		183							TCR=100% SCR=100% RQD=91%
			8	HQ		181							TCR=100% SCR=100% RQD=93%
			9	HQ		179							TCR=100% SCR=98% RQD=97%
			10	HQ		178							TCR=100% SCR=94% RQD=87%

Continued Next Page

✖ 3 ✖ 3

Numbers refer to
Sensitivity

⊙ 3%

STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC S3C3-MTO.GPJ STANTEC MARKHAM.GDT 1/12/15



RECORD OF BOREHOLE No S3C3-3

4 OF 4

METRIC

PROJECT # 110901255

PROJECT Enbridge GTA Project - DE Phase

W.P. NA

LOCATION S3C3 Highway 401

N: 4 828 130 E: 597 358 ORIGINATED BY RStroebel

DIST NA HWY 401

BOREHOLE TYPE CME, Hollow Stem Augers

COMPILED BY KRefahi

DATUM Geodetic

DATE June 5, 2014

CHECKED BY RHache

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 (%)			
							20	40	60	80	100		10	20	30		GR	SA	SI	CL
176.7						177														
30.5	END OF BOREHOLE at approximately 30.5 m below existing grade. Groundwater level not recorded due to the introduction of water for rock coring.																			

STN13-ONTARIO MTO STANTEC S3C3-MTO.GPJ STANTEC MARKHAM.GDT 1/12/15

x³ x³

Numbers refer to Sensitivity

○³% STRAIN AT FAILURE



RECORD OF BOREHOLE No S3C3-4

1 OF 4

METRIC

PROJECT # 110901255

PROJECT Enbridge GTA Project - DE Phase

W.P. NA

LOCATION S3C3 Highway 401

N: 4 020 295 E: 597 393

ORIGINATED BY MJarvis

DIST NA HWY 401

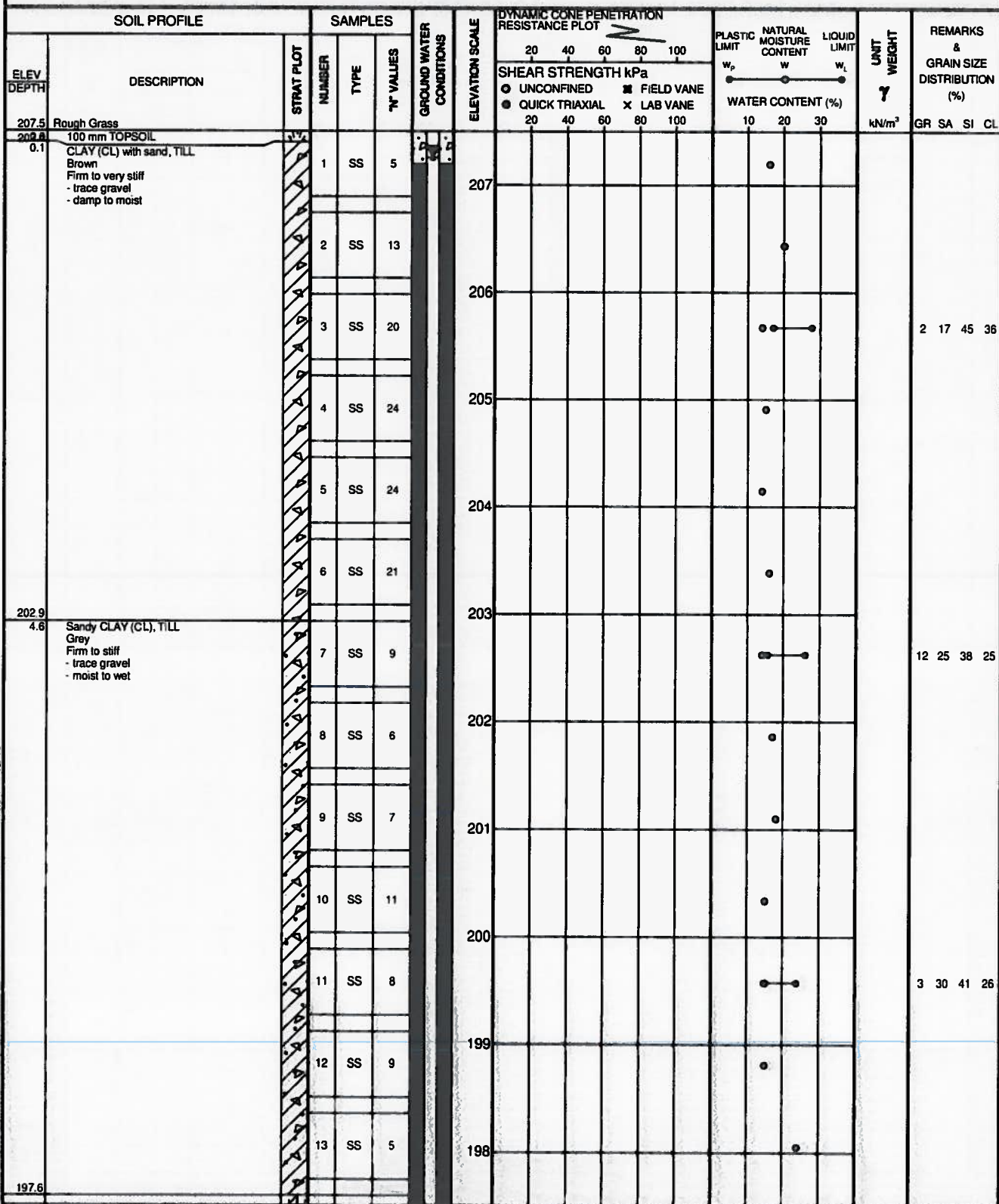
BOREHOLE TYPE CME, Hollow Stem Augers

COMPILED BY KRefahi

DATUM Geodetic

DATE September 26, 2013

CHECKED BY RHache



Continued Next Page

x 3 x 3

Numbers refer to Sensitivity

○ 3%

STRAIN AT FAILURE



RECORD OF BOREHOLE No S3C3-4

2 OF 4

METRIC

PROJECT # 110901255

PROJECT Enbridge GTA Project - DE Phase

W.P. NA

LOCATION S3C3 Highway 401

N: 4 828 295 E: 597 393 ORIGINATED BY MJanis

DIST NA HWY 401

BOREHOLE TYPE CME, Hollow Stem Augers

COMPILED BY KRefahi

DATUM Geodetic

DATE September 26, 2013

CHECKED BY RHache

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
							● UNCONFINED	✱ FIELD VANE							
							● QUICK TRIAXIAL	✱ LAB VANE							
							20 40 60 80 100	20 40 60 80 100							
9.9	Sandy silty CLAY (CL-ML), TILL Grey Stiff to hard - trace gravel - moist		14	SS	25										
			15	SS	32										9 35 39 17
			16	SS	10										
			17	SS	74										
194.5			18	SS	50/130										
13.0	Reddish brown Hard		19	SS	50/100										
			20	SS	50/130										
			21	SS	50/130										
			22	SS	50/130										4 32 43 21
			23	SS	50/130										
190.2			24	SS	50/100										
17.3	Inferred BEDROCK (Queenston Formation) Reddish brown - completely to highly weathered shale (soil-like consistency)		25	SS	50/25										
188.8															
187	SHALE with very thinly to thinly laminated limestone interbedding (Queenston Formation) Reddish brown and grey Fair quality - moderately to slightly weathered		1	HQ											TCR=94% SCR=73% ROD=73%
187.5															

STN13-ONTARIO MTO STANTEC S3C3-MTO.GPJ STANTEC MARKHAM.GDT 1/12/15

Continued Next Page

✱ 3 x 3

Numbers refer to Sensitivity

● 3% STRAIN AT FAILURE



RECORD OF BOREHOLE No S3C3-4

3 OF 4

METRIC

PROJECT # 110901255

PROJECT Enbridge GTA Project - DE Phase

W.P. NA

LOCATION S3C3 Highway 401

N: 4 825 295 E: 597 393 ORIGINATED BY MJarvis

DIST NA HWY 401

BOREHOLE TYPE CME, Hollow Stem Augers

COMPILED BY KRefahi

DATUM Geodetic

DATE September 26, 2013

CHECKED BY RHache

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa							WATER CONTENT (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
								● UNCONFINED	✕ FIELD VANE							● QUICK TRIAXIAL	✕ LAB VANE																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
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Continued Next Page

✕³ ✕³ Numbers refer to
Sensitivity

● 3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC S3C3-MTO.GPJ STANTEC MARKHAM.GDT 1/12/15



RECORD OF BOREHOLE No S3C3-4

4 OF 4

METRIC

PROJECT # 110901255

PROJECT Enbridge GTA Project - DE Phase

W.P. NA

LOCATION S3C3 Highway 401

N: 4 828 295 E: 597 393 ORIGINATED BY MJarjis

DIST NA HWY 401

BORE HOLE TYPE CME, Hollow Stem Augers

COMPILED BY KRefahi

DATUM Geodetic

DATE September 26, 2013

CHECKED BY RHache

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							
								20 40 60 80 100							
								● UNCONFINED ✕ FIELD VANE							
								● QUICK TRIAXIAL ✕ LAB VANE							
								20 40 60 80 100							
30.0	SHALE with very thinly to thinly laminated limestone interbedding (Queenston Formation) Reddish brown and grey Excellent quality - moderately to slightly weathered - close to moderate joint spacing - flat bedding oriented less than 20 deg. from horizontal		9	HQ			177								TCR=100% SCR=97% RQD=97%
							176								TCR=100% SCR=96% RQD=96%
			10	HQ			175								TCR=100% SCR=96% RQD=96%
							174								
			11	HQ			173								TCR=98% SCR=97% RQD=97%
172.4															
35.1	END OF BOREHOLE at approximately 35.1 m below existing grade. Groundwater monitoring well installed with a screen from approximately 13.7 m to 15.2 m below existing grade. Groundwater level measured at approximately 1.0 m and 0.8 m below existing grade on October 7, 2013 and February 25, 2014, respectively.														

STN13-ONTARIO MTO STANTEC S3C3-MTO.GPJ STANTEC MARKHAM.GDT 1/12/15

✱ 3 ✱ 3

Numbers refer to Sensitivity

● 3%

STRAIN AT FAILURE



RECORD OF BOREHOLE No S3C3-5

1 OF 4

METRIC

PROJECT # 110901255

PROJECT Enbridge GTA Project - DE Phase

W.P. NA

LOCATION S3C3 Highway 401

N: 4 829 091 E: 597 392 ORIGINATED BY RStroebel

DIST NA HWY 401

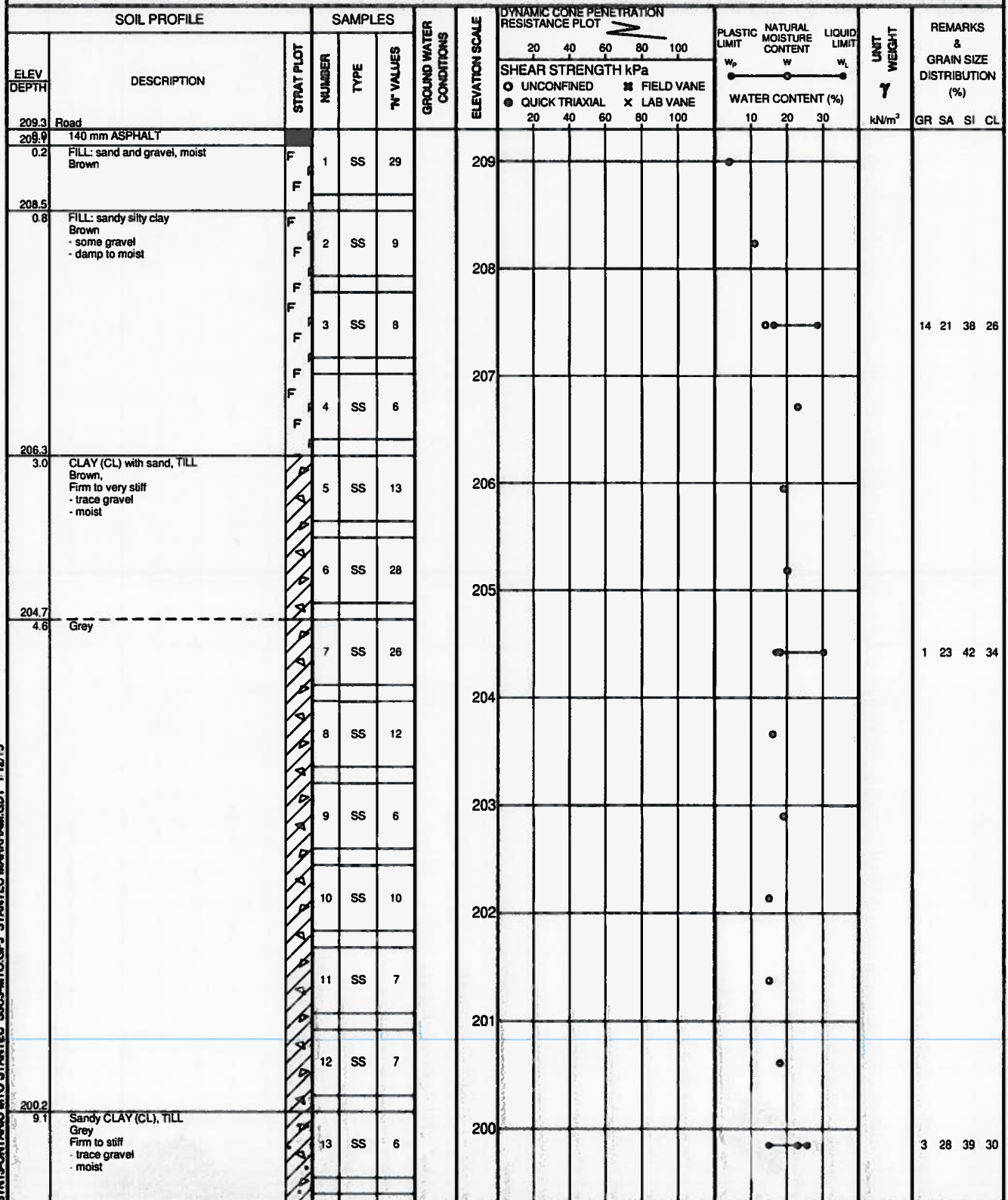
BOREHOLE TYPE CME, Hollow Stem Augers

COMPILED BY KRefahi

DATUM Geodetic

DATE May 31, 2014

CHECKED BY RHache



Continued Next Page

x 3 x 3

Numbers refer to Sensitivity

○ 3%

STRAIN AT FAILURE



RECORD OF BOREHOLE No S3C3-5

2 OF 4

METRIC

PROJECT # 110901255

PROJECT Enbridge GTA Project - DE Phase

W.P. NA

LOCATION S3C3 Highway 401

N: 4 828 091 E: 597 382 ORIGINATED BY RStroebel

DIST NA HWY 401

BOREHOLE TYPE CME, Hollow Stem Augers

COMPILED BY KRefahi

DATUM Geodetic

DATE May 31, 2014

CHECKED BY RHache

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)			
								● UNCONFINED	■ FIELD VANE	● QUICK TRIAXIAL							× LAB VANE		
							20	40	60	80	100	10	20	30	GR	SA	SI	CL	
198.6	Sandy silty CLAY (CL-ML), TILL Grey Very stiff to hard - trace gravel - moist		14	SS	12														
10.7																			
			15	SS	20														
			16	SS	86														
			17	SS	100/100														
196.3	Silty clayey SAND (SC-SM) with gravel, TILL Reddish brown Very dense - trace gravel - moist																		
13.0																			
			18	SS	100/250														
			19	SS	100/100														
195.1	Inferred BEDROCK (Queenston Formation) Reddish brown - completely to highly weathered shale (soil-like consistency)																		
14.2																			
			20	SS	100/75														
			21	SS	100/100														
193.2	SHALE with very thinly to thinly laminated limestone interbedding (Queenston Formation) Reddish brown and grey Poor to excellent quality - moderately to slightly weathered - very close to moderate joint spacing - flat bedding oriented less than 20 deg. from horizontal		22	SS	100/50														
16.1																			
			1	HQ															
			2	HQ															
			3	HQ															
189.3																			

