Foundation Investigation and Design Report

Alectra Utilities Installation below Highway404 & Highway 7 Interchange, NBM-H23-0163-AUC Project Rainbow Site 2
Markham, Ontario
MTO Central Region

Latitude: 43.846312°
Longitude: -79.370695°

Geocres No. 30M14-660

Prepared for:
NBM Engineering Inc.

Prepared by:
Stantec Consulting Ltd.
300W – 675 Cochrane Drive
Markham, ON L3R 0B8

Project No. 121625347

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UTILITY INSTALLATION BELOW HIGHWAY 404 AND HIGHWAY 7 INTERCHANGE MARKHAM, ONTARIO

1. INTRODUCTION

Stantec Consulting Ltd., (Stantec) has been retained by NBM Engineering Inc. (NBM) on behalf of Alectra Utilities (Alectra), to provide foundation engineering services in support of a trenchless utility installation below the Highway 404/Highway 7 interchange, in the City of Markham, Ontario.

The scope of work for the foundation engineering services is outlined in Stantec's proposal titled *"NBM-H23-0163-AUC-Project Rainbow Site 2 – Highway 7 from E. Valhalla Drive to Commerce Valley Drive East, Geotechnical Investigation Program"* dated June 22, 2023. This report provides factual data on the subsurface conditions at the site.

2. SITE DESCRIPTION

The site is located at the Highway 404/Highway 7 interchange in the City of Markham, Ontario. The key plan on the Borehole Locations and Soil Strata Drawing (Drawing 1) provides an overview of the site location.

At this site, Highway 404 is a freeway consisting of three southbound and three northbound lanes with fully paved inner and outer shoulders separated by an unpaved median. Further south of this site is the east /west oriented Highway 407 Electronic Toll Route with connections to Highway 404. In addition to crossing below the Highway 404 freeway, the alignment will cross below the following interchange ramps:

- Ramp Hwy. 7E-404S.
- Ramp Hwy. 7W-404S.
- Ramp Hwy.404S-407E/W.
- Ramp 407E/W-404N.
- Ramp Hwy. 7E-404N; and
- Ramp 404S-Hwy. 7E/W.

3. INVESTIGATION PROCEDURES

The field work for this project was carried out during the period March 10 to 20, 2024. Eight boreholes numbered boreholes BH 01, 02, 03, 04, 05, 06, 07 and 08 were drilled and sampled to depths ranging from 10.1 m to 18.7 m below ground surface at the approximate locations shown on Drawing 1. The boreholes were marked in the field by Stantec's staff in relation to existing features shown on the drawings provided by NBM. Boreholes were also surveyed for coordinates and geodetic elevation with a Trimble DA12 Receiver connected to the Global Navigation Satellite System. This data is summarized in the following table.

Borehole No.	Latitude and Longitude (Degrees)		MTM NAD 83 Coordinates (Zone 10)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m)	Easting (m)	Northing (m)	Easting (m)		
BH 01	43.845656	-79.373089	4 856 195.3	315 004.4	188.4	10.1
BH 02	43.845911	-79.372414	4 856 223.7	315 058.6	188.9	13.1
BH 03	43.846036	-79.371556	4 856 237.7	315 127.6	194.7	18.7
BH 04	43.846324	-79.370814	4 856 269.8	315 187.2	194.3	18.6
BH05	43.846378	-79.370133	4 856 275.8	315 241.9	193.5	17.2
BH 06	43.846567	-79.369594	4 856 296.9	315 285.2	190.4	14.2
BH 07	43.846683	-79.368989	4 856 309.9	315 333.9	189.5	13.1
BH 08	43.846908	-79.368150	4 856 335.0	315 401.3	191.1	12.6

The boreholes were drilled with track and truck mounted drill rigs supplied and operated by a specialist drilling contractor and traffic control was provided by a specialist traffic control company. Stantec's staff observed and recorded the drilling, sampling and in situ testing operations and logged the boreholes.

Samples of the overburden soils were generally obtained at intervals of 0.75 m and 1.5 m depth using a 50 mm outer diameter (O.D.) split-spoon sampler in conjunction with the Standard Penetration Testing (SPT) procedures as specified in ASTM Method D 1586[1].

Groundwater conditions were observed in the boreholes during and immediately following the drilling operations. To permit longer term ground water level monitoring, standpipe piezometers consisting of a 50 mm diameter PVC pipe with a slotted screen enclosed in sand were installed in boreholes BH 02 and 07. The remaining boreholes were backfilled in accordance with current MTO procedures and Ontario Regulation 903 (as amended).

The recovered soil samples were subjected to Visual Identification (VI). Select soil samples were also subjected to a laboratory testing programme consisting of natural moisture content, grain size distribution analyses and Atterberg Limits determinations. Soil samples were also submitted to Paracel Laboratories Ltd. for chemical testing.

4. SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1. Regional Geology

The site is located within a physiographic region known as the Peel Plain (Chapman and Putnam, 1984). The general topography of this region consists of level to gently rolling terrain, sloping southward to Lake Ontario. The Peel Plain is known to consist of generally clayey and silty soils that cover the central portion of the regions of York, Peel and Halton. There are exceptions to be noted in these major soil groups. Trains of sandy alluvium can be found at various places in the stream valleys.

1 ASTM D1586 – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of Soils.

4.2. Subsurface Conditions

Reference is made to the Record of Borehole Sheets in Appendix A. Details of the encountered soil stratigraphy are presented in this appendix and on the "Borehole Locations and Soil Strata" drawing. An overall description of the stratigraphy is given in the following paragraphs.

The stratigraphic boundaries shown on the Record of Borehole Sheets and on the interpreted stratigraphic section are inferred from non-continuous soil sampling and therefore represent transitions between soil types rather than exact planes of geological change. The subsurface conditions will vary between and beyond the borehole locations.

In summary, a flexible pavement, topsoil and firm to hard clayey silt to silty clay fill material were encountered. The native overburden deposits consist of compact to very dense sands and silts, very stiff to hard silty clay to clayey silt till and compact to very dense sandy silt to silty sand till.

4.2.1. Flexible Pavement

Boreholes BH 03 and 04 were drilled through the existing pavement of Ramp Hwy. 7E-404S and the Hwy. 404 southbound, respectively. These boreholes encountered a flexible pavement consisting of 100 mm and 450 mm thick asphaltic concrete underlain by 500 mm and 600 mm thick granular fill.

Standard Penetration tests carried out in the sand and gravel fill measured SPT N-values of 20 and 40 blows for 0.3 m of penetration indicating a compact to dense relative density.

4.2.2. Topsoil

Boreholes BH 01, 02, 06, 07 and 08 encountered approximately 75 mm to 150 mm thick topsoil layers. Topsoil thickness may vary between and beyond the boreholes.

4.2.3. Fill – Clayey Silt to Silty Clay

Clayey silt to silty clay fill material was encountered at this site. The locations, thicknesses, depths and base elevations of the clayey silt to silty clay fill are summarized in the following table.

Borehole No.	Thickness (m)	Depth (m)	Base Elevation (m)
BH 01	1.9	2.1	186.3
BH 02	2.0	2.1	186.8
BH 03	8.0	8.6	186.1
BH 04	7.6	8.6	185.7
BH 05	5.6	5.6	187.9
BH 06	2.8	2.9	187.5
BH 07	1.3	1.4	188.1
BH 08	1.5	1.6	189.5

Standard Penetration tests carried out in the clayey silt to silty clay fill measured SPT N-values of 4 to more than 100 blows for 0.3 m of penetration indicating a firm to hard consistency. The natural water content of samples of the clayey silt to silty clay fill range from 10% to 29% by weight.

Grain size distribution tests were carried out on two samples of the clayey silt to silty clay fill material and the grain size distribution curves are illustrated in Figure B1, Appendix B. The test results show a grain size distribution consisting of 2% and 4% gravel, 22% and 26% sand, 34% and 44% silt and, 26% and 42% clay size particles.

Atterberg Limits tests were also carried out on two samples of the clayey silt to silty clay fill material and the results are presented on Figure B2 in Appendix B. These results indicate that the clayey silt to silty clay fill is a low plasticity (CL) cohesive soil. The results from the Atterberg limits tests are summarized below:

Liquid Limit:	23% and 34%
Plastic Limit:	15% and 19%
Plasticity Index:	8% and 15%
Natural Moisture Content:	15% and 17%

4.2.4. Sands and Silts

Deposits ranging in composition from sandy silt to silty sand and sandy silt to silt were encountered at this site. The locations, thicknesses, depths and base elevations of the sandy silt to silty sand and sandy silt to silt soils are summarized in the following table.

