Foundation Investigation and Design Report, GTA Project, Detailed Engineering Design Phase

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Spread 2 – Crossing 11 (S2C11)
Highway 404
Markham, ON

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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 404. This crossing is designated as Spread 2 Crossing 11 (e.g. S2C11). 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 as Highway 404. 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 designated the 36 in. (914.4 mm) diameter steel pipe crossing of Highway 404 as a crossing requiring the participation of a foundation engineering consultant registered in MTO's consultant acquisition system under Medium Complexity for Tunneling Specialty Services.

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 404 is shown on Figure S2C11 in **Appendix B**.

The planned crossing is located approximately 370 m south of the interchange with the Highway 407 ETR, and approximately 1300 m north of the intersection of Highway 404 and John Street.

For purposes of this report, the orientation of Highway 404 has been taken as north-south and the orientation of the alignment of the proposed pipeline crossing has been taken as east-west.

2.2 SITE DESCRIPTION

At the crossing location, Highway 404 is an 8-lane highway (4 lanes in each direction). The highway has a center barrier and paved shoulders at the crossing location. The total width of the lanes, center barrier and shoulders at the crossing location (MTO lands) is approximately 95 m.

There are two on-ramps on the west side of and immediately adjacent to, Highway 404; these on-ramps access Highway 404 southbound from the eastbound and westbound lanes of the Highway 407 ETR. There are two off-ramps on the east side of Highway 404; these ramps are isolated and separated from Highway 404 at the crossing location and access the eastbound and westbound lanes of the Highway 407 ETR from Highway 404 northbound.

Aerial views of the crossing location are shown in **Appendix B**.

The approaches to the pipeline crossing are on lands owned by Infrastructure Ontario (IO). There is a 30.5 m wide utility corridor on the IO lands. There is a buried 2400 mm diameter sanitary sewer service in the utility corridor (adjacent to the south limit of the corridor). There is also a buried hydro-power line in the corridor that likely services the light standards on the east side of the on-ramp to the eastbound lanes of the Highway 407 ETR and high mast light standards adjacent to the main lanes of Highway 404. There are three separate high voltage overhead power transmission lines parallel to and immediately south of the utility corridor.

The closest hydro tower and hydro pole to the Preferred Pipeline Route (PPR) are located approximately 60 m and 30 m to the south of the PPR, respectively. The closest street light is located within approximately 2 m of the PPR. There is a sanitary sewer line to the immediate south of the PPR parallel to the PPR alignment.

Commercial and industrial developments exist to the south-east and residential developments to the south-west of the crossing location. Vacant formerly agricultural lands exist immediately to the west and east of the crossing. To the north of the crossing location is the Highway 407 ETR.

The Crossing Plan and Profile drawing used in the preparation of this geotechnical report illustrated the preliminary alignment of the PPR at the crossing location. The Plan and Profile drawing was titled "KP 13+282.0, NPS 36 GTA Project, Buttonville Station to Keele Station, Highway 404-HDD Crossing Method", labelled "Re-Issued For Construction" and dated September 16, 2014.

The site profile drawing for this crossing indicates that the Highway 404 off-ramps on the east side of the highway are on earth embankments approximately 7 m to 8 m high. The embankments have approximate side slopes of 3:1 to 4:1 (Horizontal:Vertical). The elevation on the travelled surface ranges from 188.0 m to 189.5 m. There is a shallow drainage ditch located on the east side of the eastern-most embankment; the bottom of the ditch is at approximately Elevation 182.0 m. The ground surface topography beyond the ditch slopes gently down at approximately 1.5% over a distance of 150 m.

The site profile indicates that the Highway 404 on-ramps on the west side of the highway are at the same elevation as Highway 404. There is a shallow drainage ditch on the west side of the on-ramps; the bottom of the ditch is at approximately Elevation 178.0 m. The ground surface topography beyond the on-ramps on the west side of the highway is flat for a distance of 30 m and then slopes up at approximately 8% over a distance of 50 m.

The ground surface cover on the lands on both sides of Highway 404 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.

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.

As a component of the Front End Engineering Design (FEED) phase for the project, Stantec advanced two (2) boreholes (denoted B8-BH1 and B8-BH2) at locations beyond the limits of the MTO designated lands. The information obtained in the boreholes was used to prepare a preliminary report, referenced as Project No. 122410813 and dated September 13, 2012, to facilitate and support the early stages of the design process.

As a component of the Pull Forward Engineering (PFE) design phase for the project, Stantec advanced an additional three (3) boreholes (denoted S2C11-3 and S2C11-4); one borehole was located in the grass median between the northbound and southbound lanes of the highway and one borehole was located to the east of the northbound lanes of the highway. The information obtained from the FEED boreholes and from the additional PFE boreholes was used to prepare a report dated September 11, 2013, to supplement the preliminary report previously provided.

The boreholes referenced in the two paragraphs above and all associated information has 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 three existing wells within 400 m of the proposed alignment for the crossing. The well records contained lithological information for overburden materials to a depth ranging from 29.6 to 54.9 m below grade. The water well records for the two wells closest to the study area encountered predominantly clay and clayey sand soils to a depth in the range of 27 to 36 m below grade. The well records indicated that the clay and clayey sand soils were underlain by fine to medium sand to gravel.

A review of the OGS database identified two geotechnical boreholes within 200 m of the crossing location (to the west). The records indicated that the boreholes encountered clayey silt to silty sand; underlain by sand. The OGS database also includes the Highway 407 interchange boreholes approximately 300 m from the crossing, one of which extended to a depth of 45 m and was terminated within very dense silty sand till.

2.3.3 Bedrock

Map 2544 indicates that the bedrock underlying the region is of the Georgian Bay Formation of Upper Ordovician age. The rock consists of a combination of limestone, dolostone, shale, and siltstone.

Bedrock was encountered at a depth of approximately 44.2 m below grade in one of the MOE water wells referenced above.

The OGS boreholes referenced above were advanced to a maximum depth of 45 m and did not encounter bedrock to the termination depth.

2.3.4 Groundwater

Two of the MOE water well records referenced above indicated a static groundwater level at approximately 6.4 and 12.2 m below grade.

The OGS geotechnical borehole records referenced above indicated static groundwater levels at depths of 4.3 m, 4.3 m, 8 m and 10.4 m below grade, translating to approximately elevations of 171.4 m, 173.4 m, 172.4 m and 171.3 m, respectively.

2.4 EXISTING STRUCTURES

The planned crossing is located approximately 370 m south of the Highway 407 bridge over Highway 404 and the associated on/off-ramps (three ramps).

There is no MTO structure within the planned crossing site.

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. For reference, consultation with MTO staff established the complexity rating for this specific undertaking as "Medium".

The scope included advancement of five (5) boreholes to supplement the initial four (4) boreholes advanced for the crossing of Highway 404 with consideration for the proposed installation method of Horizontal Directional Drilling (HDD). The borehole locations were established through discussions with the project team and with the project HDD consultant, J.D. Hair, with overview by the project pipeline consultant, Stantec's Calgary based Oil and Gas.

As referenced in the preceding sections of this report, the two boreholes (denoted B8-BH1 and B8-BH2) advanced for the FEED design phase have been incorporated herein as have the two boreholes (denoted as S2C11-3 and S2C11-4) advanced for the PFE design phase. For the Detailed Engineering (DE) Phase of the investigation, five (5) supplementary boreholes (denoted S2C11-5 to S2C11-9) were advanced at locations within the limits of the MTO lands.

The locations of all nine (9) boreholes are shown on Figure S2C11 in **Appendix B.**

For the FEED and PFE phases of investigation (boreholes B8-BH1, B8-BH2, S2C11-3 and S2C11-4) 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.

For the DE phase of investigation (boreholes S2C11-5 to S2C11-9) 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 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 S2C11-3 to S2C11-9 located within the boundaries of the Highway 404 corridor.

The FEED field investigation program was carried out on August 14 and July 17, 2012. The PFE field investigation program was carried out during the period of August 7 to 13, 2013. The DE field investigation program was carried out on July 2, 3, 26 and 29, 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.

A single groundwater monitoring well was installed in borehole S2C11-4. The well included a 3.0 m long screen installed over a depth of approximately 13.7 m to 16.7 m below existing grade within the native silty sand till to sand with sand (and gravel) stratum (further description of the soil stratigraphy encountered in the boreholes is provided in subsequent sections of this report).

The hydrogeological fieldwork component of this investigation was carried out between August 13 and November 8, 2013. The monitoring well was developed by purging pumping in excess of 10 well volumes, or approximately 181 L of groundwater from the casing.

Two in-situ falling head hydraulic conductivity tests were conducted in the well to determine the hydraulic conductivity of the silty sand till to sand with sand (and gravel) present over the screened interval. 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 for confined aquifer solutions.

The remaining boreholes were backfilled with granular bentonite to provide an impervious 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 S2C11 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, NAD 83 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 S2C11 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		B8-BH1	B8-BH2	S2C11-3	S2C11-4	S2C11-5	S2C11-6	S2C11-7	S2C11-8	S2C11-9
Approximate Distance from the PPR		38 m north	3 m south	15 m north	15 m north	20 m south	8 m north	15 m north	13 m north	20 m north
UTM Zone 17	Easting	631127.6	631521.3	631279.9	631338.3	631220.5	631255.4	631320.7	631393.2	631455.1
	Northing	4854908.8	4854972.7	4854924.8	4854941.5	4854873.5	4854910.4	4854934.6	4854953.2	4854976.6
Ground Surface Elevation (m)		178.2	182.2	178.9	180.7	181.1	179.3	179.3	189.7	188.9
Depth Drilled (m)		31.0	31.1	25.5	29.6	26.5	26.5	28.0	34.0	32.2
End of Borehole Elevation (m)		147.2	151.1	153.4	151.1	154.6	152.8	151.3	155.7	156.7
Depth Augered (m)		31.0	31.1	25.5	29.6??	26.5	26.5	28.0	34.0	32.2
Number of Soil Samples		21	21	34	39	31	31	33	42	39

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 soil samples obtained, the following scope of geotechnical laboratory testing was implemented:

- Atterberg Limits — 68 samples (includes 49 non-plastic results)
- Gradation Analysis — 75 samples
- Moisture Content — 291 samples

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 were 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.

4.0 Subsurface Conditions

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.

It should be noted that the internal diameter (I.D.) of the SPT sampler is 38 mm and hence the grain size test results and soil classifications 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 > 300 mm) were inferred to be present in particular stratums and are described separately from the gravel content.

4.2 OVERVIEW

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

- Topsoil or asphalt layer; underlain by,
- Fill materials; underlain by
- Soft to hard sandy clay to clay with sand (till); underlain by,
- Compact to very dense sandy silt to silty sand (till); underlain by,
- Compact to very dense sand with silt to sand with silt and gravel (interbedded in till layer in one borehole); underlain by,
- Hard clay in one borehole and interbedded in till in one borehole.

Static groundwater was recorded at a depth of 8.2 m below grade on August 13 and 20, 2013, and at 8.3 m below grade on November 8, 2013, in the single monitoring well installed at the site.

A stratigraphic section illustrating the soils 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

Topsoil was present at the locations of all boreholes except Borehole S2C11-6 and S2C11-8. The thickness of topsoil approximately ranged from 40 mm to 200 mm.

4.3.2 Asphalt

Asphalt pavement was present at the locations of Boreholes S2C11-6 and S2C11-8. The asphalt was approximately 60 mm and 75 mm thick at the borehole locations respectively.

4.4 FILL

A layer of fill material was encountered in boreholes B8-BH1, B8-BH2, S2C11-4, S2C11-6, S2C11-7, S2C11-8 and S2C11-9. It consisted of sand and gravel, silty sand in boreholes B8-BH1, B8-BH2, S2C11-6 and S2C11-7. In boreholes S2C11-4, S2C11-8 and S2C11-9 the fill material contained sandy clay to sandy silty clay, clay with sand and silty sand with gravel. The samples of the fill typically contained some gravel, trace rootlets, trace to some silt, some clay and some organics. Cobbles and boulders were also inferred in this material based on auger grinding and refusal. The fill extended to approximately 0.2 to 8.4 m below grade in the above-mentioned boreholes.

N-values ranging from 3 to greater than 50 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 4% to 24%.

Six gradation tests were completed on a sample of the fill. The test results are summarized in Table 4-1 below.

Table 4-1 Grain Size Distribution – Fill

Borehole	Sample	Depth (m)	Description	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
S2C11-7	SS2	1.1	Silty Sand Fill	5	47	33	15
S2C11-8	SS2	1.1	Silty Sand with Gravel Fill	35	45	16	4
S2C11-8	SS5	3.4	Sandy Clay Fill	3	35	43	19
S2C11-8	SS9	6.4	Sandy Silty Clay Fill	5	44	37	14
S2C11-9	SS3	1.8	Sandy Clay Fill	7	30	40	23
S2C11-9	SS6	4.1	Sandy Silty Clay Fill	1	33	46	20

The grain size distribution curves for the tests are shown on Figures 1 and 2 in **Appendix D**.

Atterberg Limits tests were also conducted on a portion of the samples referenced above. The results of the tests are shown in Table 4-2 below.

Table 4-2 Atterberg Limits Test Results – Fill

Borehole	Sample	Depth (m)	Description	Liquid Limit	Plastic Limit	Plasticity Index
S2C11-7	SS2	1.1	Silty Sand Fill	16	13	3
S2C11-8	SS2	1.1	Silty Sand with Gravel Fill	NP	NP	NP
S2C11-8	SS5	3.4	Sandy Clay Fill	21	12	9
S2C11-8	SS9	6.4	Sandy Silty Clay Fill	17	11	6
S2C11-9	SS3	1.8	Sandy Clay Fill	18	10	8
S2C11-9	SS6	4.1	Sandy Silty Clay Fill	17	10	7

The results of the Atterberg Limits tests are shown on Figure 3 in **Appendix D**.

In accordance with the Unified Soil Classification System, the fill samples tested can be classified as silty sand, silty sand with gravel, sandy clay and sandy silty clay.

4.5 SANDY CLAY TO CLAY WITH SAND TILL

A stratum of brown and grey sandy (and/or silty) clay to clay with sand till soil was encountered underlying the fill or topsoil materials in boreholes B8-BH1, B8-BH2, S2C11-4, S2C11-5, S2C11-6 and S2C11-9. 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. Borehole S2C11-5 included some sand. The occasional presence of cobbles and possible boulders was inferred within the sandy clay to clay with sand till in Boreholes S2C11-4, S2C11-5 and S2C11-6 based on auger grinding observed during drilling.

The stratum of sandy clay to clay with sand soil was approximately 2.8 m, 3.3 m, 4.4 m, 2.8 m, 2.6 m and 8.8 m thick and extended to depths of approximately 3.1 m, 4.1 m, 5.3 m, 3 m, 3.7 m and 15.9 m below grade in boreholes B8-BH1, B8-BH2, S2C11-4, S2C11-5, S2C11-6 and S2C11-9 respectively. The bottom elevation of the clay till ranged from 173.0 m to 178.1 m.

The consistency of the silty clay to clay with sand till soil was assessed as soft to hard, based on the results of the SPT tests (N-values ranged from 3 to above 50 blows).

The moisture content of the samples tested ranged from approximately 5% to 26%.

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

Table 4-3 Grain Size Distribution – Sandy Clay, Clay with Sand, Sandy Silty Clay Till

Borehole	Sample	Depth (m)	Description	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
B8-BH2	SS5	3.4	Sandy CLAY (CL), TILL	5	28	41	26
S2C11-4	SS3	1.8	Sandy Silty CLAY (CL-ML), TILL	5	35	42	18
S2C11-5	SS3	1.8	CLAY (CL), TILL	1	13	35	51
S2C11-6	SS3	1.8	Sandy Silty CLAY (CL-ML), TILL	8	39	32	21
S2C11-9	SS11	7.9	CLAY (CL) with sand, TILL	1	14	36	49
S2C11-9	SS16	11.7	CLAY (CL) with sand, TILL	2	16	36	46
S2C11-9	SS20	14.8	CLAY (CL) with sand, TILL	4	17	45	34

The grain size distribution curves for the tests are shown on Figures 4 and 5 in **Appendix D**.

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.

Table 4-4 Atterberg Limits Test Results – Sandy Clay, Clay with Sand, Sandy Silty Clay Till

Borehole	Sample	Depth (m)	Description	Liquid Limit	Plastic Limit	Plasticity Index
B8-BH2	SS5	3.4	Sandy CLAY (CL), TILL	25	13	12
S2C11-4	SS3	1.8	Sandy Silty CLAY (CL-ML), TILL	18	12	6
S2C11-5	SS3	1.8	CLAY (CL), TILL	38	18	20
S2C11-6	SS3	1.8	Sandy Silty CLAY (CL-ML), TILL	20	13	7
S2C11-9	SS11	7.9	CLAY (CL) with sand, TILL	38	16	22
S2C11-9	SS16	11.7	CLAY (CL) with sand, TILL	36	17	19
S2C11-9	SS20	14.8	CLAY (CL) with sand, TILL	18	10	8

The results of the Atterberg Limits tests are shown on Figure 6 in **Appendix D**.

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

4.6 SANDY SILT TO SILTY SAND TILL

Strata of grey and brown silty (and/or clayey) sand to sandy silt, silty sand with gravel and silty clayey sand with gravel till soils were encountered underlying sandy and/or silty clay till, clay with sand till or topsoil or fill in all boreholes, interbedded with a sand with silt layer in borehole S2C11-8 and interbedded with a clay layer in borehole B8-BH2. 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 sandy silt till soils 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.

In boreholes B8-BH2 and S2C11-8, this till material extended to the termination depth of the boreholes. In the other boreholes, the silty sand and sandy silt till soils had a thickness of 1.6 m to 12.2 m and extended to the depths between 5.5 m and 27.0 m below grade. The bottom elevation of the silty sand to sandy silt till ranged from 174.1 m to 161.9 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 11 blows to refusal).

The moisture content of the samples tested ranged from approximately 5% to 31%.

Grain size distribution tests were completed on thirty samples of the soil. The results of the tests are shown in Table 4-5 below.

Table 4-5 Grain Size Distribution – Silty Sand, Sandy Silt, Silty Sand with Gravel and Silty Clayey Sand with Gravel Till

Borehole	Sample	Depth (m)	Description	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
B8-BH1	SS6	4.8	Silty SAND (SM), TILL	9	46	45	
B8-BH1	SS9	9.4	Silty SAND (SM), TILL	8	78	14	
B8-BH2	SS9	9.4	Silty SAND (SM), TILL	14	40	38	8
B8-BH2	SS15	18.6	Silty SAND (SM), TILL	9	57	31	3
B8-BH2	SS20	27.7	Silty SAND (SM), TILL	5	82	11	2
S2C11-3	SS5	3.4	Silty SAND (SM), TILL	6	56	32	6
S2C11-3	SS9	6.2	Sandy SILT (ML), TILL	9	38	48	5

Borehole	Sample	Depth (m)	Description	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
S2C11-3	SS12	8.6	Silty SAND (SM), TILL	6	56	30	8
S2C11-4	SS8	5.5	Silty SAND (SM), TILL	7	74	16	3
S2C11-4	SS12	8.5	Sandy SILT (ML), TILL	2	38	55	5
S2C11-4	SS14	10.2	Silty SAND (SM), TILL	0	86	12	2
S2C11-4	SS17	12.5	Silty SAND (SM), TILL	5	51	36	8
S2C11-5	SS6	4.1	Sandy SILT (ML), TILL	3	45	40	12
S2C11-5	SS11	7.9	Silty SAND (SM), TILL	6	54	37	3
S2C11-5	SS15	11.0	Silty SAND (SM), TILL	5	55	32	8
S2C11-5	SS20	14.7	Silty SAND (SM) with Gravel, TILL	32	48	16	4
S2C11-6	SS6	4.1	Silty SAND (SM), TILL	5	53	37	5
S2C11-7	SS7	4.8	Silty Clayey SAND (SC-SM) with Gravel, TILL	22	44	25	9
S2C11-7	SS12	8.7	Silty SAND (SM), TILL	0	79	19	2
S2C11-7	SS16	11.7	Silty SAND (SM), TILL	11	48	31	10
S2C11-7	SS19	14.0	Silty SAND (SM), TILL	2	73	16	9
S2C11-8	SS14	10.2	Silty SAND (SM), TILL	5	47	38	10
S2C11-8	SS19	13.9	Silty SAND (SM), TILL	7	52	32	9
S2C11-8	SS22	16.3	Silty SAND (SM), TILL	9	46	38	7
S2C11-8	SS28	20.8	Silty SAND (SM), TILL	12	52	28	8
S2C11-8	SS32	23.8	Silty SAND (SM), TILL	13	69	15	3
S2C11-8	SS39	29.3	Silty SAND (SM), TILL	1	85	11	3
S2C11-9	SS23	17.1	Silty SAND (SM), TILL	7	51	36	6
S2C11-9	SS28	20.8	Silty SAND (SM), TILL	10	50	32	8
S2C11-9	SS30	22.4	Silty SAND (SM), TILL	1	87	10	2
S2C11-9	SS35	26.2	Silty SAND (SM), TILL	0	80	18	2

The grain size distribution curves are shown on Figures 7 to 13 in **Appendix D**.

Atterberg Limits tests were attempted on portions of the samples referenced above. The results of the tests for 27 samples indicated that the samples were non-plastic. The results of the tests which indicated some minimal plasticity are shown in Table 4-6 below.

Table 4-6 Atterberg Limits - Grain Size Distribution – Silty Sand, Sandy Silt, Silty Sand with Gravel and Silty Clayey Sand with Gravel Till

Borehole	Sample	Depth (m)	Description	Liquid Limit	Plastic Limit	Plasticity Index
S2C11-5	SS6	4.1	Sandy Silt (ML), TILL	14	11	3
S2C11-7	SS7	4.8	Silty Clayey SAND (SC-SM) with Gravel, TILL	14	10	4
S2C11-7	SS16	11.7	Silty SAND (SM), TILL	13	11	2
S2C11-8	SS14	10.2	Silty SAND (SM), TILL	14	12	2

The results of the remaining four Atterberg Limits tests are shown on Figure 14 in **Appendix D**.

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

4.7 SAND WITH SILT TO SAND WITH SILT AND GRAVELAND SILTY SAND

Strata of grey to brown sand with silt to sand with silt and gravel soils underlying silty sand till were encountered in all boreholes except borehole B8-BH2. These soils typically contained trace clay. In borehole S2C11-5, the occasional presence of cobbles and possible boulders was inferred within this soil based on auger grinding observed during drilling.

In boreholes B8-BH1 and S2C11-8 the sand with silt to sand with silt and gravel and silty sand soils had a thickness of 7.8 m and 4.6 m and extended to depths of 22.9 m and 29.0 m that correspond to the elevations of 155.3 m and 160.8 m respectively. In the other boreholes mentioned above, the sand with silt to sand with silt and gravel and silty sand extended to the termination depth of the boreholes.

The consistency of sand with silt to sand with silt and gravel soils was assessed as compact to very dense, based on the results of the SPT tests conducted (N-values ranged from 12 to 152 blows).

The moisture content of the samples tested ranged from approximately 8% to 19%.

Gradation tests were completed on samples of the soils. The test results are summarized in Table 4-7 below.

Table 4-7 Grain Size Distribution – Sand with Silt, Sand with Silt and Gravel, Silty Sand

Borehole	Sample	Depth (m)	Description	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
B8-BH1	SS13	15.5	SAND (SW-SM) with Silt and Gravel	44	46	10	
B8-BH1	SS16	20.1	SAND (SP-SM) with Silt	0	94	6	
S2C11-3	SS15	11	SAND (SW-SM) with Silt	0	88	9	3
S2C11-3	SS18	13.3	SAND (SW-SM) with Silt and Gravel	26	63	9	2
S2C11-3	SS20	14.8	SAND (SP-SM) with Silt	13	75	10	2
S2C11-3	SS24	17.8	SAND (SW-SM) with Silt	12	77	9	2
S2C11-3	SS30	22.4	SAND (SW-SM) with Silt	6	84	8	2
S2C11-3	SS33	24.7	SAND (SP-SM) with Silt and Gravel	16	73	10	1
S2C11-4	SS21	15.5	SAND (SP-SM) with Silt	0	91	7	2
S2C11-4	SS26	19.4	SAND (SP-SM) with Silt	6	83	9	2
S2C11-4	SS29	21.6	SAND (SP-SM) with Silt and Gravel	28	66	4	2
S2C11-4	SS34	25.5	Silty SAND (SM)	0	82	15	3
S2C11-4	SS38	28.5	Silty SAND (SM)	0	87	11	2
S2C11-5	SS24	17.8	SAND (SP-SM) with Silt and Gravel	34	59	5	2
S2C11-5	SS27	20.1	SAND (SW-SM) with Silt and Gravel	23	67	8	2
S2C11-5	SS30	24.7	SAND (SW-SM) with Silt	5	86	7	2
S2C11-6	SS9	6.4	SAND (SP-SM) with Silt	3	90	6	1
S2C11-6	SS13	9.4	SAND (SP-SM) with Silt and Gravel	30	61	7	2
S2C11-6	SS17	12.5	SAND (SP-SM) with Silt and Gravel	20	68	9	3
S2C11-6	SS21	15.5	SAND (SP-SM) with Silt and Gravel	16	73	9	2
S2C11-6	SS24	17.8	SAND (SW-SM) with Silt and Gravel	23	68	7	2
S2C11-6	SS28	21.6	SAND (SW-SM) with Silt and Gravel	32	59	7	2
S2C11-7	SS23	17.0	SAND (SP-SM) with Silt	0	92	6	2
S2C11-7	SS27	20.1	SAND (SW-SM) with Silt	7	84	7	2
S2C11-7	SS31	24.7	Silty SAND (SM)	3	84	11	2
S2C11-7	SS33	27.7	SAND (SP-SM) with Silt	0	91	7	2
S2C11-8	SS36	27	SAND (SP-SM) with Silt	1	91	6	2
S2C11-9	SS38	30.6	SAND (SP-SM) with Silt	6	84	8	2

The grain size distribution curves for the tests are shown on Figures 15 to 20 in **Appendix D**.

Atterberg Limits tests were also conducted on a number of the samples referenced above. The results of the tests indicated that all of the samples were non-plastic.

In accordance with the Unified Soil Classification System, the samples tested can be classified as Sand with Silt to Sand with Silt and Gravel (SW-SM) to (SP-SM) and Silty Sand (SM).

4.8 CLAY

Strata of grey clay were encountered in boreholes B8-BH1 and B8-BH2. In borehole B8-BH1 it was encountered underlying the sand with silt to sand with silt and gravel at a depth of 22.9 m below grade (Elevation 155.3 m) and extended to the termination depth of the borehole. In borehole B8-BH2, the clay layer was encountered beneath the silty sand till at the depth of 10.7 m and extended to a depth of 11.4 m below grade (elevation 170.7 m). The clay typically contained trace sand.

The consistency of the clays was assessed as hard based on the results of the SPT tests conducted (N-values ranged from 47 blows to greater than 50 blows).

The moisture content of the samples tested ranged from approximately 14% to 22%.

Grain size distribution tests were completed on two samples of the clay soil. The results of the tests are shown in Table 4-9 below.

Table 4-8 Grain Size Distribution – Clay

Borehole	Sample	Depth (m)	Description	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
B8-BH1	SS20	27.7	Clay (CL)	0	3	34	63
B8-BH2	SS10	11.0	Clay (CL)	0	13	57	30

The grain size distribution curves are shown on Figure 21 in **Appendix D**.

Atterberg Limits tests were conducted on the samples referenced above. The results of the tests are shown in Table 4-10 below.

Table 4-9 Atterberg Limits – Clay

Borehole	Sample	Depth (m)	Description	Liquid Limit	Plastic Limit	Plasticity Index
B8-BH1	SS20	27.7	Clay (CI)	42	20	22
B8-BH2	SS10	11.0	Clay (CL)	24	15	9

The results of the Atterberg Limits tests for the clay are shown on Figure 22 in **Appendix D**.

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

4.9 GROUNDWATER

The static groundwater level was recorded in monitoring well MW S2C11-4 at a depth of approximately 8.2 m below existing grade on August 13 and 20, 2013 and at 8.3 m below grade on November 8, 2013.

The monitoring well was screened across a depth of 13.7 m to 16.7 m in the underlying silty sand till and sand with silt to sand with silt and gravel soils. The groundwater level measured indicates the presence of a hydrostatic head in the silty sand and sand with silt soils. Flowing artesian conditions were not observed.

The two falling head permeability tests conducted in S2C11-4 yielded a hydraulic conductivity of 6.1×10^{-5} m/s (6.1×10^{-3} cm/s) for the combination of the silty sand till, sand with silt and sand with silt and gravel soils 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 Boreholel 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. Kasgin Khaheshi Banab, Ph.D., 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. Ron Howieson, P.Eng., and by Mr. Raymond Haché, M.Sc., P.Eng., MTO Designated Principal Contact.

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.

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

Groundwater level was measured at a minimum depth of 8.2 m below grade (corresponding to Elevation 172.5 m) in the monitoring well. This level was associated with the presence of the hydrostatic head in the underlying silty sand till soils.

Given the generally fine-grained nature of the overlying sandy clay till soils, it is unlikely that dewatering (considered herein as pumping of groundwater to depressurize or lower the groundwater table in advance of and during 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 sandy clay till soil. Given the stiff to very stiff consistency inferred from the borehole in the proximity of exit point and the fine grain nature of this soil, infiltration and seepage into the open excavation should be limited in the exit pit. In this respect, low to moderate seepage and infiltration should be anticipated in the open excavations. Given the very soft to soft consistency inferred from the borehole in the proximity of entry point, considerable infiltration and seepage into the open excavation can occur. In this respect, moderate to high seepage and infiltration should be anticipated in the open excavation in the entry pit.

In the exit pit, 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 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.

The results of the Atterberg Limits tests for the clay are shown on Figure 22 in **Appendix D**.