STN13-ONTARIO MTO STANTEC S3C3-MTO.GPJ STANTEC MARKHAM.GDT 1/12/15

Continued Next Page

× 3 × 3

Numbers refer to
Sensitivity

○ 3%

STRAIN AT FAILURE



Stantec

RECORD OF BOREHOLE No S3C3-5

3 OF 4

METRIC

PROJECT # 110901255

PROJECT Enbridge GTA Project - DE Phase

W.P. NA

LOCATION S3C3 Highway 401

N: 4 829 091 E: 597 392 ORIGINATED BY RStroebe

DIST NA HWY 401

BOREHOLE TYPE CME, Hollow Stem Augers

COMPILED BY KRefahi

DATUM Geodetic

DATE May 31, 2014

CHECKED BY RHache

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)
								● UNCONFINED	✱ FIELD VANE	● QUICK TRIAXIAL						
							20	40	60	80	100					
20.0	SHAILE with very thinly to thinly laminated limestone interbedding (Queenston Formation) Reddish brown and grey Poor to excellent quality - moderately to slightly weathered - very close to moderate joint spacing - flat bedding oriented less than 20 deg. from horizontal		4	HQ			189								TCR=100% SCR=99% RQD=97%	
								188								
								187								TCR=100% SCR=98% RQD=83%
								186								
					6	HQ			185							TCR=100% SCR=75% RQD=33%
									184							
					7	HQ			183							TCR=100% SCR=98% RQD=94%
									182							
					8	HQ			181							TCR=100% SCR=100% RQD=98%
							180									
			9	HQ											TCR=100% SCR=99% RQD=97%	

Continued Next Page

✱ 3 x 3

Numbers refer to
Sensitivity

○ 3%

STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC S3C3-MTO.GPJ STANTEC MARKHAM.GDT 1/12/15



RECORD OF BOREHOLE No S3C3-5

4 OF 4

METRIC

PROJECT # 110901255

PROJECT Enbridge GTA Project - DE Phase

W.P. NA

LOCATION S3C3 Highway 401

N: 4 828 091 E: 597 362 ORIGINATED BY RStroebel

DIST NA HWY 401

BOREHOLE TYPE CME, Hollow Stem Augers

COMPILED BY KRefahi

DATUM Geodetic

DATE May 31, 2014

CHECKED BY RHache

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
							20	40	60	80	100					
							20	40	60	80	100					
178.3	SHALE with very thinly to thinly laminated limestone interbedding (Queenston Formation) Reddish brown and grey Excellent quality - slightly weathered - moderate joint spacing - flat bedding oriented less than 20 deg. from horizontal		10	HQ			179									
31.0	END OF BOREHOLE at approximately 31.0 m below existing grade. Groundwater level not recorded due to the introduction of water for rock coring.															

STN13-ONTARIO MTO STANTEC S3C3-MTO.GPJ STANTEC MARKHAM.GDT 1/12/15

x 3 x 3

Numbers refer to Sensitivity

○ 3%

STRAIN AT FAILURE

**FOUNDATION INVESTIGATION AND DESIGN REPORT GTA PROJECT DETAILED
ENGINEERING DESIGN PHASE DOCUMENT NO.: 110901255.085 PROJECT NO.: 110901255**

Appendix D

2015-01-12

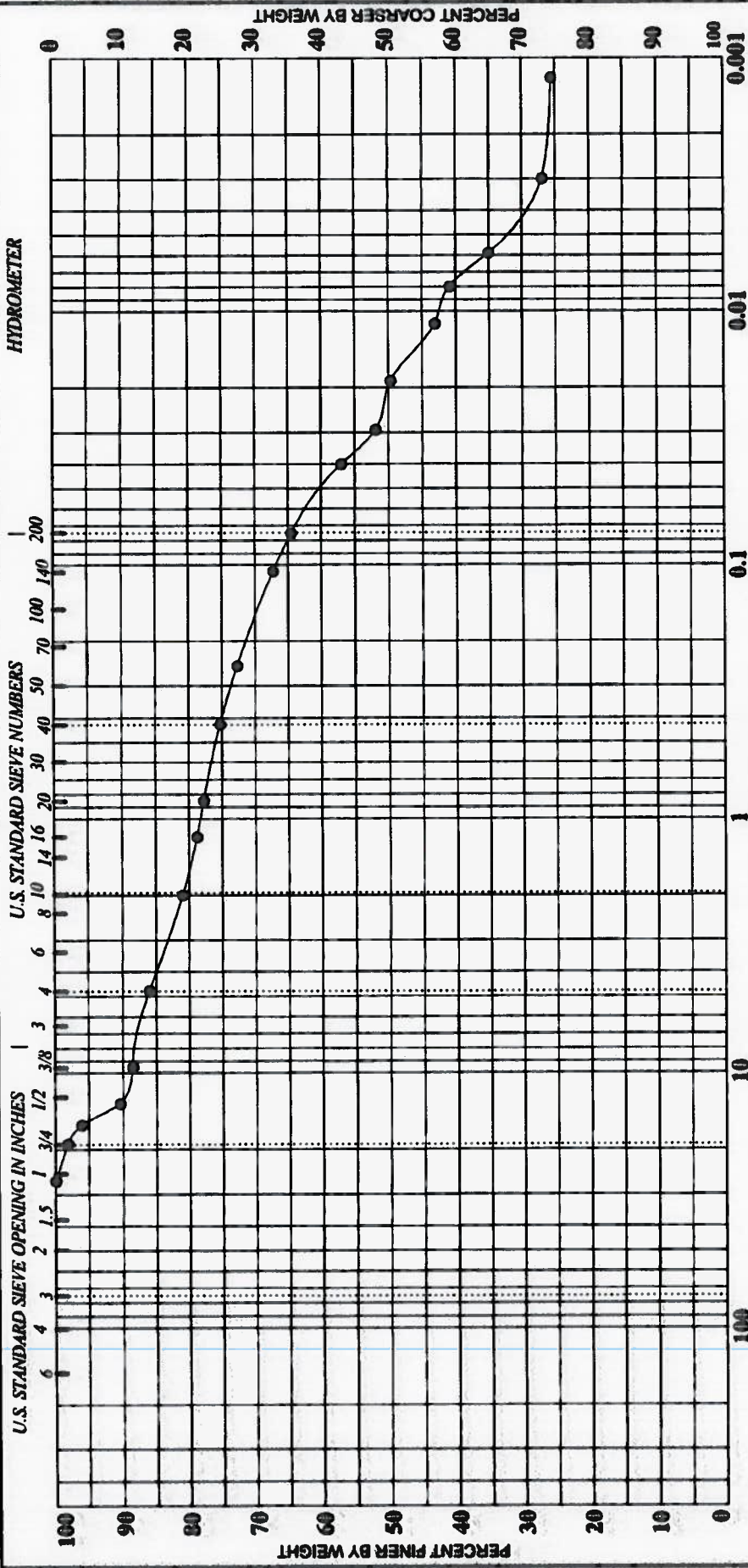
Appendix D

D.1 GEOTECHNICAL LABORATORY TEST RESULTS



Stantec

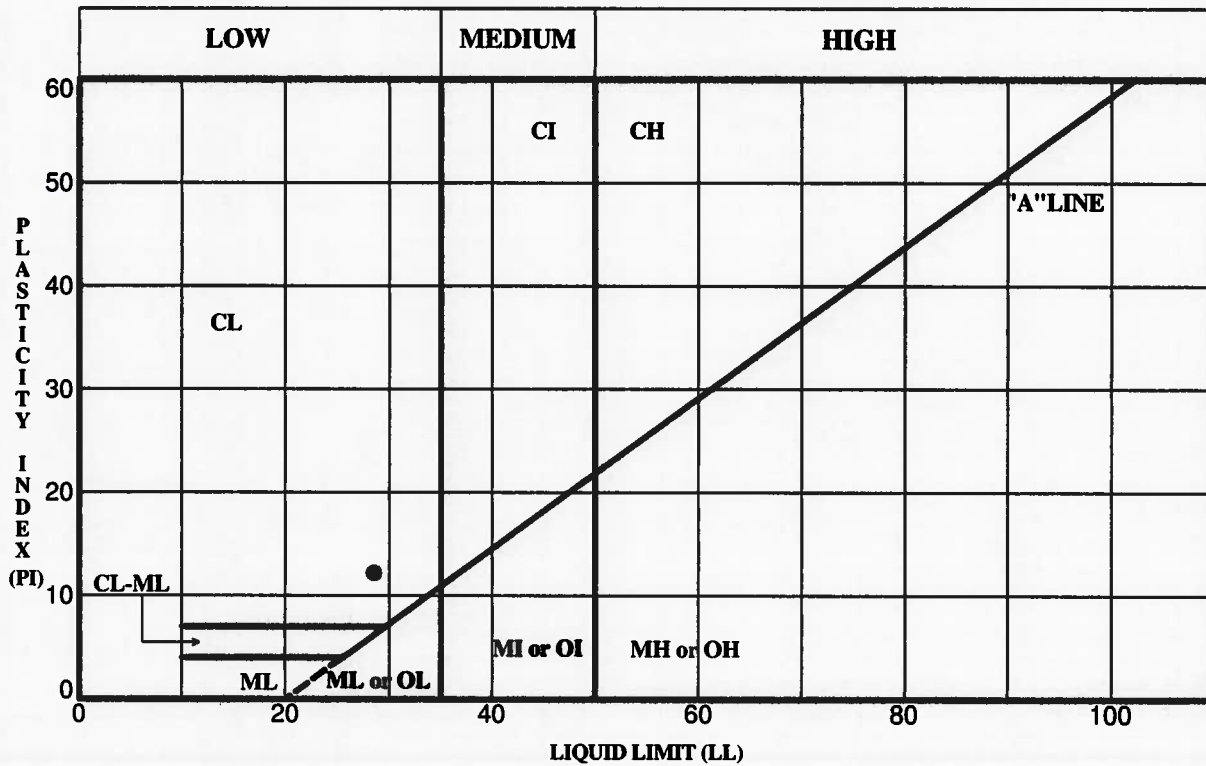
ct \\cd\159-f06\shared_projects\110901255\10-0_geotechnical\10-10_reports\3_hdd\110901255.085 - s3c3 highway 401\rev
2\110901255.085r2_geo_rpt_s3c3_20150112.docx

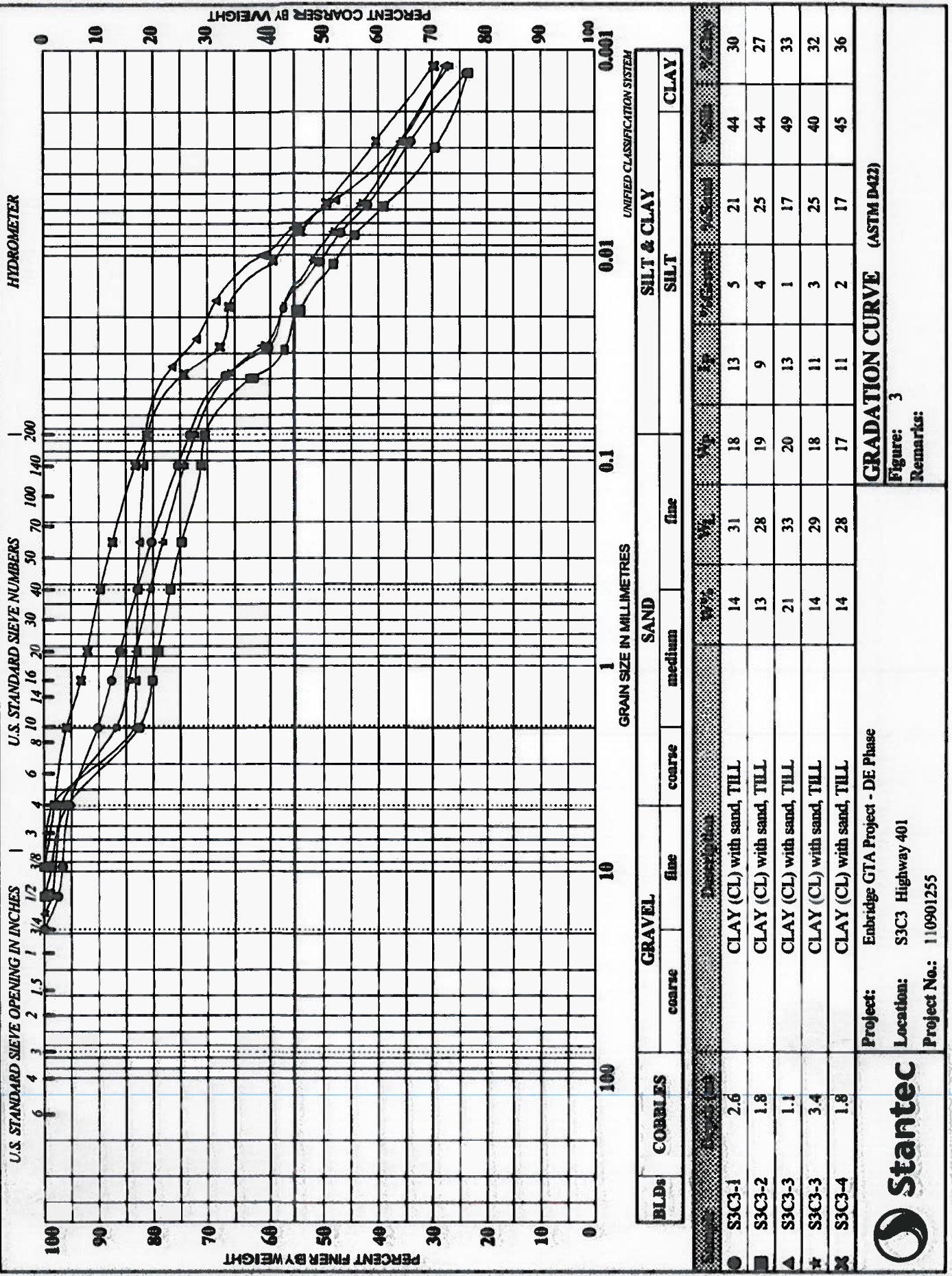


GRAVEL			SAND			SILT & CLAY		
BLD	COBBLES		coarse	fine		coarse	fine	
Description			Description			Description		
●	S3C3-5	1.8	FILL: sandy clay, some gravel			14	28	16
			W%	W _L	W _P	% Gravel	% Sand	% Fines
						12	14	22
							38	26
GRADATION CURVE (ASTM D422)								
Project: Enbridge GTA Project - DE Phase			Figure: 1					
Location: S3C3 Highway 401			Remarks:					
Project No.: 110901255								