Borehole No.	Thickness (m)	Depth (m)	Base Elevation (m)
BH 01	1.6	3.7	184.7
BH 02	2.0	4.1	184.8
BH 03	1.5	10.1	184.6
BH 04	3.0	11.6	182.7
BH 05	3.0	8.6	184.9
BH 06	4.2	7.1	183.3
BH 07	0.7	2.1	187.4
BH 08	1.3	2.9	188.2

Standard Penetration tests carried out in the sandy silt to silty sand and sandy silt to silt deposits measured SPT N-values of 12 to 52 blows for 0.3 m of penetration indicating a compact to very dense relative density. The natural water content of samples retrieved from these deposits range from 7% to 23% by weight.

Grain size distribution tests were carried out on eight samples of the sandy silt to silty sand and sandy silt to silt deposits and the grain size distribution curves are illustrated in Figure B3, Appendix B. The test results show a grain size distribution consisting of 0% to 7% gravel, 2% to 64% sand, 30% to 95% silt and 2% to 12% clay size particles.

An Atterberg Limits test was carried out on one soil sample and the results are presented on Figure B4 in Appendix B. These results indicate a non-plastic (ML) cohesionless silt. The results from the Atterberg limits tests are summarized below:

Liquid Limit:	12%
Plastic Limit:	10%
Plasticity Index:	2%
Natural Moisture Content:	7%

4.2.5. Silty Clay to Clayey Silt Till

Glacial till deposits with a soil matrix composition ranging from silty clay to clayey silt were encountered at this site. The locations, thicknesses, depths and base elevations of the silty clay to clayey silt till are summarized in the following table.

Borehole No.	Thickness (m)	Depth (m)	Base Elevation (m)
BH 01	2.2 0.5	5.9 10.1*	182.5 178.3
BH 02	3.4	7.5	181.4
BH 03	3.7	13.8	180.9
BH 04	7.0	18.6*	175.7
BH 05	8.6	17.2*	176.3
BH 06	7.1	14.2*	176.2
BH 07	1.6 5.6	3.7 13.1*	185.8 176.4
BH 08	0.8 4.4	3.7 12.6	187.4 178.5

* Borehole Termination Depth

Standard Penetration tests carried out in the silty clay to clayey silt till deposits measured SPT N-values that range from 16 to more than 100 blows for 0.3 m of penetration, indicating a very stiff to hard consistency. The natural water content of samples of the silty clay to clayey silt till deposits range from 7% to 23% by weight.

Grain size distribution tests were carried out on fifteen samples of the silty clay to clayey silt till deposits and the grain size distribution curves are illustrated in Figure B5, Appendix B. The test results show a grain size distribution consisting of 0% to 9% gravel, 0% to 45% sand, 36% to 69% silt and 14% to 54% clay size particles. Till soils can also be expected to contain random cobble and boulder inclusions.

Atterberg Limits tests were also carried out on samples of the silty clay to clayey silt till deposits and the results are plotted on the plasticity chart Figure B6, Appendix B. These results indicate that the silty clay to clayey silt till deposits are low to intermediate plasticity (CL-ML, CL and CI) cohesive soils. The results from the Atterberg limits tests are summarized below:

Liquid Limit:	14% to 37%
Plastic Limit:	10% to 21%
Plasticity Index:	4% to 17%
Natural Moisture Content:	6% to 21%

4.2.6. Sandy Silt to Silty Sand Till

Glacial till deposits with a soil matrix composition ranging from sandy silt to silty sand were encountered at this site. The locations, thicknesses, depths, and base elevations of the sandy silt to silty sand till are summarized in the following table.

Borehole No.	Thickness (m)	Depth (m)	Base Elevation (m)
BH 01	3.7	9.6	178.8
BH 02	5.6	13.1*	175.8
BH 03	4.9	18.7*	176.0
BH 07	3.8	7.5	182.0
BH 08	4.5	8.2	182.9

* Borehole Termination Depth

Standard Penetration tests carried out in the sandy silt to silty sand till deposits measured SPT N-values that range from 13 to more than 100 blows for 0.3 m of penetration, indicating a compact to very dense relative density. The natural water content of samples of the sandy silt to silty sand till deposits range from 6% to 12% by weight.

Grain size distribution tests were carried out on five samples of the sandy silt to silty sand till deposits and the results are illustrated on the grain size distribution curves in Figure B7, Appendix B. The test results show a grain size distribution consisting of 1% to 12% gravel, 41% to 76% sand, 19% to 41% silt and 4% to 13% clay size particles. Till soils can also be expected to contain random cobble and boulder inclusions.

In borehole BH 07 resistance to augering in the sandy silt to silty sand till unit was reported, suggesting that random cobble and boulder inclusions are likely present at this borehole location.

4.2.7. Ground Water Levels

The ground water conditions were observed in the boreholes during and upon completion of drilling. Standpipe piezometers were also installed in boreholes BH 02 and 07 and the measured ground water levels in the piezometers are summarized in the following table:

Borehole No	Date	Water Levels	
		Depth (m)	Elevation (m)
BH 02	April 16, 2024	2.4	186.5
	June 11, 2024	2.4	186.5
BH 07	April 16, 2024	3.6	185.9
	June 11, 2024	3.9	185.6

Based on the recorded water levels in the piezometers, ground water observations during drilling, the measured water contents of the soil samples and the change in soil colour from brown to grey, the estimated ground water table varies from elevation 186.3± m in the vicinity of borehole BH 01 increasing gradually westwards to elevation 186.7± m in the vicinity of borehole BH 05 then falling gradually to elevation 185.6± m near to borehole BH 08. The ground water level is expected to fluctuate seasonally and is expected to rise during wet periods of the year. Perched water can also be expected to occur where permeable deposits of sands and silts are underlain by relatively impermeable silty clay soils.

5. MISCELLANEOUS

The investigation was carried out using equipment supplied and operated by DBW Drilling Limited based in Ajax, Ontario. The field operations were organized by Mr. Kirby Lales, E.I.T and the drilling supervision was carried out by Mr. Akshat Shukla, E.I.T. under the direction of Mr. Gary Zhao, M.E.Sc., P.Eng. and Mr. Rehman Abdul, M.S., P.Eng. The routine laboratory testing was carried out at Stantec's laboratory in Markham Ontario.

This report was prepared by Mr. Gary Zhao, M.E.Sc., P.Eng., and reviewed by Mr. Rehman Abdul, P.Eng., a Senior Geotechnical Engineer and a Stantec Designated MTO Foundation Contact. Mr. Ron Howieson, P. Eng., carried out an independent quality control review.

STANTEC CONSULTING LTD.

LICENSED PROFESSIONAL ENGINEER
G. ZHAO
2024/10/23
PROVINCE OF ONTARIO

Gary Zhao, M.E.Sc., P.Eng.
Senior Geotechnical Engineer

LICENSED PROFESSIONAL ENGINEER
R.A. ABDUL
2024/10/23
PROVINCE OF ONTARIO

Rehman Abdul, M.S., P.Eng..
MTO Designated Foundation Contact

Ron Howieson, P.Eng.
QA/QC Reviewer

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PART B – FOUNDATION DESIGN REPORT

UTILITY INSTALLATION BELOW HIGHWAY 404 AND HIGHWAY 7 INTERCHANGE MARKHAM, ONTARIO

6. DISCUSSIONS AND ENGINEERING RECOMMENDATIONS

6.1. General

This report presents interpretation of the geotechnical data in the factual report and provides geotechnical design recommendations to assist the design team to carry out designs for the Alectra Utilities crossing under the Highway 404 and Highway 7 interchange in the City of Markham, Ontario. The discussion and recommendations presented in this report are based on our understanding of the project and our interpretation of the factual data obtained from the subsurface investigations.

Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project, and for which special provisions or operational constraints may be required in the Contract Documents. Those requiring information on the aspects of construction should make their own interpretation of the factual information provided, as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

Alectra Utilities electrical cables will be installed underground below the Highway 404 main lanes and the Highway 404/Highway 7 interchange ramps. Summarized below are the relevant design details:

- The electrical cables will be enclosed in an approximately 1067 mm (42 inches) diameter High Density Polyethylene (HDPE) pipe;
- The HDPE pipe will cross below Highway 404 and, MTO requires a minimum vertical clearance of 5 m measured from top of pavement to top of pipe;
- The HDPE pipe will cross below the Highway 404/Highway 7 interchange ramps. Below ramps MTO requires a minimum vertical clearance of 3 m measured from top of pavement to top of pipe; and
- The proposed installation will be carried out by Horizontal Directional Drilling (HDD). The HDD drive is approximately 453.0± m long extending from just west of Ramp Hwy. 7E-404S (Sta. 0+000) to just west of Ramp 404S-Hwy. 7E/W (Sta. 0+453). The design profile of the HDD bore path is shown on Drawing 1.