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

4.9 GROUNDWATER

The static groundwater level was recorded in monitoring well MW S2C11-4 at a depth of approximately 8.2 m below existing grade on August 13 and 20, 2013 and at 8.3 m below grade on November 8, 2013.

The monitoring well was screened across a depth of 13.7 m to 16.7 m in the underlying silty sand till and sand with silt to sand with silt and gravel soils. The groundwater level measured indicates the presence of a hydrostatic head in the silty sand and sand with silt soils. Flowing artesian conditions were not observed.

The two falling head permeability tests conducted in S2C11-4 yielded a hydraulic conductivity of 6.1×10^{-5} m/s (6.1×10^{-3} cm/s) for the combination of the silty sand till, sand with silt and sand with silt and gravel soils present over the screened interval.

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

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.

FOUNDATION DESIGN REPORT

FOR

Spread 2 – Crossing 11 (S2C11)
Highway 404
Markham, ONSpread 2 – Crossing 11 (S2C11)
Highway 404
Markham, 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 a 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 404 Crossing (S2C11)

7.1.2.1 Alignment

This investigation report is focused on the required crossing of Highway 404, referred to as crossing S2C11.

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 13+282.0, NPS 36 GTA Project, Buttonville Station to Keele Station, Highway 404-HDD Crossing Method", labelled "Re-Issued For Construction" and dated September 16, 2014. The drawing indicated that the installation will consist of a NPS 36 (36 inch/914.4 millimeter outside diameter) steel pipe with a wall thickness of 19.1 mm. The pipe is specified as CSA Z245.1, GR. 448, CAT II, M5C.

For reference, Design Basis Memorandum (DBM), Document No. 110901255.027, Revision 0, dated February 13, 2014, 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. This 5 m vertical clearance has considered the tolerances shown on the crossing drawing.

The horizontal separation between any existing utilities/services and the PPR was dictated to a large extent by constraints associated with establishing the overall alignment. As a result, the design of the alignment and tolerances could not consider the locations of existing utilities and services, and hence a minimum horizontal separation could not be specified in this respect. It is anticipated that the majority of concerns with respect to the horizontal separation 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. 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	467 m
• True Length	469 m
• Arc Radius	1097 m
• Ground Surface Elevation – Entry Point (east side of Highway 404)	182.0 m
• Ground Surface Elevation – Exit Point (west side of Highway 404)	182.0 m
• Ground Surface Elevation – Top of Asphalt Highway 404	178.7 m (lowest level)
• Median Pipe - Lowest Elevation (beneath Highway 404)	162.5 m
• Minimum Depth of Top of Pipe below Asphalt (Highway 404)	14.5 m (west edge)

The drawing indicates that the entry pit is located approximately 78 m beyond the toe of the embankment of the off-ramps on the east side of the highway and the exit pit is located 131 m beyond the edge on-ramps on the west side of the highway.

Based on the profile and the depths and elevations referenced above the top of pipe will be approximately 18.1 m to 25.1 m below the off-ramps on the east side of the highway, approximately 14.5 m to 15.5 m below the travelled surface of the southbound and northbound lanes of the Highway, and 13 m below the on-ramps on the west side of the highway.

The top of pipe will be approximately 11.5 m below the ditch on the west side of the on-ramps, approximately 15 m below the median between the northbound and southbound lanes, and approximately 11 m below the ditch on the east side of the off-ramps.

The top of pipe will be approximately 15 m below the existing hydro utility which is located to the immediate east of the Highway 404 and extends to 18.2 m east of the eastbound on-ramp of the Highway 407. The profile indicates that the existing 2400 mm diameter sanitary sewer is buried at a relatively shallow depth, in the order of 2 m to 4 m below grade, excluding the locations of the on-ramps on the east side of the highway where the sewer pipe is in excess of 10 m below grade in consideration of the presence of the embankments for the off-ramps. Over the bulk of the middle portion of the PPR, where the alignment is deeper, the presence of the sewer is not a concern. However, at both ends of the alignment, the HDD and the sewer will be in close proximity; the information available indicates that the horizontal separation distance between the alignment of the PPR and the sewer could be as little as 3.9 m or potentially less at the extreme end of the HDD alignment (e.g. location of the exit point). 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.

The depths noted meet the requirements of the DBM Document as referenced above.

7.1.2.2 MTO Complexity Rating for Tunneling Specialty Services

With reference to the Guidelines For Foundation Engineering issued by the MTO, and considering Highway 404 is a 400 Series Highway and a pipe diameter < 1 m, translates to a Complexity Rating for Tunneling Specialty Services (Table 1 in the Guidelines) of Medium.

7.1.2.3 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.

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.

7.1.2.4 Conceptual Construction Schedule Overview

The HDD design report referenced above estimated the HDD construction duration for the proposed crossing of Highway 404 based on a 12 hour shift per day as follows:

- Pilot Hole Duration — 3.2 days
- Pre-reaming and Pullback — 12.2 days
- Total Duration (without margin for risk) — 15.4 days

7.1.2.5 Construction Staging & Detours

The locations of the entry and exit points for the HDD are well beyond the limits of the Highway 404 corridor. The location of the exit point is within the limits of the lands designated to the Highway 407 ETR, however, is not in proximity to any existing highway infrastructure. As a result, there is no anticipation for disruption to traffic flow on the Highway as a direct result of the construction activities.

There may be constraints to traffic flow subject to the scope of the settlement monitoring program that may be required by MTO for the project as further described below.

7.2 SOIL SUMMARY AND STRATIGRAPHIC MODEL

Table G-1 in **Appendix G** 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 design should also consider the static groundwater level which was recorded at a minimum depth of 8.2 m below the existing grade, corresponding to Elevation 172.5 m, in S2C11-4. The monitoring well was screened in the silty sand till and sand with silt to sand with silt and gravel (aquifer) overlain by the sandy silty clay till soils (aquitard). The conditions described are representative of a "confined" groundwater regime and the groundwater level measured indicates the presence of a hydrostatic head in the underlying silty sand till and sand with silt soils.

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 harmonic mean 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 34.0 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 S2C11-8) were considered for purposes of assessing the Seismic Site Classification:

Table 7-1 Parameters for Seismic Site Classification

Depth	Soil	N_{60} Value
0 to 1.5 m	Silty Sand, Fill	19
1.5 to 8.4 m	Sandy Clay to Sandy Silty Clay, Fill	18
8.4 to 24.4 m	Dense to Very Dense Silty Sand, Till	100
24.4 to 28.9 m	Compact to Very Dense Sand with Silt	44
28.9 to 30.0 m	Dense Silty Sand, Till	45
Average		40

Based on the profile described above, a weighted harmonic mean N_{60} value of 40 for the upper 30 m of the stratigraphy was 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 GTA area is 0.05.

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 APPROCH

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.

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 pipeline 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 pipeline 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.

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 14.5 m to 15.5 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

Borehole [1]	Approximate Pipeline Elevation at Borehole Location (m)	Soil Strata Anticipated at the Proposed Pipeline Installation Level
B8-BH2	173.6-174.5 [2]	Very Dense Silty Sand, Till
S2C11-9	166.4-167.3 [2]	Very Dense Silty Sand, Till
S2C11-8	162.8-163.7 [2]	Compact to Very Dense Sand with Silt
S2C11-7	162.2-163.1 [2]	Dense to Very Dense Sand with Silt
S2C11-4	162.4-163.3 [2]	Very Dense Sand with Silt to Sand with Silt and Gravel
S2C11-3	162.8-163.7 [2]	Very Dense Sand with Silt to Sand with Silt and Gravel
S2C11-6	164.0-164.9 [2]	Compact to Very Dense Sand with Silt to Sand with Silt and Gravel
S2C11-5	167.2-168.1 [2]	Dense to Very Dense Silty Sand, Till
B8-BH1	177.2 – 178.1 [2]	Stiff to Very Stiff Sandy Clay, Till

Notes:

1 The boreholes have been arranged in order commencing from the Entry Point location to the Exit Point Location

2 The alignment referenced in the table was provided on the HDD Plan and Profile provided for use in preparation of this geotechnical report. 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 (except in the proximity of entry and exit points) level taken as 172.5 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.

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 404). 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 about 30 m to the south of the crossing alignment.
- The construction methodology associated with the HDD will serve to mitigate against potential disruption of the Highway 404.
- The site has sufficient space for a HDD installation.
- HDD installation in the dense to very dense silty sand till and stiff to very stiff sandy clay soils encountered in some 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 planned level of the PPR is coincident with the presence of the ground water table. 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 404, referred to as crossing S2C11.

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 sandy clay till and silty sand/sandy silt till soils. 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.
- The native soils present along the PPR alignment consisted predominantly of cohesionless soils (e.g. sandy silt, silty sand, sand with silt, sand with silt and gravel). The different grain size and compactness condition between the silt/silt with sand strata and the sandy silt to silty sand strata (and sand seams that were observed in a number of samples) can result in deflection of the drill bit. The presence of cobbles and/or boulders is typical within the Halton Till soils. Oversize materials may also 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 specialty contractor's design and construction methodology will need to consider the presence of these materials.

- 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 at the ground surface. As noted above, the PPR and the existing sanitary sewer are in close proximity in the areas of the entry and exit pits. The design plan requires that existing services (such as the sanitary sewer) be identified, marked, monitored and protected during construction to mitigate against potential disturbance or damage as a result of the HDD operations.
- 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 dense condition of the silt 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. Excluding the immediate areas of the entry and exit pits, the vertical separation between the PPR at depth and the sanitary sewer at shallow depth is in the order of 5 m to 15 m. Given this and the anticipated head loss for the inadvertent return drilling mud over this separation distance, the potential to impact the existing services is considered minimal.
- The bore will extend below the static groundwater table, measured at a minimum depth below grade of 8.2 m (corresponding to Elevation 172.5 m). The groundwater level measured in the monitoring well confirmed the presence of a hydrostatic head in the underlying silty sand/sandy silt till soil.
- The potential for the bore/drill hole to become larger than the design hole diameter due to loss of ground into the hole should be considered minimal, given the predominant soil type encountered in the boreholes (i.e. dense to very dense silty sand till and compact to very dense sand with silt and gravel). When drilling in till material, some localized soil collapse may occur along the HDD borehole where sand seams or lenses, and cobbles or boulders are present in the till soils.
- The potential for ground surface movements (i.e. settlement and heave) which could occur above the HDD alignment is considered minimal, given the predominant soil type encountered in the boreholes (i.e. dense to very dense silty sand till and compact to very dense sand with silt soils) and the presence of approximately 14.5 m to 15.5 m of soil cover over the top of the drill/bore path. The potential localized soil collapse referenced in the preceding bullet is not anticipated to contribute to ground surface movement. The potential for ground surface movement to occur is in part, dependent on the contractor's work methods, mud pressure, equipment and techniques used. Use of an annular mud pressure of similar magnitude as the total soil pressure confining the drill hole should reduce the potential for distortion or displacement in the area above the HDD borehole.
- During the drilling of Borehole S2C11-4, a segment of approximately 10 metres of rods from a depth of approximately 15.2 m to 24.4 m below grade (consistent with approximately Elevations 165.5 m to 156.3 m) was lost. Given the location of Borehole S2C11-4 and the PPR as presently intended, it is considered unlikely the HDD will intersect this location. However, any adjustment or relocation of the drill path should consider the potential adverse implication for intersecting the lost drill rods.

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	Constraints
Sandy (Silty) Clay to Clay with Sand, Till	Inferred presence of cobbles and possible boulders[1] Gravel content 1%-8%[2]
Silty Sand/ Sandy Silt, Till	Inferred presence of cobbles and possible boulders[1] Gravel content 0%-32%[2]
Sand with Silt to Sand with Silt and Gravel	Collapse of Bore Path Gravel content 0%-44%[2]
N/A	Static Groundwater Level (confined overburden 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

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 404, the exit and entry pits are in excess of 70 m from the highway corridor. As such there are no implications anticipated in this respect.

8.2 RECOMMENDATIONS

8.2.1 Non Standard Special Provision

An edited copy of the "Pipe Installation by Trenchless Method, Non Standard Special Provision (NSSP), dated February 2009 is included in **Appendix F** 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 design; 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 process;
- 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.

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.

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

Groundwater level was measured at a minimum depth of 8.2 m below grade (corresponding to Elevation 172.5 m) in the monitoring well. This level was associated with the presence of the hydrostatic head in the underlying silty sand till soils.

Given the generally fine-grained nature of the overlying sandy clay till soils, it is unlikely that dewatering (considered herein as pumping of groundwater to depressurize or lower the groundwater table in advance of and during 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 sandy clay till soil. Given the stiff to very stiff consistency inferred from the borehole in the proximity of exit point and the fine grain nature of this soil, infiltration and seepage into the open excavation should be limited in the exit pit. In this respect, low to moderate seepage and infiltration should be anticipated in the open excavations. Given the very soft to soft consistency inferred from the borehole in the proximity of entry point, considerable infiltration and seepage into the open excavation can occur. In this respect, moderate to high seepage and infiltration should be anticipated in the open excavation in the entry pit.

In the exit pit, 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 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.

In the entry pit higher volumes of groundwater infiltration may occur 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 silty sand till, 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 poles, 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 HDD borehole. 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 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 pipeline installation by trenchless technique.

9.3.3 Surface Settlement Markers and Settlement Monitoring Points

A system of surface markers and in-ground monitoring points is established in advance of the 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).

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 soil 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 stratigraphy encountered in shallow excavations was reported and discussed previously in Section 7 (all sub-sections) and Section 8.1. Reference can be made to those sections, and to the specific conditions as shown on the borehole records in **Appendix C**.

For the purpose of this report, we have presumed that temporary excavations without lateral support will only be open for a period in the order of 1 to 2 weeks. Sloughing and caving of side slopes of excavations must be anticipated for excavations that remain open for this period, particularly in the presence of adverse weather conditions.

The following comments pertain to the soil conditions specifically anticipated to be present at the locations of the entry and exit pits.

The stiff sandy clay till and dense silty sand till materials (above groundwater level) should be classified as Type 3 soils. The side slopes in unsupported excavations in Type 3 materials must not be steeper than 1H:1V (Horizontal : Vertical) in accordance with the OH&S Act.

The very soft to soft sandy clay till should be classified as Type 4 soil. The side slopes in unsupported excavations in Type 4 materials must not be steeper than 3H:1V (Horizontal : Vertical) in accordance with the OH&S Act.

Where the soils described above are water bearing (below the groundwater table) they should be considered as Type 4 soils and slopes no steeper than 3H:1V (Horizontal : Vertical) will be required.

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 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.

Any seepage and infiltration rates into open excavations to depths in the order of 1.5 m below grade, such as that required for the entry and exit pits, should be minor. As a result, water infiltration should be manageable using conventional sump pits and contractors pumps. Where sand seams are present in the till soils, additional water infiltration may occur from perched conditions in the sand seams. As referenced above, excavations that remain open for an extended period beyond that described herein may incur seepage and infiltration from precipitation and surface runoff which will increase the level of effort required for control and management in this respect.

Excavations that extend below shallow depths (e.g. below approximately 1.5 m) measured from existing grade may encounter increasing quantities of groundwater infiltration, particularly where the soil is more granular in nature and/or where sand seams are present. However, the anticipated infiltration and seepage remains minor to moderate in this respect.

It is noted that the extent of any consequences of dewatering such as settlement of adjacent ground or nearby infrastructure, is beyond the scope of this investigation.

It should be noted that consistent with the current MOE regulations, a Permit to Take Water is required for dewatering applications that require a pumping rate in excess of 50,000 L/day.

9.5 BACKFILLING

On completion of the 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
- Sand with Silt to Sand with Silt and Gravel (SP-SM/SW-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 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.

With specific regard to the till soils encountered in this investigation, the variable gravel content will likely have an implication for the respective hydraulic conductivities for the soil strata and the associated influx and seepage into open excavations.

The results of the field hydraulic conductivity test conducted in S2C11-4 yielded a hydraulic conductivity of 6×10^{-3} cm/s for the combination of the silty sand (SM) till, sand with silt (SP-SM), and sand with silt and gravel (SW-SM). This value falls within the overall range provided in the OBC for the combination of the silty sand (SM) soil referenced above.

10.0 Specifications

The following specifications should apply to the content of 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

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).

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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.

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. Kasgin Khaheshi Banab, Ph.D., P.Eng. and Mr. Khashayar Refahi, M.A.Sc., P.Eng. and reviewed by Mr. J. Brant Gill, H.B.Sc., P.Geo. and Mr. Ron Howieson, P.Eng. and approved by Mr. Raymond Haché, M.Sc., P.Eng., MTO Designated Principal Contact.

13.0 Sign-Off Sheet

Prepared by ______________________
(signature)

Khashayar Refahi

PROFESSIONAL GEOSCIENTIST
J. BRANT GILL
PRACTISING MEMBER
1640
21 · JAN · 2015
ONTARIO

Reviewed by ______________________
(signature)

J. Brant Gill

LICENSED PROFESSIONAL ENGINEER
Jan. 21/2015
R.W. HOWIESON
PROVINCE OF ONTARIO

Reviewed by ______________________
(signature)

Ron Howieson

Approved by ______________________
(signature)

Raymond Haché

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.

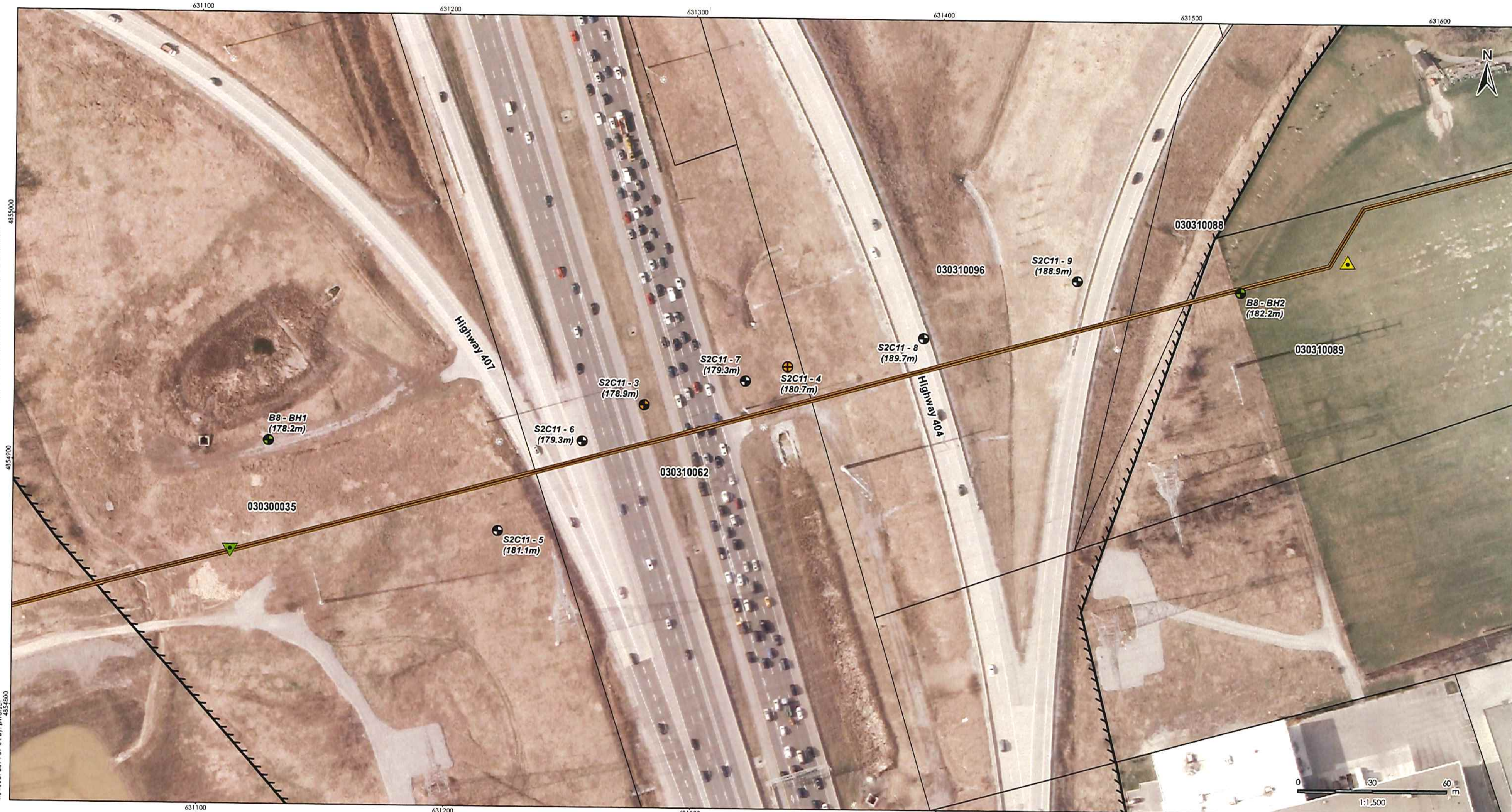
STANDARD OF CARE: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

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.

Appendix B



\\cd1215-f01\work_group\01224\active\1109\Enbridge GTA - PFE\Common Files\Drawings\1609_GIS\MXD\Geotech\DDE_Figures\MTO\110901255_MTO_BH_Detailed_Design.mxd
Revised: 2014-09-04 By: pvoorcel

September 2014
110901255

Stantec

Legend

- Borehole (FEED, 2012)
- Borehole (PFE, 2013)
- Borehole (DE, 2014)
- Borehole with Monitoring Well (PFE, 2013)
- ***(200.0m)*** Ground Surface Elevation (metres ASL)
- HDD Entry Point
- HDD Exit Point
- Enbridge GTA Route Spread 2 (Proposed)
- Property Parcel
- Limits of Highway 407 ETR Lands

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. Orthoimagery © First Base Solutions, 2014. Imagery taken in 2013.

Borehole ID	Easting	Northing
B8 - BH1	631128	4854909
B8 - BH2	631521	4854973
S2C11 - 3	631280	4854925
S2C11 - 4	631338	4854941
S2C11 - 5	631221	4854873
S2C11 - 6	631255	4854910
S2C11 - 7	631321	4854935
S2C11 - 8	631393	4854953
S2C11 - 9	631455	4854977

Client/Project

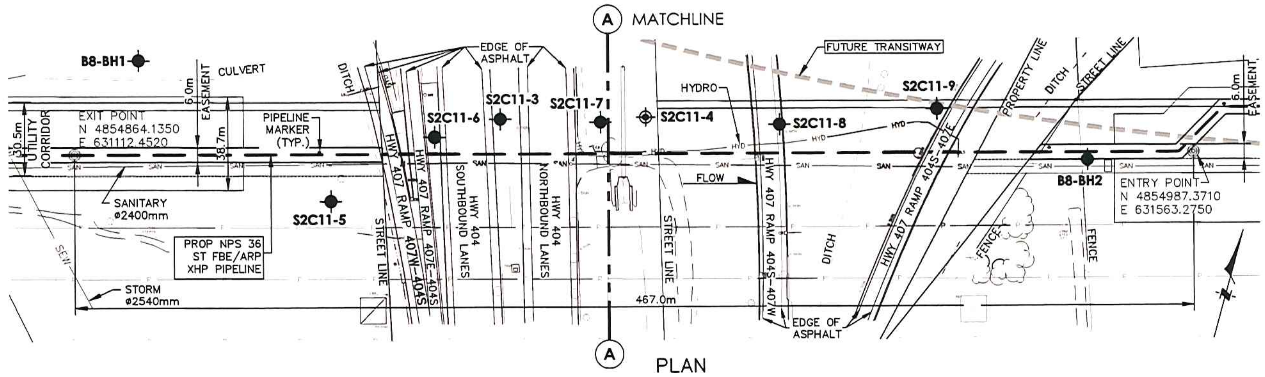
Enbridge Gas Distribution Inc.
Geotechnical - Hydrogeological Investigation
GTA Project – Detailed Engineering (DE) Phase

Figure No.

S2C11

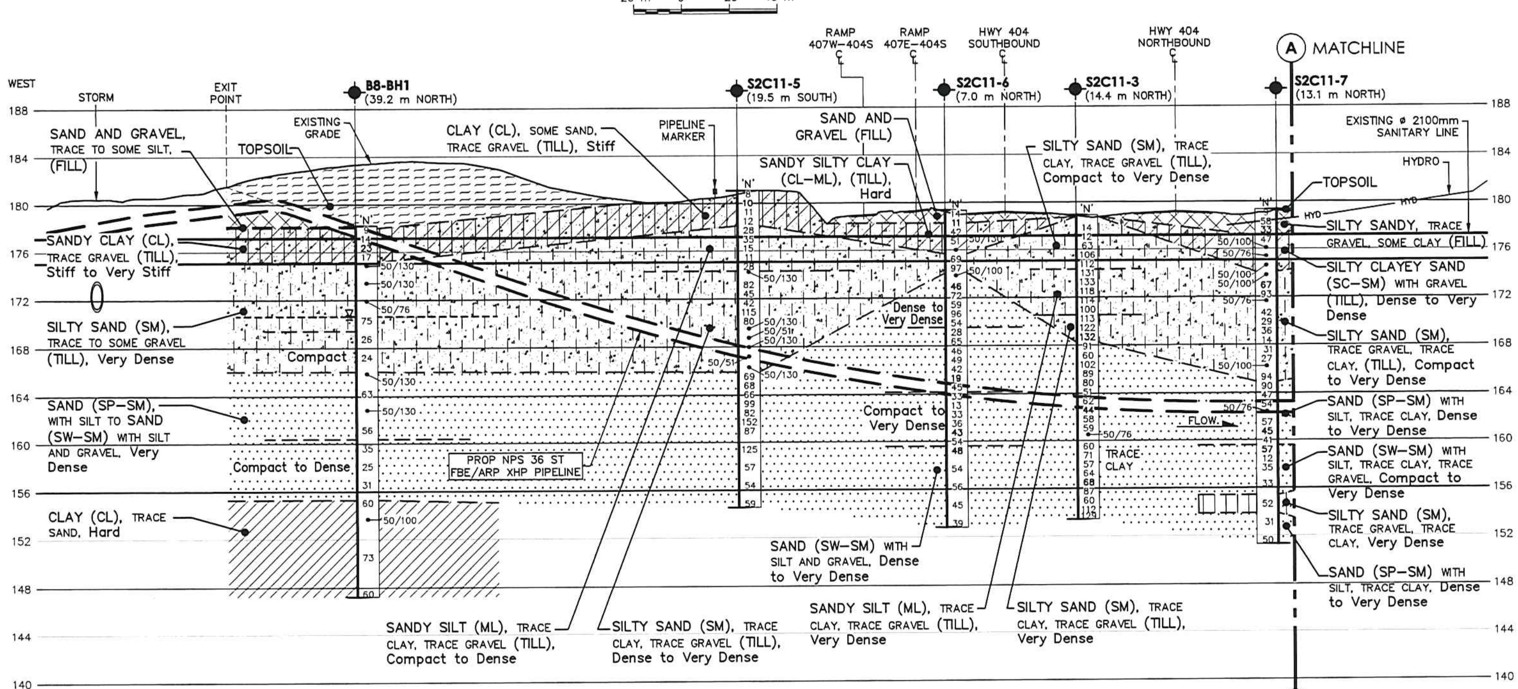
Title

Borehole Locations
Highway 404
(HDD)



PLAN

SCALE 20 m 0 20 40 m



PROFILE ALONG CL OF PREFERRED PIPELINE ROUTE

SCALE 10 m 0 10 20 m HORIZONTAL
4 m 0 4 8 m VERTICAL

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

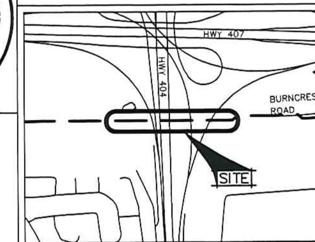
LICENSED PROFESSIONAL ENGINEER
J.G.A.R. HACHÉ
PROVINCE OF ONTARIO

PROJECT No 110901255
ENBRIDGE
GTA PROJECT

HIGHWAY 404
MARKHAM, ONTARIO
BOREHOLE LOCATIONS & SOIL STRATA

SHEET

Stantec



KEY PLAN
NOT TO SCALE

LEGEND

- Borehole
- Borehole with Monitoring Well
- N — Blows/0.3m (Std Pen Test, 475 J/blow)
- WL at Time of Investigation, Aug 2012
- (XX.X m) — Offset from CL of Preferred Pipeline Route in meters

No	ELEV	UTM ZONE 17 NAD83 COORDINATES NORTH	EAST
B8-BH1	178.2	4 854 909	631 128
B8-BH2	182.2	4 854 973	631 521
S2C11-3	178.9	4 854 925	631 280
S2C11-4	180.7	4 854 941	631 338
S2C11-5	181.1	4 854 873	631 221
S2C11-6	179.3	4 854 910	631 255
S2C11-7	179.3	4 854 935	631 321
S2C11-8	189.7	4 854 953	631 393
S2C11-9	188.9	4 854 977	631 455

NOTES

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

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

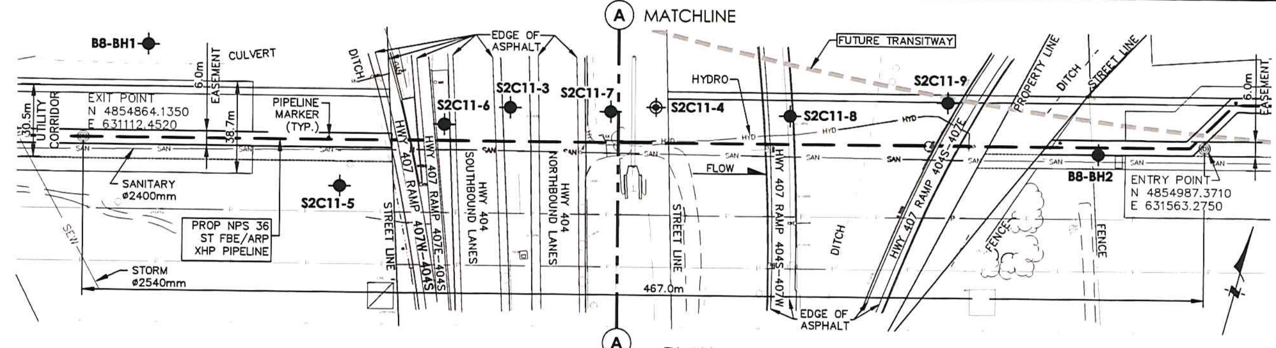
The profile does not illustrate all the utilities and services shown on the plan. The presence of utilities and services within specified horizontal and vertical separation distances of the alignment are discussed in the geotechnical report.