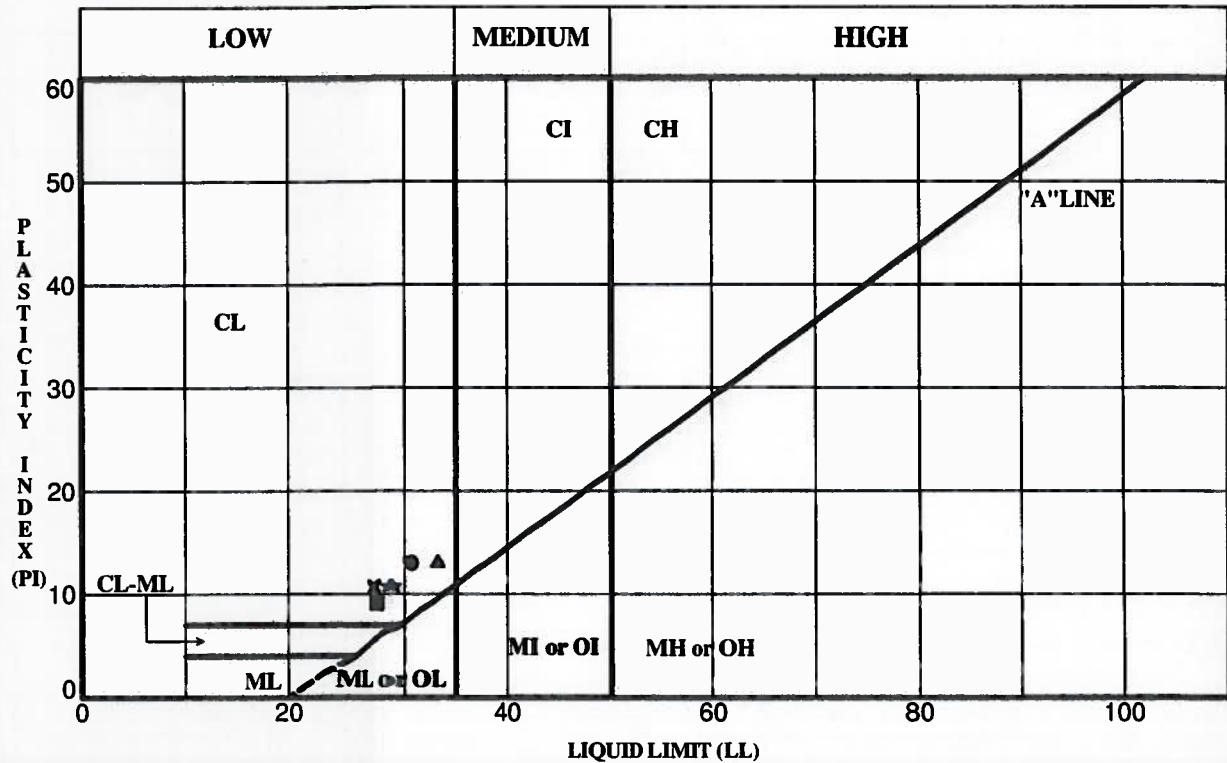


PLASTICITY CHART

[illegible]



PLASTICITY CHART



Specimen	Depth (m)	LL	PL	PI	Fines	W%	Classification
● S3C3-1	2.6	31	18	13	73	14	CLAY (CL) with sand, TILL
■ S3C3-2	1.8	28	19	9	70	13	CLAY (CL) with sand, TILL
▲ S3C3-3	1.1	33	20	13	81	21	CLAY (CL) with sand, TILL
★ S3C3-3	3.4	29	18	11	72	14	CLAY (CL) with sand, TILL
✱ S3C3-4	1.8	28	17	11	81	14	CLAY (CL) with sand, TILL
◻ S3C3-5	4.9	30	17	13	76	18	CLAY (CL) with sand, TILL



Project: Enbridge GTA Project - DE Phase

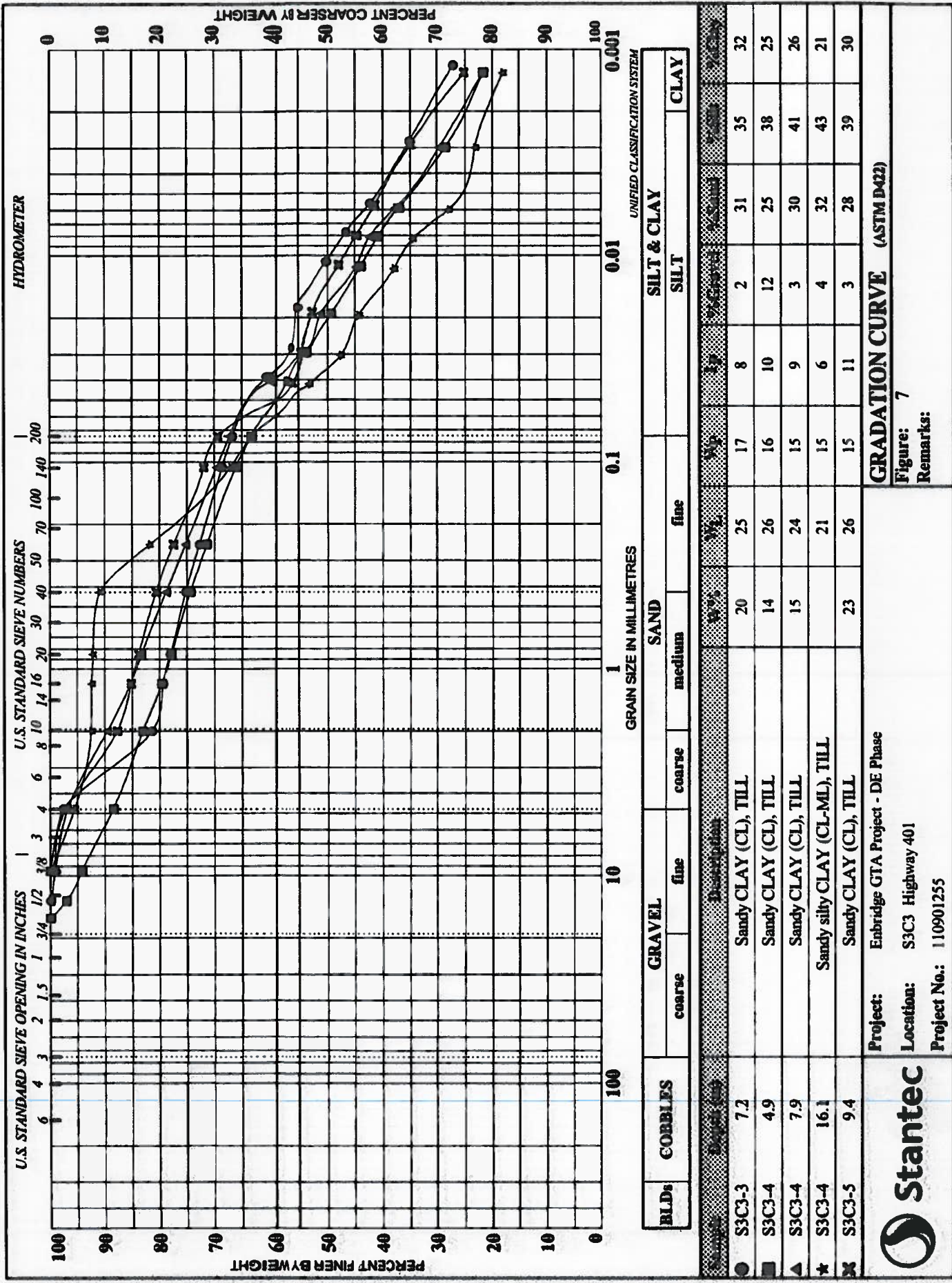
Location: S3C3 Highway 401

Project No.: 110901255

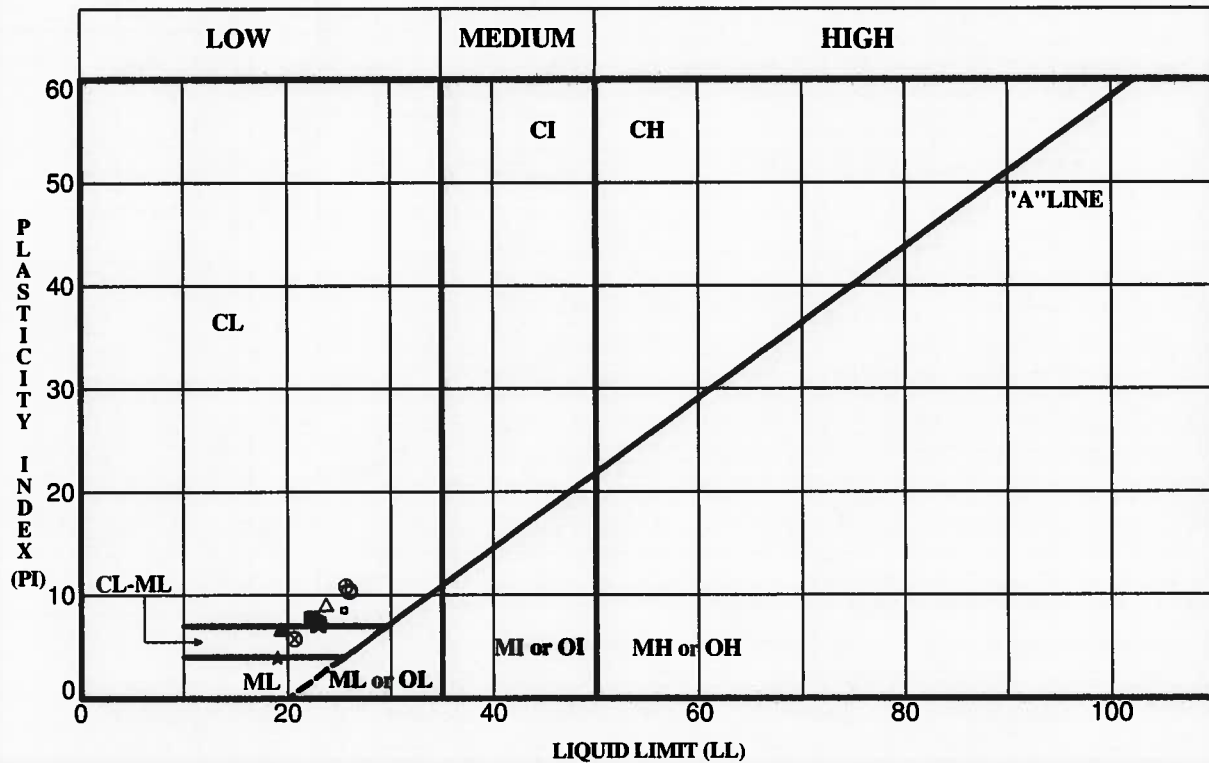
ATTERBERG LIMITS
(ASTM D4318)

Figure: 5

Remarks:



PLASTICITY CHART



Specimen	Depth (m)	LL	PL	PI	Fines	W%	Classification
● S3C3-1	5.6	23	16	7	62	14	Sandy silty CLAY (CL-ML), TILL
■ S3C3-1	7.9	22	15	7	51	14	SANDY SILTY CLAY(CL-ML)
▲ S3C3-1	8.7	19	13	6	64	12	Sandy silty CLAY (CL-ML), TILL
★ S3C3-2	3.4	19	15	4	55	9	Sandy silty CLAY (CL-ML) with gravel, TILL
✕ S3C3-2	6.4	23	16	7	61	14	Sandy silty CLAY (CL-ML), TILL
◻ S3C3-3	7.2	25	17	8	67	20	Sandy CLAY (CL), TILL
○ S3C3-4	4.9	26	16	10	63	14	Sandy CLAY (CL), TILL
△ S3C3-4	7.9	24	15	9	67	15	Sandy CLAY (CL), TILL
⊗ S3C3-4	16.1	21	15	6	63		SANDY SILTY CLAY(CL-ML)
⊕ S3C3-5	9.4	26	15	11	69	23	Sandy CLAY (CL), TILL



Project: Enbridge GTA Project - DE Phase

Location: S3C3 Highway 401

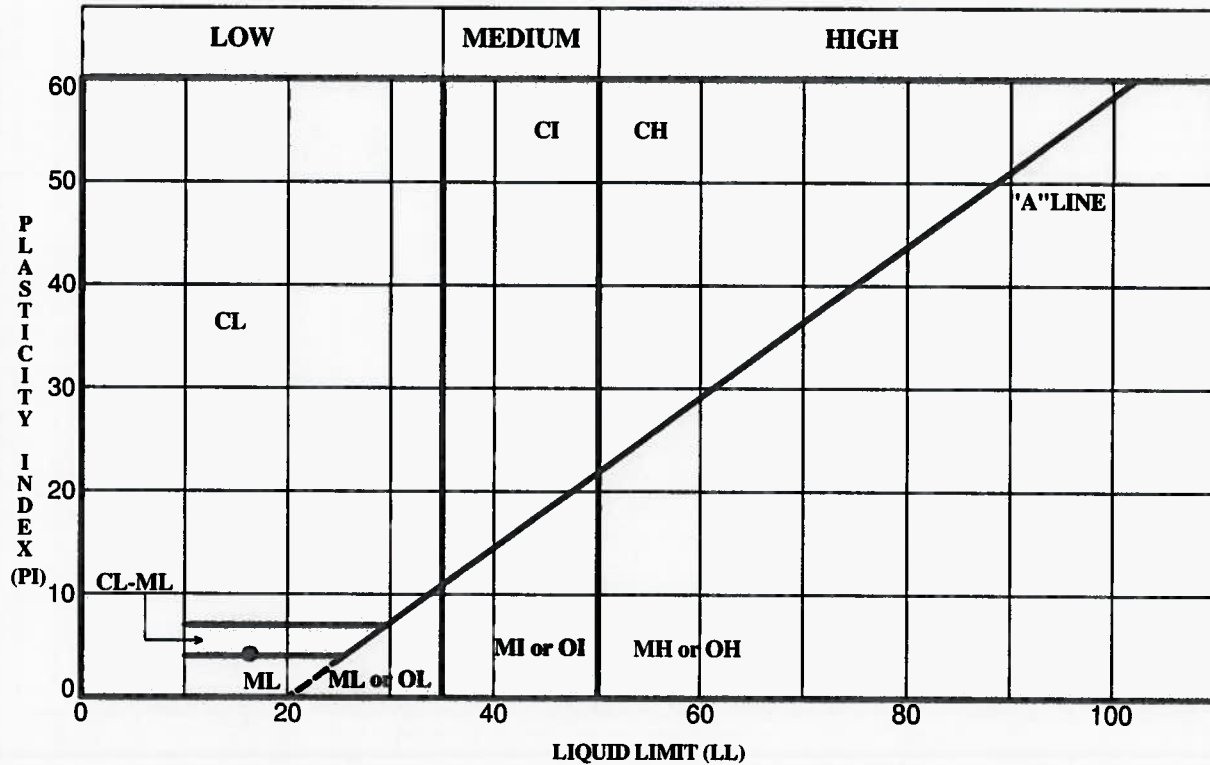
Project No.: 110901255

ATTERBERG LIMITS
(ASTM D4318)

Figure: 9

Remarks:

PLASTICITY CHART



Specimen	Depth (m)	LL	PL	PI	Fines	W %	Classification
● S3C3-5	11.0	16	12	4	50	11	Sandy silty CLAY (CL-ML), TILL



Project: Enbridge GTA Project - DE Phase

Location: S3C3 Highway 401

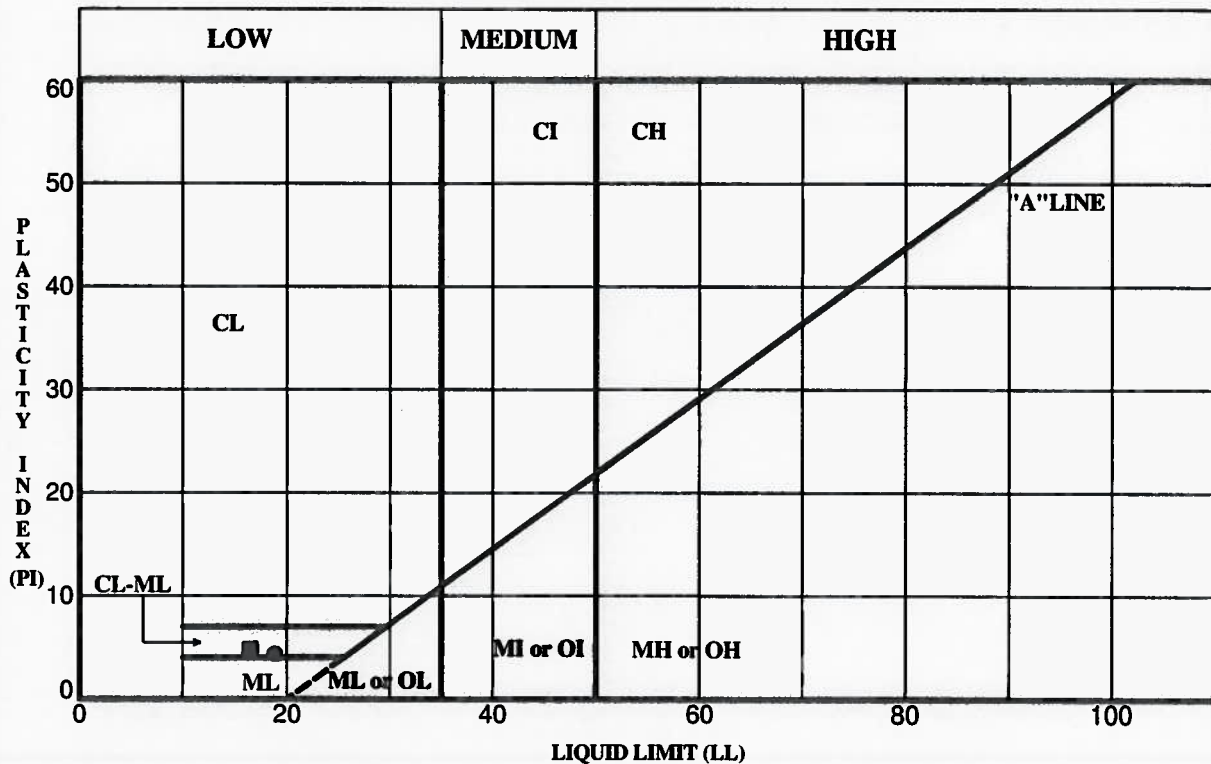
Project No.: 110901255

ATTERBERG LIMITS
(ASTM D4318)

Figure: 10

Remarks:

PLASTICITY CHART



Specimen	Depth (m)	LL	PL	PI	Fines	W%	Classification
● S3C3-3	13.8	19	14	5	38	6	Silty clayey SAND (SC-SM), TILL
■ S3C3-5	13.2	16	12	4	43	9	Silty clayey SAND (SC-SM) with gravel, TILL



Project: Enbridge GTA Project - DE Phase
Location: S3C3 Highway 401
Project No.: 110901255

ATTERBERG LIMITS
 (ASTM D4318)

Figure: 12
Remarks:

**FOUNDATION INVESTIGATION AND DESIGN REPORT GTA PROJECT DETAILED
ENGINEERING DESIGN PHASE DOCUMENT NO.: 110901255.085 PROJECT NO.: 110901255**

Appendix E

2015-01-12

Appendix E

E.1 DETAILED ROCK CORE AND PHOTOGRAPHIC DOCUMENTATION





Stantec

Project: Geotechnical Investigation - Enbridge GTA PFE

Project Number: 110901051

Location: S3C3 - 1 Highway 401

Borehole: S3C3 - 1 [15.52 m to 35.33 m]



15.52m ← RUN 1 → 17.04m
17.04m ← RUN 2 → 18.57m



18.57m ← RUN 3 → 20.09m
20.09m ← RUN 4 → 21.62m

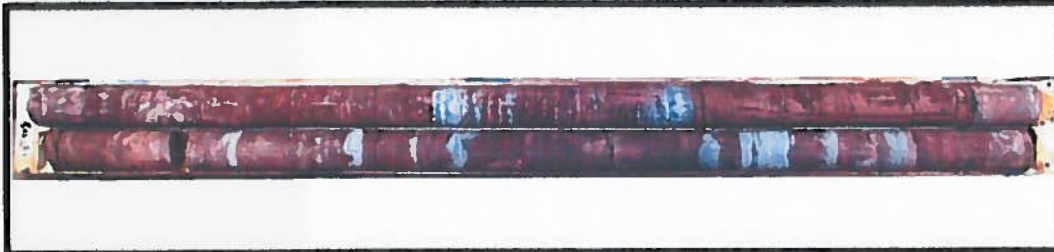


21.62m ← RUN 5 → 23.14m
23.14m ← RUN 6 → 24.66m

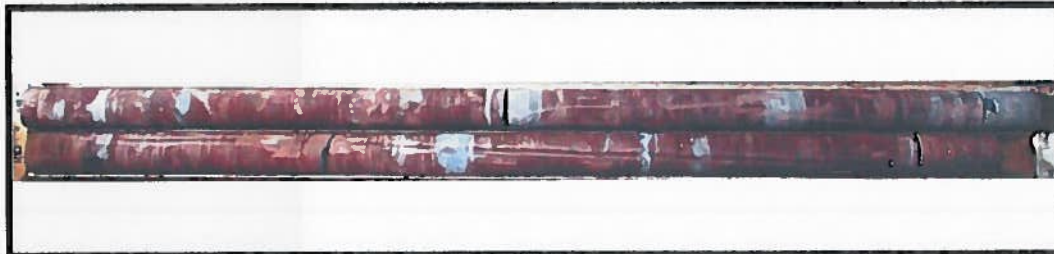


Stantec

Project:	Geotechnical Investigation - Enbridge GTA PFE
Project Number:	110901051
Location:	S3C3 - 1 Highway 401
Borehole:	S3C3 - 1 [15.52 m to 35.33 m]



24.66m	←	RUN 7	→	26.19m
26.19m	←	RUN 8	→	27.71m



27.71m	←	RUN 9	→	29.24m
29.24m	←	RUN 10	→	30.76m



30.76m	←	RUN 11	→	32.28m
32.28m	←	RUN 12	→	33.81m



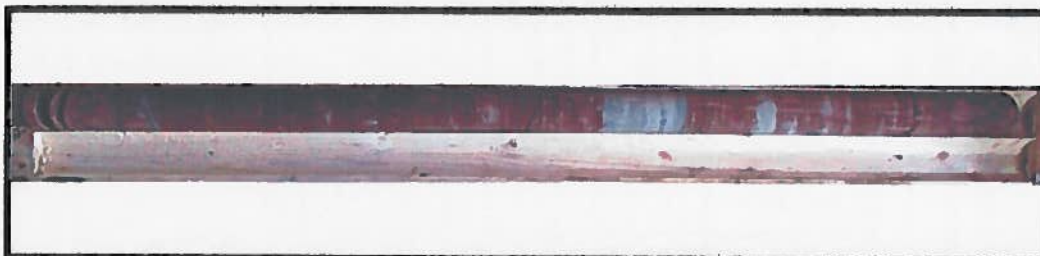
Stantec

Project: Geotechnical Investigation - Enbridge GTA PFE

Project Number: 110901051

Location: S3C3 - 1 Highway 401

Borehole: S3C3 - 1 [15.52 m to 35.33 m]



33.81m



RUN 13



35.33m



Stantec

Field Core Log

Client: Enbridge Gas Distribution Inc. Project No.: 110901051 (S3C3)
 Project: GTA - Pull forward Engineering Date: October 11, 2013
 Contractor: Terex Borehole No.: S3C3 - 1
 Logger: Junghoon Ryu

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES						OCCASIONAL FEATURES	MOHS HARDNESS	
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE			FILLING
15.52	HQ 1	100	70.8	17.04	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding	W	M		B	F	VC-C	RU	-	NC	Occasional clay soil layers up to 50 mm thick	2.0 - 3.0
17.04	HQ 2	100	80	18.57	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding	MS	M-S		B	F	VC-C	RU	-	NC	Occasional clay soil layers up to 25 mm thick	2.0 - 3.0
18.57	HQ 3	100	100	20.09	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding		S-U		B	F	VC-C	RU	-	NC		2.0 - 3.0
20.09	HQ 4	95	82.5	21.62	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding		M		B	F	VC-C	RU	-	NC		2.0 - 3.0

STRENGTH (MPa)		DISCONTINUITY TYPE		ORIENTATION		FILLING	
EH = Extremely Strong = > 250		B = Bedding Joint		F = Flat = 0-20°		T = Tight, Hard	
VS = Very Strong = 100-250		J = Cross Joint		D = Dipping = 20-50°		O = Oxidized	
S = Strong = 50-100		F = Fault		V = n-Vertical = >50°		SA = Slightly Altered, Clay Free	
MS = Medium Strong = 25-50		S = Shear Plane				S = Sandy, Clay Free	
W = Weak = 5 - 25						SI = Sandy, Silty, Minor Clay	
						NC = Non-softening Clay	
						SC = Swelling, Soft Clay	

WEATHERING		SPACING		ROUGHNESS	
U = Unweathered = No Signs		VW = Very Wide = >3m		RU = Rough Undulating	
S = Slightly = Oxidized		W = Wide = 1-3 m		RP = Rough Planar	
M = Moderately = Discoloured		M = Moderate = 0.3-1 m		SU = Smooth Undulating	
H = Highly = Friable		C = Close = 5-30 cm		SP = Smooth Planar	
C = Completely = Soil-like		VC = Very Close = <5 cm		LU = Slickensided Undulating	
				LP = Slickensided Planar	

STRENGTH (MPa)
 EH = Extremely Strong = > 250
 VS = Very Strong = 100-250
 S = Strong = 50-100
 MS = Medium Strong = 25-50
 W = Weak = 5 - 25

WEATHERING
 U = Unweathered = No Signs
 S = Slightly = Oxidized
 M = Moderately = Discoloured
 H = Highly = Friable
 C = Completely = Soil-like

DISCONTINUITY TYPE
 B = Bedding Joint
 J = Cross Joint
 F = Fault
 S = Shear Plane

ORIENTATION
 F = Flat = 0-20°
 D = Dipping = 20-50°
 V = n-Vertical = >50°

ROUGHNESS
 RU = Rough Undulating
 RP = Rough Planar
 SU = Smooth Undulating
 SP = Smooth Planar
 LU = Slickensided Undulating
 LP = Slickensided Planar

FILLING
 T = Tight, Hard
 O = Oxidized
 SA = Slightly Altered, Clay Free
 S = Sandy, Clay Free
 SI = Sandy, Silty, Minor Clay
 NC = Non-softening Clay
 SC = Swelling, Soft Clay

SPACING
 VW = Very Wide = >3m
 W = Wide = 1-3 m
 M = Moderate = 0.3-1 m
 C = Close = 5-30 cm
 VC = Very Close = <5 cm



Stantec

Field Core Log

Client: Enbridge Gas Distribution Inc.

Project: GTA - Pull forward Engineering

Contractor: Terex

Project No.: 110901051 (S3C3)

Date: October 11, 2013

Borehole No.: S3C3 - 1

Logger: Junghoon Ryu

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES						OCCASIONAL FEATURES	MOHS HARDNESS
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	
21.62	HQ 5	100	65	23.14	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding		C-M		B	F	VC-C	RU	-	NC	2.0 - 3.0
23.14	HQ 6	96.7	78.8	24.66	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding	W	M		B	F	VC-C	RU	-	NC	2.0 - 3.0
24.66	HQ 7	100	87.5	26.19	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding	W	S		B	F	VC-C	RU	-	NC	2.0 - 3.0
26.19	HQ 8	95.8	95	27.71	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding	S	S		B	F	VC-C	RU	-	NC	2.0 - 3.0

STRENGTH (MPa)

EH = Extremely Strong = > 250
VS = Very Strong = 100-250
S = Strong = 50-100
MS = Medium Strong = 25-50
W = Weak = 5 - 25

WEATHERING

U = Unweathered = No Signs
S = Slightly = Oxidized
M = Moderately = Discoloured
H = Highly = Friable
C = Completely = Soil-like

DISCONTINUITY TYPE

B = Bedding Joint
J = Cross Joint
F = Fault
S = Shear Plane

ORIENTATION

F = Flat = 0-20°
D = Dipping = 20-50°
V = n-Vertical = >50°

FILLING

T = Tight, Hard
O = Oxidized
SA = Slightly Altered, Clay Free
S = Sandy, Clay Free
SI = Sandy, Silty, Minor Clay
NC = Non-softening Clay
SC = Swelling, Soft Clay

ROUGHNESS

RU = Rough Undulating
RP = Rough Planar
SU = Smooth Undulating
SP = Smooth Planar
LU = Slickensided Undulating
LP = Slickensided Planar

SPACING

VW = Very Wide = >3m
W = Wide = 1-3 m
M = Moderate = 0.3-1 m
C = Close = 5-30 cm
VC = Very Close = <5 cm



Stantec

Field Core Log

Client:

Enbridge Gas Distribution Inc.

Project:

GTA - Pull forward Engineering

Contractor:

Terex

Project No.:

110901051 (S3C3)

Date:

October 11, 2013

Borehole No.:

S3C3 - 1

Logger:

Junghoon Ryu

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% ROD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES						OCCASIONAL FEATURES	MOHS HARDNESS
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	
27.71	HQ 9	100	100	29.24	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding	MS	S-U		B	F	VC-C	RU	-	NC	2.0 - 3.0
29.24	HQ 10	96	95.8	30.76	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding	W	S		B	F	VC-C	RU	-	NC	2.0 - 3.0
30.76	HQ 11	100	100	32.28	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding	MS	S-U		B	F	VC-C	RU	-	NC	2.0 - 3.0
32.28	HQ 12	97.5	98	33.81	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding	MS	S-U		B	F	VC-C	RU	-	NC	2.0 - 3.0

STRENGTH (MPa)
EH = Extremely Strong = > 250
VS = Very Strong = 100-250
S = Strong = 50-100
MS = Medium Strong = 25-50
W = Weak = 5 - 25

WEATHERING
U = Unweathered = No Signs
S = Slightly = Oxidized
M = Moderately = Discoloured
H = Highly = Friable
C = Completely = Soil-like

SPACING
VW = Very Wide = >3m
W = Wide = 1-3 m
M = Moderate = 0.3-1 m
C = Close = 5-30 cm
VC = Very Close = <5 cm

DISCONTINUITY TYPE
B = Bedding Joint
J = Cross Joint
F = Fault
S = Shear Plane

ORIENTATION
F = Flat = 0-20°
D = Dipping = 20-50°
V = n-Vertical = >50°

FILLING
T = Tight, Hard
O = Oxidized
SA = Slightly Altered, Clay Free
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SI = Sandy, Silty, Minor Clay
NC = Non-softening Clay
SC = Swelling, Soft Clay

ROUGHNESS
RU = Rough Undulating
RP = Rough Planar
SU = Smooth Undulating
SP = Smooth Planar
LU = Slickensided Undulating
LP = Slickensided Planar



Stantec

Field Core Log

Client:

Enbridge Gas Distribution Inc.