6.2. Installation Methods

The diameter, length and anticipated subsurface conditions limit the range of installation techniques that are economically viable. Each method considered has advantages, disadvantages, or limitations and these are discussed further below.

Ground behaviour will be, in part, dependent on the installation method adopted and this report provides guidance on the influence of ground behaviour on some possible installation methods. It should not be construed that the Contractor is restricted to the methods considered herein. If an alternative method is selected, the Contractor must make his own interpretation of the anticipated ground behaviour and the performance requirements pertaining to MTO's infrastructure, based on the factual information provided in this report under Part A, Foundation Investigation Report.

The construction methodologies evaluated and the recommendations for selecting the preferred method took into consideration the risks and consequences of each alternative, relative construction costs, as well as the need to minimize traffic disruptions and reduce user delay costs during construction. A trenchless alternative is generally more expensive compared to an open-cut excavation, and there is always a possibility that excavations may be required to retrieve tunnelling equipment or, equipment may have to be abandoned if adverse subsurface conditions are encountered.

Trenchless installation methods such as microtunnelling were considered but this methodology is ruled out as being uneconomical. A supported open cut excavation was also considered. However, the major disadvantages with an open cut installation are the requirement for proper construction staging to minimize traffic disruption, the need for relatively large and deep excavations; and the potential for post construction settlement of the backfill materials. Due to major road disruptions and huge user delay costs, an open cut excavation was not considered as a practical construction alternative.

6.2.1. Horizontal Directional Drilling (HDD)

Horizontal directional drilling involves drilling an initial pilot hole from an entry point to an exit point and drilling mud is used to support the drill hole sidewalls. Following completion of the pilot hole, the hole is reamed successively in increasing diameters until the hole is of sufficient size to permit installation of a product pipe. The product pipe is then typically installed by attaching it to the drill rods and pulling it back through the hole from the exit point to the entry point.

HDD can be carried out in both soil and rock, and there are no specific limitations below ground water. Some restrictions may apply in very loose coarse sand or gravel. These soils will tend to collapse in the bore path causing either excessive spoil removal or in some cases stopping the installation. The accuracy of HDD is dependent on the accuracy in determining the drill head location and depth. Accuracy is typically 2% to 5% of the depth.

The HDD alignment is designed such that the radii of curvature of all sections of the alignment (including those which may involve complex curves), are sufficiently large such that the HDD drill rods, and product pipe can accommodate the proposed curvature. The minimum radius of curvature will be dependent on the contractor's drill rod size and length, and the flexibility of the product pipe. HDD shall be carried out in accordance with the Non-Standard Special Provision *"Pipe Installation By Trenchless Method"* a copy of which is included in Appendix D.

6.3. Assessment of Tunnelling

To reduce the risk of subsidence or heave, tunnelling installations require a minimum depth of overburden cover over the tunnel crown. As the depth of overburden cover decreases, the risk of concentrated subsidence or heave increases, as does the risk of extreme events such as sinkholes, or in the case of HDD, frac-outs forming at the ground surface. In Ontario, the general practice is to maintain a minimum depth of cover equivalent to 2 to 3 tunnel diameters.

There are inherent risks and consequences involved with trenchless installations that could include some or all of the following:

- Obstructions within the tunnel reach including cobbles and boulders that could increase the level of construction effort. Adequate equipment such as mandrels, pneumatic breakers or chisels, and augers are required to break and remove obstructions. If such efforts prove futile the tunnel will have to be abandoned or, an open cut excavation would be required to remove the obstruction.

- Inability to correct for line and grade within the design tolerances. If misalignment occurs, it may be necessary to abandon the bore and grout the excavation. Alternatively, an open cut excavation may be the most efficient way of completing the installation.

Table 1 following the text of this report, provides a summary of the HDD Bore Path elevations, Bore Path dimension, the range of depths of overburden cover, the Depth of Cover to HDD Bore Path Diameter Ratios and the subsurface conditions encountered in the boreholes from ground surface to the HDD bore path.

The SPT N-values and the coefficient of uniformity (which is an indication of how well the soil is graded and is expressed as the ratio of the particle size at which 60% of the particles are finer than to the particle size at which 10% are finer than), assist in classifying the soil behaviour according to the Tunnelman's Ground Classification System (Terzaghi, 1950). This system is commonly used to describe the potential behaviour of an unsupported tunnel face during excavation, and it uses qualitative "stand-up time" criteria to classify the ground at and above the tunnel face into the following principal categories: firm, slow ravelling, fast ravelling, squeezing, cohesive running, running, flowing and swelling. Efforts to predict soil behaviour must also be tempered by experience and engineering judgement.

The soil conditions within the HDD bore path are classified in Table 2 following the text of this report. The soil conditions generally range from "firm to slow ravelling," "cohesive running" and "running to flowing." It is therefore essential to select a suitable drill mud and to control the drill mud viscosity, application pressure and volume, to maintain a stable bore path.

6.4. Settlement

The zone of influence of soils disturbed by the HDD operations will be about two tunnel diameters and construction of the HDD bore path will result in ground movements that will produce a settlement trough above and ahead of the bore path.

After a tunnel is constructed, the transverse settlement trough that develops can be described by a Gaussian distribution curve as:

$$S = S_{max}\ \exp\left(\frac{-x^2}{2i^2}\right)$$

Where
- S = settlement observed at a distance x from the tunnel axis;
- S_{max} = maximum settlement above the tunnel axis;
- x = horizontal distance from the tunnel axis; and
- i = horizontal distance from the tunnel axis to the inflexion point on the settlement trough.

The settlement trough induced by tunnelling can be characterized by means of two parameters namely the volume of settlement per unit length of tunnel (V_s) and the horizontal distance from the tunnel axis to the inflexion point (i).

The volume of the settlement trough (V_s) is difficult to evaluate as this parameter is dependent on construction methods and workmanship. This parameter (V_s) is usually compared to the volume of ground loss produced at the tunnel level and is expressed as a percentage of the theoretical volume of excavated soils (V_t).

Correlations by Mair and Taylor (1997) concluded that the parameter i, can be reasonably estimated using the following expression:

$i = K\,Z$

Where K = is the trough width parameter and its value is a function of ground type; and
Z = depth to the tunnel centre line.

The equations outlined above were used to estimate settlement due to tunnelling. Trough width parameters of 0.4 and 0.5 were selected for tunnels in non-cohesive and cohesive soils respectively. The estimated maximum settlement below Highway 404 and the interchange ramps assuming a 3% volume of ground loss, is not expected to exceed 8± mm. This estimate assumes that the work will be carried out by experienced tunnellers with great care and good workmanship and that the HDD bore diameter will not exceed 30% of the pipe outside diameter. However, more ground loss and settlement can occur if unanticipated conditions such as cobbles and boulders are encountered in the HDD bore path.

Holding grade on the planned bore path can be difficult because cobbles tend to shift and move around which also creates difficulties during the pullback process. To mitigate excessive ground loss, it is imperative that the Contractor have on site proper HDD drill bits for drilling through cobbles and also back reamers and pulling heads that move cobbles around the hole to allow the product pipe to be installed. The drill string forces will have to be closely controlled to prevent dislodging cobbles from the soil structure. Bore support is also critical and it is likely that the HDD fluid will have to be modified i.e. a higher concentration of bentonite and polymers will be required to maintain bore stability.

6.5. Instrumentation and Monitoring

A condition survey shall be carried out prior to construction, to document the existing conditions of the pavement and embankments. The purpose of the condition survey is to establish a baseline condition for determining any restoration that may be required due to construction impacts. An instrumentation and monitoring program has been developed for this project consistent with the *"Guidelines for Foundation Engineering Services (MTO, 2022)"* and modified as appropriate. The instrumentation includes arrays of in-ground and surface monitoring points aligned perpendicular to the HDD alignment and reflective targets affixed to the hydro poles. These monitoring points are considered sufficient in providing an advance indicator of subsurface disturbance and the potential for settlement/heave at the ground surface due to the HDD operation. The instrumentation and monitoring program is required to:

- Document the effects of the installation on the overlying roadway, embankments and hydro poles;
- Obtain prior warning of ground movements that could occur due to construction methods and equipment or, unforeseen ground condition;
- Verify the Contractor's compliance with the settlement limits imposed in the Contract; and,
- Allow adjustments to be made to the HDD methodology such that the established settlement limits are not exceeded.