REVISIONS No	DATE	DESCRIPTION
1	14-11-07	ISSUED FOR PERMIT

GEOCRES No

HWY No N/A | DIST
SUBM'D KR | CHECKED | DATE 2014-11-07 | SITE S2C11
DRAWN GBB | CHECKED | APPROVED | DWG 1

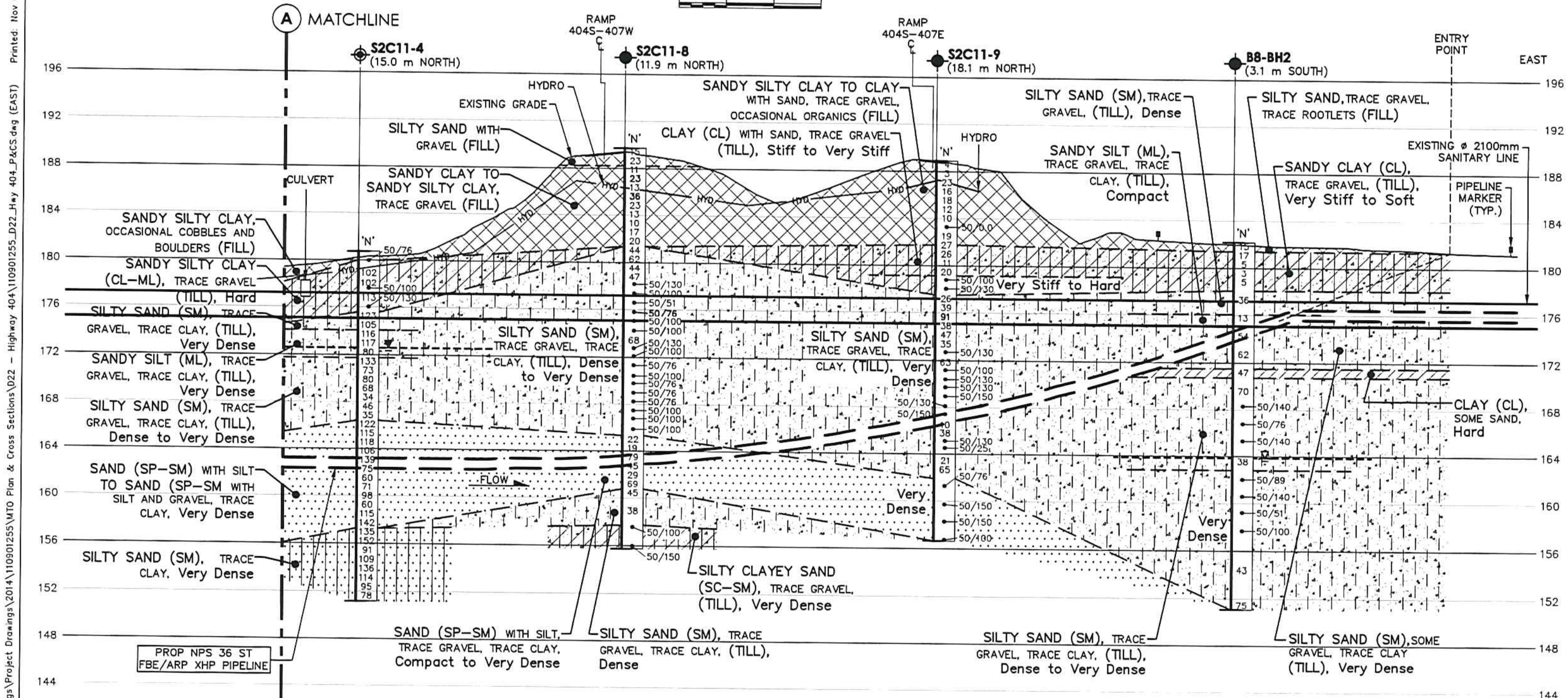
DRAWING NAME: 110901255_D22_Hwy404_P&CS.dwg
CREATED BY: GBB MODIFIED:
T:\Autocad\Drawings\Project Drawings\2014\110901255\MTO Plan & Cross Sections\D22 - Highway 404\110901255_D22_Hwy 404_P&CS.dwg (D22-WEST) Printed: Nov 07, 2014



PLAN

SCALE 20 m 0 20 40 m

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



PROFILE ALONG CL OF PREFERRED PIPELINE ROUTE

SCALE 10 m 0 10 20 m HORIZONTAL
4 m 0 4 8 m VERTICAL

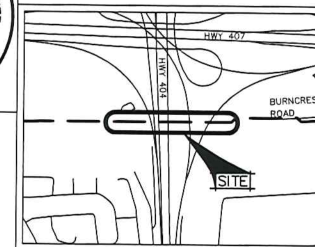
PROJECT No 110901255
ENBRIDGE
GTA PROJECT

HIGHWAY 404
MARKHAM, ONTARIO
BOREHOLE LOCATIONS & SOIL STRATA

SHEET

LICENSED PROFESSIONAL ENGINEER
J.G.A.R. HACHÉ
PROVINCE OF ONTARIO

Stantec



KEY PLAN
NOT TO SCALE

LEGEND

Symbol	Description
⊕	Borehole
⊕	Borehole with Monitoring Well
N	Blows/0.3m (Std Pen Test, 475 J/blow)
▽	WL at Time of Investigation, July 2012
▼	WL Measured August 2013
(XX.X m)	Offset from CL of Preferred Pipeline Route in meters

No	ELEV	UTM ZONE 17 NAD83 COORDINATES NORTH	EAST
B8-BH1	178.2	4 854 909	631 128
B8-BH2	182.2	4 854 973	631 521
S2C11-3	178.9	4 854 925	631 280
S2C11-4	180.7	4 854 941	631 338
S2C11-5	181.1	4 854 873	631 221
S2C11-6	179.3	4 854 910	631 255
S2C11-7	179.3	4 854 935	631 321
S2C11-8	189.7	4 854 953	631 393
S2C11-9	188.9	4 854 977	631 455

=NOTES=

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

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

The profile does not illustrate all the utilities and services shown on the plan. The presence of utilities and services within specified horizontal and vertical separation distances of the alignment are discussed in the geotechnical report.

REVISIONS No	DATE	DESCRIPTION
1	14-11-07	ISSUED FOR PERMIT

GEOCRES No

HWY No N/A			DIST
SUBM'D KR	CHECKED	DATE 2014-11-07	SITE S2C11
DRAWN GBB	CHECKED	APPROVED	DWG 2

DRAWING NAME: 110901255_D22_Hwy404_P&CS.dwg
CREATED BY: GBB
MODIFIED:
T:\Autocad\Drawings\Project Drawings\2014\110901255\MTO Plan & Cross Sections\D22 - Highway 404\110901255_D22_Hwy 404_P&CS.dwg (EAST) Printed: Nov 07, 2014

MINISTRY OF TRANSPORTATION, ONTARIO PH-D-717 86-05

SITE PHOTOS - Location of Proposed HDD Crossing of Highway 404 - Images obtained from Google Earth, Dated July 2012.

Photo 1: Center lane of Highway 404 North, facing north.

Photo 2: Center lane of Highway 404 North, facing south (crossing location shown by green line).

Photo 3: Center lane of Highway 404 North, facing east.

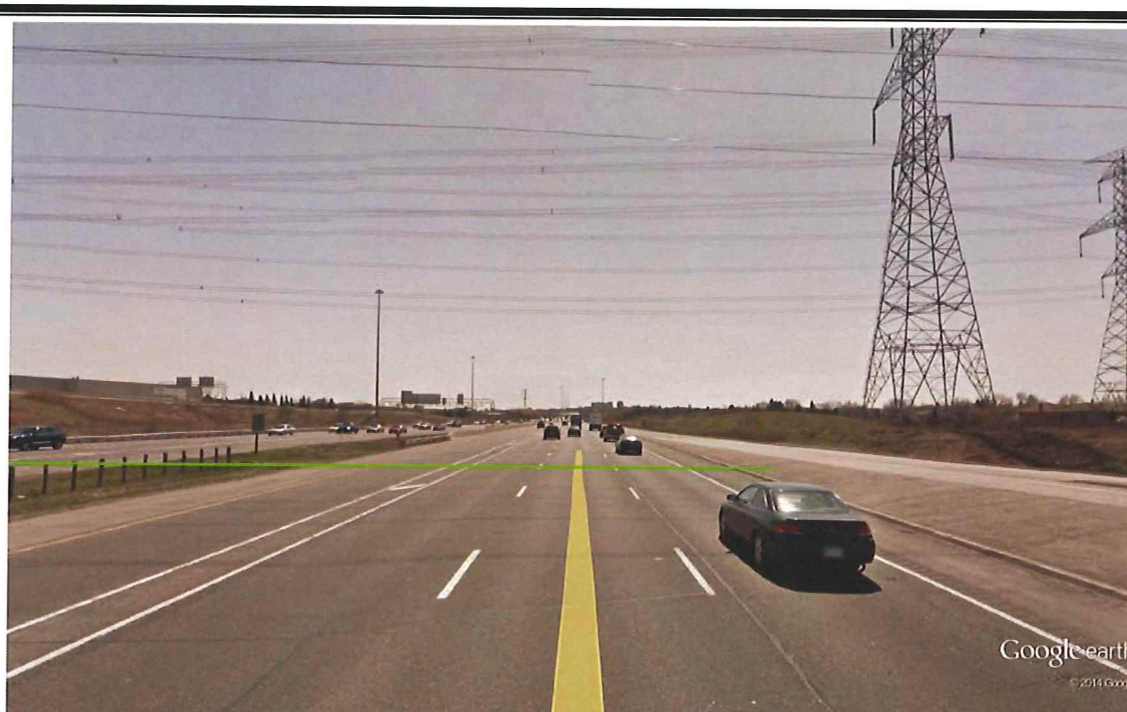


Photo 4: Center lane of Highway 404 South, facing south (crossing location shown by green line).

Photo 5: Center lane of Highway 404 South, facing north.

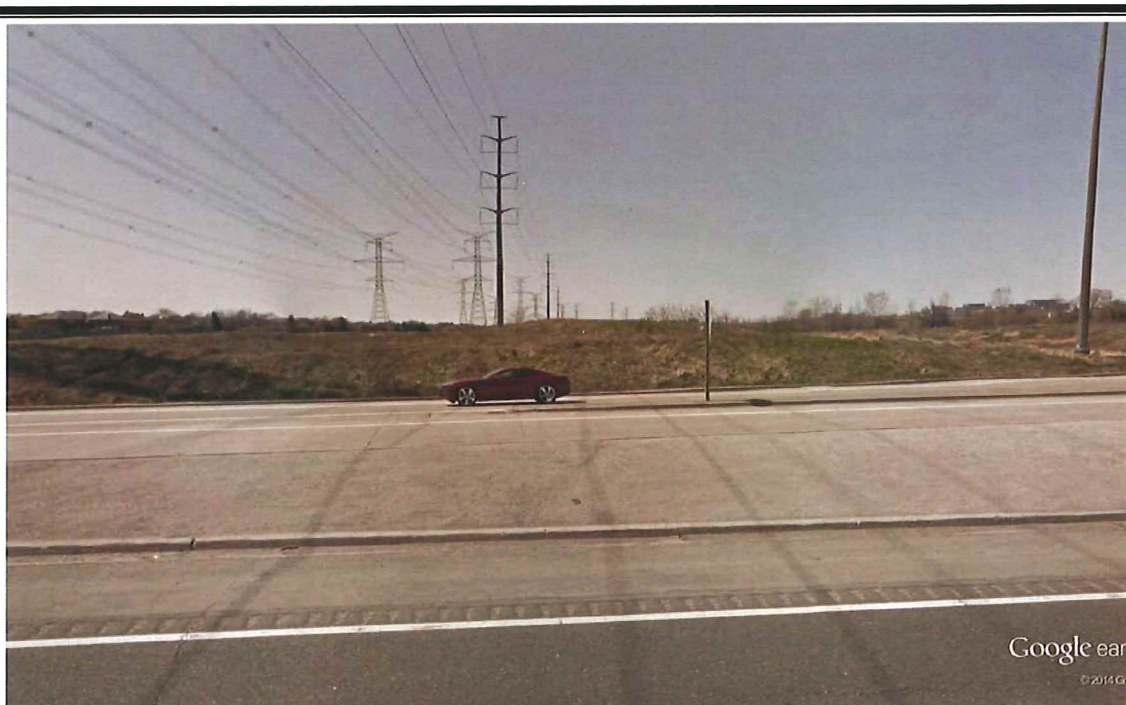


Photo 6: Center lane of Highway 404 South, facing west.

Photo 7: Highway 407 West exit ramp from Highway 404 North, facing north (crossing location shown by green line).

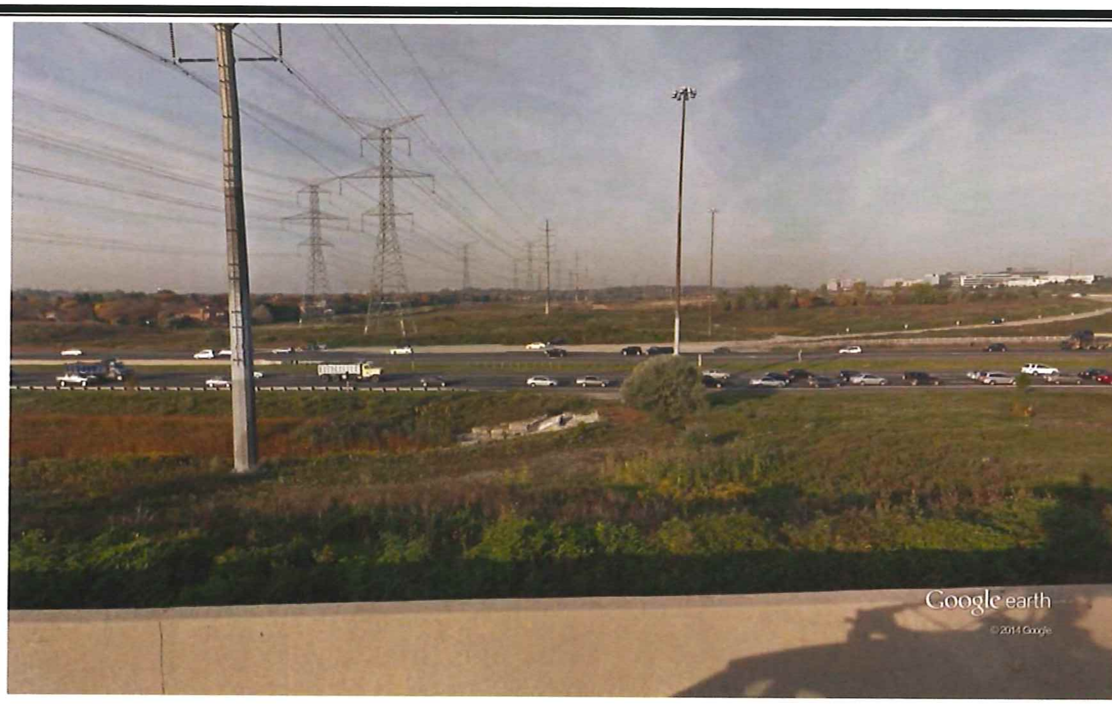


Photo 8: Highway 407 West exit ramp from Highway 404 North, facing west.

Photo 9: Highway 407 East exit ramp from Highway 404 North, facing north (crossing location shown by green line).

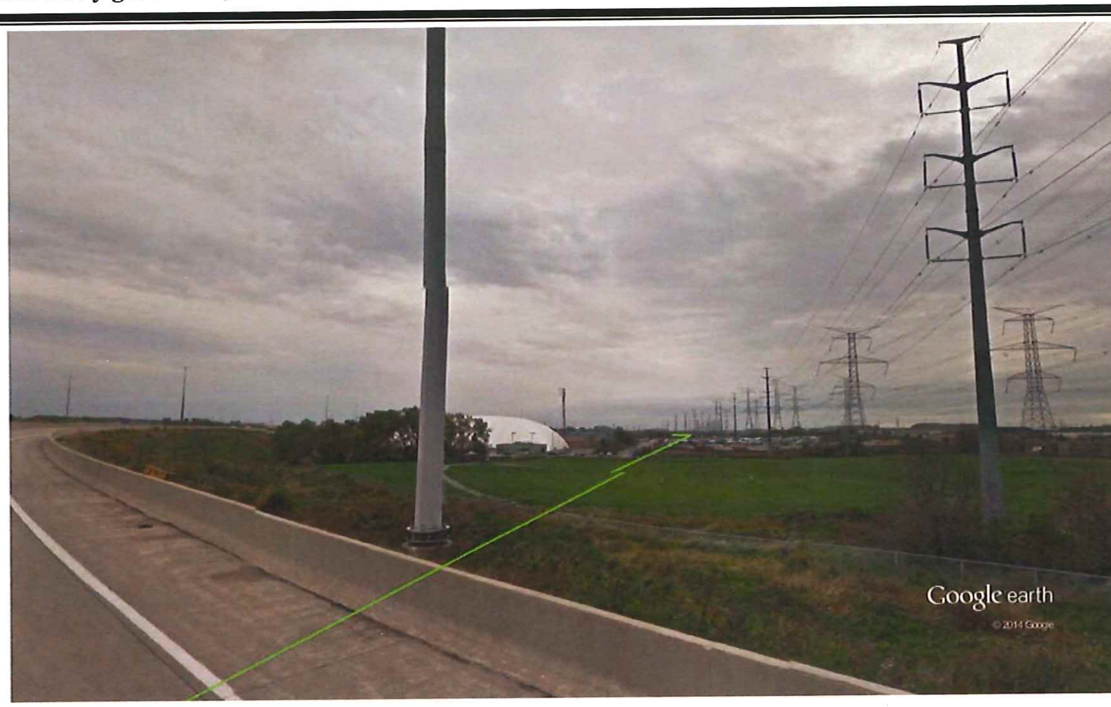


Photo 10: Highway 407 East exit ramp from Highway 404 North, facing east (crossing location shown by green line).

Appendix C

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.

Boulders Cobbles Gravel | Sand | Silt | Clay | Organics | Asphalt | Concrete | Fill | Igneous Bedrock | Metamorphic Bedrock | Sedimentary Bedrock

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
γ	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

Stantec

RECORD OF BOREHOLE No B8-BH1

METRIC

PROJECT # 110901255	PROJECT Enbridge GTA Project - DE Phase		
W.P. NA	LOCATION S2C11 - Highway 404	N: 4 854 909 E: 631 128	ORIGINATED BY SWarren
DIST NA HWY 404	BOREHOLE TYPE CME, Hollow Stem Auger		COMPILED BY bvujanovic
DATUM Geodetic	DATE August 14, 2012		CHECKED BY RHache

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
208.7	Rough Grass					
208.6 / 0.0	40 mm TOPSOIL					
208.5 / 0.2	Sand and gravel, trace to some silt (FILL) Grey - damp	1	SS	9		
	Sandy CLAY (CL), TILL Brown to grey Stiff to very stiff - trace gravel - damp to moist	2	SS	14		
		3	SS	23		
		4	SS	17		
205.6 / 3.0	Silty SAND (SM), TILL Grey Very dense - trace to some gravel - moist	5	SS	50/130		
	- frequent cobbles and possible boulders inferred based on auger grinding between 4.9 mbg and 7.0 mbg	6	SS	50/130		Non-Plastic 9 46 (45)
		7	SS	50/76		
	- wet - occasional cobbles and possible boulders inferred based on auger grinding between 7.6 mbg and 7.9 mbg	8	SS	75	▽ (at approx. elev. 201.2)	
	- occasional cobbles and possible boulders inferred based on auger grinding between 8.8 mbg and 9.1 mbg - compact	9	SS	26		8 78 (14)

Elevation scale: 208, 207, 206, 205, 204, 203, 202, 201, 200, 199

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED; ✖ FIELD VANE; ● QUICK TRIAXIAL; × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

Continued Next Page

✖³, ×³: Numbers refer to Sensitivity   O ³% STRAIN AT FAILURE

Stantec **RECORD OF BOREHOLE No B8-BH1** **METRIC**

PROJECT # 110901255	PROJECT Enbridge GTA Project - DE Phase		
W.P. NA	LOCATION S2C11 - Highway 404	N: 4 854 909 E: 631 128	ORIGINATED BY SWarren
DIST NA HWY 404	BOREHOLE TYPE CME, Hollow Stem Auger		COMPILED BY bvujanovic
DATUM Geodetic	DATE August 14, 2012		CHECKED BY RHache

Column headings: SOIL PROFILE (ELEV / DEPTH; DESCRIPTION; STRAT PLOT) | SAMPLES (NUMBER; TYPE; "N" VALUES) | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, ✖ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100) | PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30 | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

ELEV / DEPTH	DESCRIPTION
	Silty SAND (SM), TILL Grey Compact - trace to some gravel - wet
196.5 / 12.2	SAND (SP-SM) with silt to SAND (SW-SM) with silt and gravel Grey Very dense - wet ... - dense (near elev. 190)

NUMBER	TYPE	"N" VALUES	REMARKS (GR SA SI CL)
10	SS	24	
11	SS	50/130	
12	SS	63	
13	SS	50/130	44 46 (10)
14	SS	56	
15	SS	35	

Elevation scale: 198, 197, 196, 195, 194, 193, 192, 191, 190, 189

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✖³, ×³: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No B8-BH1

PROJECT # 110901255	PROJECT Enbridge GTA Project - DE Phase		
W.P. NA	LOCATION S2C11 - Highway 404	N: 4 854 909 E: 631 128	ORIGINATED BY SWarren
DIST NA HWY 404	BOREHOLE TYPE CME, Hollow Stem Auger		COMPILED BY bvujanovic
DATUM Geodetic	DATE August 14, 2012		CHECKED BY RHache

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND (SP-SM) with silt to SAND (SW-SM) with silt and gravel Grey Compact to dense - wet - pressurized layer	16	SS	25			0 94 (6)
					188		
		17	SS	31	187		
					186		
185.8 22.9	CLAY (CL) Grey Hard - trace sand - moist to wet	18	SS	60			
					185		
		19	SS	50/100	184		
					183		
					182		
		20	SS	73	181	41.8504	0 3 34 63
					180		
					179		

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, ● QUICK TRIAXIAL, ✖ FIELD VANE, × LAB VANE, 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L, WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

✖3, ×3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

Stantec

RECORD OF BOREHOLE No B8-BH1

METRIC

PROJECT # 110901255 | PROJECT Enbridge GTA Project - DE Phase

W.P. NA | LOCATION S2C11 - Highway 404 | N: 4 854 909 E: 631 128 | ORIGINATED BY SWarren

DIST NA HWY 404 | BOREHOLE TYPE CME, Hollow Stem Auger | COMPILED BY bvujanovic

DATUM Geodetic | DATE August 14, 2012 | CHECKED BY RHache

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	STRAT PLOT	NUMBER (SAMPLES)	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (O UNCONFINED, ✖ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	CLAY (CL) Grey Hard - trace sand - moist to wet		21	SS	60		178		o (≈21)		
177.7 31.0	END OF BOREHOLE at approximately 31.0 m below existing grade Groundwater level in open borehole measured at approximately 7.8 m below existing grade.										

STN13-ONTARIO MTO STANTEC S2C11-MTO.GPJ STANTEC MARKHAM.GDT 1/20/15

✖ 3, × 3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No B8-BH2

PROJECT #	110901255	PROJECT	Enbridge GTA Project - DE Phase		
W.P.	NA	LOCATION	S2C11 - Highway 404 N: 4 854 973 E: 631 521	ORIGINATED BY	SWarren
DIST	NA HWY 404	BOREHOLE TYPE	CME, Hollow Stem Auger	COMPILED BY	bvujanovic
DATUM	Geodetic	DATE	July 17, 2012	CHECKED BY	RHache

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
182.2	Rough Grass
182.1 / 0.1	125 mm TOPSOIL; Silty sand, trace gravel, trace rootlets (FILL), Brown - damp
181.4 / 0.8	Sandy CLAY (CL), TILL, Brown, Very stiff to soft - trace gravel - damp to moist
178.1 / 4.1	Silty SAND (SM), TILL, Grey, Dense - trace gravel - moist; - occasional cobbles and possible boulders inferred based on auger grinding between 5.5 mbg and 6.1 mbg
176.1 / 6.1	Sandy SILT (ML), TILL, grey, Compact - trace gravel - trace clay - moist
175.0 / 7.2	Silty SAND (SM), TILL, Grey, Very dense - some gravel, trace clay - moist - frequent cobbles and possible boulders inferred based on auger grinding between 8.2 mbg and 10.7 mbg

SAMPLES

NUMBER	TYPE	"N" VALUES	Remarks & Grain Size Distribution (%) GR SA SI CL
1	SS	15	
2	SS	17	
3	SS	5	
4	SS	3	
5	SS	5	5 28 41 26
6	SS	36	
7	SS	13	
8	SS	54	
9	SS	62	Non-Plastic; 14 40 38 8

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (182 to 173); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, ✖ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

✖³, ×³: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

Stantec

RECORD OF BOREHOLE No B8-BH2

METRIC

PROJECT # 110901255 | PROJECT Enbridge GTA Project - DE Phase

W.P. NA | LOCATION S2C11 - Highway 404 | N: 4 854 973 E: 631 521 | ORIGINATED BY SWarren

DIST NA HWY 404 | BOREHOLE TYPE CME, Hollow Stem Auger | COMPILED BY bvujanovic

DATUM Geodetic | DATE July 17, 2012 | CHECKED BY RHache

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Silty SAND (SM), TILL Grey Very dense					172		
171.5 10.7	CLAY (CL) Grey Hard - some sand - moist	10	SS	47				0 13 57 30
170.8 11.4	Silty SAND (SM), TILL Grey Dense to very dense - trace gravel, trace clay - moist - occasional cobbles and possible boulders inferred based on auger grinding between 11.4 mbg and 11.7 mbg					171		
		11	SS	70		170		
	- occasional cobbles and possible boulders inferred based on auger grinding between 13.1 mbg and 13.4 mbg					169		
		12	SS	50/140				
	- frequent cobbles and possible boulders inferred based on auger grinding between 14.5 mbg and 15.2 mbg					168		
		13	SS	50/76		167		
		14	SS	50/140		166		
	- moist to wet	15	SS	38	▽	164		9 57 31 3
						163		

Dynamic Cone Penetration Resistance Plot: 20 40 60 80 100
Shear Strength kPa: O UNCONFINED, ● QUICK TRIAXIAL, ✖ FIELD VANE, × LAB VANE; 20 40 60 80 100
Plastic Limit W_P — Natural Moisture Content W — Liquid Limit W_L; Water Content (%) 10 20 30
Unit Weight γ kN/m³

Continued Next Page

✖³, ×³: Numbers refer to Sensitivity   O ³% STRAIN AT FAILURE

PROJECT # 110901255 PROJECT Enbridge GTA Project - DE Phase

W.P. NA LOCATION S2C11 - Highway 404 N: 4 854 973 E: 631 521 ORIGINATED BY SWarren

DIST NA HWY 404 BOREHOLE TYPE CME, Hollow Stem Auger COMPILED BY bvujanovic

DATUM Geodetic DATE July 17, 2012 CHECKED BY RHache

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O UNCONFINED, ✖ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Silty SAND (SM), TILL Grey Very dense - trace gravel, trace clay - moist to wet		16	SS	50/89		162				
							161				
			17	SS	50/140				o		
							160				
			18	SS	50/51				o		
							159				
	- occasional cobbles and possible boulders inferred based on auger grinding between 23.5 mbg and 24.4 mbg										
							158				
	- some gravel		19	SS	50/100				o		
							157				
							156				
							155				
	- dense		20	SS	43				o		5 82 11 2
							154				
							153				

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✖ 3, × 3: Numbers refer to Sensitivity O 3% STRAIN AT FAILURE

Stantec

RECORD OF BOREHOLE No B8-BH2

METRIC

PROJECT # 110901255	PROJECT Enbridge GTA Project - DE Phase		
W.P. NA	LOCATION S2C11 - Highway 404	N: 4 854 973 E: 631 521	ORIGINATED BY SWarren
DIST NA HWY 404	BOREHOLE TYPE CME, Hollow Stem Auger		COMPILED BY bvujanovic
DATUM Geodetic	DATE July 17, 2012		CHECKED BY RHache

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: O UNCONFINED, ✖ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Silty SAND (SM), TILL Grey Very dense - some gravel, trace clay - moist to wet						152				
			21	SS	75				o		
151.1 31.1	END OF BOREHOLE at approximately 31.1 m below existing grade. Groundwater level in open borehole measured at approximately 18.3 m below existing grade.										