Project:

GTA - Pull forward Engineering

Contractor:

Terex

Project No.:

110901051 (S3C3)

Date:

October 11, 2013

Borehole No.:

S3C3 - 1

Logger:

Jungheon Ryu

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% ROD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES						OCCASIONAL FEATURES	MOHS HARDNESS
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	
33.81	HQ 13	96.7	90	35.33	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding	MS	S-U		B	F	VC-C	RU	-	NC	2.0 - 3.0
									B	F	VC-C	RU	-	NC	
									B	F	VC-C	RU	-	NC	

STRENGTH (MPa)

EH = Extremely Strong = > 250
VS = Very Strong = 100-250
S = Strong = 50-100
MS = Medium Strong = 25-50
W = Weak = 5 - 25

DISCONTINUITY TYPE

B = Bedding Joint
J = Cross Joint
F = Fault
S = Shear Plane

ORIENTATION

F = Flat = 0-20°
D = Dipping = 20-50°
V = n-Vertical = >50°

ROUGHNESS

RU = Rough Undulating
RP = Rough Planar
SU = Smooth Undulating
SP = Smooth Planar
LU = Slickensided Undulating
LP = Slickensided Planar

FILLING

T = Tight, Hard
O = Oxidized
SA = Slightly Altered, Clay Free
S = Sandy, Clay Free
SI = Sandy, Silty, Minor Clay
NC = Non-softening Clay
SC = Swelling, Soft Clay

WEATHERING

U = Unweathered = No Signs
S = Slightly = Oxidized
M = Moderately = Discoloured
H = Highly = Friable
C = Completely = Soil-like

SPACING

VW = Very Wide = >3m
W = Wide = 1-3 m
M = Moderate = 0.3-1 m
C = Close = 5-30 cm
VC = Very Close = <5 cm

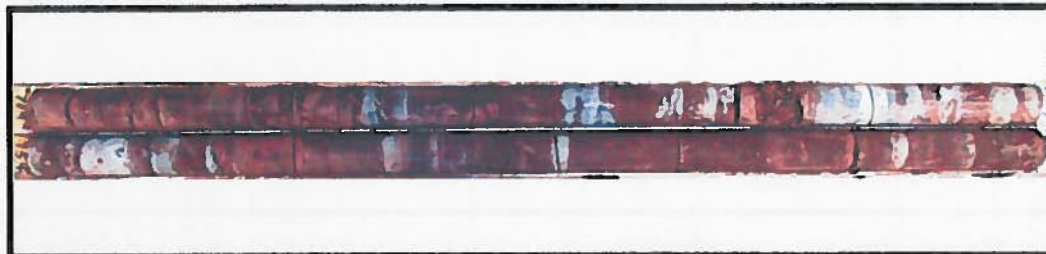


Stantec

Project:	Geotechnical Investigation - Enbridge GTA PFE
Project Number:	110901051
Location:	S3C3 - 4 Highway 401
Borehole:	S3C3 - 4 [18.67 m to 35.05 m]



18.67m	←	RUN 1	→	20.04m
20.04m	←	RUN 2	→	21.56m



21.56m	←	RUN 3	→	23.09m
23.09m	←	RUN 4	→	24.69m



24.67m	←	RUN 5	→	26.21m
26.21m	←	RUN 6	→	27.64m

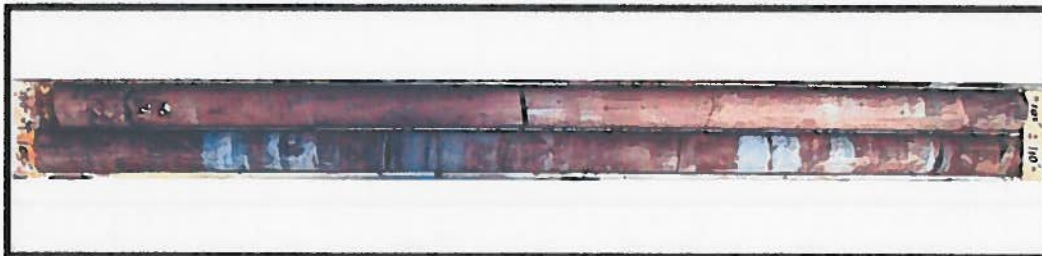


Stantec

Project:	Geotechnical Investigation - Enbridge GTA PFE
Project Number:	110901051
Location:	S3C3 - 4 Highway 401
Borehole:	S3C3 - 4 [18.67 m to 35.05 m]



27.64m	←	RUN 7	→	29.11m
29.11m	←	RUN 8	→	30.48m



30.48m	←	RUN 9	→	32.00m
32.00m	←	RUN 10	→	33.53m



33.53m	←	RUN 11	→	35.05m
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Stantec

Field Core Log

Client: Enbridge Gas Distribution Inc. Project No.: 110901051 (S3C3)
 Project: GTA - Pull forward Engineering Date: October 11, 2013
 Contractor: Terex Borehole No.: S3C3 - 4
 Logger: Junghoon Ryu

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	MOHS HARDNESS
18.67	HQ 1	94	73	20.04	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding	VW	M		B	F	VC-C	RU	-	NC	Occasional clay soil layers up to 75 mm thick	2.0 - 3.0
20.04	HQ 2	98	53	21.56	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding	W	M		B	F	VC-C	RU	-	NC	Occasional clay soil layers up to 25 mm thick	2.0 - 3.0
21.56	HQ 3	100	59	23.09	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding		M-S		B	F	VC-C	RU	-	NC	Occasional clay soil layers up to 75 mm thick	2.0 - 3.0
23.09	HQ 4	95	81	24.69	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding	W	S		B	F	VC-C	RU	-	NC		2.0 - 3.0

STRENGTH (MPa)
 EH = Extremely Strong = > 250
 VS = Very Strong = 100-250
 S = Strong = 50-100
 MS = Medium Strong = 25-50
 W = Weak = 5 - 25

WEATHERING
 U = Unweathered = No Signs
 S = Slightly = Oxidized
 M = Moderately = Discoloured
 H = Highly = Friable
 C = Completely = Soil-like

DISCONTINUITY TYPE
 B = Bedding Joint
 J = Cross Joint
 F = Fault
 S = Shear Plane

ORIENTATION
 F = Flat = 0-20°
 D = Dipping = 20-50°
 V = n-Vertical = >50°

ROUGHNESS
 RU = Rough Undulating
 RP = Rough Planar
 SU = Smooth Undulating
 SP = Smooth Planar
 LU = Slickensided Undulating
 LP = Slickensided Planar

SPACING
 VW = Very Wide = >3m
 W = Wide = 1-3 m
 M = Moderate = 0.3-1 m
 C = Close = 5-30 cm
 VC = Very Close = <5 cm

FILLING
 T = Tight, Hard
 O = Oxidized
 SA = Slightly Altered, Clay Free
 S = Sandy, Clay Free
 SI = Sandy, Silty, Minor Clay
 NC = Non-softening Clay
 SC = Swelling, Soft Clay



Stantec

Field Core Log

Client:

Enbridge Gas Distribution Inc.

Project:

GTA - Pull forward Engineering

Contractor:

Terex

Project No.:

110901051 (S3C9)

Date:

October 11, 2013

Borehole No.:

S3C3 - 4

Logger:

Junghoon Ryu

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% ROD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES						OCCASIONAL FEATURES	MOHS HARDNESS
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	
24.69	HQ 5	100	92	26.21	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding	W	U		B	F	VC-C	RU	-	NC	2.0 - 3.0
									B	F	VC-C	RU	-	NC	
									B	F	VC-C	RU	-	NC	
									B	F	VC-C	RU	-	NC	
26.21	HQ 6	100	99	27.64	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding		U		B	F	VC-C	RU	-	NC	3.0
									B	F	VC-C	RU	-	NC	
									B	F	VC-C	RU	-	NC	
									B	F	VC-C	RU	-	NC	
27.64	HQ 7	100	91	29.11	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding		U		B	F	VC-C	RU	-	NC	3.0
									B	F	VC-C	RU	-	NC	
									B	F	VC-C	RU	-	NC	
									B	F	VC-C	RU	-	NC	
29.11	HQ 8	100	67	30.48	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding	MS	U		B	F	VC-C	RU	-	NC	3.0
									B	F	VC-C	RU	-	NC	
									B	F	VC-C	RU	-	NC	
									B	F	VC-C	RU	-	NC	

STRENGTH (MPa)

EH = Extremely Strong = > 250
VS = Very Strong = 100-250
S = Strong = 50-100
MS = Medium Strong = 25-50
W = Weak = 5 - 25

VW = Very Weak = 1-5
EW = Extremely Weak = < 1

DISCONTINUITY TYPE

B = Bedding Joint
J = Cross Joint
F = Fault
S = Shear Plane

ORIENTATION

F = Flat = 0-20°
D = Dipping = 20-50°
V = n-Vertical = >50°

FILLING

T = Tight, Hard
O = Oxidized
SA = Slightly Altered, Clay Free
S = Sandy, Clay Free
SI = Silty, Minor Clay
NC = Non-softening Clay
SC = Swelling, Soft Clay

WEATHERING

U = Unweathered = No Signs
S = Slightly = Oxidized
M = Moderately = Discoloured
H = Highly = Friable
C = Completely = Soil-like

SPACING

VW = Very Wide = >3m
W = Wide = 1-3 m
M = Moderate = 0.3-1 m
C = Close = 5-30 cm
VC = Very Close = <5 cm

ROUGHNESS

RU = Rough Undulating
RP = Rough Planar
SU = Smooth Undulating
SP = Smooth Planar
LU = Slickensided Undulating
LP = Slickensided Planar



Stantec

Field Core Log

Client: Enbridge Gas Distribution Inc. Project No.: 110901051 (S3C3)
 Project: GTA - Pull forward Engineering Date: October 11, 2013
 Contractor: Terex Borehole No.: S3C3 - 4
 Logger: Junghoon Ryu

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% ROD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES						OCCASIONAL FEATURES	MOHS HARDNESS
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	
30.48	HQ 9	100	97	32.00	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding		U		B	F	VC-C	RU	-	NC	
									B	F	VC-C	RU	-	NC	3.0
									B	F	VC-C	RU	-	NC	
32.00	HQ 10	100	96	33.53	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding	MS	U		B	F	VC-C	RU	-	NC	
									B	F	VC-C	RU	-	NC	3.0
									B	F	VC-C	RU	-	NC	
33.53	HQ 11	98	97	35.05	Reddish Brown and Greyish Green Queenston SHALE with Grey LIMESTONE Interbedding	MS	U		B	F	VC-C	RU	-	NC	
									B	F	VC-C	RU	-	NC	3.0
									B	F	VC-C	RU	-	NC	

STRENGTH (MPa)
 EH = Extremely Strong = > 250
 VS = Very Strong = 100-250
 S = Strong = 50-100
 MS = Medium Strong = 25-50
 W = Weak = 5 - 25

WEATHERING
 U = Unweathered = No Signs
 S = Slightly = Oxidized
 M = Moderately = Discoloured
 H = Highly = Friable
 C = Completely = Soil-like

DISCONTINUITY TYPE
 B = Bedding Joint
 J = Cross Joint
 F = Fault
 S = Shear Plane

ORIENTATION
 F = Flat = 0-20°
 D = Dipping = 20-50°
 V = n-Vertical = >50°

ROUGHNESS
 RU = Rough Undulating
 RP = Rough Planar
 SU = Smooth Undulating
 SP = Smooth Planar
 LU = Slickensided Undulating
 LP = Slickensided Planar

SPACING
 VW = Very Wide = >3m
 W = Wide = 1-3 m
 M = Moderate = 0.3-1 m
 C = Close = 5-30 cm
 VC = Very Close = <5 cm

FILLING
 T = Tight, Hard
 O = Oxidized
 SA = Slightly Altered, Clay Free
 S = Sandy, Clay Free
 Si = Sandy, Silty, Minor Clay
 NC = Non-softening Clay
 SC = Swelling, Soft Clay



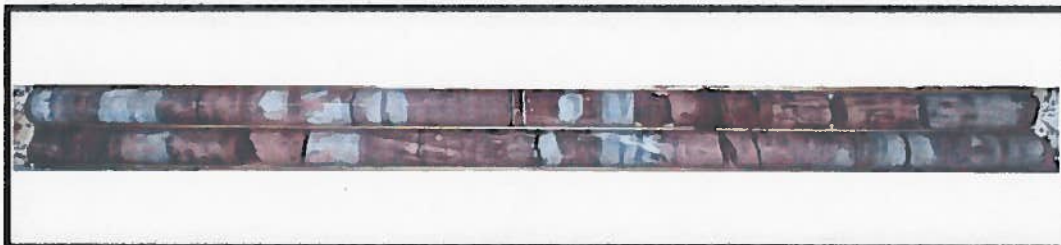
Project:	Enbridge - GTA Project - Detailed Engineering Phase		
Project Number:	110901255		
Location:	Highway 401		
Borehole:	S3C3 - 2	Depth (m):	14.32 m to 30.70 m



14.32m	←	RUN 1	→	15.84m
15.84m	←	RUN 2	→	17.36m



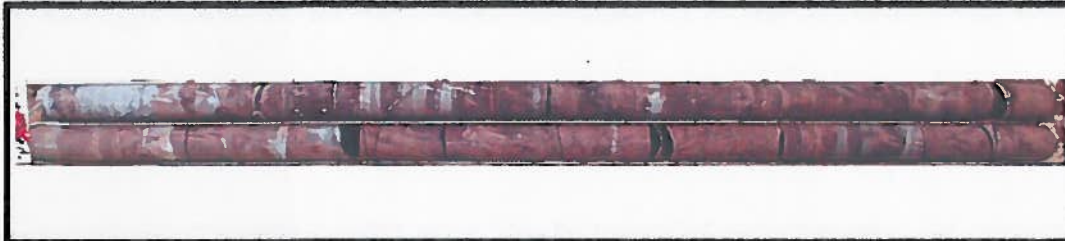
17.36m	←	RUN 3	→	18.88m
18.88m	←	RUN 4	→	20.40m