The Settlement Monitoring Plan presented in Appendix C illustrates the approximate locations of the monitoring instruments and provide typical instrument details. The monitoring point locations are approximate and shall be confirmed by the Contractor in consultation with the Geotechnical Engineer and MTO prior to installation. Instrument locations may have to be adjusted in the field to suit local conditions/constraints.

Monitoring points shall be installed under the supervision of a geotechnical engineer at least fourteen days prior to any tunnelling operation. Before the start of tunnelling, all monitoring points shall be surveyed for elevation at least once per day on three consecutive days to establish a pre-construction baseline.

Over the duration of the HDD drive, all points behind the face of the excavation and those within 10 m in front of the face, shall be surveyed for elevation at the frequencies specified below:

- Monitoring points shall be surveyed a minimum of three times per day; and
- Monitoring is also required during off-shift and weekend periods, and a minimum of three sets of readings should be taken every day.

After tunnelling has been completed, the contractor shall survey the monitoring points as specified below:

- Once daily for ten days;
- Then once every 3 days for 15 days; and
- Then once every 10 days for 30 days.

A specialist surveying firm registered in Ontario and MTO's RAQS shall be retained to confirm the set-up and to carry out the monitoring during construction under the direction of a Licensed Professional Surveyor. The equipment and procedures must be capable of surveying the instruments laterally and vertically to within ±2 mm. The survey data shall be submitted by the surveyor to Stantec, the Contract Administrator, Owner, and MTO on an ongoing basis, for prompt review.

Below the Highway 404 lanes, shoulders and interchange ramps, and hydro poles, a Review Level of 10 mm and an Alert Level of 15 mm is considered appropriate for horizontal and vertical displacements. The following procedure should be followed if displacements reach the Review and Alert Levels.

- If the Review Level is reached all parties shall be notified immediately, the monitoring frequency shall also be increased and remain increased until all ground movements have essentially ceased. The Contractor shall provide a formal plan that clearly states what measures will be taken to ensure that the Alert Level is not reached and shall plan for remedial highway works if warranted; and,
- If the Alert Level is reached, the Contractor shall stop all work and the Contract Administrator, the Owner, and MTO shall have the authority to order the Contractor to alter the construction methodology to maintain integrity of existing conditions. The Contractor Administrator, the Owner, and MTO shall also have the authority to order the Contractor to make the mined excavation stable and suspend all tunnelling until an approved mitigation solution is developed. The Contractor must have an emergency plan in place to ensure public safety and shall arrange for immediate repairs to the highway if warranted.

6.6. Excavations for Entry and Exit Pits and Manholes

At the entry and exit points of the HDD operation supported open excavations will be required to install utility manholes and also to contain the drilling fluid. Tabulated below are the approximate entry and exit point locations, a summary of the soil units at these locations for 2.0 m deep excavations and the anticipated soil conditions at the excavation base (outlined in bold letters). The estimated ground water level, the anticipated ground behaviour and suggested treatments that will be required to maintain base stability are also included in the table.

Entry and Exit Point Excavations – Summarized Ground Conditions and Treatments

Location	Approximate Station and Borehole No.	Ground Water Level Relative to Excavation Base (m)	Remarks
West Limit	0+000 (BH 01)	Below Base	• **Stiff to very stiff clayey silt fill** • **Compact sandy silt** • Maintain dry excavation by pumping from filtered sumps
East Limit	0+453 (BH 08)	Below Base	• **Firm to stiff clayey silt to silty clay fill** • **Compact to dense sandy silt to silty sand** • Maintain dry excavation by pumping from filtered sumps.

6.7. Trenching, Backfilling and Compaction Requirements

The majority of the fill and native site soils are generally considered suitable for reuse as backfill in trenches and at entry and exit point excavations, provided they are free of topsoil, organic material or other deleterious material. Trench backfill materials should be placed in maximum 300 mm loose lifts and uniformly compacted to at least 95% of Standard Proctor Maximum Dry Density (SPMDD).

To achieve the specified compaction, soils must neither be too wet nor too dry of their optimum moisture content. Soils that are too wet cannot be used immediately because the material will have to be dried to a moisture content of ± 2% of optimum. If the construction operations are time sensitive, the use of imported granular material may be considered. Soils that are dry of optimum can be used immediately provided that the material is moisture conditioned (i.e. water added) to achieve a moisture content of ± 2% of optimum.

Normal post-construction settlement of the compacted backfill equivalent to about 1% of the backfill height should be anticipated. Most of this settlement will take place within about six months following the completion of the backfilling operations. If this post-construction settlement cannot be tolerated, it is recommended that the trench be backfilled with Granular “B” Type I compacted to a minimum of 98% of the material’s SPMDD at a moisture content within ± 2% of the optimum value.

Utility installations shall conform to the requirements of OPSD 2100.060 and OPSD 2100.010 as appropriate. Additional bedding and backfill requirements that may be imposed by the supplier and Alectra Utilities must also be followed.

For cable installations in trenches, prior to placing the sand bedding any accumulation of water at the base of the excavation shall be removed and any soft/loose soils should be subexcavated and replaced with compacted sand fill.

The bedding material should be placed in 150 mm thick loose lifts and uniformly compacted to at least 95% of the materials SPMDD using suitable vibratory compaction equipment. Trenching, backfilling and compacting should be carried out in accordance with OPSS.PROV 401.

6.8. Temporary Protection Systems

Decisions regarding shoring methods and sequencing are the responsibility of the Contractor. Temporary protection systems shall be designed in accordance with OPSS.PROV 539 and the designs shall be carried out by a licensed Professional Engineer experienced in shoring design. Support systems for shallower excavations shall be installed in accordance with OPSS.PROV. 404. All temporary protection systems installed within the MTO and Municipal Right-Of-Way shall be removed after construction is complete.

The shape of the soil pressure distribution diagram behind a temporary protection system depends upon the type of soil to be supported and the amount of movement that can be permitted. The sequence of work will also alter the shape of the shoring pressure diagram during the various construction phases.

Earth pressure computations must also take into account the ground water level. Above the ground water level, earth pressure is computed using the bulk unit weight of the retained soil. Below the ground water level, the earth pressures are computed using the submerged unit weight of the soil. A hydrostatic pressure is also applied if the retained soil is not fully drained.

Flexible shoring should be designed on the basis of the active earth pressure coefficient (K_a). In this case, the performance level should be Level 2 – Angular Distortion 1:200 but shall not be more than 25 mm. Where limited shoring movement (Performance Level 1A or 1B) is required, the design should be based on the at rest earth pressure coefficient (K_o). For “kick out” design the lateral resistance should be computed on the basis of the passive earth pressure coefficient (K_p). It should be noted that the lateral earth pressure coefficients chosen for design require certain movements for the active and passive conditions to be mobilized.

If required, the appropriate lateral earth pressure parameters for use in the design of temporary protection systems are provided in the following table. The lateral earth pressure coefficients are based on the assumption that the ground surface behind the temporary protection system is horizontal. Where the retained ground is sloping, the lateral earth pressure coefficients shall be adjusted to account for the slope and, these earth pressure coefficients can be estimated from the equations provided on Figure C 6,29 and Figure C 6.30 of the Canadian Highway Bridge Design Code (CHBDC) S6.1:19. The values provided in the following table are guideline values and the responsibility for selecting the appropriate design parameters is the responsibility of the shoring designer.

Temporary Protection System Design Parameters

Stratigraphic Unit	Friction Angle ϕ (degrees)	Unit Weight γ (kN/m^3)	Active Earth Pressure Coefficient	At - Rest Earth Pressure Coefficient	Passive Earth Pressure Coefficient
			K_a	K_o	K_p
Fill Soils	28	19	0.36	0.53	2.77
Sands and Silts	30	20	0.33	0.50	3.00
Silty Clay to Clayey Silt Till	29	21	0.35	0.52	2.88
Sandy Silt to Silty Sand Till	33	22	0.29	0.46	3.39

The lateral earth pressure coefficients tabulated above are ultimate values and require specific movements for the active and passive conditions to be mobilized. The values to use in design can be estimated from Figure C6.27 in the CHBDC S6.1:19.

6.9. Erosion Control

Proper erosion control measures shall be implemented both during construction and permanently. Temporary erosion and sediment control must be provided in accordance with OPSS.PROV 805 and, excavated areas as well as areas disturbed by construction shall be reinstated with permanent erosion protection in accordance with OPSS.PROV 803 and OPSS.PROV 804.