✖³, ×³: Numbers refer to Sensitivity   O ³% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC S2C11-MTO.GPJ STANTEC MARKHAM.GDT 1/20/15

Stantec RECORD OF BOREHOLE No S2C11-3 METRIC

PROJECT # 110901255 PROJECT Enbridge GTA Project - DE Phase

W.P. NA LOCATION S2C11 - Highway 404 N: 4 854 925 E: 631 280 ORIGINATED BY DStunden

DIST NA HWY 404 BOREHOLE TYPE CME, Hollow Stem Auger COMPILED BY KRefahi

DATUM Geodetic DATE August 12 and 13, 2013 CHECKED BY RHache

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
178.9	Rough Grass					
178.7	150 mm TOPSOIL					
0.2	Silty SAND (SM), TILL Brown Compact to very dense - trace gravel - trace clay - moist	1	AS	50/		
		2	SS	14	178	
		3	SS	12	177	
		4	SS	63	176	
		5	SS	106		Non-Plastic 6 56 32 6
		6	SS	112	175	
174.3 / 4.6	Sandy SILT (ML), TILL Brown Very dense - trace gravel - trace clay - moist	7	SS	131	174	
		8	SS	133	173	
		9	SS	50/ 118		Non-Plastic 9 38 48 5
		10	SS	114	172	
		11	SS	100	171	
170.5 / 8.4	Silty SAND (SM), TILL Brown to grey Very dense - trace gravel - trace clay - moist	12	SS	113	170	Non-Plastic 6 56 30 8
		13	SS	122	169	

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED, ● QUICK TRIAXIAL, ✖ FIELD VANE, × LAB VANE

PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L — WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

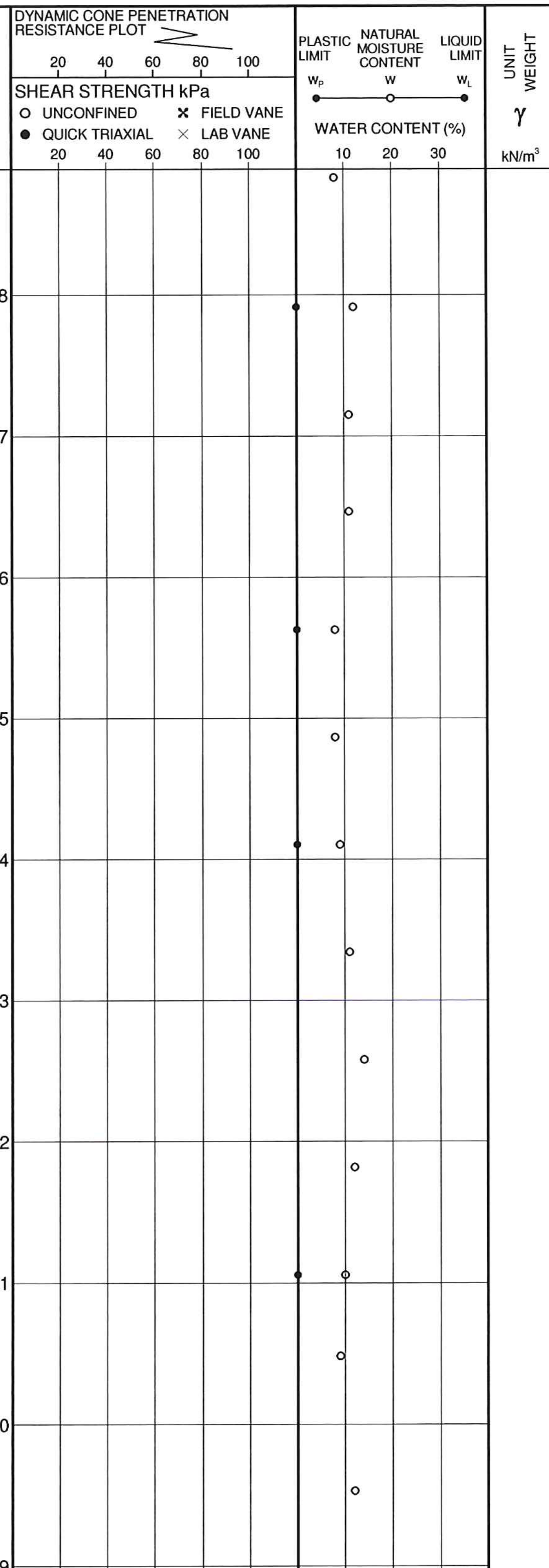
Continued Next Page

✖3, ×3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

Stantec

PROJECT # 110901255 | PROJECT Enbridge GTA Project - DE Phase
W.P. NA | LOCATION S2C11 - Highway 404 | N: 4 854 925 E: 631 280 | ORIGINATED BY DStunden
DIST NA HWY 404 | BOREHOLE TYPE CME, Hollow Stem Auger | COMPILED BY KRefahi
DATUM Geodetic | DATE August 12 and 13, 2013 | CHECKED BY RHache

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Silty SAND (SM), TILL Brown to grey Very dense	14	SS	132		
168.2 10.7	SAND (SP-SM) with silt to SAND (SW-SM) with silt and gravel Grey Very dense - trace clay - moist to wet	15	SS	91	168	Non-Plastic 0 88 9 3
		16	SS	60	167	
		17	SS	102	166	
		18	SS	89		Non-Plastic 26 63 9 2
		19	SS	80	165	
		20	SS	51	164	Non-Plastic 13 75 10 2
		21	SS	62	163	
		22	SS	44	162	
		23	SS	58		
		24	SS	59	161	Non-Plastic 12 77 9 2
		25	SS	100/75	160	
		26	SS	60	159	



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×³, ×³: Numbers refer to Sensitivity   O³% STRAIN AT FAILURE

Stantec — RECORD OF BOREHOLE No S2C11-3 — METRIC

PROJECT # 110901255 | PROJECT Enbridge GTA Project - DE Phase
W.P. NA | LOCATION S2C11 - Highway 404 | N: 4 854 925 E: 631 280 | ORIGINATED BY DStunden
DIST NA | HWY 404 | BOREHOLE TYPE CME, Hollow Stem Auger | COMPILED BY KRefahi
DATUM Geodetic | DATE August 12 and 13, 2013 | CHECKED BY RHache

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND (SP-SM) with silt to SAND (SW-SM) with silt and gravel Grey Very dense - trace clay - wet	27	SS	71		
		28	SS	57	158	
		29	SS	64	157	
		30	SS	68		Non-Plastic 6 84 8 2
		31	SS	87	156	
		32	SS	60	155	
		33	SS	112	154	Non-Plastic 16 73 10 1
153.4 / 25.5		34	SS	129		
	END OF BOREHOLE at approximately 25.5 m below existing grade. Groundwater level not measured in open borehole due to the introduction of water during borehole drilling process.					

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, ● QUICK TRIAXIAL, ✕ FIELD VANE, × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L, WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³

$\times^3, \times^3$: Numbers refer to Sensitivity — $O^{3\%}$ STRAIN AT FAILURE

Stantec

RECORD OF BOREHOLE No S2C11-4

METRIC

PROJECT # 110901255	PROJECT Enbridge GTA Project - DE Phase		
W.P. NA	LOCATION S2C11 - Highway 404	N: 4 854 941 E: 631 338	ORIGINATED BY DStunden
DIST NA HWY 404	BOREHOLE TYPE CME, Hollow Stem Auger		COMPILED BY bvujanovic
DATUM Geodetic	DATE August 7 - 9, 2013		CHECKED BY RHache

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
180.7	Rough Grass					
180.5	150 mm TOPSOIL					
0.2	Sandy silty clay, occasional cobbles and boulders (FILL) Brown - moist	1	AS	50/		
					180	
179.8		2	SS	>100		
0.9	Sandy silty CLAY (CL-ML), TILL Brown Hard - trace gravel - moist - inferred occasional cobbles and possible boulders based on auger grinding at 3.0 mbg					
					179	
		3	SS	102		5 35 42 18
		4	SS	102		
					178	
		5	AS	>100		
					177	
		6	SS	113		
		7	SS	105	176	
175.4				50/		Non-Plastic
5.3	Silty SAND (SM), TILL Brown Very dense - trace gravel - trace clay - moist	8	SS	123		7 74 16 3
					175	
		9	SS	105		
					174	
173.8						
6.9	Sandy SILT (ML), TILL Brown Very dense - trace gravel - trace clay - moist to wet	10	SS	116		
		11	SS	117	173	
				50/		Non-Plastic
		12	SS	80		2 38 55 5
					172	
171.5						
9.1	Silty SAND (SM), TILL Brown Dense to very dense	13	SS	133		
					171	

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED ✖ FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m³

Continued Next Page

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

STN13-ONTARIO MTO STANTEC S2C11-MTO.GPJ STANTEC MARKHAM.GDT 1/20/15

Stantec — RECORD OF BOREHOLE No S2C11-4

 METRIC

PROJECT # 110901255	PROJECT Enbridge GTA Project - DE Phase		
W.P. NA	LOCATION S2C11 - Highway 404	N: 4 854 941 E: 631 338	ORIGINATED BY DStunden
DIST NA HWY 404	BOREHOLE TYPE CME, Hollow Stem Auger		COMPILED BY bvujanovic
DATUM Geodetic	DATE August 7 - 9, 2013		CHECKED BY RHache

Column headings: SOIL PROFILE (ELEV / DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (O UNCONFINED, ✖ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) (GR SA SI CL)

Elevation scale: 170, 169, 168, 167, 166, 165, 164, 163, 162, 161

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Silty SAND (SM), TILL Brown Dense to very dense - trace gravel - trace clay - moist to wet	14	SS	73	0 86 12 2
		15	SS	80	
		16	SS	68	
		17	SS	34	Non-Plastic 5 51 36 8
		18	SS	46	
		19	SS	35	
166.2 14.5	SAND (SP-SM) with silt to SAND (SP-SM) with silt and gravel Brown Very dense - trace clay - wet	20	SS	122	
		21	SS	115	Non-Plastic 0 91 7 2
		22	SS	118	
163.9 16.8	Grey	23	SS	106	
		24	SS	139	
		25	SS	75	
		26	SS	60	Non-Plastic 6 83 9 2

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✖³, ×³: Numbers refer to Sensitivity   O ³% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC S2C11-MTO.GPJ STANTEC MARKHAM.GDT 1/20/15

Stantec

RECORD OF BOREHOLE No S2C11-4

METRIC

PROJECT # 110901255	PROJECT Enbridge GTA Project - DE Phase		
W.P. NA	LOCATION S2C11 - Highway 404	N: 4 854 941 E: 631 338	ORIGINATED BY DStunden
DIST NA HWY 404	BOREHOLE TYPE CME, Hollow Stem Auger		COMPILED BY bvujanovic
DATUM Geodetic	DATE August 7 - 9, 2013		CHECKED BY RHache

Chart legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: O UNCONFINED, ✖ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND (SP-SM) with silt to SAND (SP-SM) with silt and gravel Grey Very dense - trace clay - wet	27	SS	71		
		28	SS	98	160	
		29	SS	60	159	Non-Plastic 28 66 4 2
		30	SS	115		
		31	SS	142	158	
157.1 23.6	Silty SAND (SM) Grey Very dense - trace clay - wet	32	SS	135	157	
		33	SS	152	156	
		34	SS	91	155	Non-Plastic 0 82 15 3
		35	SS	109		
		36	SS	136	154	
		37	SS	114	153	
		38	SS	95	152	Non-Plastic 0 87 11 2
		39	SS	78		
151.1 29.6	END OF BOREHOLE at approximately 29.6 m below existing grade.					

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✖³, ×³: Numbers refer to Sensitivity   O³% STRAIN AT FAILURE

Stantec

RECORD OF BOREHOLE No S2C11-4

METRIC

PROJECT # 110901255 PROJECT Enbridge GTA Project - DE Phase

W.P. NA LOCATION S2C11 - Highway 404 N: 4 854 941 E: 631 338 ORIGINATED BY DStunden

DIST NA HWY 404 BOREHOLE TYPE CME, Hollow Stem Auger COMPILED BY bvujanovic

DATUM Geodetic DATE August 7 - 9, 2013 CHECKED BY RHache

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O UNCONFINED, ✖ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
	Groundwater level in open borehole not measured due to the introduction of water into the borehole during drilling process. Groundwater monitoring well installed with a screen from approximately 13.7 m to 16.7 m below existing grade. Groundwater level measured at approximately 8.2 m below existing grade both on August 13 and 20, 2013 and at 8.3 m below grade on November 8, 2013.										

✖³, ×³: Numbers refer to Sensitivity O 3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC S2C11-MTO.GPJ STANTEC MARKHAM.GDT 1/20/15

PROJECT # 110901255	PROJECT Enbridge GTA Project - DE Phase		
W.P. NA	LOCATION S2C11 - Highway 404	N: 4 854 941 E: 631 338	ORIGINATED BY DStunden
DIST NA HWY 404	BOREHOLE TYPE CME, Hollow Stem Auger		COMPILED BY KRefahi
DATUM Geodetic	DATE August 7 - 9, 2013		CHECKED BY RHache

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa: O UNCONFINED, ✕ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Groundwater level in open borehole not measured due to the introduction of water into the borehole during drilling process. Groundwater monitoring well installed with a screen from approximately 13.7 m to 16.7 m below existing grade. Groundwater level measured at approximately 8.2 m below existing grade both on August 13 and 20, 2013 and at 8.3 m below grade on November 8, 2013.										

$\times^3$, $\times^3$: Numbers refer to Sensitivity   O $^{3\%}$ STRAIN AT FAILURE

Stantec — **RECORD OF BOREHOLE No S2C11-5** **METRIC**

PROJECT # 110901255 — PROJECT Enbridge GTA Project - DE Phase

W.P. NA — LOCATION S2C11 - Highway 404 — N: 4 854 873 E: 631 221 — ORIGINATED BY BLao

DIST NA HWY 404 — BOREHOLE TYPE CME, Hollow Stem Auger — COMPILED BY KRefahi

DATUM Geodetic — DATE June 26, 2014 — CHECKED BY RHache

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
181.1	Rough Grass				181	
180.9 / 0.2	200 mm TOPSOIL					
	CLAY (CL), TILL Brown Stiff - some sand - trace gravel - moist - inferred occasional cobbles and possible boulders based on auger grinding at 0.6 mbg to 1.4 mbg	1	SS	8		
		2	SS	10	180	
		3	SS	11	179	1 13 35 51
		4	SS	12		
178.1 / 3.0	Sandy SILT (ML), TILL Brown Compact to dense - trace clay - trace gravel - moist	5	SS	28	178	
		6	SS	35	177	3 45 40 12
176.6 / 4.5	Grey	7	SS	15	176	
		8	SS	11	175	
		9	SS	28		
174.3 / 6.8	Silty SAND (SM), TILL Grey Dense to very dense - trace clay - trace gravel - moist - inferred occasional cobbles and possible boulders based on auger grinding between 6.8 mbg and 15.1 mbg	10	SS	50/0.0	174	
		11	SS	82	173	Non-Plastic 6 54 37 3
		12	SS	45	172	
		13	SS	42		

Column headings also include: STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, ● QUICK TRIAXIAL, ✕ FIELD VANE, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L, WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³.

Continued Next Page

$\times^3, \times^3$: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

PROJECT # 110901255 PROJECT Enbridge GTA Project - DE Phase

W.P. NA LOCATION S2C11 - Highway 404 N: 4 854 873 E: 631 221 ORIGINATED BY BLao

DIST NA HWY 404 BOREHOLE TYPE CME, Hollow Stem Auger COMPILED BY KRefahi

DATUM Geodetic DATE June 26, 2014 CHECKED BY RHache

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	W (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Silty SAND (SM), TILL Grey Dense to very dense - trace clay - trace gravel - moist - inferred occasional cobbles and possible boulders based on auger grinding between 6.8 mbg and 15.1 mbg	14	SS	115	171		
		15	SS	80	170		Non-Plastic 5 55 32 8
		16	SS	50/130	169		
		17	SS	50/51			
		18	SS	50/130	168		
		19	SS	50/51	167		
	- with gravel	20	SS	50/130			Non-Plastic 32 48 16 4
165.9 15.2	SAND (SP-SM) with silt to SAND (SW-SM) with silt and gravel Grey Very dense - trace clay - wet - inferred occasional cobbles and possible boulders based on auger grinding between 15.2 mbg and 26.5 mbg	21	SS	69	166		
		22	SS	68	165		
		23	SS	66	164		
		24	SS	99	163		Non-Plastic 34 59 5 2
		25	SS	82	162		
		26	SS	152			Non-Plastic

Continued Next Page

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: O UNCONFINED, × FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; STRAT PLOT; GROUND WATER CONDITIONS.

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

Stantec — RECORD OF BOREHOLE No S2C11-5

METRIC

PROJECT # 110901255 | PROJECT Enbridge GTA Project - DE Phase
W.P. NA | LOCATION S2C11 - Highway 404 | N: 4 854 873 E: 631 221 | ORIGINATED BY BLao
DIST NA HWY 404 | BOREHOLE TYPE CME, Hollow Stem Auger | COMPILED BY KRefahi
DATUM Geodetic | DATE June 26, 2014 | CHECKED BY RHache

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND (SP-SM) with silt to SAND (SW-SM) with silt and gravel Grey Very dense - trace clay - wet - inferred occasional cobbles and possible boulders based on auger grinding between 15.2 mbg and 26.5 mbg.	27	SS	87	161	23 67 8 2
					160	
		28	SS	125	159	
		29	SS	57	158	
					157	
		30	SS	54	156	Non-Plastic 5 86 7 2
		31	SS	59	155	
154.6 26.5	END OF BOREHOLE at approximately 26.5 m below existing grade. Groundwater level in open borehole not measured due to the introduction of water into the borehole during drilling.					

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED, ✖ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m³

✖3, ×3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC S2C11-MTO.GPJ STANTEC MARKHAM.GDT 1/20/15

Stantec

RECORD OF BOREHOLE No S2C11-6

METRIC

PROJECT # 110901255 | PROJECT Enbridge GTA Project - DE Phase

W.P. NA | LOCATION S2C11 - Highway 404 | N: 4 854 910 E: 631 255 | ORIGINATED BY AHatch

DIST NA HWY 404 | BOREHOLE TYPE CME, Hollow Stem Auger | COMPILED BY KRefahi

DATUM Geodetic | DATE July 2, 2014 | CHECKED BY RHache

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
179.3	Road				
179.2 / 0.1	60 mm ASPHALT				
	Sand and gravel (FILL) Brown - damp	1	SS	14	
		2	SS	11	
178.2 / 1.1	Sandy silty CLAY (CL-ML), TILL Brown Hard - moist - inferred occasional cobbles and possible boulders based on auger grinding between 2.3 mbg and 3.8 mbg.				
		3	SS	42	8 39 32 21
		4	SS	51	
		5	SS	50/130	
175.6 / 3.7	Silty SAND (SM), TILL Brown Very dense - trace clay - trace gravel - moist				Non-Plastic
		6	SS	69	5 53 37 5
		7	SS	97	
174.0 / 5.3	SAND (SP-SM) with silt to SAND (SP-SM) with silt and gravel Brown Dense to very dense - occasional gravel layers inferred at 5.2 mbg - moist to wet	8	SS	50/100	
		9	SS	46	Non-Plastic 3 90 6 1
		10	SS	72	
		11	SS	59	
		12	SS	96	
		13	SS	54	Non-Plastic 30 61 7 2

Chart columns: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (179, 178, 177, 176, 175, 174, 173, 172, 171, 170); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, ✕ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L — WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³.

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✕³, ×³: Numbers refer to Sensitivity   O^3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC S2C11-MTO.GPJ STANTEC MARKHAM.GDT 1/20/15

Stantec — RECORD OF BOREHOLE No S2C11-6 — METRIC

PROJECT # 110901255 | PROJECT Enbridge GTA Project - DE Phase
W.P. NA | LOCATION S2C11 - Highway 404 | N: 4 854 910 E: 631 255 | ORIGINATED BY AHatch
DIST NA HWY 404 | BOREHOLE TYPE CME, Hollow Stem Auger | COMPILED BY KRefahi
DATUM Geodetic | DATE July 2, 2014 | CHECKED BY RHache

SOIL PROFILE: ELEV/DEPTH, DESCRIPTION, STRAT PLOT | SAMPLES: NUMBER, TYPE, "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, ● QUICK TRIAXIAL, ✕ FIELD VANE, × LAB VANE; 20 40 60 80 100) | PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30 | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

SAND (SP-SM) with silt to SAND (SW-SM) with silt and gravel
Brown
Compact to very dense
- moist to wet

164.1 / 15.2 — Grey

Number	Type	"N" Values	Elevation scale	Remarks (GR SA SI CL)
14	SS	28	169	
15	SS	65	168	
16	SS	46		
17	SS	49	167	Non-Plastic 20 68 9 3
18	SS	42	166	
19	SS	19	165	
20	SS	45		
21	SS	33	164	Non-Plastic 16 73 9 2
22	SS	13	163	
23	SS	33	162	
24	SS	36		Non-Plastic 23 68 7 2
25	SS	43	161	
26	SS	54	160	

Continued Next Page

✕ ³, × ³: Numbers refer to Sensitivity   O ³% STRAIN AT FAILURE

PROJECT # 110901255 PROJECT Enbridge GTA Project - DE Phase

W.P. NA LOCATION S2C11 - Highway 404 N: 4 854 910 E: 631 255 ORIGINATED BY AHatch

DIST NA HWY 404 BOREHOLE TYPE CME, Hollow Stem Auger COMPILED BY KRefahi

DATUM Geodetic DATE July 2, 2014 CHECKED BY RHache

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND (SW-SM) with silt and gravel Grey Dense to very dense - moist to wet	27	SS	48	159		
		28	SS	54	158		Non-Plastic 32 59 7 2
		29	SS	56	157 / 156		
		30	SS	45	155 / 154		
		31	SS	39	153		
152.8 26.5	END OF BOREHOLE at approximately 26.5 m below existing grade.						

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED, ● QUICK TRIAXIAL, ✕ FIELD VANE, × LAB VANE — 20 40 60 80 100
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m³

✕3, ×3: Numbers refer to Sensitivity O 3% STRAIN AT FAILURE

Stantec

RECORD OF BOREHOLE No S2C11-7

METRIC

PROJECT # 110901255	PROJECT Enbridge GTA Project - DE Phase		
W.P. NA	LOCATION S2C11 - Highway 404	N: 4 854 935 E: 631 321	ORIGINATED BY JRyu
DIST NA HWY 404	BOREHOLE TYPE CME, Hollow Stem Auger		COMPILED BY KRefahi
DATUM Geodetic	DATE July 3, 2014		CHECKED BY RHache

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
179.3	Rough Grass					
179.1	150 mm TOPSOIL					
0.2	Silty sand, trace gravel, some clay (FILL) Brown - inferred occasional cobbles and possible boulders based on auger grinding between 0.15 mbg and 2.1 mbg.	1	SS	9	179	
		2	SS	58	178	5 47 33 15
		3	SS	33		
177.1 / 2.2	Silty clayey SAND (SC-SM) with gravel, TILL Brown Dense to very dense - moist - inferred occasional cobbles and possible boulders based on auger grinding between 2.2 mbg and 6.8 mbg	4	SS	47	177	
		5	SS	>100	176	
		6	SS	100/75	175	
		7	SS	100/100		22 44 25 9
174.0 / 5.3	Silty SAND (SM), TILL Grey Compact to very dense - trace gravel - trace clay - moist	8	SS	100/100	174	
		9	SS	67	173	
		10	SS	93	172	
		11	SS	>100	171	
		12	SS	42		Non-Plastic 0 79 19 2
	- inferred occasional cobbles and possible boulders based on auger grinding at 9.6 mbg.	13	SS	29	170	

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa (O UNCONFINED, ✖ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L, WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

✖ 3, × 3: Numbers refer to Sensitivity

O 3% STRAIN AT FAILURE

Stantec — RECORD OF BOREHOLE No S2C11-7 — METRIC

PROJECT # 110901255	PROJECT Enbridge GTA Project - DE Phase		
W.P. NA	LOCATION S2C11 - Highway 404	N: 4 854 935 E: 631 321	ORIGINATED BY JRyu
DIST NA HWY 404	BOREHOLE TYPE CME, Hollow Stem Auger		COMPILED BY KRefahi
DATUM Geodetic	DATE July 3, 2014		CHECKED BY RHache

Column headings: SOIL PROFILE (ELEV / DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (O UNCONFINED, ✖ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L — WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) (GR SA SI CL)

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS / GRAIN SIZE (GR SA SI CL)
	Silty SAND (SM), TILL Grey Compact to very dense - trace to some gravel - trace to some clay - moist	14	SS	36	169	
		15	SS	14	168	
		16	SS	31		11 48 31 10
		17	SS	27	167	
		18	SS	>100	166	
		19	SS	94		Non-Plastic 2 73 16 9
164.9 14.4	SAND (SP-SM) with silt Grey Dense to very dense - trace clay - moist				165	
		20	SS	90	164	
		21	SS	47		
		22	SS	54	163	
		23	SS	50/ >100		Non-Plastic 0 92 6 2
		24	SS	57	162	
		25	SS	45	161	
		26	SS	41	160	
						Non-Plastic

Continued Next Page

✖ 3, × 3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

Stantec

RECORD OF BOREHOLE No S2C11-7

METRIC

PROJECT # 110901255 | PROJECT Enbridge GTA Project - DE Phase
W.P. NA | LOCATION S2C11 - Highway 404 | N: 4 854 935 E: 631 321 | ORIGINATED BY JRyu
DIST NA HWY 404 | BOREHOLE TYPE CME, Hollow Stem Auger | COMPILED BY KRefahi
DATUM Geodetic | DATE July 3, 2014 | CHECKED BY RHache

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND (SW-SM) with silt Grey Compact to very dense - trace clay - trace gravel - moist	27	SS	57	159	7 84 7 2
		28	SS	12	158	
		29	SS	35	157	
		30	SS	33	156	
155.4 23.9	Silty SAND (SM) Grey Very dense - trace gravel - trace clay - moist	31	SS	52	155	Non-Plastic 3 84 11 2
153.8 25.5	SAND (SP-SM) with silt Grey Dense to very dense - trace clay - moist	32	SS	31	154, 153	
		33	SS	50	152	Non-Plastic 0 91 7 2
151.3 28.0	END OF BOREHOLE at approximately 28.0 m below existing grade. Groundwater level in open borehole not measured due to the introduction of water into the borehole during drilling.					

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O UNCONFINED, ✕ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%).

✕3, ×3: Numbers refer to Sensitivity O 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No S2C11-8

Stantec — METRIC

PROJECT # 110901255	PROJECT Enbridge GTA Project - DE Phase		
W.P. NA	LOCATION S2C11 - Highway 404	N: 4 854 953 E: 631 393	ORIGINATED BY BLao
DIST NA HWY 404	BOREHOLE TYPE CME, Hollow Stem Auger		COMPILED BY KRefahi
DATUM Geodetic	DATE July 29, 2014		CHECKED BY RHache

ELEV DEPTH	DESCRIPTION (SOIL PROFILE)	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
189.7	Road							
189.6 / 0.1	75 mm ASPHALT							
	Silty sand with gravel (FILL) Grey - damp	FILL	1	SS	15			
							189	Non-Plastic
			2	SS	23			35 45 16 4
188.2 / 1.5	Sandy clay to sandy silty clay, trace gravel (FILL) Brown - inferred occasional cobbles and possible boulders based on auger grinding between 1.5 mbg and 4.0 mbg. - moist	FILL	3	SS	11		188	
			4	SS	23		187	
			5	SS	13			3 35 43 19
							186	
			6	SS	36			
			7	SS	23		185	
			8	SS	13		184	
			9	SS	10			5 44 37 14
			10	SS	17		183	
			11	SS	20		182	
181.3 / 8.4	Silty SAND (SM), TILL Brown Dense to very dense - trace gravel - trace clay - moist	TILL	12	SS	44		181	
			13	SS	62		180	

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED, ✖ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m³

Continued Next Page

✖ 3, × 3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

Stantec — RECORD OF BOREHOLE No S2C11-8

METRIC

PROJECT # 110901255 | PROJECT Enbridge GTA Project - DE Phase

W.P. NA | LOCATION S2C11 - Highway 404 | N: 4 854 953 E: 631 393 | ORIGINATED BY BLao

DIST NA HWY 404 | BOREHOLE TYPE CME, Hollow Stem Auger | COMPILED BY KRefahi

DATUM Geodetic | DATE July 29, 2014 | CHECKED BY RHache

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%) (approx.)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Silty SAND (SM), TILL Brown Very dense - trace gravel - trace clay - moist	14	SS	44		o (Wp–WL plotted)	5 47 38 10
					179		
		15	SS	47		o	
		16	SS	>100	178	o	
		17	SS	>100		o	
					177		
		18	SS	>100		o	
		19	SS	50/ >100	176	o	Non-Plastic 7 52 32 9
		20	SS	>100	175	o	
		21	SS	>100		o	
					174		
		22	SS	68		o	Non-Plastic 9 46 38 7
172.9 16.8	Grey				173		
		23	SS	>100		o	
		24	SS	>100	172	o	
		25	SS	>100		o	
					171		
		26	SS	>100		o	
					170		
		27	SS	>100		68 (DCPT)	

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O UNCONFINED, ● QUICK TRIAXIAL, ✕ FIELD VANE, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; GROUND WATER CONDITIONS; STRAT PLOT.