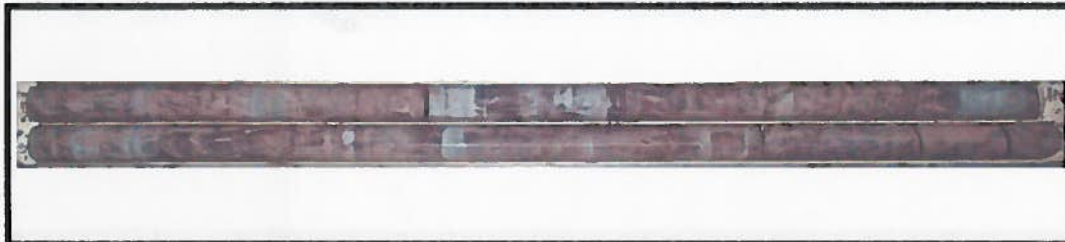
20.40m	←	RUN 5	→	21.92m
21.92m	←	RUN 6	→	23.44m



Project:	Enbridge - GTA Project - Detailed Engineering Phase		
Project Number:	110901255		
Location:	Highway 401		
Borehole:	S3C3-2	Depth (m):	14.32 m to 30.70 m



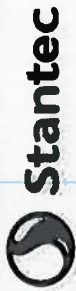
23.44m	←	RUN 7	→	24.96m
24.96m	←	RUN 8	→	26.48m



26.48m	←	RUN 9	→	28.00m
28.00m	←	RUN 10	→	29.52m



29.52m	←	RUN 11	→	30.71m
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Field Core Log

Client: Enbridge Gas Distribution Inc.
Project: Enbridge - GTA Project - Detailed Engineering Phase
Contractor: Terex Drilling Solutions

Project No.: 110901255
Date: June 9, 2014
Borehole No.: S3C3-2
Logger: Junghoon Ryu

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% ROD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES						OCCASIONAL FEATURES	MOHS HARDNESS
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE		
14.32	HQ 1	95	55	15.84	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding		M		B	F	VC-C	RU	-	NC	2.0-3.0
									B	F	VC-C	RU	-	NC	
									B	F	VC-C	RU	-	NC	
15.84	HQ 2	100	100	17.36	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding		M		B	F	C-M	RU	-	NC	2.0-3.0
									B	F	C-M	RU	-	NC	
									B	F	C-M	RU	-	NC	
17.36	HQ 3	100	100	18.88	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding		S		B	F	M	RU	-	NC	2.0-3.0
									B	F	M	RU	-	NC	
									B	F	M	RU	-	NC	
18.88	HQ 4	97	97	20.40	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding		S		B	F	M	RU	-	NC	2.0-3.0
									B	F	M	RU	-	NC	
									B	F	M	RU	-	NC	

STRENGTH (MPa)
EH = Extremely Strong = > 250
VS = Very Strong = 100-250
S = Strong = 50-100
MS = Medium Strong = 25-50
W = Weak = 5 - 25

WEATHERING
U = Unweathered = No Signs
S = Slightly = Oxidized
M = Moderately = Discoloured
H = Highly = Friable
C = Completely = Soil-like

DISCONTINUITY TYPE
B = Bedding Joint
J = Cross Joint
F = Fault
S = Shear Plane

SPACING
VW = Very Wide = >3m
W = Wide = 1-3 m
M = Moderate = 0.3-1 m
C = Close = 5-30 cm
VC = Very Close = <5 cm

ORIENTATION
F = Flat = 0-20°
D = Dipping = 20-50°
V = n-Vertical = >50°

ROUGHNESS
RU = Rough Undulating
RP = Rough Planar
SU = Smooth Undulating
SP = Smooth Planar
LU = Slickensided Undulating
LP = Slickensided Planar

FILLING
T = Tight, Hard
O = Oxidized
SA = Slightly Altered, Clay Free
S = Sandy, Clay Free
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NC = Non-softening Clay
SC = Swelling, Soft Clay



Stantec

Field Core Log

Client: Enbridge Gas Distribution Inc.
Project: Enbridge - GTA Project - Detailed Engineering Phase
Contractor: Terex Drilling Solutions

Project No.: 110901255
Date: June 9, 2014
Borehole No.: S3C3-2
Logger: Junghoon Ryu

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% ROD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES						OCCASIONAL FEATURES	MOHS HARDNESS
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	
20.40	HQ 5	97	83	21.92	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding	S			B	F	M	RU	-	NC	2.0-3.0
									B	F	M	RU	-	NC	
									B	F	M	RU	-	NC	
21.92	HQ 6	97	97	23.44	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding	S			B	F	M	RU	-	NC	2.0-3.0
									B	F	M	RU	-	NC	
									B	F	M	RU	-	NC	
23.44	HQ 7	98	98	24.96	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding	S			B	F	M	RU	-	NC	2.0-3.0
									B	F	M	RU	-	NC	
									B	F	M	RU	-	NC	
24.96	HQ 8	100	100	26.48	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding	S			B	F	M	RU	-	NC	2.0-3.0
									B	F	M	RU	-	NC	
									B	F	M	RU	-	NC	

STRENGTH (MPa)
EH = Extremely Strong = > 250
VS = Very Strong = 100-250
S = Strong = 50-100
MS = Medium Strong = 25-50
W = Weak = 5 - 25

WEATHERING
U = Unweathered = No Signs
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DISCONTINUITY TYPE
B = Bedding Joint
J = Cross Joint
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SPACING
VW = Very Wide = >3m
W = Wide = 1-3 m
M = Moderate = 0.3-1 m
C = Close = 5-30 cm
VC = Very Close = <5 cm

ORIENTATION
F = Flat = 0-20°
D = Dipping = 20-50°
V = n-Vertical = >50°

FILLING
T = Tight, Hard
O = Oxidized
SA = Slightly Altered, Clay Free
S = Sandy, Clay Free
SI = Sandy, Silty, Minor Clay
NC = Non-softening Clay
SC = Swelling, Soft Clay

ROUGHNESS
RU = Rough Undulating
RP = Rough Planar
SU = Smooth Undulating
SP = Smooth Planar
LU = Slickensided Undulating
LP = Slickensided Planar



Stantec

Field Core Log

Client:

Enbridge Gas Distribution Inc.

Project:

Enbridge - GTA Project - Detailed Engineering Phase

Contractor:

Terex Drilling Solutions

Project No.:

110901255

Date:

June 9, 2014

Borehole No.:

S3C3-2

Logger:

Junghoon Ryu

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% ROD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES						OCCASIONAL FEATURES	MOHS HARDNESS	
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE			FILLING
26.48	HQ 9	100	100	28.00	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE interbedding		S		B	F	M	RU	-	NC		2.0-3.0
									B	F	M	RU	-	NC		
									B	F	M	RU	-	NC		
28.00	HQ 10	100	100	29.52	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE interbedding		S		B	F	M	RU	-	NC		2.0-3.0
									B	F	M	RU	-	NC		
									B	F	M	RU	-	NC		
29.52	HQ 11	100	100	30.71	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE interbedding		S		B	F	M	RU	-	NC		2.0-3.0
									B	F	M	RU	-	NC		
									B	F	M	RU	-	NC		

EH = Extremely Strong = > 250

VS = Very Strong = 100-250

S = Strong = 50-100

MS = Medium Strong = 25-50

W = Weak = 5 - 25

WEATHERING

U = Unweathered = No Signs

S = Slightly - Oxidized

M = Moderately = Discoloured

H = Highly = Friable

C = Completely = Soil-like

STRENGTH (MPa)

VW = Very Weak = 1-5

EW = Extremely Weak = < 1

DISCONTINUITY TYPE

B = Bedding Joint

J = Cross Joint

F = Fault

S = Shear Plane

ORIENTATION

F = Flat = 0-20°

D = Dipping = 20-50°

V = n-Vertical = >50°

FILLING

T = Tight, Hard

O = Oxidized

SA = Slightly Altered, Clay Free

S = Sandy, Clay Free

SI = Sandy, Silty, Minor Clay

NC = Non-softening Clay

SC = Swelling, Soft Clay

SPACING

VW = Very Wide = >3m

W = Wide = 1-3 m

M = Moderate = 0.3-1 m

C = Close = 5-30 cm

VC = Very Close = <5 cm

ROUGHNESS

RU = Rough Undulating

RP = Rough Planar

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SP = Smooth Planar

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LP = Slickensided Planar

STRENGTH (MPa)

EH = Extremely Strong = > 250
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M = Moderately = Discoloured
H = Highly = Friable
C = Completely = Soil-like

DISCONTINUITY TYPE

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J = Cross Joint
F = Fault
S = Shear Plane

SPACING

VW = Very Wide = >3m
W = Wide = 1-3 m
M = Moderate = 0.3-1 m
C = Close = 5-30 cm
VC = Very Close = <5 cm

ORIENTATION

F = Flat = 0-20°
D = Dipping = 20-50°
V = n-Vertical = >50°

ROUGHNESS

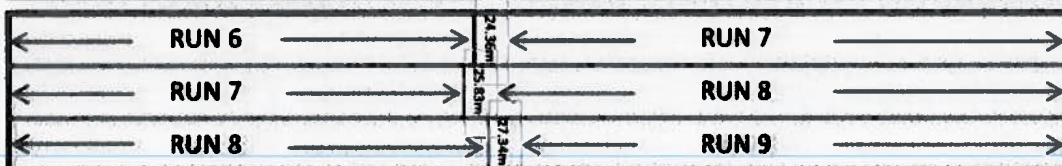
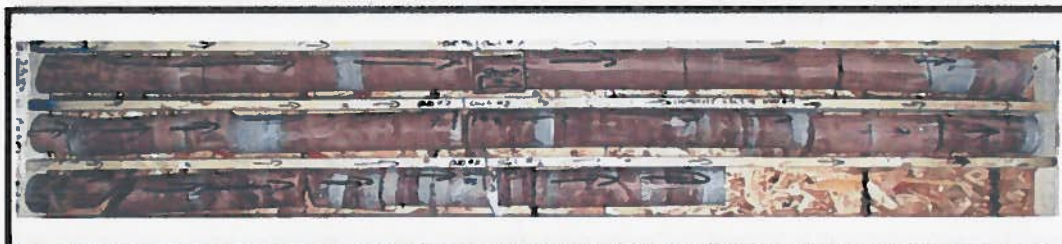
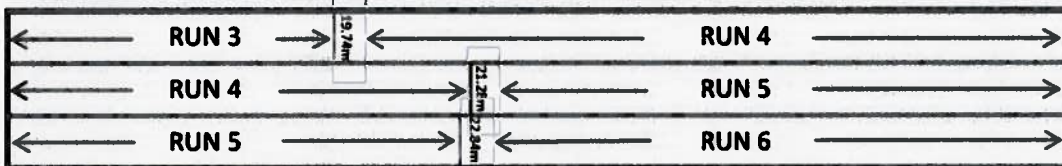
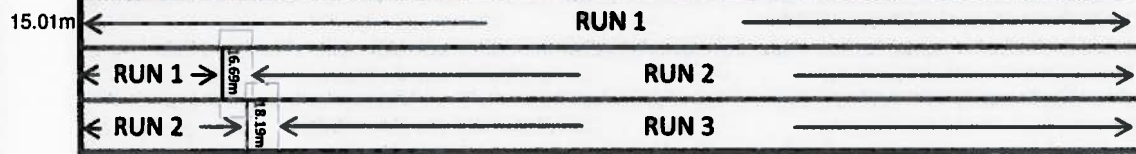
RU = Rough Undulating
RP = Rough Planar
SU = Smooth Undulating
SP = Smooth Planar
LU = Slickensided Undulating
LP = Slickensided Planar

FILLING

T = Tight, Hard
O = Oxidized
SA = Slightly Altered, Clay Free
S = Sandy, Clay Free
SI = Sandy, Silty, Minor Clay
NC = Non-softening Clay
SC = Swelling, Soft Clay



Project:	Enbridge - GTA Project - Detailed Engineering Phase		
Project Number:	110901255		
Location:	Highway 401		
Borehole:	S3C3-3	Depth (m):	15.01 m to 30.05 m





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Project: Enbridge - GTA Project - Detailed Engineering Phase

Project Number: 110901255

Location: Highway 401

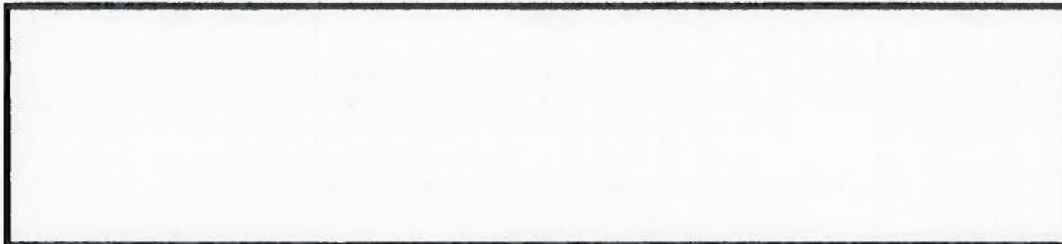
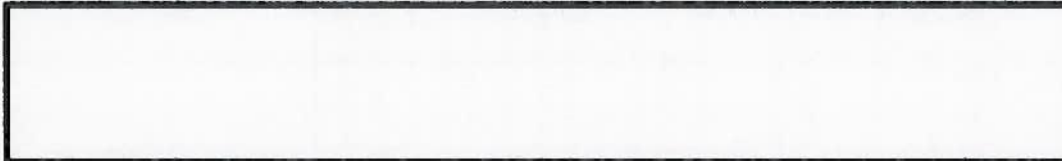
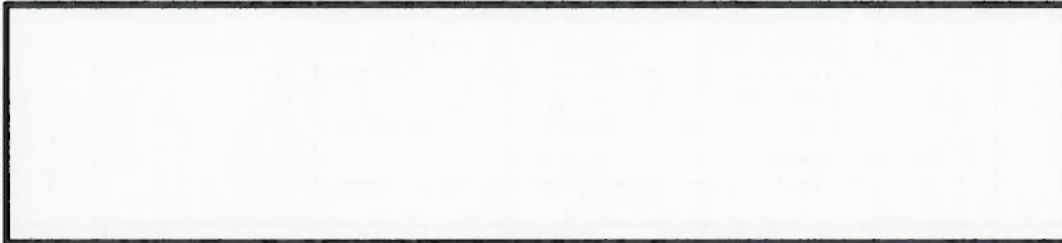
Borehole: S3C3-3 **Depth (m):**



27.34m ← **RUN 9** → 28.90m

28.90m ← **RUN 10** →

← **RUN 10** →





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Field Core Log

Client:

Enbridge Gas Distribution Inc.