6.10. OHSA Soil Classification

All excavations must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act (OHSA) and Regulations for Construction Projects. Where workers must enter excavations extending deeper than 1.2 m, the trench walls must be suitably sloped and/or braced in accordance with the OHSA. For temporary excavations that will not exceed 2 m in depth, the OHSA soil classifications are:

- Fill soils – Type 3 soil; and
- Sands and silts – Type 3 soil above the ground water level and Type 4 soil below the ground water level.

The side slopes of temporary excavations may be formed no steeper than 1H:1V for Type 1, 2 and 3 soils and 3H:1V or flatter for Type 4 soils. If an excavation contains more than one type of soil, the excavation requirements should be based on the highest soil type number. Excavations at steeper inclinations will require temporary support. Excavations should be carried out in accordance with OPSS.PROV 401.

6.11. Ground Water Control

Surface water and ground water control will be required to maintain sufficiently dry conditions during construction. Extensive dewatering techniques will not be required where open cut excavations are made through and into relatively impermeable silty clay to clayey silt soils. In more permeable soils such as sands, ground water inflow can be expected to be higher if perched water is encountered. However, the ground water inflow into excavations from perched water is expected to subside over a short period of time. Therefore, surface settlement due to dewatering activities is expected to be negligible.

Any surface water run-off into excavations as well as minor subsurface seepage from any wet seams within the overburden can be controlled by employing a system of gravity drainage and pumping from strategically placed filtered sumps. The design, installation, operation and maintenance of the dewatering system is the Contractor's responsibility.

6.12. Design Frost Depth

At this site, a depth of 1.2 m of earth cover should be provided for protection from frost penetration (OPSD 3090.101 Foundation Frost Penetration Depths for Southern Ontario).

6.13. Corrosivity

The analytical results from corrosivity tests provided in Appendix B are used for assessing the corrosivity potential of soil to ductile iron pipe in accordance with the 10-point soil evaluation procedure described in ANSI/AWWA C105/A21.5 Standard. Based on this soil corrosivity scale, a total of 10 points or more indicates that the soil is corrosive to as-manufactured ductile iron pipe (DIP), and additional corrosion protection measures are recommended. Based on the analytical results, the Corrosivity Indices of two tested samples are 5.5.

The water-soluble sulphate concentrations of tested samples were compared to Table 3 of the Canadian Standards Association A23-1-19. The results indicate that the degree of exposure is low i.e. less than the moderate range.

6.14. HDD Considerations

It is anticipated that the HDD operation will be advanced through firm to hard clayey silt to silty clay fill, compact to very dense sands and silts, very stiff to hard silty clay to clayey silt till and compact to very dense sandy silt to silty sand till.

There is a potential for deviation in the alignment if obstructions are encountered in the fill soils and cobbles and boulders are encountered in the till soils. The contractor shall select appropriate equipment including drill bits and reamers in order to deal with the subsurface soil conditions and any obstructions that may have to be removed or pulverized to prevent misalignment of the bore.

High fluid pressures that may develop during drilling may also require the installation of pressure relief pits in order to mitigate "frac outs". Pressure relief pits will also minimize the potential for "hydrolock", which is a condition where cuttings within the bore path inhibits mud circulation which then causes pressure build-up ahead of the advancing pipe. The maximum drilling fluid pressures and static confining stresses shall also be considered by the Contractor in the design of the HDD bore path.

Prior to construction the contractor shall submit for review a comprehensive drilling plan that addresses all aspects of the HDD operation, such as equipment type, drilling fluids to be used, bore path design, pull back calculations and construction methodology. The borehole locations in this study shall also be located in the field and, the Contractor shall offset the horizontal alignment of the proposed HDD bore path a minimum distance of 2.0± m relative to the borehole locations to mitigate the potential of frac-out through the boreholes.

7. CLOSURE

This report was prepared by Mr. Gary Zhao, M.E.Sc., P.Eng., and reviewed by Mr. Rehman Abdul, P.Eng., a Senior Geotechnical Engineer and a Stantec Designated MTO Foundation Contact Mr. Ron Howieson, P. Eng., carried out an independent quality control review.

STANTEC CONSULTING LTD.

LICENSED PROFESSIONAL ENGINEER
G. ZHAO
2024/10/23
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
R.A. ABDUL
2024/10/23
PROVINCE OF ONTARIO

Gary Zhao, M.E.Sc., P.Eng.
Senior Geotechnical Engineer

Rehman Abdul, M.S., P.Eng..
MTO Designated Foundation Contact

Ron Howieson, P.Eng.
QA/QC Reviewer

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Canadian Highway Bridge Design Code (CHBDC) S6-14, CSA Group, December 2014. and *Commentary on CSA, S6.14, Canadian Highway Bridge Design Code, S6. 1-14.* December 2014.

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Mair, R. J. and Taylor, R. N. (1997). *Bored tunnelling in the urban environment, Theme Lecture*, Plenary Session 4, 14th International Conference on Soil Mechanics and Foundation Engineering, Hamburg, 6-12 September.

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Ontario Provincial Standard Specifications (OPSS)

OPSS.MUNI 450	Construction Specification For Pipeline and Utility Installation In Soil By Horizontal Directional Drilling.
OPSS.PROV 401	Construction Specification For Trenching, Backfilling and Compacting
OPSS.PROV 404	Construction Specification For Support Systems
OPSS.PROV 539	Construction Specification For Temporary Protection Systems.
OPSS.PROV 803	Construction Specification For Sodding.
OPSS.PROV 804	Construction Specification For Seed and Cover.
OPSS.PROV 805	Construction Specification For Temporary Erosion And Sediment Control Measures.

Ontario Provincial Standard Drawings (OPSD)

OPSD 2100.060	Rigid Ducts Encased In Concrete.
OPSD 2100.010	Cable Installation in Trenches.
OPSD 3090.101	Foundation Frost Penetration Depths for Southern Ontario.

TUNNELMAN'S GROUND CLASSIFICATION FOR SOILS[1]

CLASSIFICATION		BEHAVIOUR	TYPICAL SOIL TYPES
Firm		Heading can be advanced without initial support, and final lining can be constructed before ground starts to move.	Loess above water table; hard clay, marl, cemented sand and gravel when not highly overstressed.
Ravelling	Slow ravelling ----- Fast ravelling	Chunks or flakes of material begin to drop out of the arch or walls sometime after the ground has been exposed, due to loosening or to overstress and "brittle" fracture (ground separates or breaks along distinct surfaces, opposed to squeezing ground). In fast ravelling ground, the process starts within a few minutes, otherwise the ground is slow ravelling.	Residual soils or sand with small amounts of binder may be fast ravelling below the water table, slow ravelling above. Stiff fissured clays may be slow or fast ravelling depending upon degree of overstress.
Squeezing		Ground squeezes or extrudes plastically into tunnel, without visible fracturing or loss of continuity, and without perceptible increase in water content. Ductile, plastic yield and flow due to overstress.	Ground with low frictional strength. Rate of squeeze depends on degree of overstress. Occurs at shallow to medium depth in clay of very soft to medium consistency. Stiff to hard clay under high cover may move in combination of ravelling at excavation surface and squeezing at depth behind surface
Running	Cohesive running ----- Running	Granular materials without cohesion are unstable at a slope greater than their angle of repose (approximately 30° – 35°). When exposed at steeper slopes they run like granulated sugar or dune sand until the slope flattens to the angle of repose.	Clean, dry granular materials. Apparent cohesion in moist sand, or weak cementation in any granular soil, may allow the material to stand for a brief period of ravelling before it breaks down and runs. Such behavior is cohesive-running.
Flowing		A mixture of soil and water flows into the tunnel like a viscous fluid. The material can enter the tunnel from the invert as well as from the face, crown, and walls, and can flow for great distances, completely filling the tunnel in some cases.	Below the water table in silt, sand, or gravel without enough clay content to give significant cohesion and plasticity. May also occur in highly sensitive clay when such material is disturbed.
Swelling		Ground absorbs water, increases in volume, and expands slowly into the tunnel.	Highly preconsolidated clay with plasticity index in excess of about 30, generally containing significant percentages of montmorillonite.