Continued Next Page

$\times^3, \times^3$: Numbers refer to Sensitivity $O^{3\%}$ STRAIN AT FAILURE

Stantec

RECORD OF BOREHOLE No S2C11-8

METRIC

PROJECT # 110901255 | PROJECT Enbridge GTA Project - DE Phase

W.P. NA | LOCATION S2C11 - Highway 404 | N: 4 854 953 E: 631 393 | ORIGINATED BY BLao

DIST NA HWY 404 | BOREHOLE TYPE CME, Hollow Stem Auger | COMPILED BY KRefahi

DATUM Geodetic | DATE July 29, 2014 | CHECKED BY RHache

ELEV DEPTH	SOIL PROFILE DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Silty SAND (SM), TILL Brown Very dense - trace gravel - trace clay - moist	28	SS	50/ >100	Non-Plastic 12 52 28 8
		29	SS	>100	
		30	SS	>100	
		31	SS	100/100	
		32	SS	50/ >100	Non-Plastic 13 69 15 3
165.3 24.4	SAND (SP-SM) with silt Grey Compact to very dense - trace gravel - trace clay - wet	33	SS	22	
		34	SS	19	
		35	SS	79	
		36	SS	45	Non-Plastic 1 91 6 2
		37	SS	29	
		38	SS	69	
160.8 29.0	Silty SAND (SM), TILL Grey Dense - trace gravel	39	SS	45	Non-Plastic 1 85 11 3

ELEVATION SCALE: 169, 168, 167, 166, 165, 164, 163, 162, 161, 160

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED; ✖ FIELD VANE; ● QUICK TRIAXIAL; × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

Continued Next Page

✖ 3, × 3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

PROJECT # 110901255	PROJECT Enbridge GTA Project - DE Phase		
W.P. NA	LOCATION S2C11 - Highway 404	N: 4 854 953 E: 631 393	ORIGINATED BY BLao
DIST NA HWY 404	BOREHOLE TYPE CME, Hollow Stem Auger		COMPILED BY KRefahi
DATUM Geodetic	DATE July 29, 2014		CHECKED BY RHache

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	GR	SA	SI	CL
	Silty SAND (SM), TILL Grey Dense - inferred occasional cobbles and possible boulders based on auger grinding at 31.0 mbg. - trace gravel - trace clay - wet	40	SS	38	159				
					158				
157.7 32.0	Silty clayey SAND (SC-SM), TILL Grey Very dense - trace gravel - moist	41	SS	>100	157				
155.7		42	SS	>100	156	4	64	21	11
34.0	END OF BOREHOLE at approximately 34.0 m below existing grade. Groundwater level in open borehole not measured due to the introduction of water into the borehole during drilling.								

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: O UNCONFINED, ✖ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL; STRAT PLOT.

$\times^3, \times^3$: Numbers refer to Sensitivity $O^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No S2C11-9

METRIC

Stantec

PROJECT #	110901255	PROJECT	Enbridge GTA Project - DE Phase
W.P.	NA	LOCATION	S2C11 - Highway 404 — N: 4 854 977 E: 631 455
DIST	NA — HWY 404	BOREHOLE TYPE	CME, Hollow Stem Auger
DATUM	Geodetic	DATE	July 29, 2014

ORIGINATED BY: BGraham
COMPILED BY: KRefahi
CHECKED BY: RHache

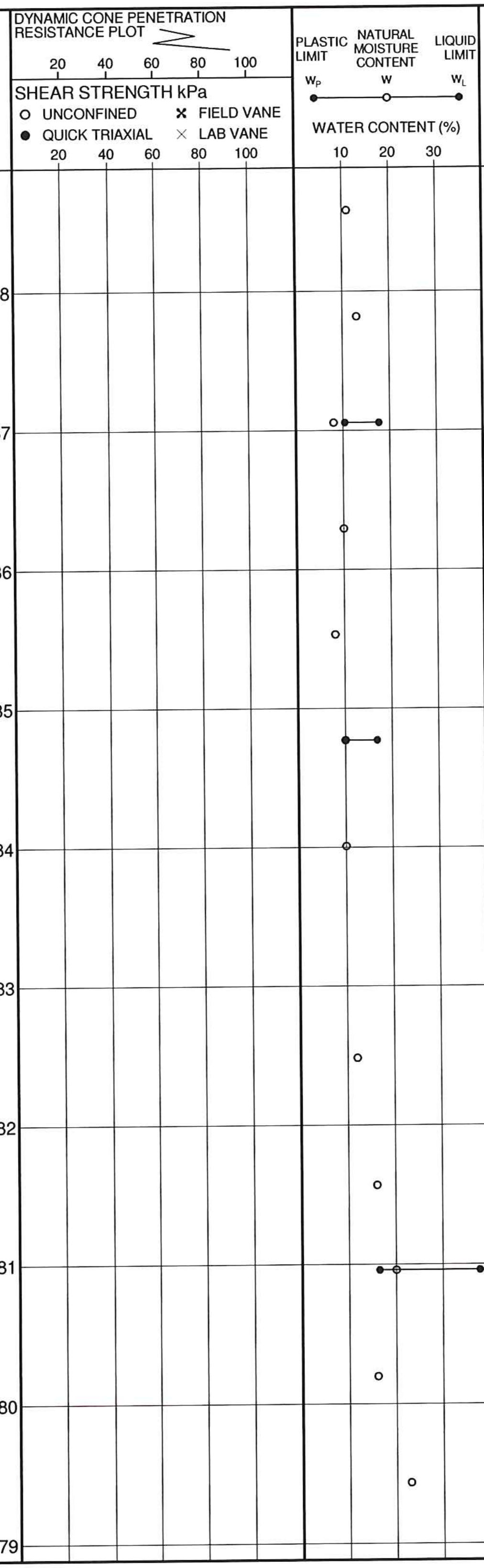
SOIL PROFILE

- **188.9** — Rough Grass
- **188.8 / 0.1** — 75 mm TOPSOIL
- Sandy silty clay to clay with sand, trace gravel, occasional organic inclusions (FILL)
  Brown
  - moist
  - No sample recovered for SS 8. Drilled through a boulder from 5.3 mbg to 5.9 mbg.
- **181.7 / 7.2** — CLAY (CL) with sand, TILL
  Brown
  Stiff to very stiff
  - trace gravel
  - moist

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	4	
2	SS	3	
3	SS	23	7 30 40 23
4	SS	16	
5	SS	18	
6	SS	12	1 33 46 20
7	SS	10	
8	SS	50/	
9	SS	19	
10	SS	27	
11	SS	26	1 14 36 49
12	SS	11	
13	SS	20	

Elevation scale: 188, 187, 186, 185, 184, 183, 182, 181, 180, 179



UNIT WEIGHT γ kN/m³

Continued Next Page

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

STN13-ONTARIO MTO STANTEC S2C11-MTO.GPJ STANTEC MARKHAM.GDT 1/20/15

Stantec — **RECORD OF BOREHOLE No S2C11-9** **METRIC**

PROJECT # 110901255 — PROJECT Enbridge GTA Project - DE Phase

W.P. NA — LOCATION S2C11 - Highway 404 — N: 4 854 977 E: 631 455 — ORIGINATED BY BGraham

DIST NA HWY 404 — BOREHOLE TYPE CME, Hollow Stem Auger — COMPILED BY KRefahi

DATUM Geodetic — DATE July 29, 2014 — CHECKED BY RHache

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	CLAY (CL) with sand, TILL Brown Very stiff to hard - trace gravel - moist	14	SS	>>100		
		15	SS	>100	178	
177.5 / 11.4	Grey	16	SS	26	177	2 16 36 46
		17	SS	39	176	
		18	SS	91		
		19	SS	38	175	
		20	SS	47	174	4 17 45 34
		21	SS	35		
173.0 / 15.9	Silty SAND (SM), TILL Grey Very dense - trace clay - trace gravel - moist	22	SS	>100	173	
		23	SS	63	172	Non-Plastic 7 51 36 6
		24	SS	>100	171	
		25	SS	>100	170	
		26	SS	>100	169	

Columns: STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, ● QUICK TRIAXIAL, ✖ FIELD VANE, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³

Continued Next Page

✖³, ×³: Numbers refer to Sensitivity — O 3% STRAIN AT FAILURE

Stantec

RECORD OF BOREHOLE No S2C11-9 — METRIC

PROJECT # 110901255 | PROJECT Enbridge GTA Project - DE Phase

W.P. NA | LOCATION S2C11 - Highway 404 | N: 4 854 977 E: 631 455 | ORIGINATED BY BGraham

DIST NA HWY 404 | BOREHOLE TYPE CME, Hollow Stem Auger | COMPILED BY KRefahi

DATUM Geodetic | DATE July 29, 2014 | CHECKED BY RHache

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa — O UNCONFINED, ✕ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Soil Profile

ELEV / DEPTH	DESCRIPTION
	Silty SAND (SM), TILL Grey Compact to very dense - trace clay - trace to some gravel - moist
161.9 / 27.0	Sand (SP-SM) with silt Grey Very dense - trace clay - trace gravel - moist to wet

Samples

NUMBER	TYPE	"N" VALUES	REMARKS (GR SA SI CL)
27	SS	>100	
28	SS	>100	Non-Plastic 10 50 32 8
29	SS	>100	
30	SS	10	Non-Plastic 1 87 10 2
31	SS	38	
32	SS	>100	
33	SS	100/25	
34	SS	21	
35	SS	65	Non-Plastic 0 80 18 2
36	SS	>100	
37	SS	>100	

ELEVATION SCALE: 168, 167, 166, 165, 164, 163, 162, 161, 160, 159

Continued Next Page

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

Stantec

RECORD OF BOREHOLE No S2C11-9

METRIC

PROJECT # 110901255 PROJECT Enbridge GTA Project - DE Phase

W.P. NA LOCATION S2C11 - Highway 404 N: 4 854 977 E: 631 455 ORIGINATED BY BGraham

DIST NA HWY 404 BOREHOLE TYPE CME, Hollow Stem Auger COMPILED BY KRefahi

DATUM Geodetic DATE July 29, 2014 CHECKED BY RHache

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (O UNCONFINED, ● QUICK TRIAXIAL, ✖ FIELD VANE, × LAB VANE)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Sand (SP-SM) with silt Grey Very dense - trace clay - trace gravel - moist to wet		38	SS	50/ >100						Non-Plastic 6 84 8 2
							158				
							157				
156.6			39	SS	>100						
32.3	END OF BOREHOLE at approximately 32.2 m below existing grade. Water level in open borehole not measured due to introduction of water during drilling.										

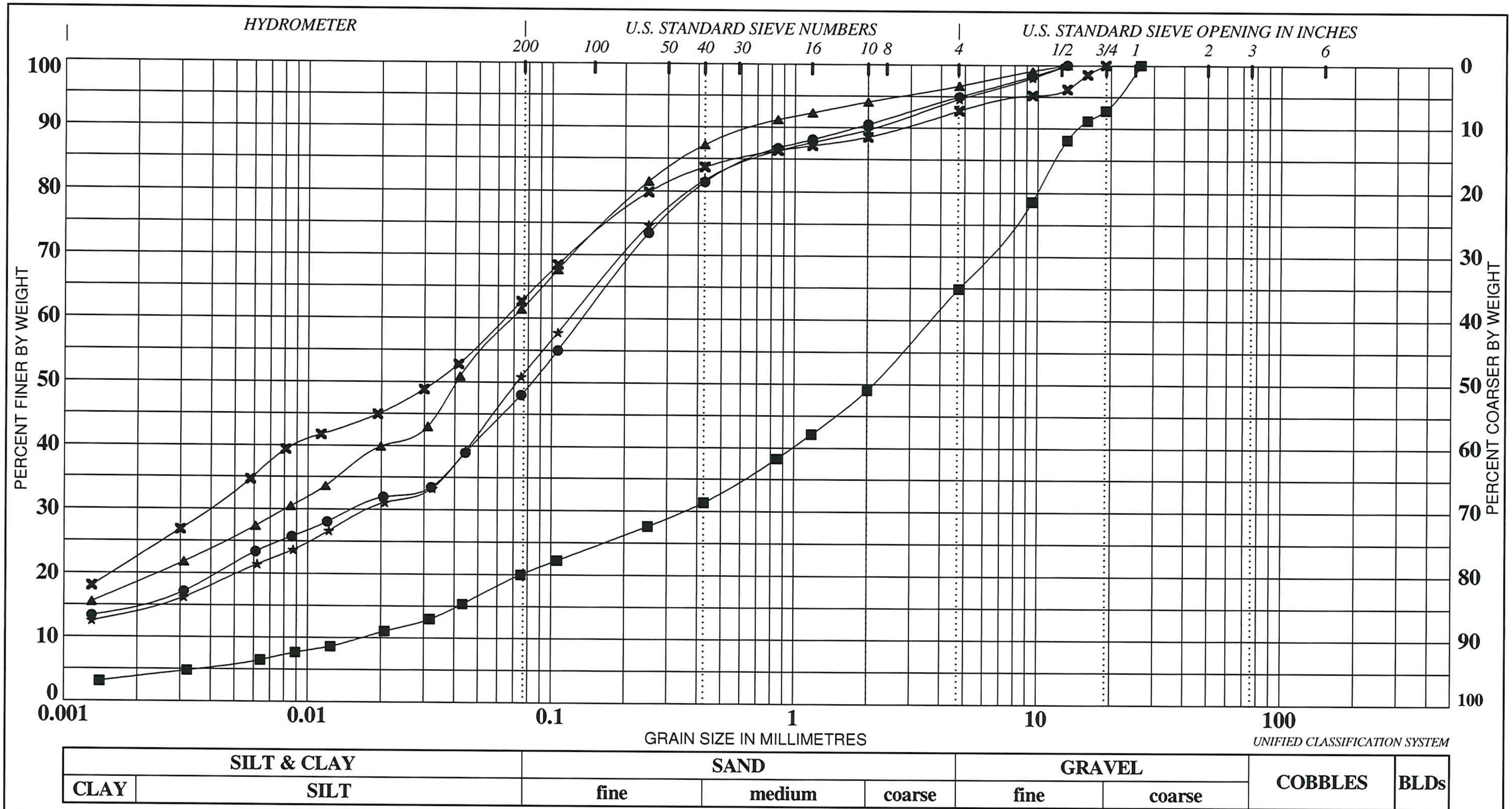
STN13-ONTARIO MTO STANTEC S2C11-MTO.GPJ STANTEC MARKHAM.GDT 1/20/15

✖ ^{3}, × ^{3}: Numbers refer to Sensitivity   O $^{3\%}$ STRAIN AT FAILURE

FOUNDATION INVESTIGATION AND DESIGN REPORT,
GTA PROJECT,
DETAILED ENGINEERING DESIGN PHASE
DOCUMENT NO.: 110901255.076
PROJECT NO.: 110901255

Appendix D

D.1 GEOTECHNICAL LABORATORY TEST RESULTS

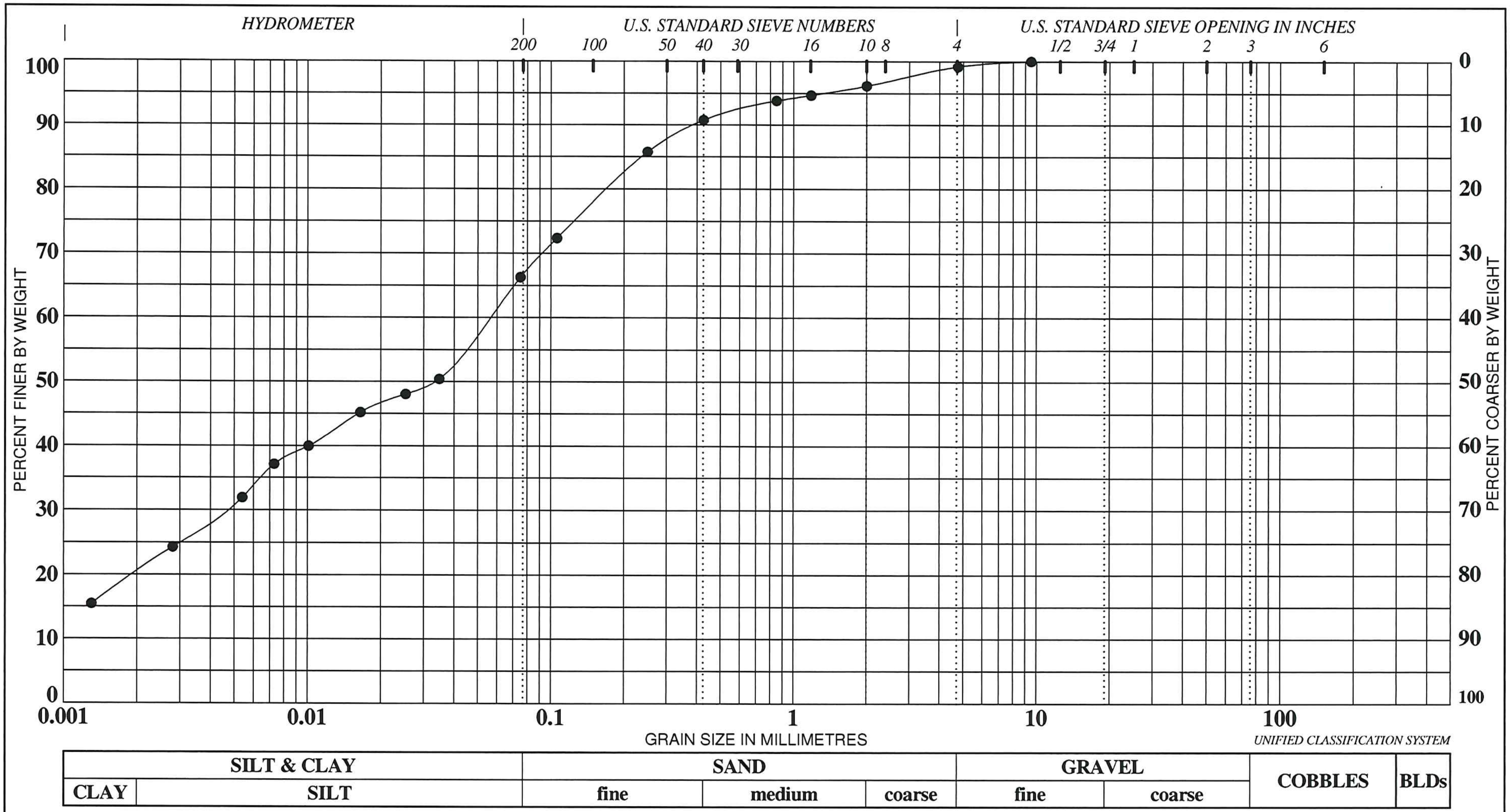


Sample		Depth (m)	Description	W%	W_L	W_P	I_P	%Gravel	%Sand	%Silt	%Clay
●	S2C11-7	1.1	Silty sand (FILL)	8	16	13	3	5	47	33	15
■	S2C11-8	1.1	Silty sand with gravel (FILL)	5	NP	NP	NP	35	45	16	4
▲	S2C11-8	3.4	Sandy clay (FILL)	9	21	12	9	3	35	43	19
★	S2C11-8	6.4	Sandy silty clay (FILL)	9	17	11	6	5	44	37	14
✖	S2C11-9	1.8	Sandy clay (FILL)	8	18	10	8	7	30	40	23

Stantec

Project: Enbridge GTA Project - DE Phase
Location: S2C11 - Highway 404
Project No.: 110901255

GRADATION CURVE (ASTM D422)
Figure: 1
Remarks:



Sample	Depth (m)	Description	W%	W_L	W_P	I_P	%Gravel	%Sand	%Silt	%Clay
● S2C11-9	4.1	Sandy silty clay (FILL)	10	17	10	7	1	33	46	20

Stantec

Project: Enbridge GTA Project - DE Phase

Location: S2C11 - Highway 404

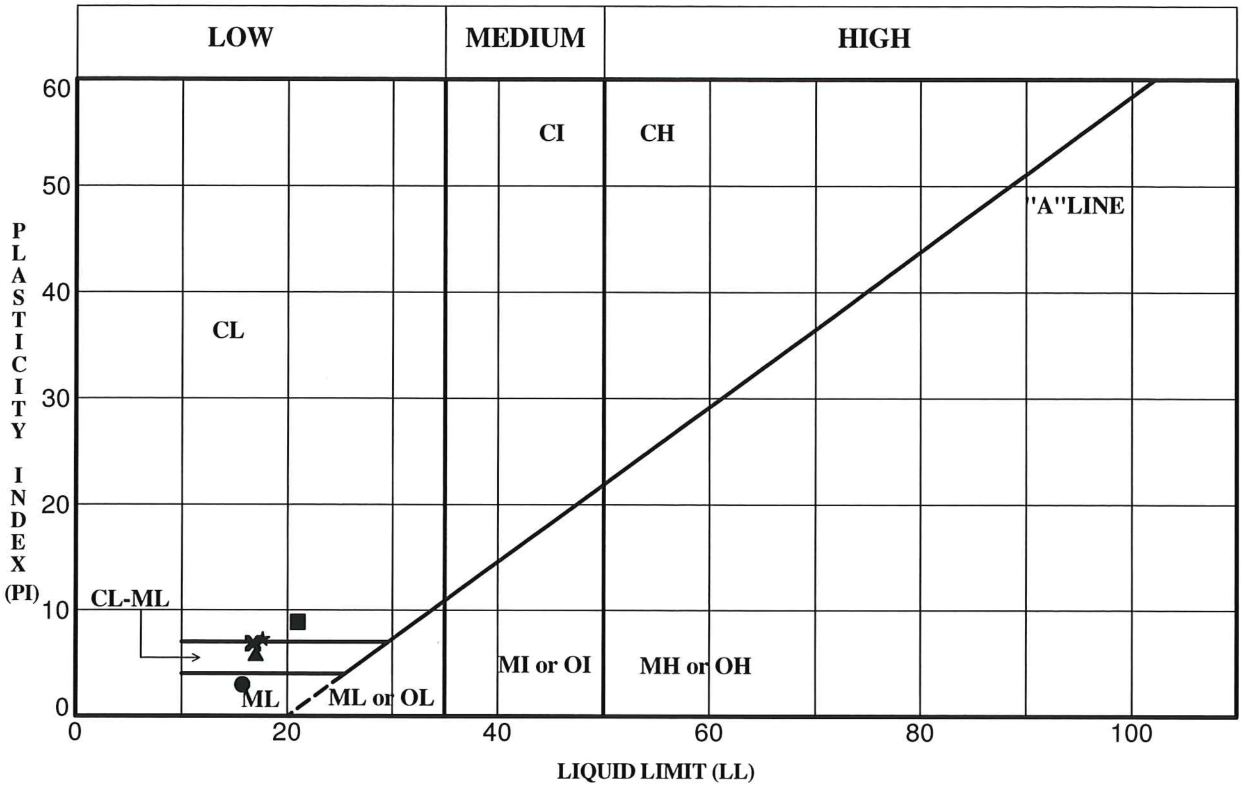
Project No.: 110901255

GRADATION CURVE (ASTM D422)

Figure: 2

Remarks:

PLASTICITY CHART



	Specimen	Depth (m)	LL	PL	PI	Fines	W%	Classification
●	S2C11-7	1.1	16	13	3	48	8	Silty sand (FILL)
■	S2C11-8	3.4	21	12	9	61	9	Sandy clay (FILL)
▲	S2C11-8	6.4	17	11	6	51	9	Sandy silty clay (FILL)
★	S2C11-9	1.8	18	10	8	63	8	Sandy clay (FILL)
✖	S2C11-9	4.1	17	10	7	66	10	Sandy silty clay (FILL)

Stantec

Project: Enbridge GTA Project - DE Phase

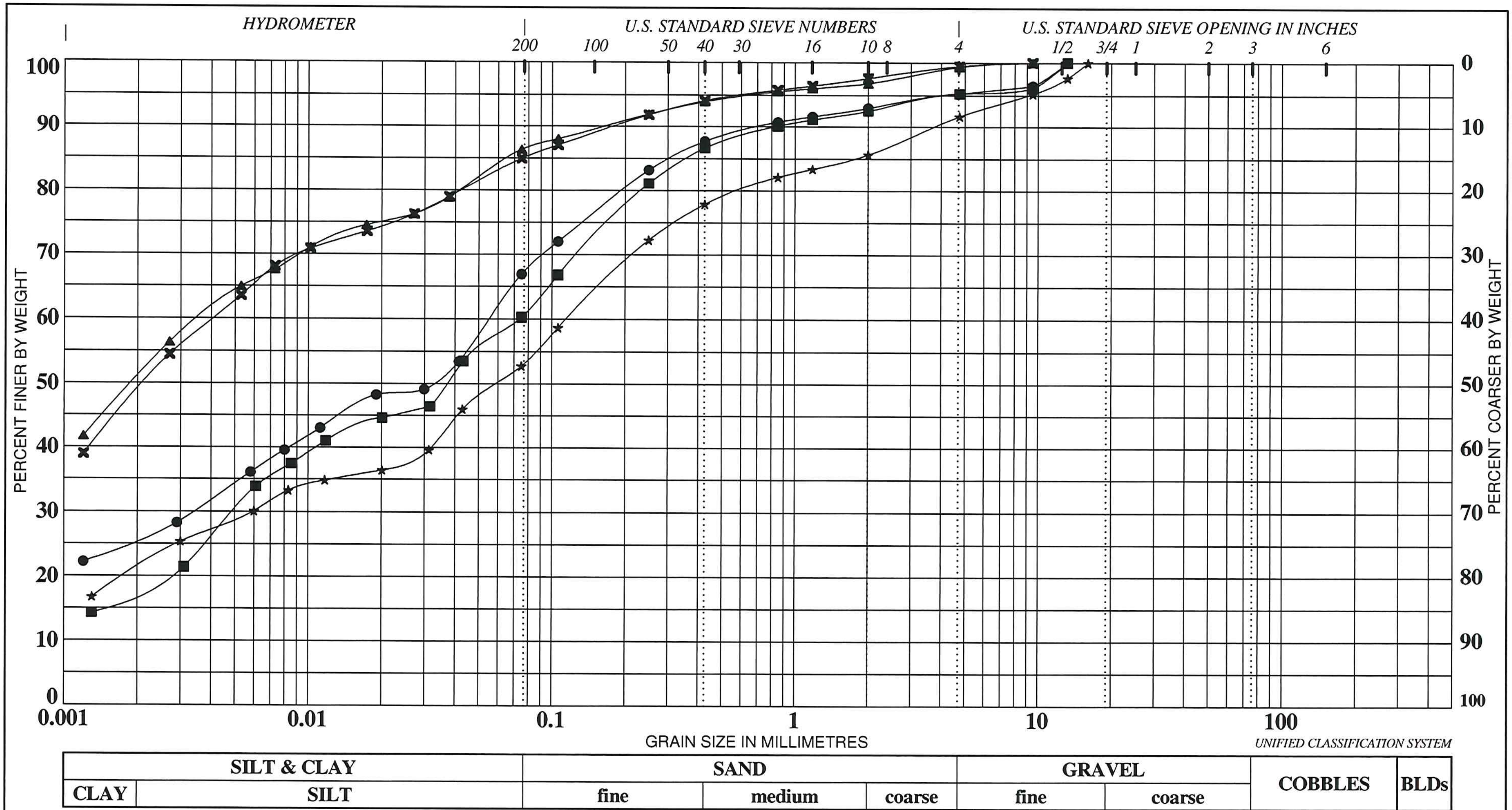
Location: S2C11 - Highway 404

Project No.: 110901255

ATTERBERG LIMITS
(ASTM D4318)

Figure: 3

Remarks:



Sample		Depth (m)	Description	W%	W_L	W_P	I_P	%Gravel	%Sand	%Silt	%Clay
●	B8-BH2	3.4	Sandy CLAY (CL), TILL	17	25	13	12	5	28	41	26
■	S2C11-4	1.8	Sandy silty CLAY (CL-ML), TILL	12	18	12	6	5	35	42	18
▲	S2C11-5	1.8	CLAY (CL), TILL	24	38	18	20	1	13	35	51
★	S2C11-6	1.8	Sandy silty CLAY (CL-ML), TILL	10	20	13	7	8	39	32	21
✖	S2C11-9	7.9	CLAY (CL) with sand, TILL	20	38	16	22	1	14	36	49

Stantec

Project: Enbridge GTA Project - DE Phase

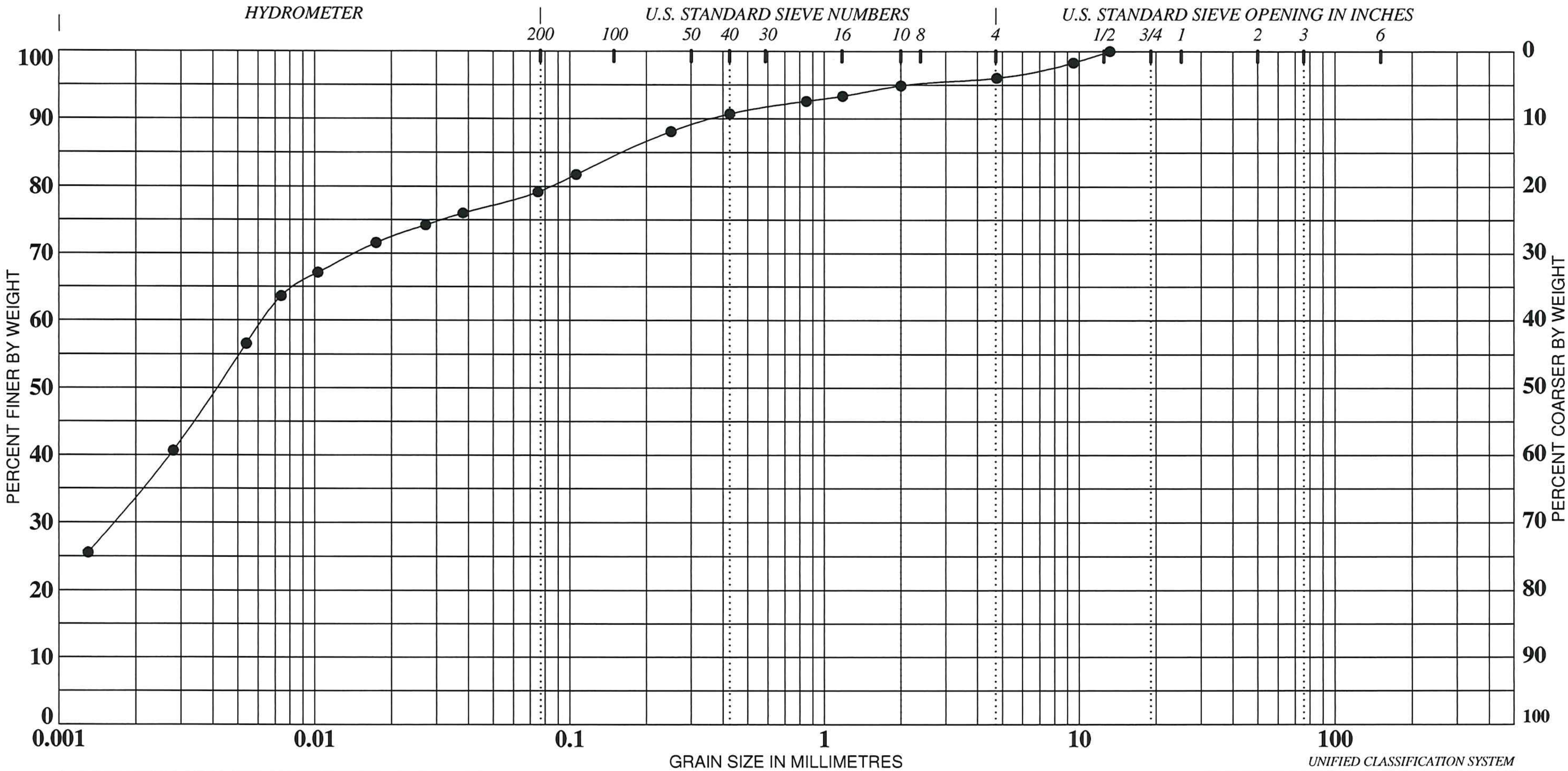
Location: S2C11 - Highway 404

Project No.: 110901255

GRADATION CURVE (ASTM D422)