Project:

Enbridge - GTA Project - Detailed Engineering Phase

Contractor:

Geo-Environmental

Project No.:

110901255

Date:

June 9, 2014

Borehole No.:

S3C3-3

Logger:

Junghoon Ryu

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES						OCCASIONAL FEATURES	MOHS HARDNESS	
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE			FILLING
15.01	HQ 1	100	80	16.69	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding	M-S			B	F	VC-C	RU	-	NC		2.0 - 3.0
									B	F	VC-C	RU	-	NC		
									B	F	VC-C	RU	-	NC		
16.69	HQ 2	100	88	18.19	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding	M-S			B	F	VC-C	RU	-	NC		2.0 - 3.0
									B	F	VC-C	RU	-	NC		
									B	F	VC-C	RU	-	NC		
19.74	HQ 3	100	87	21.28	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding	M-S			B	F	VC-C	RU	-	NC		2.0 - 3.0
									B	F	VC-C	RU	-	NC		
									B	F	VC-C	RU	-	NC		
21.28	HQ 4	100	95	22.84	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding	M-S			B	F	VC-C	RU	-	NC		2.0 - 3.0
									B	F	VC-C	RU	-	NC		
									B	F	VC-C	RU	-	NC		

STRENGTH (MPa)		DISCONTINUITY TYPE		ORIENTATION		FILLING	
EH = Extremely Strong = > 250		B = Bedding Joint		F = Flat = 0-20°		T = Tight, Hard	
VS = Very Strong = 100-250		J = Cross Joint		D = Dipping = 20-50°		O = Oxidized	
S = Strong = 50-100		F = Fault		V = n-Vertical = >50°		SA = Slightly Altered, Clay Free	
MS = Medium Strong = 25-50		S = Shear Plane				S = Sandy, Clay Free	
W = Weak = 5 - 25						SI = Sandy, Silty, Minor Clay	
WEATHERING		SPACING		ROUGHNESS			
U = Unweathered = No Signs		VW = Very Wide = >3m		RU = Rough Undulating		NC = Non-softening Clay	
S = Slightly = Oxidized		W = Wide = 1-3 m		RP = Rough Planar		SC = Swelling, Soft Clay	
M = Moderately = Discoloured		M = Moderate = 0.3-1 m		SU = Smooth Undulating			
H = Highly = Friable		C = Close = 5-30 cm		SP = Smooth Planar			
C = Completely = Soil-like		VC = Very Close = <5 cm		LU = Slickensided Undulating			
				LP = Slickensided Planar			

STRENGTH (MPa)

EH = Extremely Strong = > 250
VS = Very Strong = 100-250
S = Strong = 50-100
MS = Medium Strong = 25-50
W = Weak = 5 - 25

VW = Very Weak = 1-5
EW = Extremely Weak = < 1

WEATHERING

U = Unweathered = No Signs
S = Slightly = Oxidized
M = Moderately = Discoloured
H = Highly = Friable
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DISCONTINUITY TYPE

B = Bedding Joint
J = Cross Joint
F = Fault
S = Shear Plane

SPACING

VW = Very Wide = >3m
W = Wide = 1-3 m
M = Moderate = 0.3-1 m
C = Close = 5-30 cm
VC = Very Close = <5 cm

ORIENTATION

F = Flat = 0-20°
D = Dipping = 20-50°
V = n-Vertical = >50°

ROUGHNESS

RU = Rough Undulating
RP = Rough Planar
SU = Smooth Undulating
SP = Smooth Planar
LU = Slickensided Undulating
LP = Slickensided Planar

FILLING

T = Tight, Hard
O = Oxidized
SA = Slightly Altered, Clay Free
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NC = Non-softening Clay
SC = Swelling, Soft Clay



Stantec

Field Core Log

Client:
Project:
Contractor:

Enbridge Gas Distribution Inc.
Enbridge - GTA Project - Detailed Engineering Phase
Geo-Environmental

Project No.: 110901255
Date: June 9, 2014
Borehole No.: S3C3-3
Logger: Jungheon Ryu

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% ROD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES						OCCASIONAL FEATURES	MOHS HARDNESS	
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE			FILLING
21.28	HQ 5	95	53	22.84	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding		S		B	F	VC-C	RU	-	NC		2.0 - 3.0
									B	F	VC-C	RU	-	NC		
									B	F	VC-C	RU	-	NC		
22.84	HQ 6	100	87	24.36	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding		S		B	F	VC-C	RU	-	NC		2.0 - 3.0
									B	F	VC-C	RU	-	NC		
									B	F	VC-C	RU	-	NC		
24.36	HQ 7	100	91	25.83	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding		S		B	F	C-M	RU	-	NC		2.0 - 3.0
									B	F	C-M	RU	-	NC		
									B	F	C-M	RU	-	NC		
25.83	HQ 8	100	93	27.34	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding		S		B	F	C-M	RU	-	NC		2.0 - 3.0
									B	F	C-M	RU	-	NC		
									B	F	C-M	RU	-	NC		

EH = Extremely Strong = > 250
VS = Very Strong = 100-250
S = Strong = 50-100
MS = Medium Strong = 25-50
W = Weak = 5 - 25

STRENGTH (MPa)
VW = Very Weak = 1-5
EW = Extremely Weak = < 1

DISCONTINUITY TYPE
B = Bedding Joint
J = Cross Joint
F = Fault
S = Shear Plane

WEATHERING
U = Unweathered = No Signs
S = Slightly = Oxidized
M = Moderately = Discoloured
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SPACING
VW = Very Wide = >3m
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RU = Rough Undulating
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SP = Smooth Planar
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ORIENTATION
F = Flat = 0-20°
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VW = Very Wide = >3m
W = Wide = 1-3 m
M = Moderate = 0.3-1 m
C = Close = 5-30 cm
VC = Very Close = <5 cm



Field Core Log

Geo-Environmental

Lozzer:

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% ROD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES							OCCASIONAL FEATURES	MOHS HARDNESS
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING		
27.34	HQ 9	100	97	28.90	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding		S		B	F	C-M	RU	-	NC		2.0 - 3.0
									B	F	M	RU	-	NC		
									B	F	M	RU	-	NC		
									B	F	M	RU	-	NC		
28.90	HQ 10	100	87	30.50	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding		S		B	F	C-M	RU	-	NC		2.0 - 3.0
									B	F	C-M	RU	-	NC		

STRENGTH (MPa)
EH = Extremely Strong = > 250
VS = Very Strong = 100-250
S = Strong = 50-100
MS = Medium Strong = 25-50
W = Weak = 5 - 25

DISCONTINUITY TYPE
B = Bedding Joint
J = Cross Joint
F = Fault
S = Shear Plane

ORIENTATION
F = Flat = 0-20°
D = Dipping = 20-50°
V = n-Vertical = >50°

WEATHERING
U = Unweathered = No Signs
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VW = Very Wide = >3m
W = Wide = 1-3 m
M = Moderate = 0.3-1 m
C = Close = 5-30 cm
VC = Very Close = <5 cm

ROUGHNESS
RU = Rough Undulating
RP = Rough Planar
SU = Smooth Undulating
SP = Smooth Planar
LU = Slickensided Undulating
LP = Slickensided Planar

FILLING
T = Tight, Hard
O = Oxidized
SA = Slightly Altered, Clay Free
S = Sandy, Clay Free
SI = Sandy, Silty, Minor Clay
NC = Non-softening Clay
SC = Swelling, Soft Clay



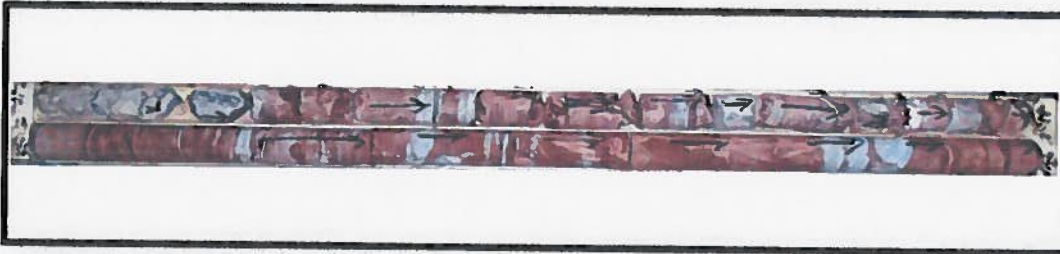
Stantec

Project: Enbridge - GTA Project - Detailed Engineering Phase

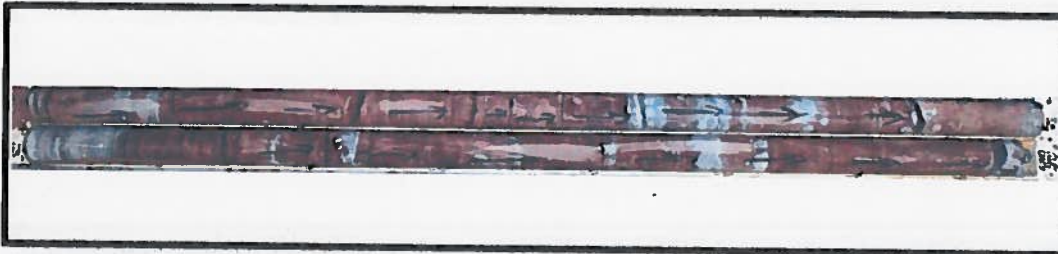
Project Number: 110901255

Location: Highway 401

Borehole: S3C3-5 **Depth (m):** 15.65 m to 30.63 m



15.65m	←	RUN 1	→	17.17m
17.17m	←	RUN 2	→	18.69m



18.69m	←	RUN 3	→	20.22m
20.22m	←	RUN 4	→	21.74m



21.74m	←	RUN 5	→	23.34m
23.34m	←	RUN 6	→	24.79m



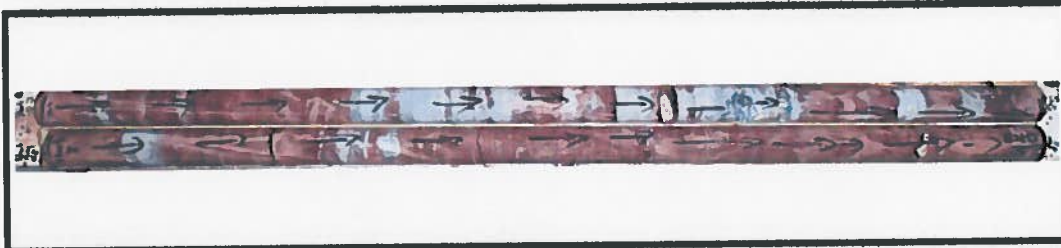
Stantec

Project: Enbridge - GTA Project - Detailed Engineering Phase

Project Number: 110901255

Location: Highway 401

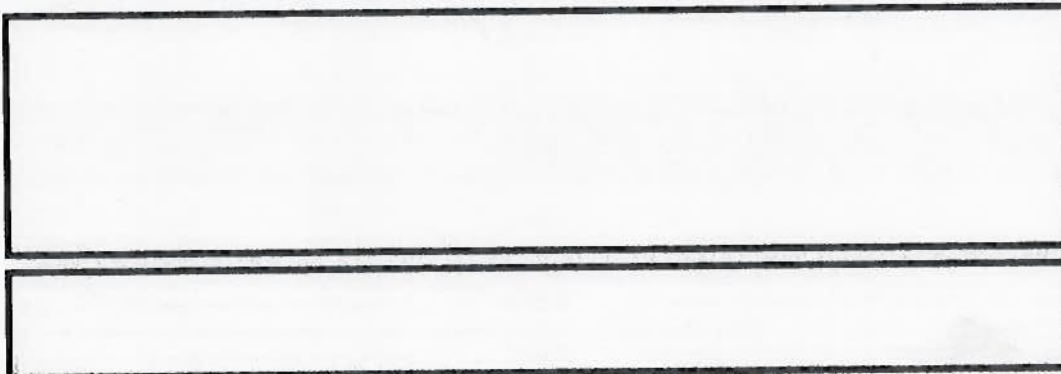
Borehole: S3C3-5 **Depth (m):** 15.65 m to 30.63 m

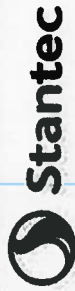


24.79m	←		RUN 7		→	26.31m
26.31m	←		RUN 8		→	27.84m



27.84m	←		RUN 9		→	29.36m
29.36m	←		RUN 10		→	30.63m





Field Core Log

Client:

Enbridge Gas Distribution Inc.

Project:

Enbridge - GTA Project - Detailed Engineering Phase

Contractor:

Terex Drilling Solutions

Project No.:

110901255

Date:

June 9, 2014

Borehole No.:

S3C3-5

Logger:

Junghoon Ryu

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% ROD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES						OCCASIONAL FEATURES	MOHS HARDNESS	
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE			FILLING
15.65	HQ 1	95	40	17.17	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding		M-S		B	F	VC-C	RU	-	NC		2.0-3.0
									B	F	VC-C	RU	-	NC		
									B	F	VC-C	RU	-	NC		
17.17	HQ 2	100	89	18.69	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding		S		B	F	C-M	RU	-	NC		2.0-3.0
									B	F	C-M	RU	-	NC		
									B	F	VC-C	RU	-	NC		
18.69	HQ 3	100	91	20.22	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding		S		B	F	C-M	RU	-	NC		2.0-3.0
									B	F	VC-C	RU	-	NC		
									B	F	C-M	RU	-	NC		
20.22	HQ 4	100	97	21.74	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding		S		B	F	C-M	RU	-	NC		2.0-3.0
									B	F	C-M	RU	-	NC		
									B	F	M	RU	-	NC		
									B	F	C-M	RU	-	NC		

STRENGTH (MPa)

EH = Extremely Strong = > 250
VS = Very Strong = 100-250
S = Strong = 50-100
MS = Medium Strong = 25-50
W = Weak = 5 - 25

WEATHERING

U = Unweathered = No Signs
S = Slightly = Oxidized
M = Moderately = Discoloured
H = Highly = Friable
C = Completely = Soil-like

DISCONTINUITY TYPE

B = Bedding Joint
J = Cross Joint
F = Fault
S = Shear Plane

SPACING

VW = Very Wide = >3m
W = Wide = 1-3 m
M = Moderate = 0.3-1 m
C = Close = 5-30 cm
VC = Very Close = <5 cm

ORIENTATION

F = Flat = 0-20°
D = Dipping = 20-50°
V = n-Vertical = >50°

ROUGHNESS

RU = Rough Undulating
RP = Rough Planar
SU = Smooth Undulating
SP = Smooth Planar
LU = Slickensided Undulating
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FILLING

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SI = Sandy, Silty, Minor Clay
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SC = Swelling, Soft Clay



Stantec

Field Core Log

Client:
Project:
Contractor:

Enbridge Gas Distribution Inc.
Enbridge - GTA Project - Detailed Engineering Phase
Terex Drilling Solutions

Project No.: 110901255
Date: June 9, 2014
Borehole No.: S3C3-5
Logger: Junghoon Ryu

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RDP	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES						OCCASIONAL FEATURES	MOHS HARDNESS
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	
21.74	HQ 5	100	83	23.34	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding		S		B	F	C-M	RU	-	NC	2.0-3.0
23.34	HQ 6	100	33	24.79	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding		M		B	F	VC-C	RU	-	NC	2.0-3.0
24.79	HQ 7	100	94	26.31	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding		S		B	F	M	RU	-	NC	2.0-3.0
26.31	HQ 8	100	98	27.84	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding		S		B	F	M	RU	-	NC	2.0-3.0

STRENGTH (MPa)
EH = Extremely Strong = > 250
VS = Very Strong = 100-250
S = Strong = 50-100
MS = Medium Strong = 25-50
W = Weak = 5 - 25

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M = Moderate = 0.3-1 m
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VC = Very Close = <5 cm

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T = Tight, Hard
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SA = Slightly Altered, Clay Free
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SI = Sandy, Silty, Minor Clay
NC = Non-softening Clay
SC = Swelling, Soft Clay



Stantec

Field Core Log

Client: Enbridge Gas Distribution Inc.
Project: Enbridge - GTA Project - Detailed Engineering Phase
Contractor: Terex Drilling Solutions

Project No.: 110901255
Date: June 9, 2014
Borehole No.: S3C3-5
Logger: Junghoon Ryu