1 Modified by Heuer (1974) from Terzaghi (1950)

TABLE 1
CONSTRUCTABILITY REVIEW OF HORIZONTAL DIRECTIONAL DRILLING

Max Bore Path Diameter[1] (mm)	Approximate Station and Bore Path Invert Elevation (m)		Proposed HDD Length (m)	Depth of Overburden Cover (m)	Depth of Cover to HDD Bore Path Diameter Ratio	Anticipated Subsurface Conditions Within the Zone of Tunnelling	Estimated Ground Water Depth Relative to HDD Bore Path Invert
	From	To					
1387	0+000 EL: 188.7±	0+025 EL: 184.0±	25 ±	0.0 to 4.1±	0.0 – 2.9	Stiff to very stiff clayey silt fill; Compact sandy silt; and Very stiff to hard silty clay to clayey silt till.	2.4 m± below to 2.3 m± above
	0+025 EL: 184.0±	0+285 EL: 184.0±	260 ±	4.1 to 10.9±	2.9 – 7.7	Compact sandy silt; Very stiff to hard silty clay to clayey silt till; and Compact to dense sandy silt to silt.	2.1 m± to 3.5 m± above
	0+285 EL: 184.0±	0+310 EL. 182.0±	25 ±	8.1 to 8.5	5.8 to 6.1	Compact to dense sandy silt to silt; Compact to dense sandy silt to silty sand; and Very stiff to hard silty clay to clayey silt till.	3.5 m± to 4.7 m± above
	0+310 EL. 182.0±	0+420 EL. 182.0±	110 ±	4.1 to 8.4	2.9 to 6.0	Hard silty clay to clayey silt till; and Very dense sandy silt to silty sand till.	3.9 m± to 4.7 m± above
	0+420 EL: 182.0±	0+453 EL: 189.9±	33 ±	0.0 to 6.7±	0.0 – 4.8	Firm to stiff clayey silt to silty clay fill; Compact to dense sandy silt to silty sand; Hard clayey silt till; and Very dense silty sand to sandy silt till.	5.5 m± below to 4.3 m± above

1. Estimated maximum bore path diameter taking into consideration that the allowable overcut cannot exceed 30% of the pipe outer diameter.

TABLE 2
FEASIBILITY OF HORIZONTAL DIRECTIONAL DRILLING

Max Bore Path Diameter[1] (mm)	Approximate Station and Bore Path Invert Elevation (m)		Depth of Overburden Cover (m)	Reference Borehole Number	Soil Conditions[2] (Ground surface to pipe invert)	Fines Content[3] (%)	SPT N-Values	Coefficient of Uniformity[4]	Soil Behaviour (Within the HDD Bore Path)
	From	To							
1387	0+000 EL: 188.7±	0+025 EL: 184.0±	0.0 to 4.1±	BH 01	**Fill - Clayey Silt to Silty Clay**	–[5]	10 – 19	–[5]	Slow Ravelling
					Sandy Silt	79	12 – 13	9	Running to Flowing
					Silty Clay to Clayey Silt Till	50	27 – 46	–[5]	Firm to Slow Ravelling
	0+025 EL: 184.0±	0+285 EL: 184.0±	4.1 to 10.9±	BH 01	Fill - Clayey Silt to Silty Clay	–[5]	10 – 19	–[5]	Slow Ravelling
					Sandy Silt	79	12 – 13	9	Running to Flowing
					Silty Clay to Clayey Silt Till	50	27 – 46	–[5]	Firm to Slow Ravelling
				BH 02	Fill – Clayey Silt	–[5]	20 – > 100/0.3m	–[5]	–
					Sandy Silt	80	12 – 27	9	Running to Flowing
					Silty Clay to Clayey Silt Till	58 – 91	16 – 29	–[5]	Firm to Slow Ravelling
				BH 03	Fill – Sand and Gravel	–[5]	20	–[5]	–
					Fill Clayey Silt to Silty Clay	70	11 – 24	–[5]	–
					Sandy Silt to Silt	98	34	5	Running to Flowing
					Silty Clay to Clayey Silt Till	89	24 – 28	–[5]	Firm to Slow Ravelling
				BH 04	Fill – Sand and Gravel	–[5]	40	–[5]	–
					Fill Clayey Silt to Silty Clay	76	19 – 61	–[5]	–
					Sandy Silt	73	17 – 25	3	Running to Flowing
				BH 05	Fill Clayey Silt to Silty Clay	–[5]	16 – > 100/0.3m	–[5]	–
					Sandy Silt to Silt	92	29 – 34	9	Running to Flowing
					Silty Clay to Clayey Silt Till	78 – 92	25 –> 100/0.3m	–[5]	Firm to Slow Ravelling
	0+285 EL: 184.0±	0+310 EL. 182.0±	8.1 to 8.5	BH 05	Fill Clayey Silt to Silty Clay	–[5]	16 – > 100/0.3m	–[5]	–
					Sandy Silt to Silt	92	29 – 34	9	Running to Flowing
					Silty Clay to Clayey Silt Till	78 – 92	25 –> 100/0.3m	–[5]	Firm to Slow Ravelling
				BH 06	Fill Clayey Silt to Silty Clay	–[5]	4 – 30	–[5]	–
					Sandy Silt to Silty Sand	35 – 51	21 – 35	30 – > 50	–
					Silty Clay to Clayey Silt Till	64	42 – > 100/0.3m	–[5]	Firm to Slow Ravelling
	0+310 EL. 182.0±	0+420 EL. 182.0±	4.1 to 8.4	BH 06	Fill Clayey Silt to Silty Clay	–[5]	4 – 30	–[5]	–
					Sandy Silt to Silty Sand	35 – 51	21 – 35	30 – > 50	Running to Flowing
					Silty Clay to Clayey Silt Till	64	42 – > 100/0.3m	–[5]	Firm to Slow Ravelling
				BH 07	Fill – Clayey Silt	–[5]	12 – 35	–[5]	–
					Sandy Silt to Silty Sand	–[5]	52	–[5]	–
					Clayey Silt Till	52	33 – 49	–[5]	–
					Sandy Silt to Silty Sand Till	44	73 – > 100/0.3m	> 50	Cohesive Running
					Silty Clay to Clayey Silt Till	100	45 – > 100/0.3m	–[5]	Firm to Slow Ravelling
	0+420 EL: 182.0±	0+453 EL: 189.9±	0.0 to 6.7±	BH 07	Fill – Clayey Silt	–[5]	12 – 35	–[5]	–
					Sandy Silt to Silty Sand	–[5]	52	–[5]	–
					Clayey Silt Till	52	33 – 49	–[5]	–
					Sandy Silt to Silty Sand Till	44	73 – > 100/0.3m	> 50	Cohesive Running
					Silty Clay to Clayey Silt Till	100	45 – > 100/0.3m	–[5]	Firm to Slow Ravelling
				BH08	**Fill - Clayey Silt to Silty Clay**	–[5]	6 – 10	–[5]	Slow Ravelling
					Sandy Silt to Silty Sand	45	21 – 42	> 50	Running to Flowing
					Clayey Silt Till	–[5]	33	–[5]	Firm to Slow Ravelling
					Silty Sand to Sandy Silt Till	23	57 – > 100/0.3m	12	Cohesive Running

1. Estimated maximum tunnel diameter taking into consideration that the allowable overcut cannot exceed 30% of the pipe outer diameter.
2. Soil conditions from ground surface to pipe invert; bold soil conditions indicate soil conditions within tunnel horizon.
3. Fines content is defined as the percentage by weight of soil particles passing the No. 200 Sieve.
4. Coefficient of uniformity of soil within and above the tunnel horizon reported for coarse grained soils only. Not applicable for fine grained soils.
5. No tests performed within that area of interest, or the Coefficient of Uniformity parameter is not applicable for that specific soil type

DRAWINGS

LICENSED PROFESSIONAL ENGINEER
G. ZHAO
100185521
2024-10-23
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
R.ABDUL
100055415
2024-10-23
PROVINCE OF ONTARIO

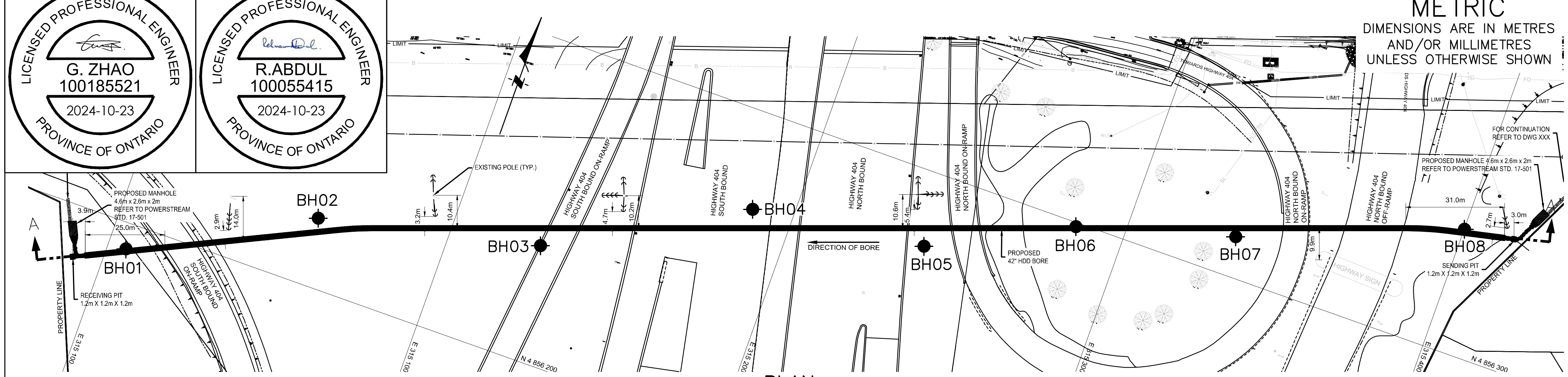
METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