Figure: 4

Remarks:



SILT & CLAY		SAND			GRAVEL		COBBLES	BLDs
CLAY	SILT	fine	medium	coarse	fine	coarse		

	Sample	Depth (m)	Description	W%	W_L	W_P	I_P	%Gravel	%Sand	%Silt	%Clay
●	S2C11-9	14.8	CLAY (CL) with sand, TILL	13	18	10	8	4	17	45	34

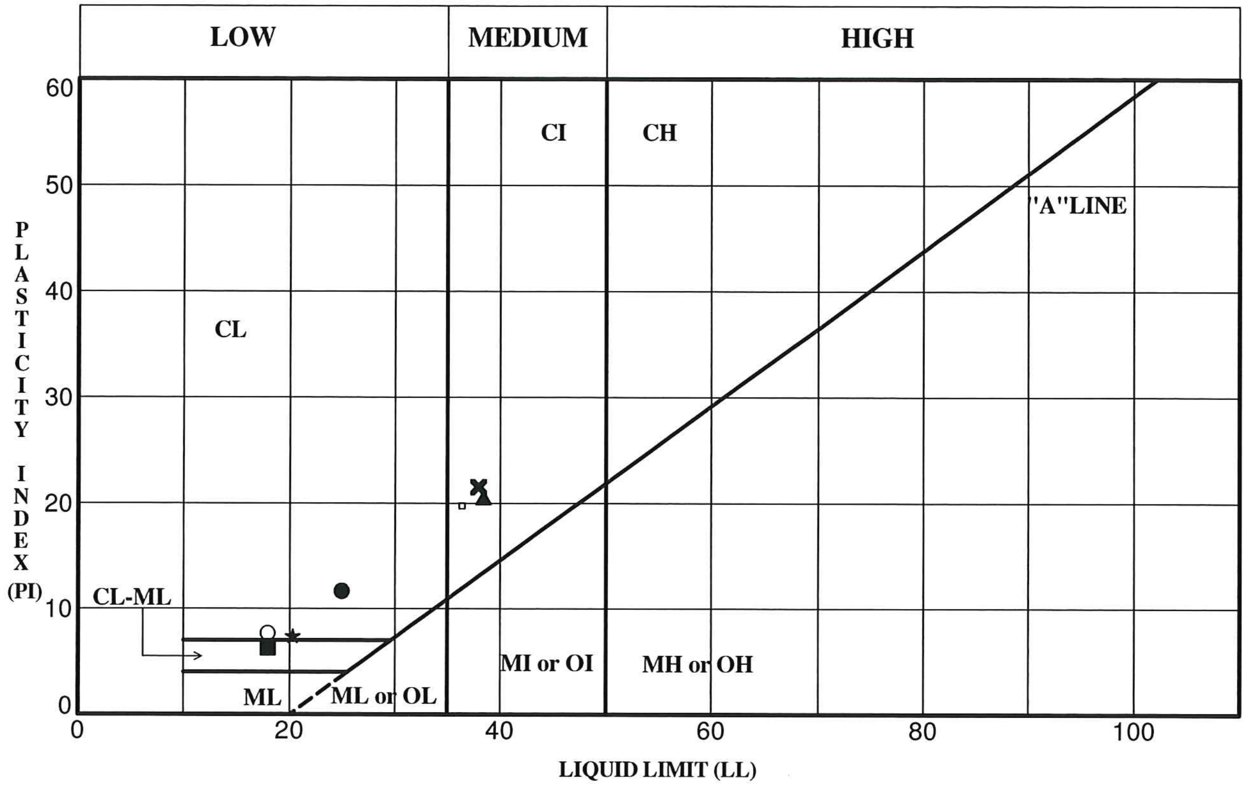
Stantec

Project: Enbridge GTA Project - DE Phase
Location: S2C11 - Highway 404
Project No.: 110901255

GRADATION CURVE (ASTM D422)

Figure: 5
Remarks:

PLASTICITY CHART



	Specimen	Depth (m)	LL	PL	PI	Fines	W%	Classification
●	B8-BH2	3.4	25	13	12	67	17	Sandy CLAY (CL), TILL
■	S2C11-4	1.8	18	12	6	60	12	Sandy silty CLAY (CL-ML), TILL
▲	S2C11-5	1.8	38	18	20	86	24	CLAY (CL), TILL
★	S2C11-6	1.8	20	13	7	53	10	Sandy silty CLAY (CL-ML), TILL
✖	S2C11-9	7.9	38	16	22	85	20	CLAY (CL) with sand, TILL
▫	S2C11-9	11.7	36	17	19	82	17	CLAY (CL) with sand, TILL
○	S2C11-9	14.8	18	10	8	79	13	CLAY (CL) with sand, TILL

STN13-ATTERBERG MTO S2C11-MTO.GPJ MM.GDT 1/14/15

Stantec

Project: Enbridge GTA Project - DE Phase

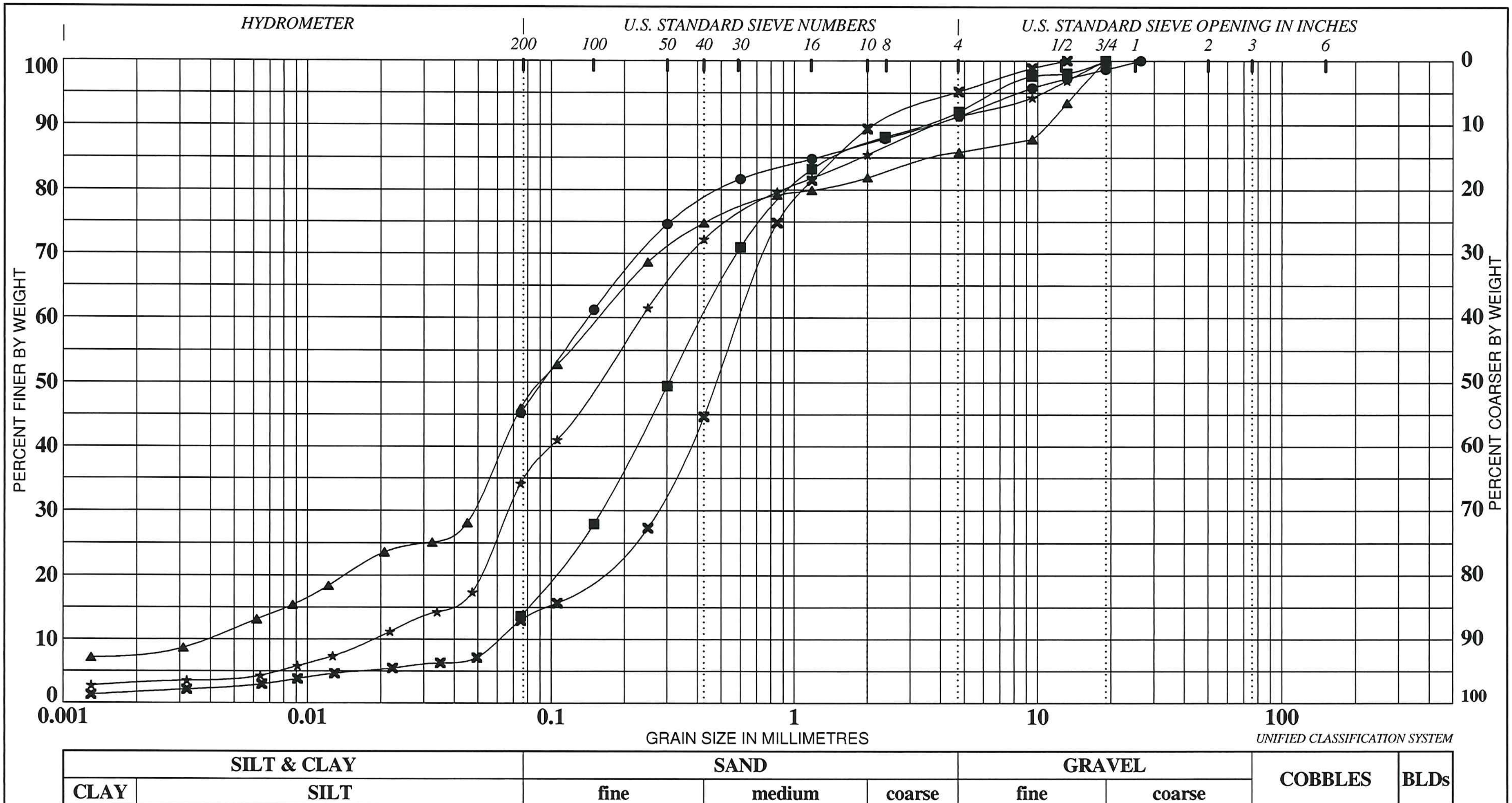
Location: S2C11 - Highway 404

Project No.: 110901255

ATTERBERG LIMITS
(ASTM D4318)

Figure: 6

Remarks:



Sample		Depth (m)	Description	W%	W_L	W_P	I_P	%Gravel	%Sand	%Silt	%Clay
●	B8-BH1	4.8	Silty SAND (SM), TILL	7	NP	NP	NP	9	46	45	
■	B8-BH1	9.4	Silty SAND (SM), TILL	12				8	78	14	
▲	B8-BH2	9.4	Silty SAND (SM), TILL	7	NP	NP	NP	14	40	38	8
★	B8-BH2	18.6	Silty SAND (SM), TILL	9				9	57	31	3
✖	B8-BH2	27.7	Silty SAND (SM), TILL	11				5	82	11	2

Stantec

Project: Enbridge GTA Project - DE Phase

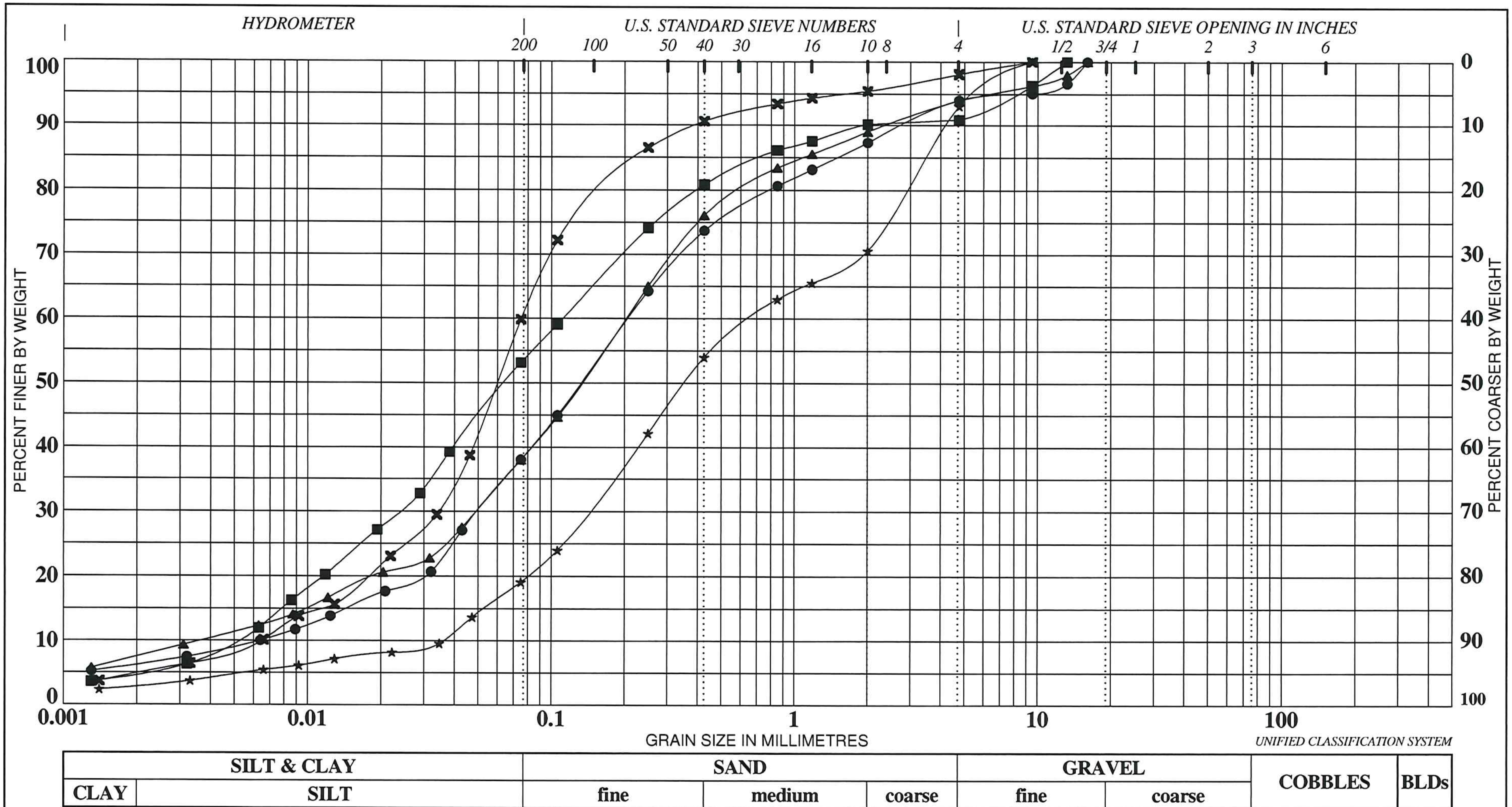
Location: S2C11 - Highway 404

Project No.: 110901255

GRADATION CURVE (ASTM D422)

Figure: 7

Remarks:



Sample		Depth (m)	Description	W%	W_L	W_P	I_P	%Gravel	%Sand	%Silt	%Clay
●	S2C11-3	3.4	Silty SAND (SM), TILL	7	NP	NP	NP	6	56	32	6
■	S2C11-3	6.2	Sandy SILT (ML), TILL	13	NP	NP	NP	9	38	48	5
▲	S2C11-3	8.6	Silty SAND (SM), TILL	7	NP	NP	NP	6	56	30	8
★	S2C11-4	5.5	Silty SAND (SM), TILL	11	NP	NP	NP	7	74	16	3
✖	S2C11-4	8.5	Sandy SILT (ML), TILL	14	NP	NP	NP	2	38	55	5

Stantec

Project: Enbridge GTA Project - DE Phase

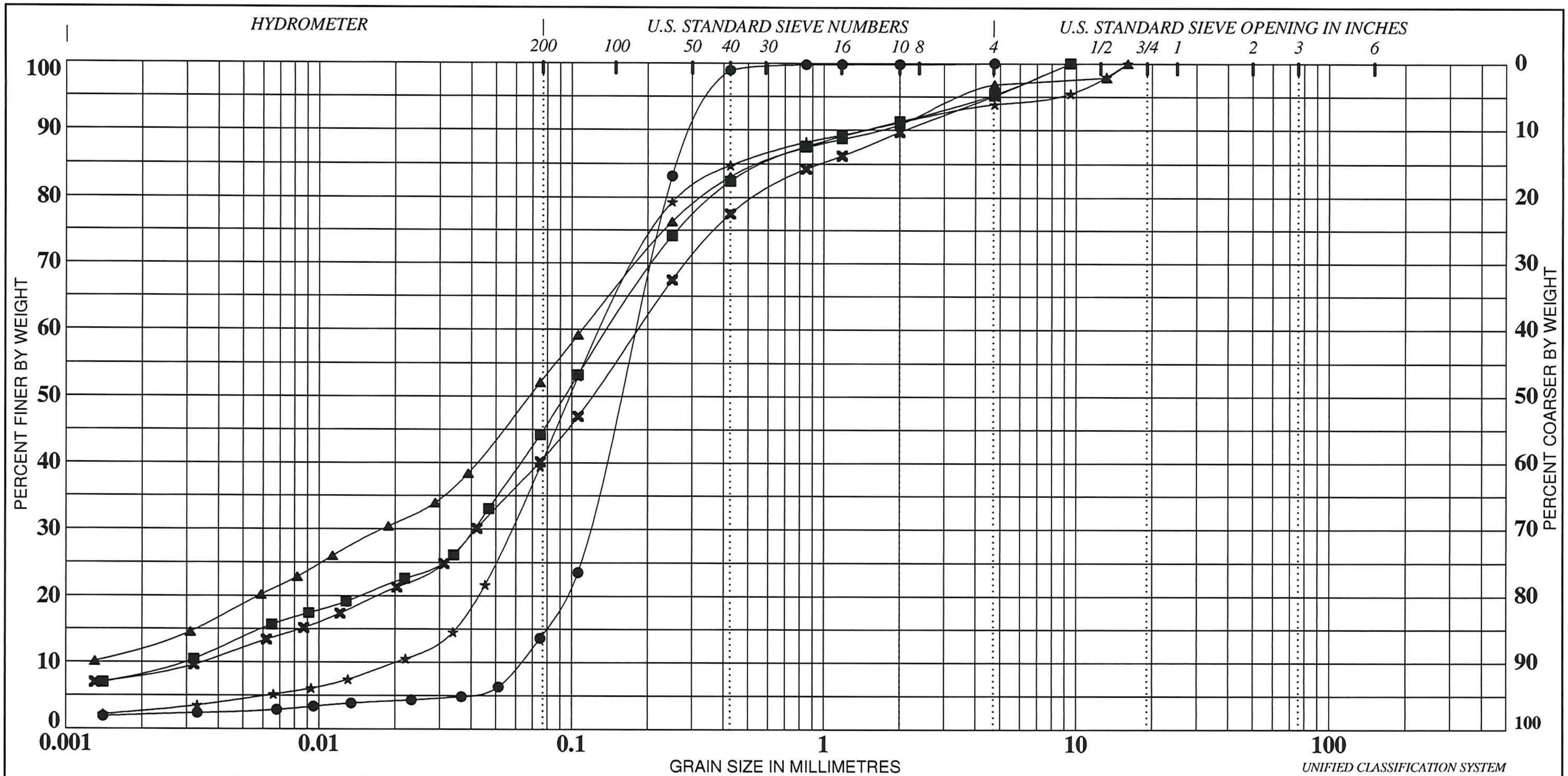
Location: S2C11 - Highway 404

Project No.: 110901255

GRADATION CURVE (ASTM D422)

Figure: 8

Remarks:



SILT & CLAY		SAND			GRAVEL		COBBLES	BLDs
CLAY	SILT	fine	medium	coarse	fine	coarse		

	Sample	Depth (m)	Description	W%	W_L	W_P	I_P	%Gravel	%Sand	%Silt	%Clay
●	S2C11-4	10.2	Silty SAND (SM), TILL	18	NP	NP	NP	0	86	12	2
■	S2C11-4	12.5	Silty SAND (SM), TILL	12	NP	NP	NP	5	51	36	8
▲	S2C11-5	4.1	Sandy SILT (ML), TILL	7	14	11	3	3	45	40	12
★	S2C11-5	7.9	Silty SAND (SM), TILL	12	NP	NP	NP	6	54	37	3
✖	S2C11-5	11.0	Silty SAND (SM), TILL	8	NP	NP	NP	5	55	32	8

Stantec

Project: Enbridge GTA Project - DE Phase

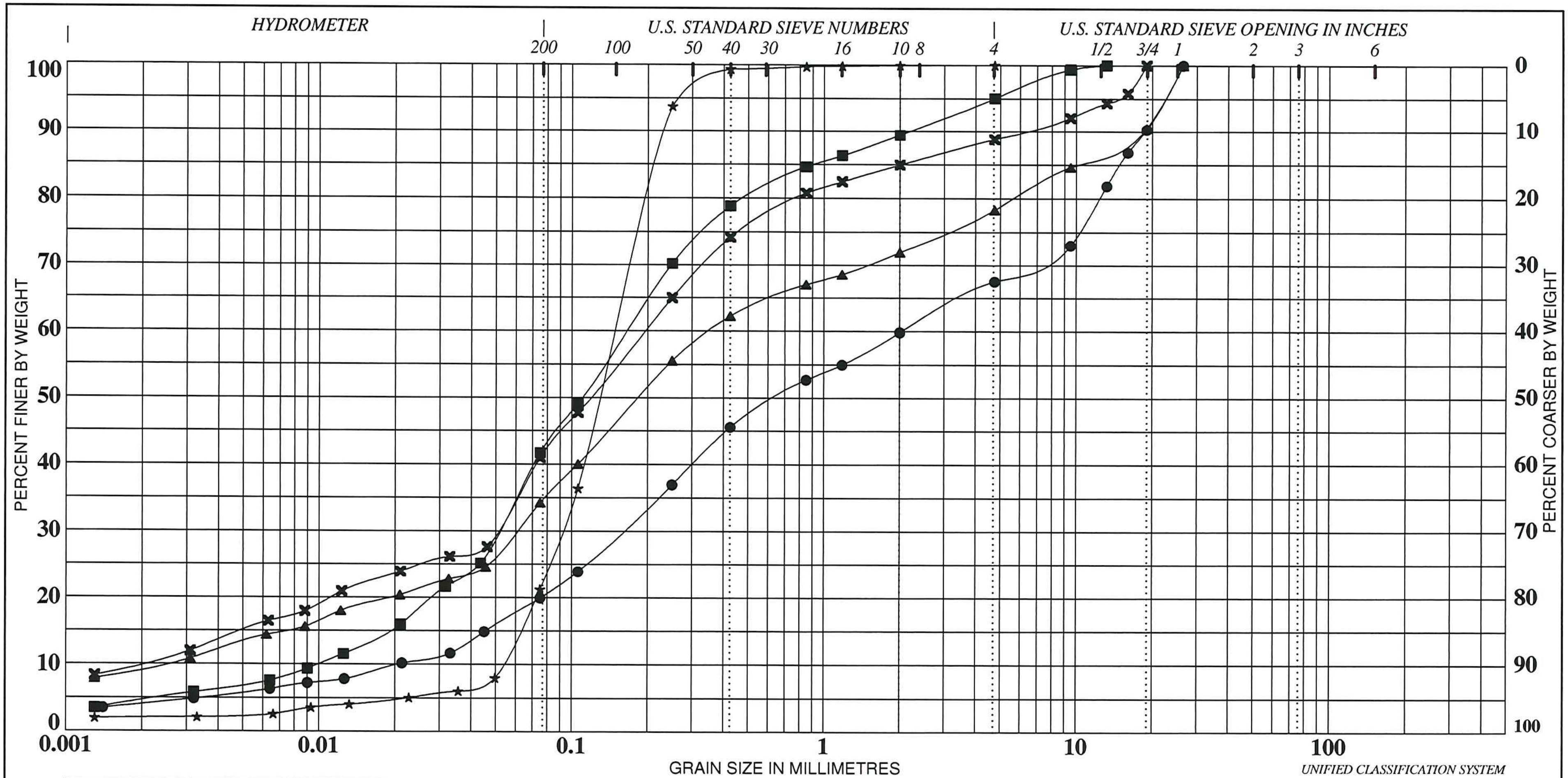
Location: S2C11 - Highway 404

Project No.: 110901255

GRADATION CURVE (ASTM D422)

Figure: 9

Remarks:



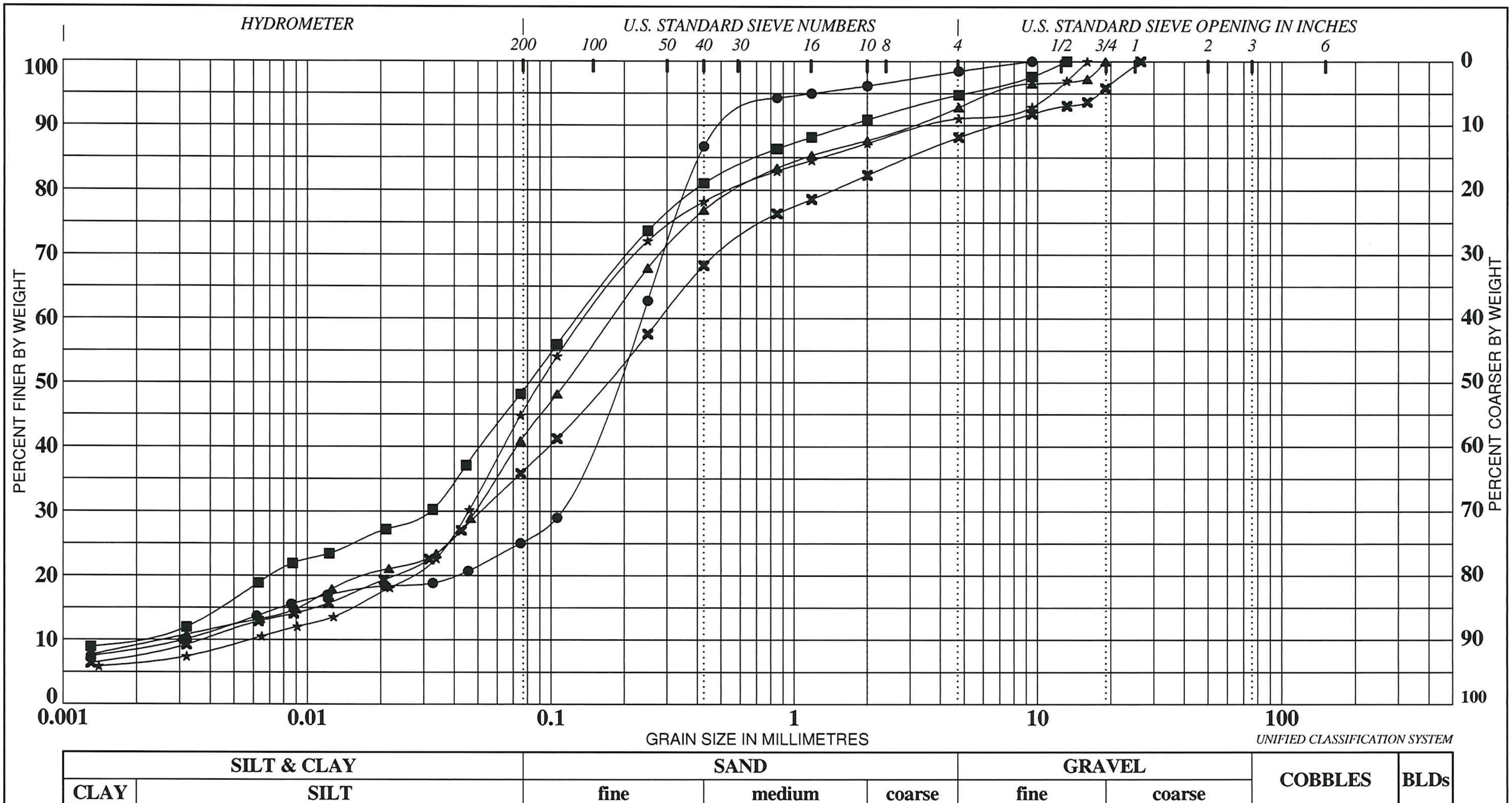
SILT & CLAY		SAND			GRAVEL		COBBLES	BLDs
CLAY	SILT	fine	medium	coarse	fine	coarse		

Sample		Depth (m)	Description	W%	W_L	W_P	I_P	%Gravel	%Sand	%Silt	%Clay
●	S2C11-5	14.7	Silty SAND (SM) with gravel, TILL	5	NP	NP	NP	32	48	16	4
■	S2C11-6	4.1	Silty SAND (SM), TILL	13	NP	NP	NP	5	53	37	5
▲	S2C11-7	4.8	Silty clayey SAND (SC-SM) with gravel, TILL	7	14	10	4	22	44	25	9
★	S2C11-7	8.7	Silty SAND (SM), TILL	20	NP	NP	NP	0	79	19	2
✖	S2C11-7	11.7	Silty SAND (SM), TILL	11	13	11	2	11	48	31	10

Stantec

Project: Enbridge GTA Project - DE Phase
Location: S2C11 - Highway 404
Project No.: 110901255

GRADATION CURVE (ASTM D422)
Figure: 10
Remarks:

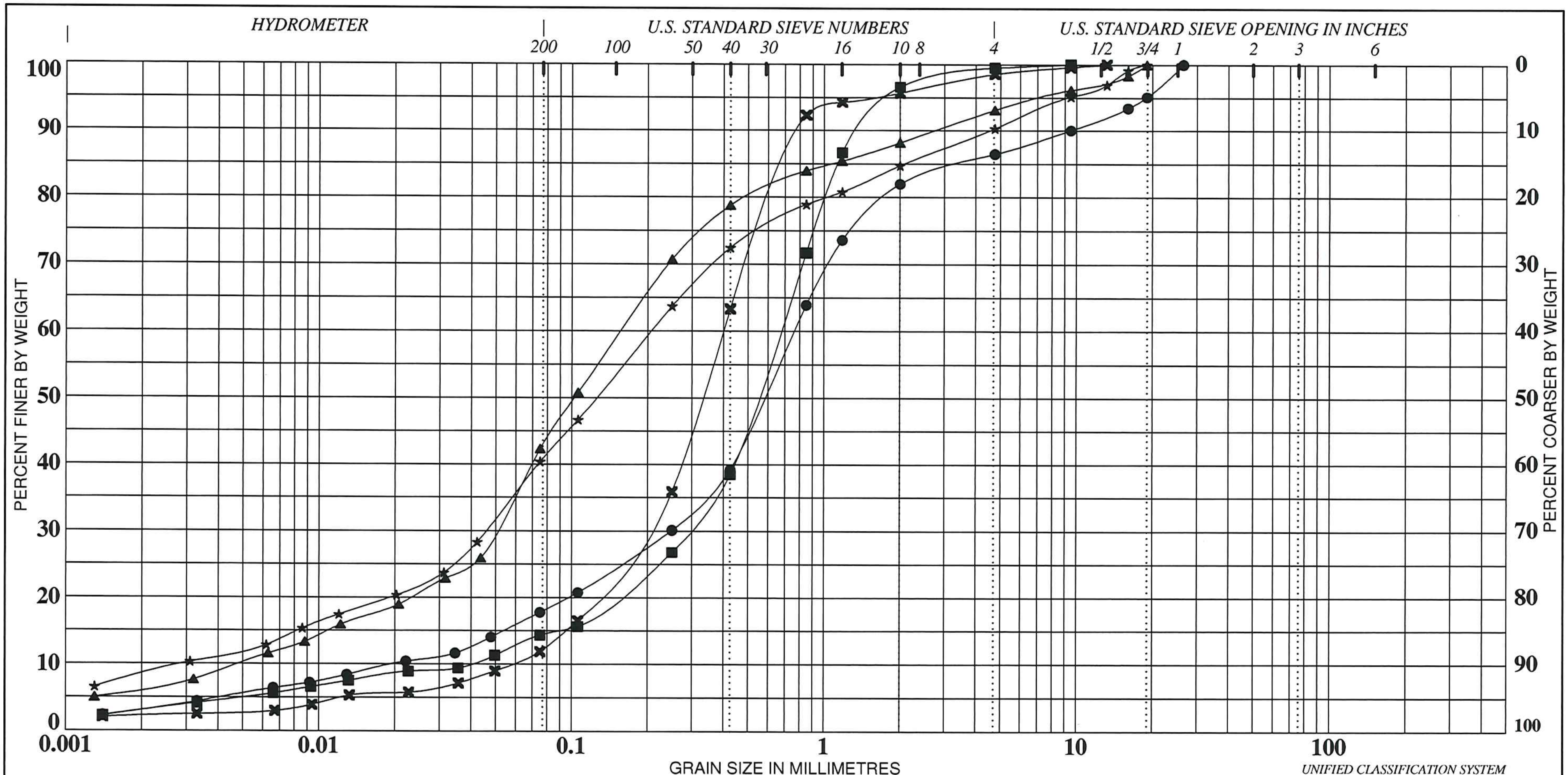


Sample		Depth (m)	Description	W%	W_L	W_P	I_P	%Gravel	%Sand	%Silt	%Clay
●	S2C11-7	14.0	Silty SAND (SM), TILL	13	NP	NP	NP	2	73	16	9
■	S2C11-8	10.2	Silty SAND (SM), TILL	7	14	12	2	5	47	38	10
▲	S2C11-8	13.9	Silty SAND (SM), TILL	7	NP	NP	NP	7	52	32	9
★	S2C11-8	16.3	Silty SAND (SM), TILL	12	NP	NP	NP	9	46	38	7
✖	S2C11-8	20.8	Silty SAND (SM), TILL	6	NP	NP	NP	12	52	28	8

Stantec

Project: Enbridge GTA Project - DE Phase
Location: S2C11 - Highway 404
Project No.: 110901255

GRADATION CURVE (ASTM D422)
Figure: 11
Remarks:



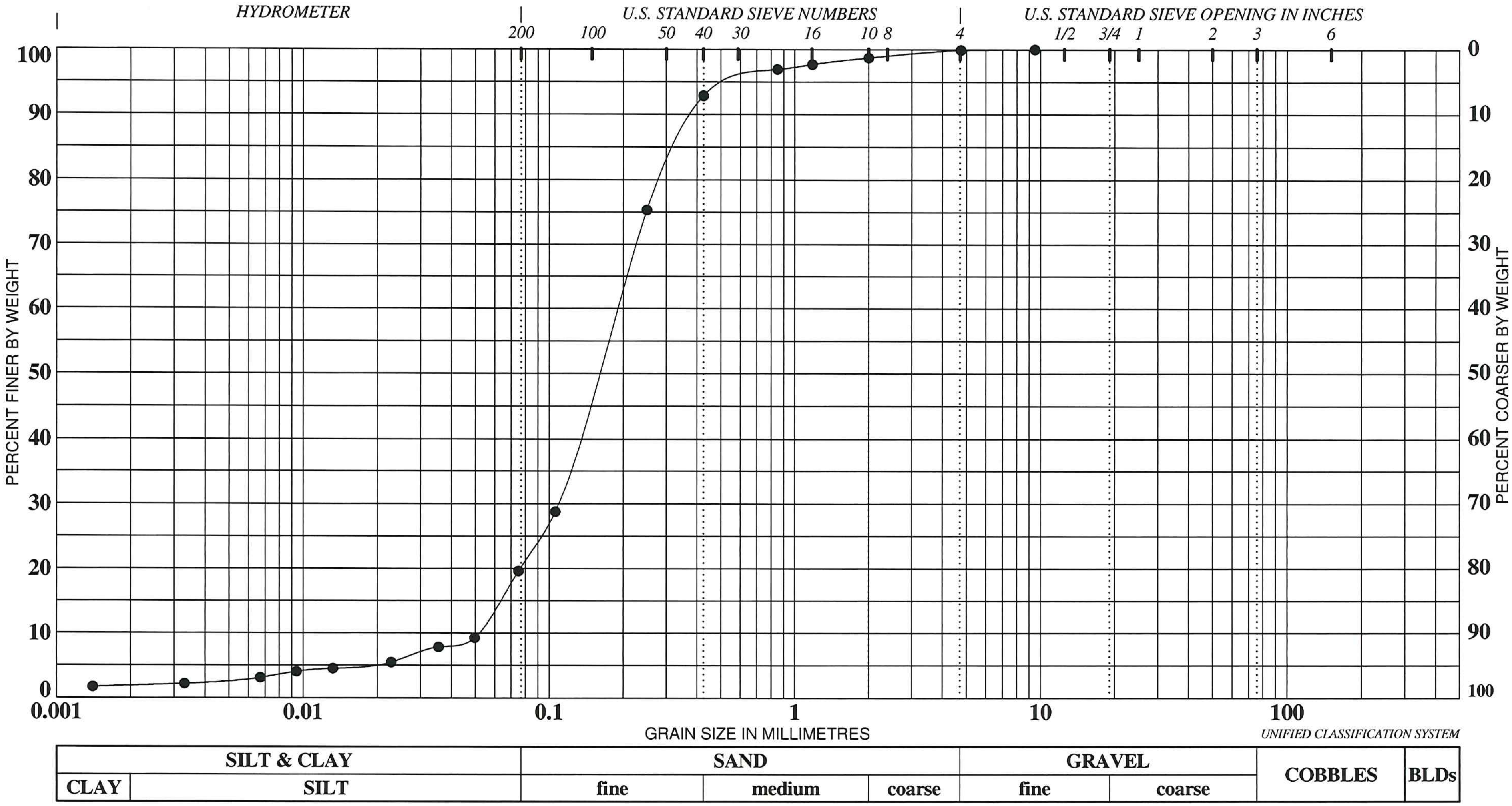
SILT & CLAY		SAND			GRAVEL		COBBLES	BLDs
CLAY	SILT	fine	medium	coarse	fine	coarse		

Sample		Depth (m)	Description	W%	W_L	W_P	I_P	%Gravel	%Sand	%Silt	%Clay
●	S2C11-8	23.8	Silty SAND (SM), TILL	10	NP	NP	NP	13	69	15	3
■	S2C11-8	29.3	Silty SAND (SM), TILL	15	NP	NP	NP	1	85	11	3
▲	S2C11-9	17.1	Silty SAND (SM), TILL	8	NP	NP	NP	7	51	36	6
★	S2C11-9	20.8	Silty SAND (SM), TILL	6	NP	NP	NP	10	50	32	8
✖	S2C11-9	22.4	Silty SAND (SM), TILL	31	NP	NP	NP	1	87	10	2

Stantec

Project: Enbridge GTA Project - DE Phase
Location: S2C11 - Highway 404
Project No.: 110901255

GRADATION CURVE (ASTM D422)
Figure: 12
Remarks:



Sample	Depth (m)	Description	W%	W_L	W_P	I_P	%Gravel	%Sand	%Silt	%Clay
● S2C11-9	26.2	Silty SAND (SM), TILL	16	NP	NP	NP	0	80	18	2

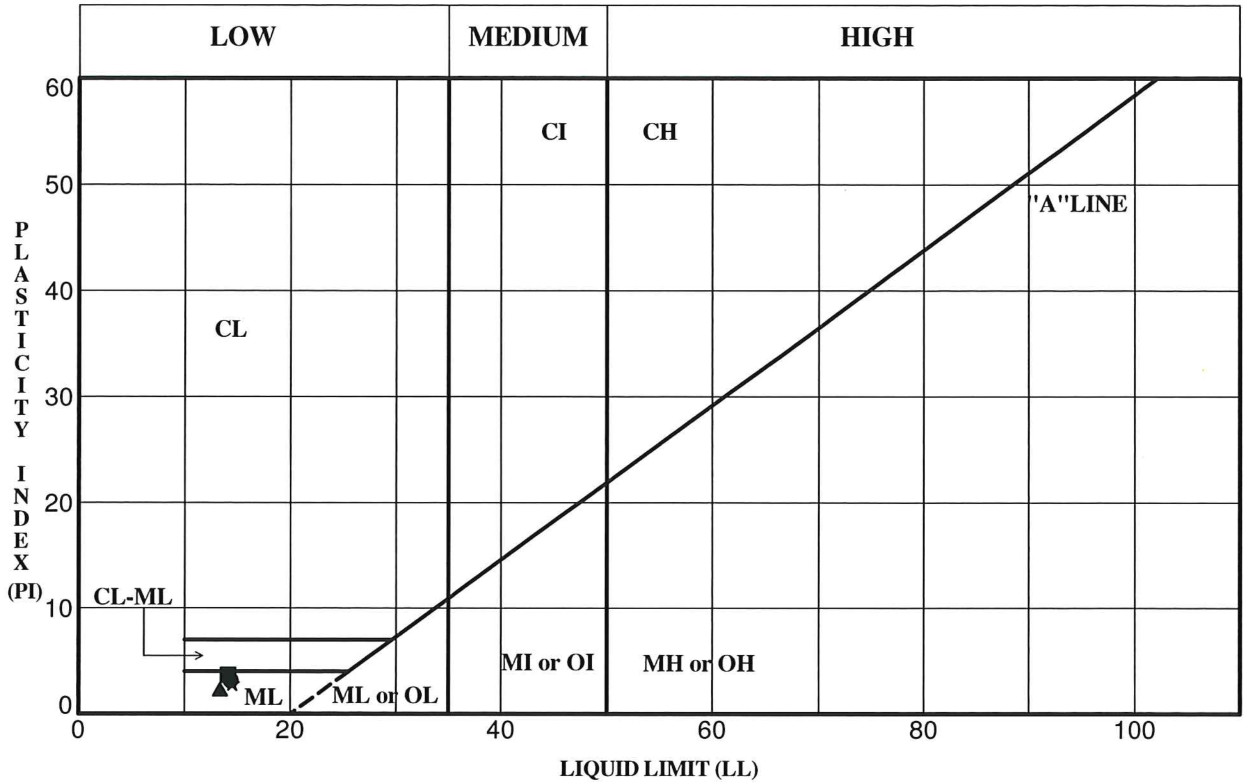
Stantec

Project: Enbridge GTA Project - DE Phase
Location: S2C11 - Highway 404
Project No.: 110901255

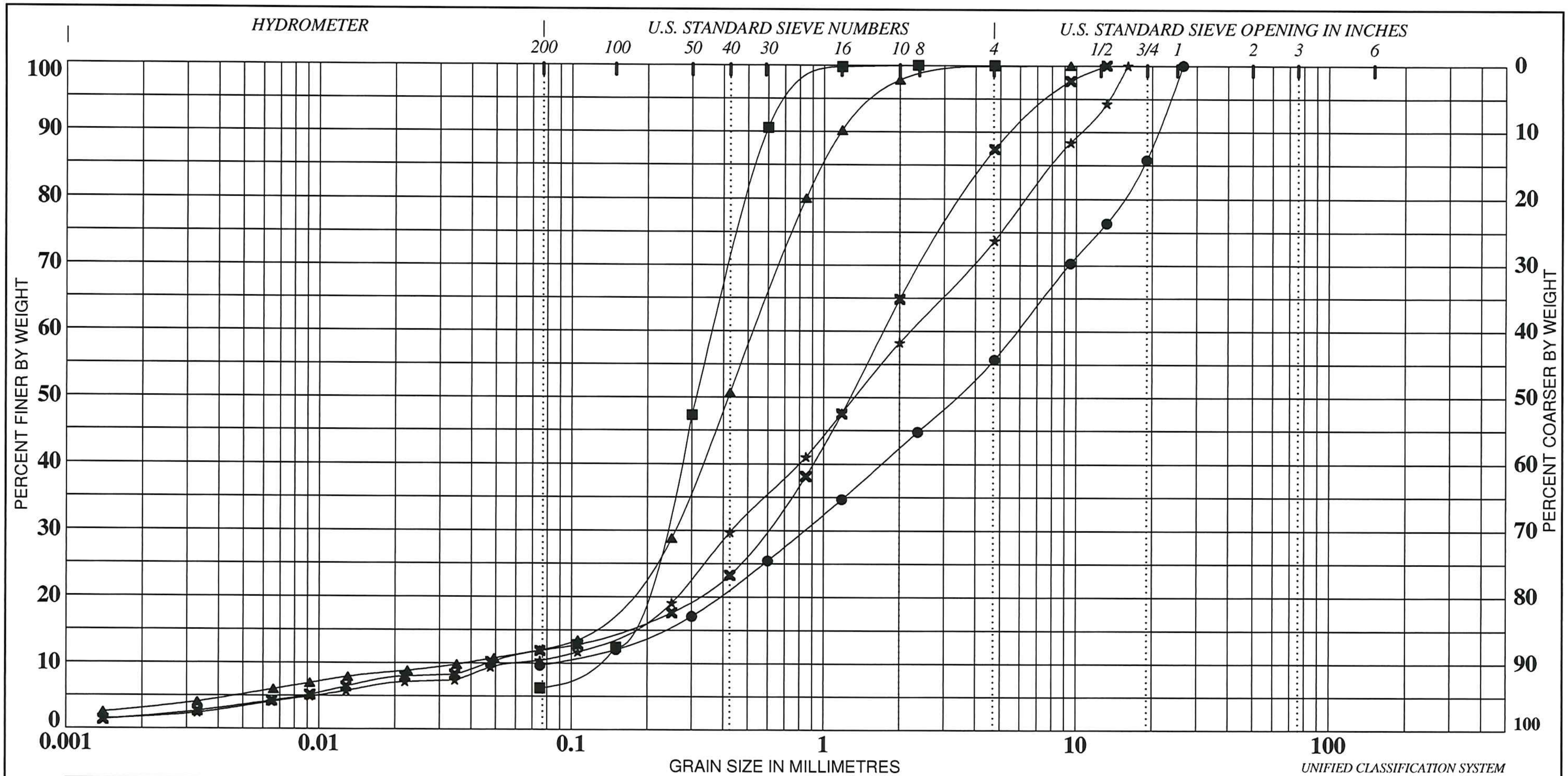
GRADATION CURVE (ASTM D422)

Figure: 13
Remarks:

PLASTICITY CHART



	Specimen	Depth (m)	LL	PL	PI	Fines	W%	Classification
●	S2C11-5	4.1	14	11	3	52	7	Sandy SILT (ML), TILL
■	S2C11-7	4.8	14	10	4	34	7	Silty clayey SAND (SC-SM) with gravel, TILL
▲	S2C11-7	11.7	13	11	2	41	11	Silty SAND (SM), TILL
★	S2C11-8	10.2	14	12	2	48	7	Silty SAND (SM), TILL



SILT & CLAY		SAND			GRAVEL		COBBLES	BLDs
CLAY	SILT	fine	medium	coarse	fine	coarse		

Sample		Depth (m)	Description	W%	W_L	W_P	I_P	%Gravel	%Sand	%Silt	%Clay
●	B8-BH1	15.5	SAND (SW-SM) with silt and gravel	8				44	46	10	
■	B8-BH1	20.1	SAND (SP-SM) with silt	19				0	94	6	
▲	S2C11-3	11.0	SAND (SW-SM) with silt	12	NP	NP	NP	0	88	9	3
★	S2C11-3	13.3	SAND (SW-SM) with silt and gravel	8	NP	NP	NP	26	63	9	2
✖	S2C11-3	14.8	SAND (SP-SM) with silt	9	NP	NP	NP	13	75	10	2

Stantec

Project: Enbridge GTA Project - DE Phase

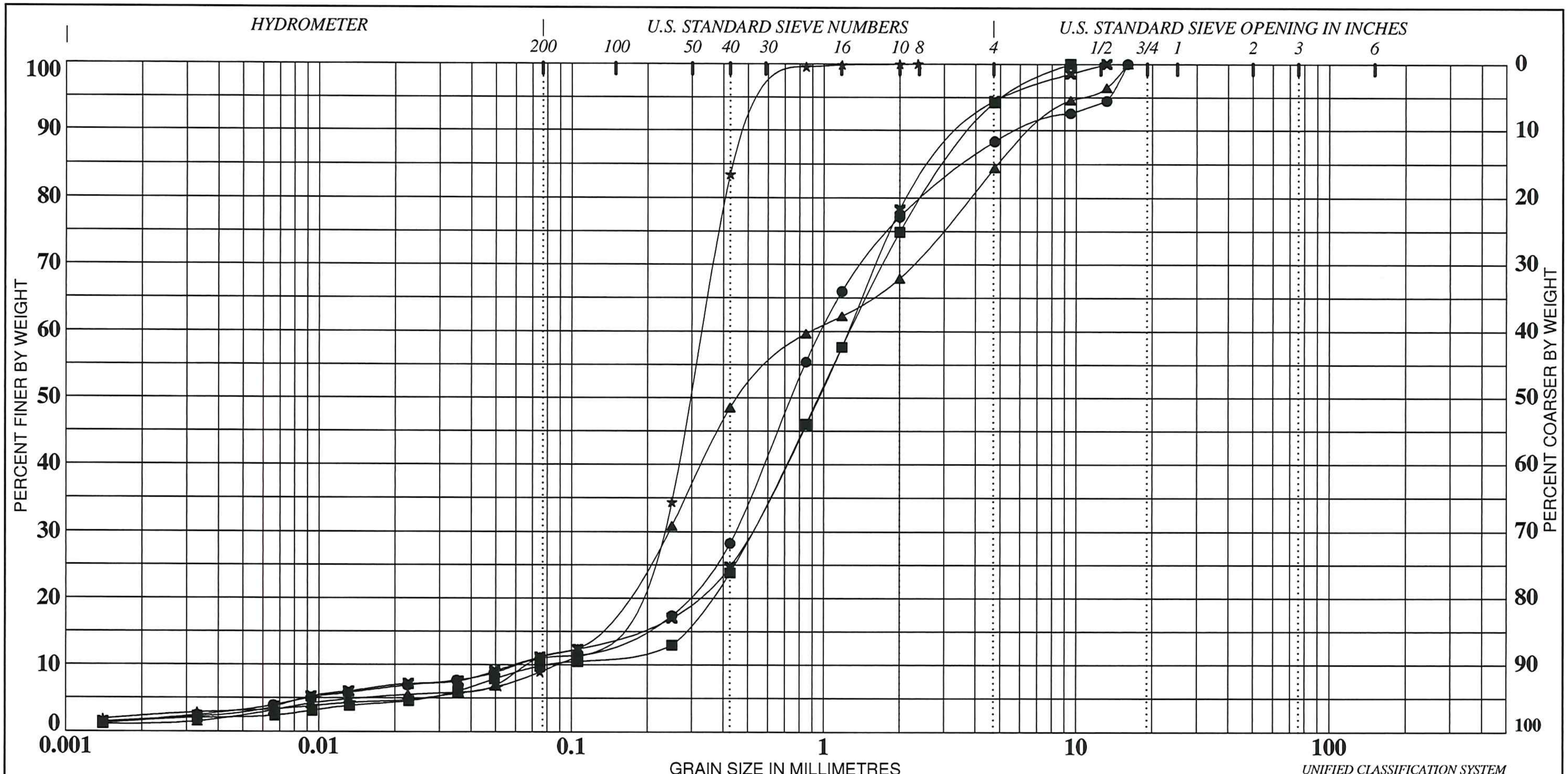
Location: S2C11 - Highway 404

Project No.: 110901255

GRADATION CURVE (ASTM D422)

Figure: 15

Remarks:



SILT & CLAY		SAND			GRAVEL		COBBLES	BLDs
CLAY	SILT	fine	medium	coarse	fine	coarse		

Sample		Depth (m)	Description	W%	W_L	W_P	I_P	%Gravel	%Sand	%Silt	%Clay
●	S2C11-3	17.8	SAND (SW-SM) with silt	10	NP	NP	NP	12	77	9	2
■	S2C11-3	22.4	SAND (SW-SM) with silt	13	NP	NP	NP	6	84	8	2
▲	S2C11-3	24.7	SAND (SP-SM) with silt and gravel	11	NP	NP	NP	16	73	10	1
★	S2C11-4	15.5	SAND (SP-SM) with silt	18	NP	NP	NP	0	91	7	2
✖	S2C11-4	19.4	SAND (SP-SM) with silt	11	NP	NP	NP	6	83	9	2

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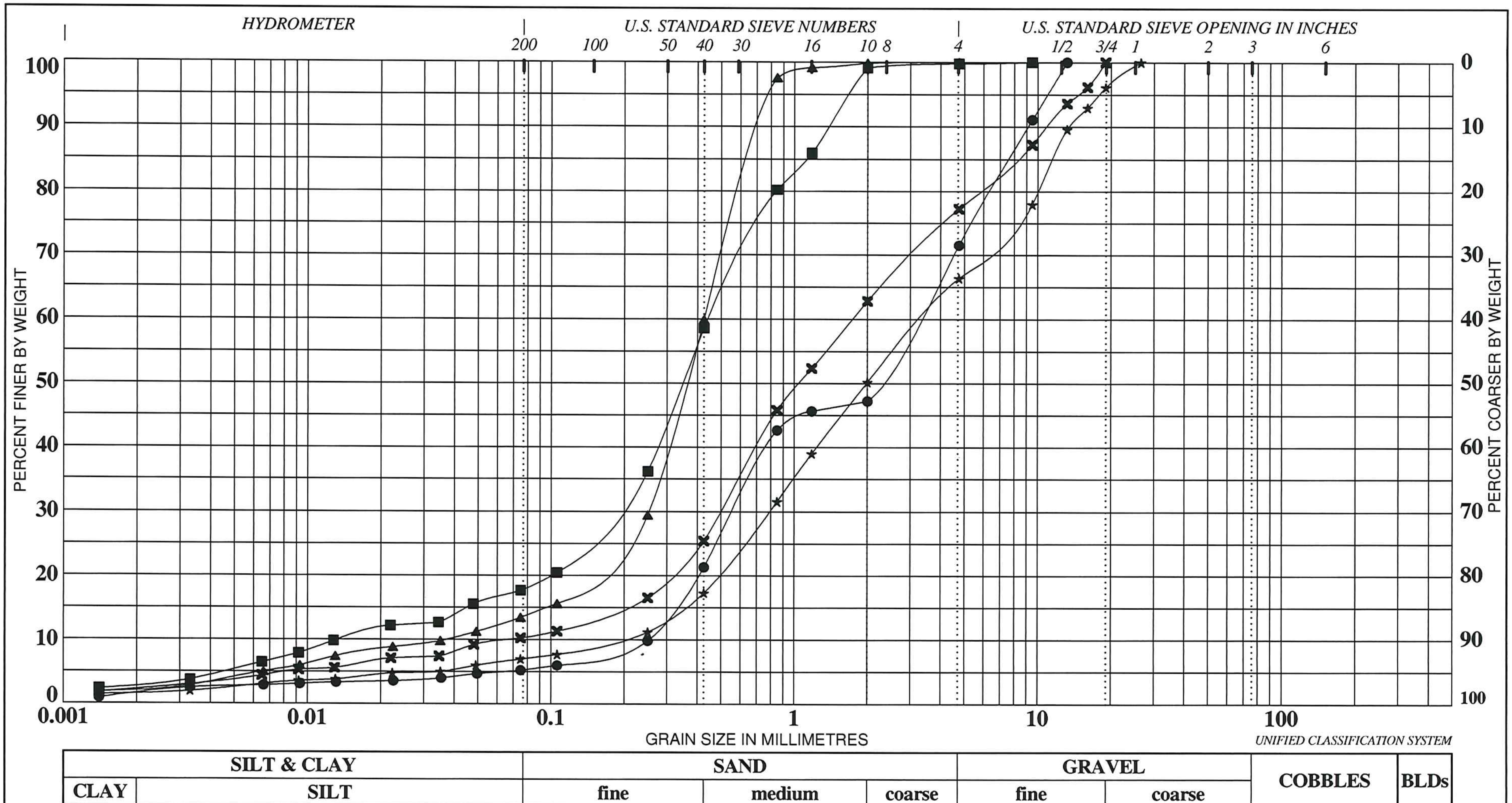
Project: Enbridge GTA Project - DE Phase
Location: S2C11 - Highway 404
Project No.: 110901255

GRADATION CURVE (ASTM D422)
Figure: 16
Remarks:



Sample		Depth (m)	Description	W%	W_L	W_P	I_P	%Gravel	%Sand	%Silt	%Clay
●	S2C11-4	21.6	POORLY GRADED SAND with SILT and GRAVEL(SP-SM)	16	NP	NP	NP	28	66	4	2
■	S2C11-4	25.5	Silty SAND (SM)	10	NP	NP	NP	0	82	15	3
▲	S2C11-4	28.5	Silty SAND (SM)	17	NP	NP	NP	0	87	11	2
★	S2C11-5	17.8	SAND (SP-SM) with silt and gravel	9	NP	NP	NP	34	59	5	2
✖	S2C11-5	20.1	SAND (SW-SM) with silt and gravel	9	NP	NP	NP	23	67	8	2

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Project: Enbridge GTA Project - DE Phase

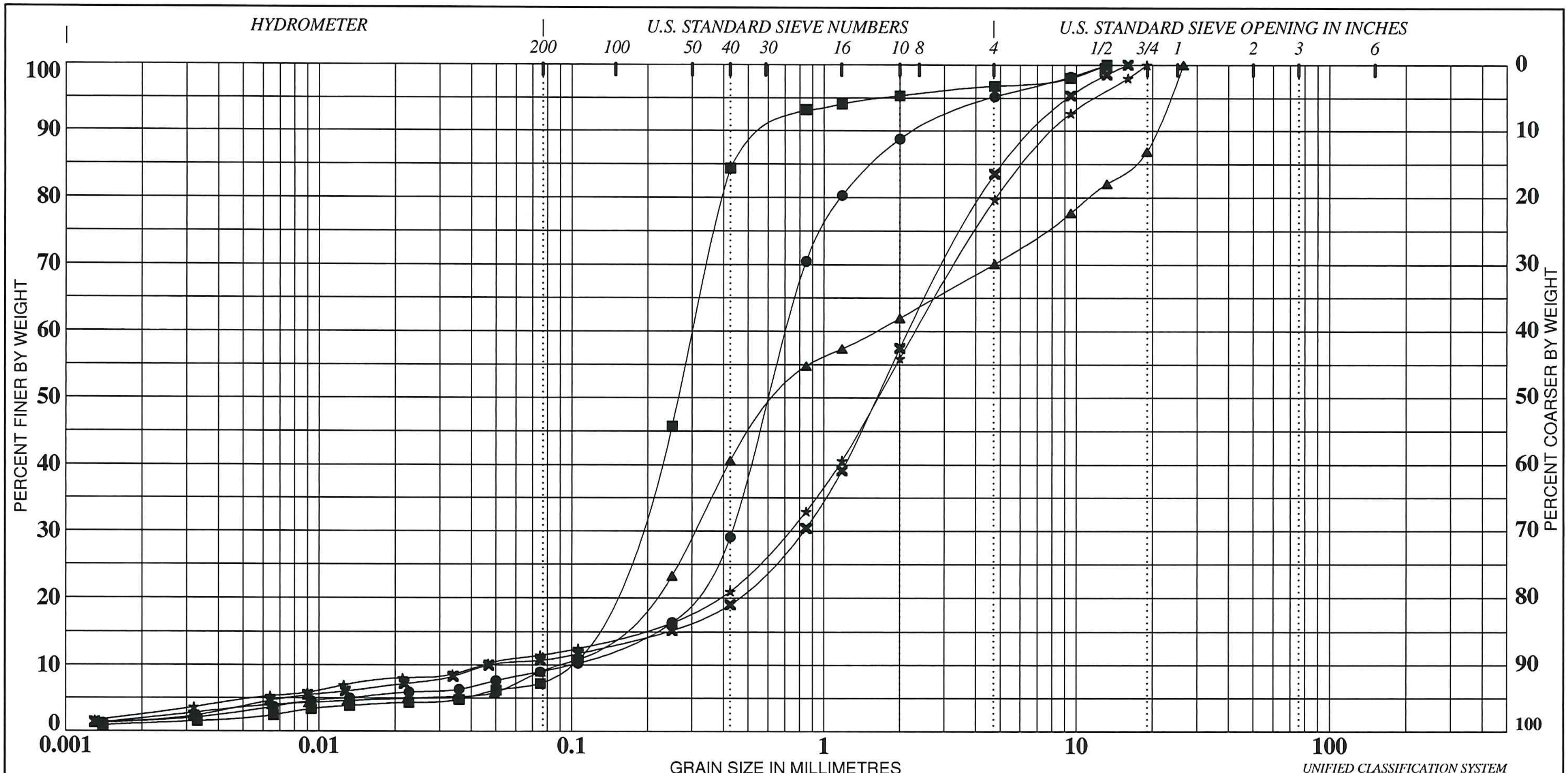
Location: S2C11 - Highway 404

Project No.: 110901255

GRADATION CURVE (ASTM D422)