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% ROD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES						OCCASIONAL FEATURES	MOHS HARDNESS	
								NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE			FILLING
27.84	HQ 9	100	97	29.36	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding		S		B	F	M	RU	-	NC		2.0-3.0
									B	F	M	RU	-	NC		
									B	F	C-M	RU	-	NC		
29.36	HQ 10	100	100	30.63	Reddish Brown and Grey Queenston SHALE with Grey LIMESTONE Interbedding		S		B	F	M	RU	-	NC		2.0-3.0
									B	F	M	RU	-	NC		
									B	F	M	RU	-	NC		

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C = Completely = Soil-like

WV = Very Wide = >3m

W = Wide = 1-3 m

M = Moderate = 0.3-1 m

C = Close = 5-30 cm

VC = Very Close = <5 cm

STRENGTH (MPa)

VW = Very Weak = 1-5

EW = Extremely Weak = < 1

DISCONTINUITY TYPE

B = Bedding Joint

J = Cross Joint

F = Fault

S = Shear Plane

ORIENTATION

F = Flat = 0-20°

D = Dipping = 20-50°

V = n-Vertical = >50°

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ORIENTATION

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NC = Non-swelling Clay
SC = Swelling, Soft Clay

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**FOUNDATION INVESTIGATION AND DESIGN REPORT GTA PROJECT DETAILED
ENGINEERING DESIGN PHASE DOCUMENT NO.: 110901255.085 PROJECT NO.: 110901255**

Appendix F
2015-01-12

Appendix F

F.1 NATIONAL BUILDING CODE SEISMIC HAZARD CALCULATION



2010 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

Requested by: ,

October 21, 2013

Site Coordinates: 43.5992 North 79.7942 West

User File Reference:

National Building Code ground motions:

2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.2)	Sa(0.5)	Sa(1.0)	Sa(2.0)	PGA (g)
0.237	0.135	0.063	0.020	0.132

Notes. Spectral and peak hazard values are determined for firm ground (NBCC 2010 soil class C - average shear wave velocity 360-750 m/s). Median (50th percentile) values are given in units of g. 5% damped spectral acceleration (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are tabulated. Only 2 significant figures are to be used. *These values have been interpolated from a 10 km spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the calculated values.*

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.2)	0.027	0.087	0.147
Sa(0.5)	0.015	0.049	0.079
Sa(1.0)	0.008	0.026	0.041
Sa(2.0)	0.003	0.009	0.013
PGA	0.009	0.039	0.072

References

National Building Code of Canada 2010 NRCC no. 53301; sections 4.1.8, 9.20.1.2, 9.23.10.2, 9.31.6.2, and 6.2.1.3

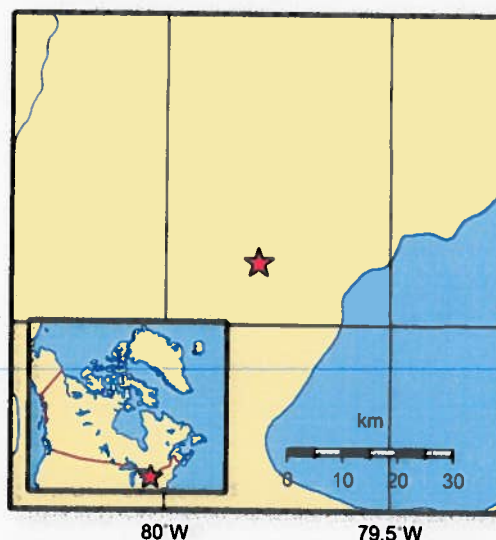
Appendix C: Climatic Information for Building Design in Canada - table in Appendix C starting on page C-11 of Division B, volume 2

User's Guide - NBC 2010, Structural Commentaries NRCC no. 53543 (in preparation)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File xxxx
Fourth generation seismic hazard maps of Canada: Maps and grid values to be used with the 2010 National Building Code of Canada (in preparation)

See the websites www.EarthquakesCanada.ca and www.nationalcodes.ca for more information

Aussi disponible en français



**FOUNDATION INVESTIGATION AND DESIGN REPORT GTA PROJECT DETAILED
ENGINEERING DESIGN PHASE DOCUMENT NO.: 110901255.085 PROJECT NO.: 110901255**

Appendix G
2015-01-12

Appendix G

G.1 NSSP PIPE INSTALLATION BY TRENCHLESS METHOD



PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Non Standard Special Provision

July 2014

1. SCOPE

This specification covers the general requirements for the installation of pipes by trenchless methods.

The Contractor shall determine the most appropriate **method of installation**. **Specifications for Jack & Bore, Pipe Ramming, Directional Drilling, and Tunneling** are provided herein, and shall be applied to the installation method considered feasible by the Contractor.

OPSS 415 (Construction Specification for Pipeline and Utility 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) shall not be used to do the work for the above tender item.

2. REFERENCES

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

Foundation Investigation and Design Report

GTA Project Detailed Engineering Design Phase, S3C3 – Highway 401, Mississauga, ON
Project No. 110901255
Document No. 110901255.085

Instrumentation and Monitoring Plan for Trenchless Pipeline Installation

GTA Project Detailed Engineering Design Phase, S3C3 – Highway 401, Mississauga, ON
Project No. 110901255
Document No. 110901255.334

Ontario Provincial Standard Specifications, General

OPSS 180 Management and Disposal of Excess Material

Ontario Provincial Standard Specifications, Construction

OPSS 504 Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 507 Site Restoration Following Installation of Pipelines, Utilities and Associated Structures in Open Cut
OPSS 514 Trenching, Backfilling, and Compaction
OPSS 517 Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS 538 Support Systems
OPSS 539 Protection Schemes

Ontario Provincial Standard Specifications, Material

OPSS 1004 Aggregates - Miscellaneous
OPSS 1350 Concrete - Materials and Production
OPSS 1440 Steel Reinforcement for Concrete
OPSS 1802 Smooth Walled Steel Pipe

MTO Specifications

OPSS 1820	Material Specification for Circular Concrete Pipe
OPSS 1840	Material Specification for Non-Pressure Polyethylene 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 Polyelofin 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:

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.

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.

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.

steel 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.

Entry/Exit HDD/
Bore pits and or

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.

Tunnelling: an underground method of constructing a passage open at both ends that involves installing a pipe.

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.

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 (1) 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; and
- Design assumption and material data when materials other than those specified are proposed for use.
- 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 jacking procedures, including methodology to handle obstructions and preventing 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, layout 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 excavation
Jacking/Ramming/Directional Drilling of Casing/Liner
Excavation and Dewatering
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 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 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 1004 wetted with only sufficient water to make the mixture plastic.

5.06 Jack & Bore Materials

5.06.01 Pipe Materials

Steel pipe shall conform with ASTM A252-95 welded joints suitable for jacking operations. The Contractor shall select pipe class for pipe jacking.

Concrete pipe as per OPSS 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. A minimum wall thickness of 50 mm and minimum yield strength of 240 MPa is required.

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 accordance with 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.

Joining 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 joining process.

Joining 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 to provide support and stability to the excavation.~~

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 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 Jack & Bore Equipment

~~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 explosives or rock fracturing chemicals shall only be considered subject to a field demonstration satisfactory to the Ministry prior to its use.~~

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 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;

to be defined on the Contractors HDD execution plan

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.

conforms to the HDD design alignment specifications.

7.01.02 Shafts Entry/Exit HDD/Bore pits

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

Shafts shall be maintained in a drained condition.

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

7.01.03 Protection Systems

The construction of all protection systems shall be according to OPSS 539. Where the stability, safety, or function of an existing roadway, watercourse, other works, proposed works or ESA's may be impaired due to

the method of operation, protection shall be provided. ~~Protection systems include primary liner and portal excavation support systems.~~ 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 504.

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.

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer's handling and storage recommendations shall be followed.

and as otherwise specified
in Contract Documents,
Client Construction
Specifications and the Oil
and Gas Construction Best
practices

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 514.

7.01.09 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.

7.01.10 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.~~

7.01.11 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.

7.01.12 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 median end of the pipe to the outlet end to confirm gravity flow conditions.

7.01.13 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.**

7.01.14 Site Restoration

Site restoration shall be according to OPSS 507.

7.01.15 Supervision

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

7.02 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 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

Owner's
Representative

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.~~

Owner's Representative

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

pre-welded and
hydrotested in
accordance with
approved construction
specifications

,if workspace allows, otherwise the
pullback operation will stop to allow
for additional pullback section(s) to
be welded onto the previous
section and then resume.

7.04.06.01 General

The product shall be ~~joined according to manufacturer's recommendations~~. The length of the product to be pulled shall be ~~joined 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 manufacturer's 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~~.

Owner's representative

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~~.

Owner's representative

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 oversized objects from the face. Continuous ground support shall be maintained during excavation.~~

~~As the excavation progresses, the Contractor shall continuously monitor (every 2m) 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 as shown on the Contract Drawings.

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 Subsection 4.02, 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 of sequence of construction or ground stabilization measures to mitigate further ground displacement.

If the 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 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 providing all labour, equipment and materials required for excavation (regardless of material encountered), dewatering, sheathing and shoring, supply and installation of pipe liners, settlement monitoring and instrumentations site restoration and for 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 boulder/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.~~

Notes to Designer:

- ~~• Under Section 7.01.06, minimum horizontal and vertical clearances to existing facilities shall be identified in the Contract Documents. 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. The number of exposures required to monitor work progress shall be specified in the Contract Documents.~~

**FOUNDATION INVESTIGATION AND DESIGN REPORT GTA PROJECT DETAILED
ENGINEERING DESIGN PHASE DOCUMENT NO.: 110901255.085 PROJECT NO.: 110901255**

Appendix H
2015-01-12

Appendix H

H.1 SOIL PARAMETERS FOR HYDROFRACTURE ANALYSIS



Table 1: Soil/Rock Parameters for Hydrofracture Analysis

Borehole	Elevation (m)	Soil/Rock Description	Soil Classification USCS / Bedrock Formation	Compactness / Consistency	Unit Weight, γ (kN/m ³)	Undrained Shear Strength, S_u (kPa)	Effective Internal Friction Angle, ϕ' (degrees)	Young's Modulus (MPa)	Poisson's Ratio
S3C3-1	206.8 to 202.6	Clay with Sand, Till	CL	Stiff to hard	21.5	100	30	75	0.45
	202.6 to 194.5	Sandy Silty Clay, Till	CL-ML	Stiff to hard	21.5	75	28	50	0.45
	194.5 to 191.6	Highly to completely weathered Shale (Soil-Like)	Queenston	N/A	23	200	32	200	0.4
	196.1 to 171.8	Poor quality or better Shale	Queenston	N/A	26	75 (equivalent cohesion, C') ¹ 35 (equivalent friction angle, ϕ') ¹		1000	0.32
S3C3-2	207.0 to 204.6	Clay with Sand, Till	CL	Firm to very stiff	21	50	28	25	0.45
	204.6 to 200.4	Sandy Silty Clay to Sandy Silty Clay with Gravel, Till	CL-ML	Very stiff to firm	21	50	28	25	0.45
	200.4 to 198.8	Sandy Silty Clay to Sandy Silty Clay with Gravel, Till	CL-ML	Firm to soft	19.5	25	26	10	0.45
	198.8 to 196.8	Silty Clayey Sand, Till	SC-SM	Compact to Dense	21.5	N/A	30	20	0.35
	196.8 to 193.7	Sandy Clay, Till	CL	Hard	20.5	200	30	100	0.45
	193.7 to 192.9	Highly to completely weathered Shale	Queenston	N/A	23	200	32	200	0.4
	192.9 to 176.5	Poor quality or better Shale	Queenston	Poor quality or better shale	26	75 (equivalent cohesion, C') ¹ 35 (equivalent friction angle, ϕ') ¹		1000	0.32
S3C3-3	206.9 to 201.1	Clay with Sand, Till	CL	Firm to hard	21.5	75	28	50	0.45
	201.1 to 198.0	Sandy Clay, Till	CL	Stiff to firm	19.5	25	26	10	0.45
	198.0 to 196.7	Silty Sand, Till	SM	Very dense	21.5	N/A	34	75	0.35
	196.7 to 193.0	Silty Clayey Sand, Till	SC-SM	Very dense	21.5	N/A	34	75	0.35
	193.0 to 192.1	Highly to completely weathered Shale	Queenston	N/A	23	200	32	200	0.4
	192.1 to 176.7	Poor quality or better Shale	Queenston	N/A	26	75 (equivalent cohesion, C') ¹ 35 (equivalent friction angle, ϕ') ¹		1000	0.32
S3C3-4	207.4 to 202.9	Clay with Sand, Till	CL	Firm to very stiff	21	50	28	25	0.45
	202.9 to 197.5	Sandy Clay, Till	CL	Firm to stiff	21	25	26	10	0.45

Table 1: Soil/Rock Parameters for Hydrofracture Analysis

Borehole	Elevation (m)	Soil/Rock Description	Soil Classification USCS / Bedrock Formation	Compactness / Consistency	Unit Weight, γ (kN/m^3)	Undrained Shear Strength, S_u (kPa)	Effective Internal Friction Angle, ϕ' (degrees)	Young's Modulus (MPa)	Poisson's Ratio
	197.5 to 194.5	Sandy Silty Clay, Till	CL-ML	Stiff to hard	21.5	100	30	75	0.45
	194.5 to 190.2	Sandy Silty Clay, Till	CL-ML	Hard	21.5	200	32	150	0.45
	190.2 to 188.8	Highly to completely weathered Shale (Soil-Like)	Queenston	N/A	23	200	32	200	0.4
	188.8 to 172.4	Poor quality or better Shale	Queenston	N/A	26	75 (equivalent cohesion, c') ¹ 35 (equivalent friction angle, ϕ') ¹		1000	0.32
S3C3-5	209.2 to 208.5	Sand and Gravel	FILL	Compact	21	N/A	30	25	0.4
	208.5 to 206.3	Sandy Silty Clay	FILL	Firm to stiff	20	25	26	10	0.45
	206.3 to 200.2	CLAY with Sand, Till	CL	Firm to very stiff	21.5	50	28	25	0.45
	200.2 to 198.6	Sandy Clay, Till	CL	Firm to stiff	21.5	50	28	25	0.45
	198.6 to 196.4	Sandy Silty Clay, Till	(CL-ML)	Very stiff to hard	21.5	150	30	100	0.45
	196.4 to 195.1	Silty Clayey Sand with Gravel, Till	SC-SM	Very dense	21.5	N/A	34	75	0.35
	195.1 to 193.2	Highly to completely weathered Shale (Soil-Like)	Queenston	N/A	23	200	32	200	0.4
	193.2 to 178.3	Poor quality or better Shale	Queenston	N/A	26	75 (equivalent cohesion, c') ¹ 35 (equivalent friction angle, ϕ') ¹		1000	0.32

Notes:

- Parameters provided are based on Hoek-Brown Failure Criterion for Tunneling Application.
- Calculations for drained conditions should consider the following: $c' = 0$ and ϕ' as obtained from the table above.
- Calculations for undrained conditions should consider the following: c (commonly denoted as S_u) as obtained from the table above and $\phi = 0^\circ$.
- The total overburden pressure, P_o , may be calculated using the total unit weights provided in the table above. The effective overburden pressure, P_o' , may be calculated as P_o minus the hydrostatic pressure calculated based on the ground water level as provided in the geotechnical report.