HIGHWAY 404
PROJECT RAINBOW SITE 2
BOREHOLE LOCATIONS & SOIL STRATA

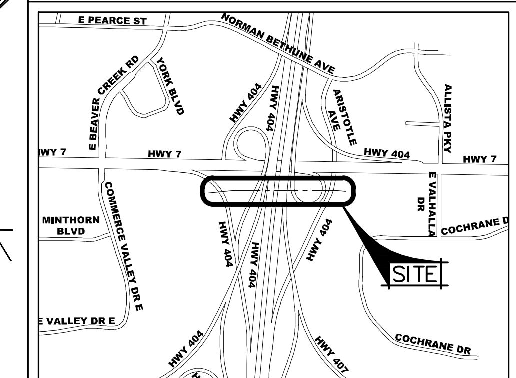
SHEET

Stantec



PLAN

SCALE
15m 0 15 30m

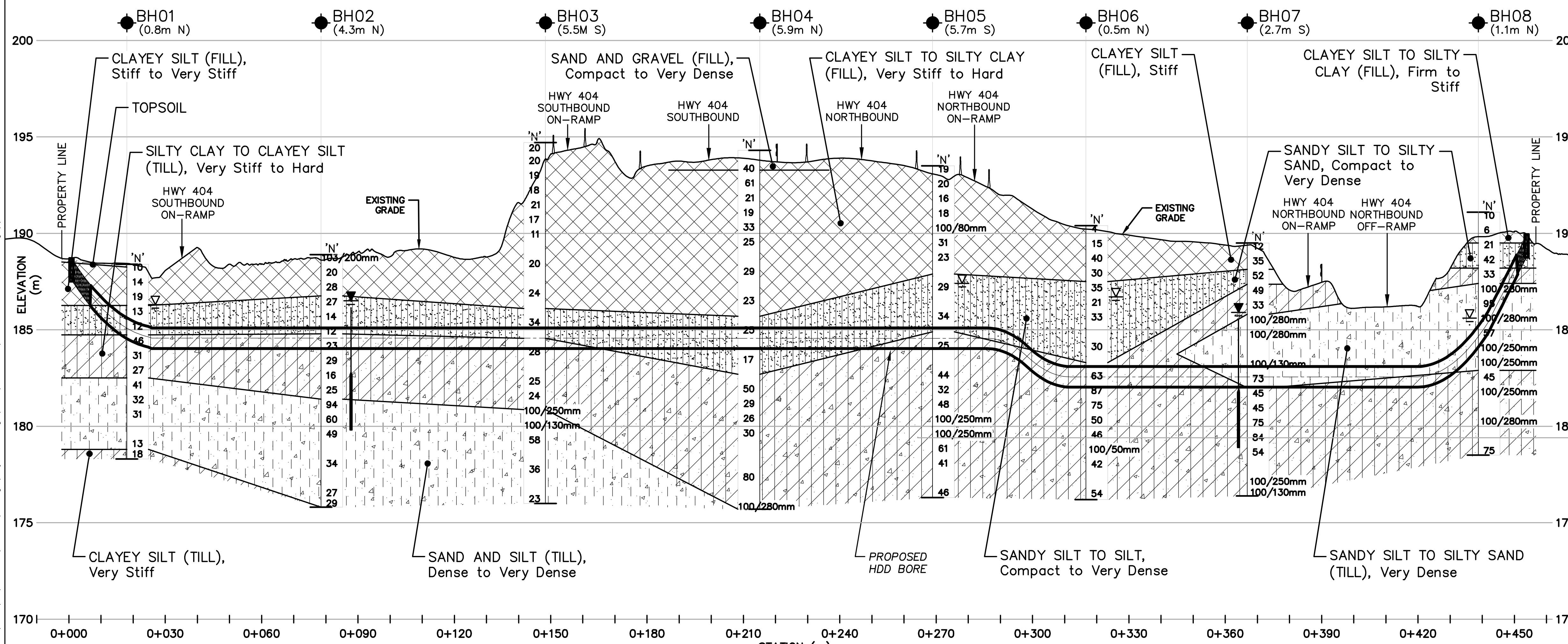


KEY PLAN
200m 0 200 400m

LEGEND

Symbol	Description
(borehole symbol)	Borehole
(x.x m)	Offset from Cross Section Line in meters
N	Blows/0.3m (Std Pen Test, 475 J/blow)
(open triangle)	WL at Time of Investigation March 2024
(solid triangle)	WL in Piezometer

No	ELEVATION	MTM ZONE 10 COORDINATES NORTH	EAST
BH01	188.4	4 856 195.3	315 004.4
BH02	188.9	4 856 223.7	315 058.6
BH03	194.7	4 856 237.7	315 127.6
BH04	194.3	4 856 269.8	315 187.2
BH05	193.5	4 856 275.8	315 241.9
BH06	190.4	4 856 296.9	315 285.2
BH07	189.5	4 856 309.9	315 333.9
BH08	191.1	4 856 335.0	315 401.3



CROSS SECTION A–A'

SCALE
15m 0 15 30m HORIZONTAL
2.5m 0 2.5 5m VERTICAL

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 and may not be consistent with final design configuration as shown elsewhere in the contract documents.

REVISIONS	DATE	BY	DESCRIPTION

GEOCRES No 30M14-660

HWY No 404			DIST CENTRAL
SUBM'D GZ	CHECKED	DATE 2024-06-26	SITE
DRAWN GBB	CHECKED GZ	APPROVED RA	DWG 1

DRAWING NAME: 121625347_P&P_240626.dwg
CREATED BY: GBB
MODIFIED:
MODDATE
\\cd0218-ppfss01\ottawa$\DATA\DB\CADDATA\Autocad\Drawings\Project Drawings\2024\121625347\121625347_P&P_240626.dwg (1) Printed: Oct 22, 2024

APPENDIX A
Record of Borehole Sheets

Stantec

STATEMENT OF GENERAL CONDITIONS

USE OF THIS REPORT: This professional work product (“hereinafter referred to as the Report”) has been prepared for the sole benefit of the Client in accordance with Stantec’s contract with the Client. While the Report may be provided by the Client to applicable authorities having jurisdiction and to other third parties in connection with the project, Stantec disclaims any legal duty based upon warranty, reliance, or any other theory to any third party, and will not be liable to such third party for any damages or losses of any kind that may result.

BASIS OF THIS REPORT: This Report relates solely to the site-specific project for which Stantec was retained and the stated purpose for which the Report was prepared. The information, opinions, conclusions and/or recommendations made in this Report are in accordance with Stantec’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 the scope of work was conducted and do not take into account any subsequent changes. 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 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. This Report is not to be used or relied on for any variation or extension of the project, or for any other project or purpose or site, and any unauthorized use or reliance is at the recipient’s own risk.

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.

PROVIDED INFORMATION: Stantec has assumed all information received from the Client and third parties in the preparation of this Report to be correct. While Stantec has exercised a customary level of judgment or due diligence in the use of such information, Stantec assumes no responsibility for the consequences of any error or omission contained therein.

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 at the time of the scope of 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 behaviour. 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 and/or sample locations, Stantec 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 will not be responsible to any party for damages incurred as a result of failing to notify Stantec that differing site or subsurface conditions are present upon becoming aware of such conditions.

PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec geotechnical engineers, sufficiently ahead of initiating the next project stage (e.g., 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 (e.g., field observations and testing) during construction are a necessary part of the evaluation of subsurface conditions and site work. Site work relating to the recommendations included in this Report should only be carried out in the presence of a qualified geotechnical engineer; Stantec cannot be responsible for site work carried out without being present.