Figure: 17

Remarks:



SILT & CLAY		SAND			GRAVEL		COBBLES	BLDs
CLAY	SILT	fine	medium	coarse	fine	coarse		

	Sample	Depth (m)	Description	W%	W_L	W_P	I_P	%Gravel	%Sand	%Silt	%Clay
●	S2C11-5	24.7	SAND (SW-SM) with silt	13	NP	NP	NP	5	86	7	2
■	S2C11-6	6.4	SAND (SP-SM) with silt	17	NP	NP	NP	3	90	6	1
▲	S2C11-6	9.4	SAND (SP-SM) with silt and gravel	11	NP	NP	NP	30	61	7	2
★	S2C11-6	12.5	SAND (SP-SM) with silt and gravel	11	NP	NP	NP	20	68	9	3
✖	S2C11-6	15.5	SAND (SP-SM) with silt and gravel	11	NP	NP	NP	16	73	9	2

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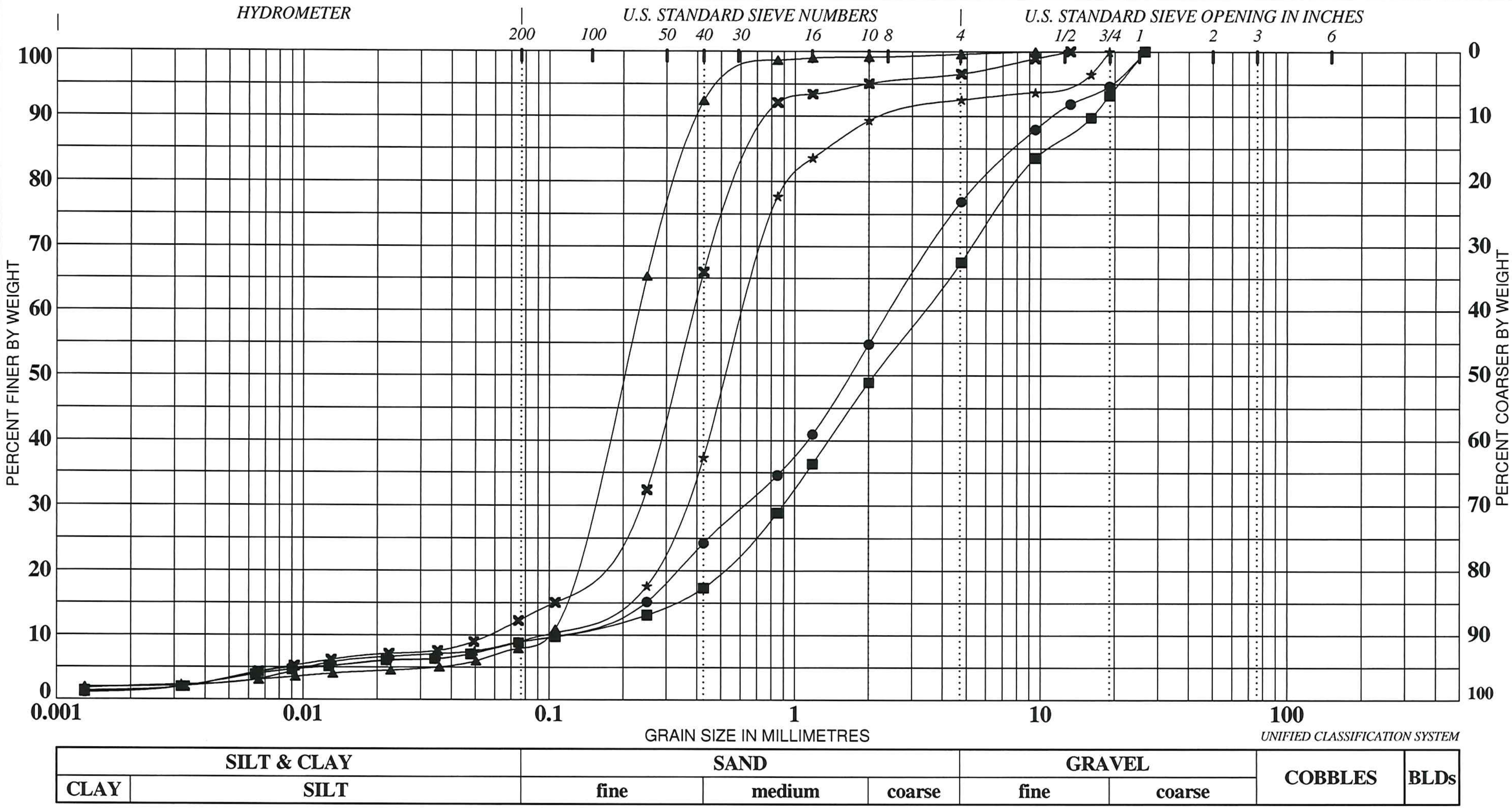
Project: Enbridge GTA Project - DE Phase
Location: S2C11 - Highway 404
Project No.: 110901255

GRADATION CURVE (ASTM D422)
Figure: 18
Remarks:



Sample		Depth (m)	Description	W%	W_L	W_P	I_P	%Gravel	%Sand	%Silt	%Clay
●	S2C11-6	17.8	SAND (SW-SM) with silt and gravel	9	NP	NP	NP	23	68	7	2
■	S2C11-6	21.6	SAND (SW-SM) with silt and gravel	8	NP	NP	NP	32	59	7	2
▲	S2C11-7	17.0	SAND (SP-SM) with silt	19	NP	NP	NP	0	92	6	2
★	S2C11-7	20.1	WELL-GRADED SAND with SILT(SW-SM)	15	NP	NP	NP	7	84	7	2
✖	S2C11-7	24.7	Silty SAND (SM)	15	NP	NP	NP	3	84	11	2

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Project: Enbridge GTA Project - DE Phase

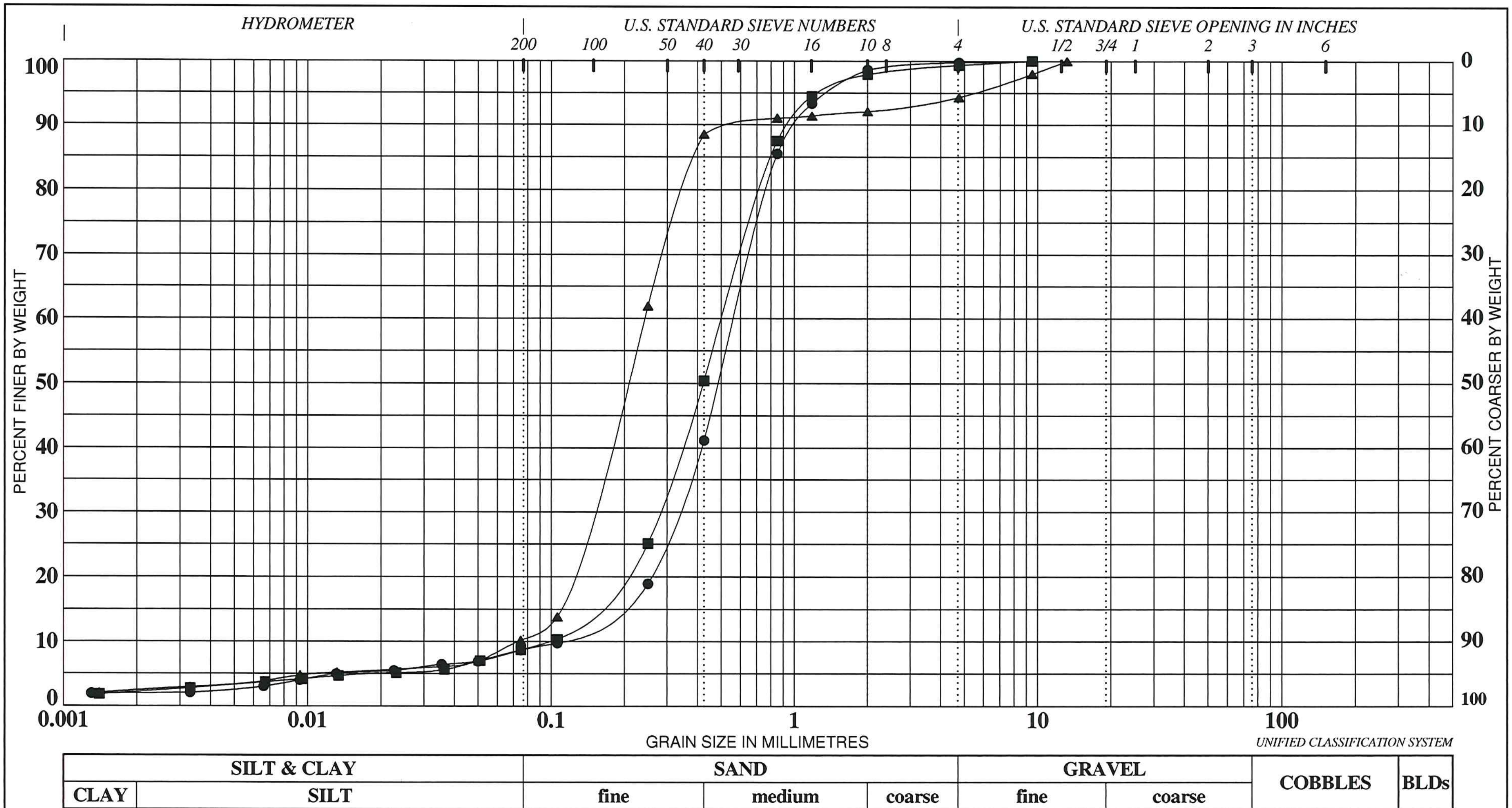
Location: S2C11 - Highway 404

Project No.: 110901255

GRADATION CURVE (ASTM D422)

Figure: 19

Remarks:



Sample		Depth (m)	Description	W%	W_L	W_P	I_P	%Gravel	%Sand	%Silt	%Clay
●	S2C11-7	27.7	SAND (SP-SM) with silt	17	NP	NP	NP	0	91	7	2
■	S2C11-8	27.0	SAND (SP-SM) with silt	15	NP	NP	NP	1	91	6	2
▲	S2C11-9	30.6	SAND (SP-SM) with silt	17	NP	NP	NP	6	84	8	2

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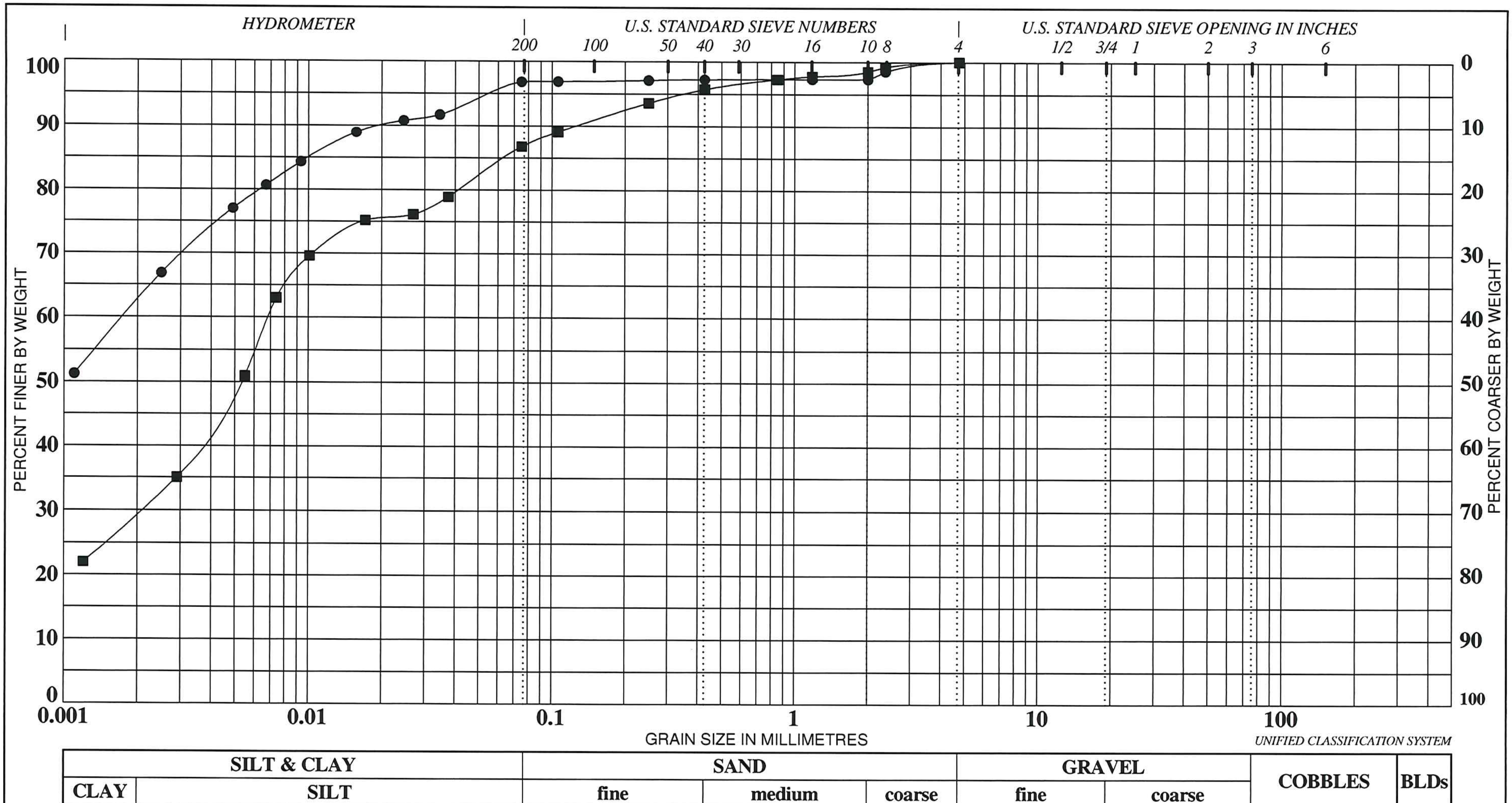
Project: Enbridge GTA Project - DE Phase
Location: S2C11 - Highway 404
Project No.: 110901255

GRADATION CURVE (ASTM D422)
Figure: 20
Remarks:



Sample	Depth (m)	Description	W%	W_L	W_P	I_P	%Gravel	%Sand	%Silt	%Clay
● B8-BH1	27.7	CLAY (CL)	22	42	20	22	0	3	34	63
■ B8-BH2	11.0	CLAY (CL)	14	24	15	9	0	13	57	30

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Project: Enbridge GTA Project - DE Phase

Location: S2C11 - Highway 404

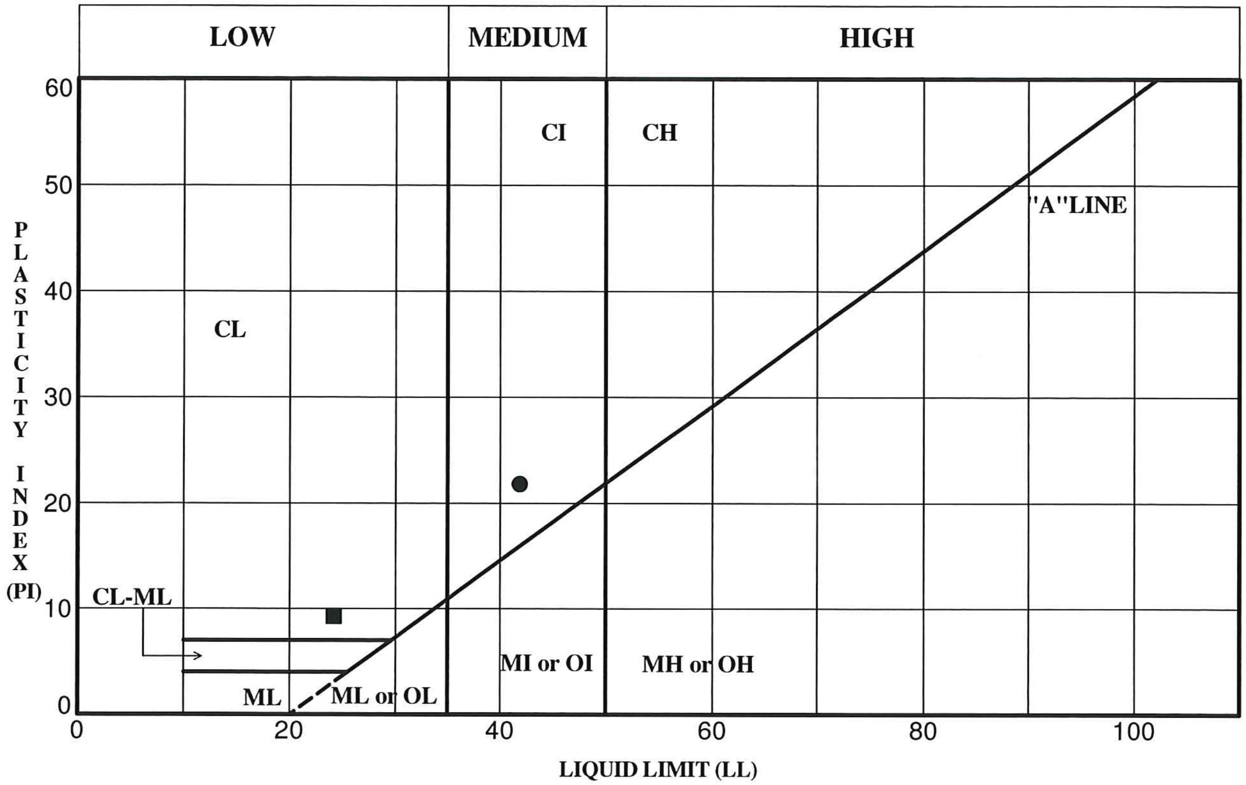
Project No.: 110901255

GRADATION CURVE (ASTM D422)

Figure: 21

Remarks:

PLASTICITY CHART



	Specimen	Depth (m)	LL	PL	PI	Fines	W%	Classification
●	B8-BH1	27.7	42	20	22	97	22	CLAY (CL)
■	B8-BH2	11.0	24	15	9	87	14	CLAY (CL)

STN13-ATTERBERG MTO S2C11-MTO.GPJ MM.GDT 1/14/15

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Project: Enbridge GTA Project - DE Phase

Location: S2C11 - Highway 404

Project No.: 110901255

ATTERBERG LIMITS
(ASTM D4318)

Figure: 22

Remarks:

Appendix E

E.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: , Stantec Consulting Ltd. August 14, 2013

Site Coordinates: 43.8362 North 79.3663 West

User File Reference: S2C11 - Highway 404

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)
0.185	0.111	0.067	0.021	0.069

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	0.076	0.118
Sa(0.5)	0.016	0.047	0.071
Sa(1.0)	0.009	0.028	0.044
Sa(2.0)	0.003	0.009	0.014
PGA	0.008	0.027	0.041

References

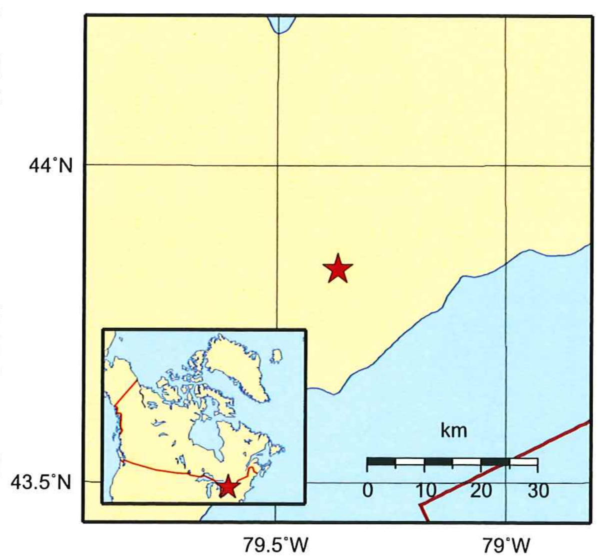
National Building Code of Canada 2010 NRCC no. 53301; sections 4.1.8, 9.20.1.2, 9.23.10.2, 9.31.6.2, and 6.2.1.3
Appendix C: Climatic Information for Building Design in Canada - table in Appendix C starting on page C-11 of Division B, volume 2

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



Appendix F

F.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, S2C11 – Highway 404, Markham, ON
Project No. 110901255
Document No. 110901255.076

Instrumentation and Monitoring Plan for Trenchless Pipeline Installation
GTA Project Detailed Engineering Design Phase, S2C11 – Highway 404, Markham, ON
Project No. 110901255
Document No. 110901255.332

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.

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

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

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

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

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

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

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

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

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

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 according to CAN/CSA-B182.6 or ASTM F894.

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

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

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

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

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

5.09 Tunnelling Materials

5.09.01 Primary Liner

Tunnelling methods will require installation of a primary liner 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;

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

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

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

7.01.02 Shafts

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.

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 each crossing within the pipe alignment and shall be suitable to advance through such obstructions such as cobbles and boulders and address the potential for deflection off these obstruction and/or soil conditions.

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

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

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

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

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

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

7.04.04 Drilling Fluid Fracture (Frac-Out)

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

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

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

7.04.05 Reaming

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

7.04.06 Product Installation

7.04.06.01 General

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

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

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

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

7.04.06.02 Pullback and Grouting

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

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

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

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

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

7. 05 Tunnelling Installation

7.05.01 General

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

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

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

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

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.*

Appendix G

G.1 SOIL PARAMETERS FOR HYDROFRACTURE ANALYSIS

GTA PROJECT DETAILED
ENGINEERING DESIGN PHASE
S2C11 - Highway 404
Table 1: Soil/Rock Parameters for Hydrofracture Analysis

Borehole	Elevation (m)	Soil Description	Soil Classification USCS	Compactness / Consistency	Unit Weight, ɣ (kN/m^3)	Undrained Shear Strength, S_u (kPa)	Effective Internal Friction Angle, Ø' (degrees)	Young's Modulus (MPa)	Poisson's Ratio
B8-BH1	178.1 to 178.0	Sandy CLAY, TILL	(CL)	Stiff to very stiff	21.5	75	28	50	0.45
	178.0 to 175.2	Sand and gravel	FILL	N/A	21	N/A	30	25	0.4
	175.2 to 166.0	Silty SAND, TILL	(SM)	Compact to very dense	21.5	N/A	30	20	0.35
	166.0 to 165.7	SAND with silt and gravel	(SW-SM)	Very dense	21.5	N/A	32	35	0.35
	165.7 to 163	SAND with silt	(SP-SM)	Very dense	21.5	N/A	32	35	0.35
	163 to 161.4	SAND with silt and gravel	(SW-SM)	Very dense	21.5	N/A	32	35	0.35
	161.4 to 155.3	SAND with silt	(SP-SM)	Compact to very dense	21.5	N/A	30	20	0.35
	155.3 to 147.2	CLAY	(CL)	Hard	20.5	200	30	100	0.45
B8-BH2	182.1 to 181.4	Silty sand	FILL	N/A	20	N/A	28	5	0.35
	181.4 to 178.1	Sandy CLAY, TILL	(CL)	Soft to very stiff	19.5	25	26	10	0.45
	178.1 to 176.1	Silty SAND, TILL	(SM)	Dense	21.5	N/A	32	35	0.35
	176.1 to 175.0	Sandy SILT, TILL	(ML)	Compact	20.5	N/A	28	10	0.35
	175.0 to 171.5	Silty SAND, TILL	(SM)	Very dense	21.5	N/A	34	75	0.35
	171.5 to 170.7	CLAY	(CL)	Hard	20.5	150	28	75	0.45
	170.7 to 151.1	Silty SAND, TILL	(SM)	Dense to very dense	21.5	N/A	32	35	0.35
S2C11-3	178.7 to 174.3	Silty SAND, TILL	(SM)	Compact to very dense	21.5	N/A	30	20	0.35
	174.3 to 170.5	Sandy SILT, TILL	(ML)	Very dense	21.5	N/A	32	50	0.35
	170.5 to 168.2	Silty SAND, TILL	(SM)	Very dense	21.5	N/A	34	75	0.35
	168.2 to 153.4	SAND with silt to SAND with silt and gravel	(SP-SM)	Very dense	21.5	N/A	32	35	0.35
S2C11-4	180.6 to179.8	Sandy silty CLAY	FILL	N/A	20	25	26	10	0.45
	179.8 to 175.4	Sandy silty CLAY, TILL	(CL-ML)	Hard	21.5	200	32	150	0.45
	175.4 to 173.9	Silty SAND, TILL	(SM)	Very dense	21.5	N/A	34	75	0.35
	173.9 to 171.6	Sandy SILT, TILL	(ML)	Very dense	21.5	N/A	32	50	0.35
	171.6 to 166.3	Silty SAND	(SM)	Very dense	21.5	N/A	32	35	0.35
	166.3 to 157.1	Silty SAND, TILL	(SM)	Dense to very dense	21.5	N/A	32	35	0.35
	157.1 to 151.2	SAND with silt to SAND with silt and gravel	(SP-SM)	Very dense	21.5	N/A	32	35	0.35
S2C11-5	180.9 to 178.1	CLAY, TILL	(CL)	Stiff	19	50	26	25	0.45
	178.1 to 174.3	Sandy SILT, TILL	(ML)	Compact to dense	21.5	N/A	30	25	0.35
	174.3 to 165.9	Silty SAND, TILL	(SM)	Dense to very dense	21.5	N/A	32	35	0.35
	165.9 to 154.6	SAND with silt to SAND with silt and gravel	(SP-SM), (SW-SM)	Very dense	21.5	N/A	32	35	0.35
S2C11-6	179.2 to 178.3	Sand and gravel, FILL	FILL	N/A	21	N/A	30	25	0.4
	178.3 to 175.7	Sandy silty CLAY, TILL	(CL-ML)	Hard	20.5	150	28	75	0.45
	175.7 to 174.1	Silty SAND, TILL	(SM)	Very dense	21.5	N/A	34	75	0.35
	174.1 to 169.3	SAND with silt to SAND with silt and gravel	(SP-SM)	Dense to very dense	21.5	N/A	32	35	0.35

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Borehole	Elevation (m)	Soil Description	Soil Classification USCS	Compactness / Consistency	Unit Weight, γ (kN/m^3)	Undrained Shear Strength, S_u (kPa)	Effective Internal Friction Angle, Ø' (degrees)	Young's Modulus (MPa)	Poisson's Ratio
	169.3 to 159.3	SAND with silt to SAND with silt and gravel	(SP-SM), (SW-SM)	Compact to very dense	21.5	N/A	30	20	0.35
	159.3 to 152.8	SAND with silt and gravel	(SW-SM)	Dense to very dense	21.5	N/A	32	35	0.35
S2C11-7	179.2 to 177.1	Silty sand	FILL	N/A	20	N/A	28	5	0.35
	177.1 to 174.1	Silty clayey SAND with gravel	(SC-SM)	Dense to very dense	21.5	N/A	32	35	0.35
	174.1 to 164.9	Silty SAND, TILL	(SM)	Compact to very dense	21.5	N/A	30	20	0.35
	164.9 to 159.3	SAND with silt	(SM)	Dense to very dense	21.5	N/A	32	35	0.35
	159.3 to 155.4	SAND with silt	(SW-SM)	Compact to very dense	21.5	N/A	32	35	0.35
	155.4 to 153.9	Silty SAND	(SM)	Very dense	21.5	N/A	32	35	0.35
	153.9 to 151.3	SAND with silt	(SP-SM)	Dense to very dense	21.5	N/A	32	35	0.35
S2C11-8	189.6 to 188.2	Silty sand with gravel, FILL	FILL	N/A	20	N/A	28	5	0.35
	188.2 to 181.4	Sandy clay to sandy silty clay	FILL	N/A	20	25	26	10	0.45
	181.4 to 165.4	Silty SAND, TILL	(SM)	Dense to very dense	21.5	N/A	32	35	0.35
	165.4 to 160.8	SAND with silt	(SP-SM)	Compact to very dense	21.5	N/A	30	20	0.35
	160.8 to 157.7	Silty SAND, TILL	(SM)	Dense	21.5	N/A	32	35	0.35
	157.7 to 155.8	Silty clayey SAND, TILL	(SC-SM)	Very dense	21.5	N/A	32	35	0.35
S2C11-9	188.8 to 181.8	Sandy silty clay to clay with sand	FILL	N/A	20	25	26	10	0.45
	181.8 to 178.9	CLAY with sand, TILL	(CL)	stiff to very stiff	20.5	100	28	50	0.45
	178.9 to 173.0	CLAY with sand, TILL	(CL)	Very stiff to hard	20.5	150	28	75	0.45
	173.0 to 161.9	Silty SAND, TILL	(SM)	Compcat to Very dense	21.5	N/A	30	20	0.35
	161.9 to 156.7	SAND with silt	(SP-SM)	Very dense	21.5	N/A	32	35	0.35

Notes:

1. Calculations for drained conditions should consider the following: c′ = 0 and ø′ as obtained from the table above.
2. Calculations for undrained conditions should consider the following: c (commonly denoted as S_u) as obtained from the table above and ø = 0°.
3. 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.