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	Meta-morphic Bedrock	Sedi-mentary 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

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No BH01

METRIC

W.P.		LOCATION	Coords: E315004.4 N4856195.3
DIST	Central	HWY	404
BOREHOLE TYPE	Solid Stem Auger	DATUM	Geodetic
DATE	2024.03.10 - 2024.03.11	LATITUDE	43.845656
LONGITUDE	-79.373089	ORIGINATED BY	AS
COMPILED BY	GZ	CHECKED BY	RA

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
188.4	Ground Surface
188.2 / 0.0	150mm TOPSOIL
0.2	**FILL**: clayey silt, trace sand to sandy, trace gravel, stiff to very stiff, brown to black, moist
186.3 / 2.1	**SANDY SILT**, trace clay, compact, brown to grey, moist to wet
184.7 / 3.7	**SILTY CLAY to CLAYEY SILT**, sandy, trace gravel, very stiff to hard, grey, moist (GLACIAL TILL)
182.5 / 5.9	**SAND and SILT**, trace clay, trace to some gravel, dense to compact, grey, moist (GLACIAL TILL)
178.8 / 9.6	**CLAYEY SILT**, tace sand, trace gravel, very stiff, grey, moist (GLACIAL TILL)
178.3 / 10.1	**End of Borehole**

Unstabilized water level measured at 2.1 m below ground surface; borehole caved at 2.7 m below ground surface upon completion of drilling.

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	10	
2	SS	14	
3	SS	19	
4	SS	13	0 21 75 4
5	SS	12	
6	SS	46	
7	SS	31	5 45 36 14
8	SS	27	
9	SS	41	
10	SS	32	12 41 39 8
11	SS	31	
12	SS	13	
13	SS	18	

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (188, 187, 186, 185, 184, 183, 182, 181, 180, 179); 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 (%) (20 40 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No BH02

METRIC

W.P. ______ LOCATION Coords: E315058.6 N4856223.7 ORIGINATED BY AS

DIST Central HWY 404 BOREHOLE TYPE Solid Stem Auger COMPILED BY GZ

DATUM Geodetic DATE 2024.03.11 - 2024.03.12 LATITUDE 43.845911 LONGITUDE -79.372414 CHECKED BY RA

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
188.9	Ground Surface				
188.8 / 0.1	100mm TOPSOIL	1	SS	103/200mm	
	FILL: clayey silt, trace to some sand, trace gravel, trace rootlets, very stiff, brown to black, moist	2	SS	20	
		3	SS	28	
186.8 / 2.1	**SANDY SILT**, trace clay, compact, brown to grey, moist to wet	4	SS	27	0 20 76 4
		5	SS	14	
		6	SS	12	
184.8 / 4.1	**SILTY CLAY to CLAYEY SILT**, trace sand to sandy, trace gravel, very stiff, grey, moist (GLACIAL TILL)	7	SS	23	9 33 38 20
		8	SS	29	
		9	SS	16	
		10	SS	25	2 7 52 39
181.4 / 7.5	**SAND and SILT**, trace clay, trace to some gravel, compact to very dense, grey, moist to wet (GLACIAL TILL)	11	SS	94	
		12	SS	60	
		13	SS	49	10 45 37 8
		14	SS	34	
		15	SS	27	
		16	SS	29	
175.8 / 13.1	**End of Borehole**				

Piezometer installation consists of a 50 mm diameter PVC pipe with a 3 m slotted screen from 6.1m to 9.1m.

Water Level Readings

Date	Depth (m)	Ele. (m)
04/18/24	2.4	186.5
06/11/24	2.4	186.5

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (188–176); 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 (%) 20 40 60; UNIT WEIGHT γ kN/m^3.

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

RECORD OF BOREHOLE No BH03

METRIC

W.P. ______ LOCATION Coords: E315127.6 N4856237.7 ORIGINATED BY AS

DIST Central HWY 404 BOREHOLE TYPE Hollow Stem Auger and Mud Rotary COMPILED BY GZ

DATUM Geodetic DATE 2024.03.18 - 2024.03.19 LATITUDE 43.846036 LONGITUDE -79.371556 CHECKED BY RA

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
194.7	Ground Surface				
194.6 / 0.1	100 mm Asphalt				
	FILL: sand and gravel, trace silt, compact, brown, moist	1	SS	20	
194.1 / 0.6	**FILL**: clayey silt to silty clay, trace sand to sandy, trace gravel, stiff to very stiff, brown to grey, moist	2	SS	20	
		3	SS	19	
		4	SS	18	
		5	SS	21	
		6	SS	17	4 26 44 26 Switched to mud rotary
		7	SS	11	
		8	SS	20	
		9	SS	24	
186.1 / 8.6	**SANDY SILT to SILT**, trace sand, trace clay, dense, grey, wet	10	SS	34	0 2 95 3
184.6 / 10.1	**SILTY CLAY to CLAYEY SILT**, sandy to some sand, trace gravel, very stiff to hard, grey, moist (GLACIAL TILL)	11	SS	28	
		12	SS	25	0 11 38 51
		13	SS	24	
180.9 / 13.8	**SAND and SILT**, trace clay, trace gravel, compact to very dense, grey, moist to wet (GLACIAL TILL)	14	SS	100/ 250mm	
		15	SS	100/ 130mm	

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (194 to 180); 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 (%) 20 40 60; UNIT WEIGHT γ kN/m³.

Continued Next Page

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

RECORD OF BOREHOLE No BH03

METRIC

W.P. ______ LOCATION Coords: E315127.6 N4856237.7 ORIGINATED BY AS

DIST Central HWY 404 BOREHOLE TYPE Hollow Stem Auger and Mud Rotary COMPILED BY GZ

DATUM Geodetic DATE 2024.03.18 - 2024.03.19 LATITUDE 43.846036 LONGITUDE -79.371556 CHECKED BY RA

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	SAND and SILT, trace clay, trace gravel, compact to very dense, grey, moist to wet (GLACIAL TILL) *(continued)*	16	SS	58	179					
		17	SS	36	178	o	3	48	41	8
					177					
176.0		18	SS	23	176					
18.7	**End of Borehole** Unstabilized water level and cave-in were not measured. Borehole filled with mud rotary drilling fluid.									

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; 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 (%) (20, 40, 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

RECORD OF BOREHOLE No BH04

METRIC

W.P.		LOCATION	Coords: E315187.2 N4856269.8	ORIGINATED BY	AS
DIST Central	HWY 404	BOREHOLE TYPE	Hollow Stem Auger	COMPILED BY	GZ
DATUM Geodetic		DATE 2024.03.19 - 2024.03.20	LATITUDE 43.846324 LONGITUDE -79.370814	CHECKED BY	RA

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
194.3	Ground Surface
0.0	450 mm Asphalt
193.9 / 0.4	**FILL**: sand and gravel, trace silt, compact to very dense, brown, moist
193.3 / 1.0	**FILL**: clayey silt to silty clay, trace sand to sandy, trace gravel, trace rootlets, trace red brick fragments, very stiff to hard, moist
185.7 / 8.6	**SANDY SILT**, trace clay, compact, brown to grey, wet
182.7 / 11.6	**SILTY CLAY to CLAYEY SILT**, sandy to some sand, trace gravel, very stiff to hard, grey, moist (GLACIAL TILL)

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	AS		
2	SS	40	
3	SS	61	
4	SS	21	
5	SS	19	Water added into open hole
6	SS	33	
7	SS	25	
8	SS	29	2 22 34 42
9	SS	23	
10	SS	25	
11	SS	17	0 27 71 2
12	SS	50	
13	SS	29	3 36 44 17
14	SS	26	
15	SS	30	6 23 37 34

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (194, 193, 192, 191, 190, 189, 188, 187, 186, 185, 184, 183, 182, 181, 180); 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 (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

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

RECORD OF BOREHOLE No BH04

METRIC

W.P. ______ LOCATION Coords: E315187.2 N4856269.8 ORIGINATED BY AS

DIST Central HWY 404 BOREHOLE TYPE Hollow Stem Auger COMPILED BY GZ

DATUM Geodetic DATE 2024.03.19 - 2024.03.20 LATITUDE 43.846324 LONGITUDE -79.370814 CHECKED BY RA

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SILTY CLAY to CLAYEY SILT, sandy to some sand, trace gravel, very stiff to hard, grey, moist (GLACIAL TILL) *(continued)*						179				
							178				
			16	SS	80						
							177				
							176				
175.7			17	SS	100/ 280mm						0 0 69 31
18.6	**End of Borehole** Unstabilized water level was not measured. Borheole filled with drilling fluid.										

Legend: ○ UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × LAB VANE

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

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Ontario

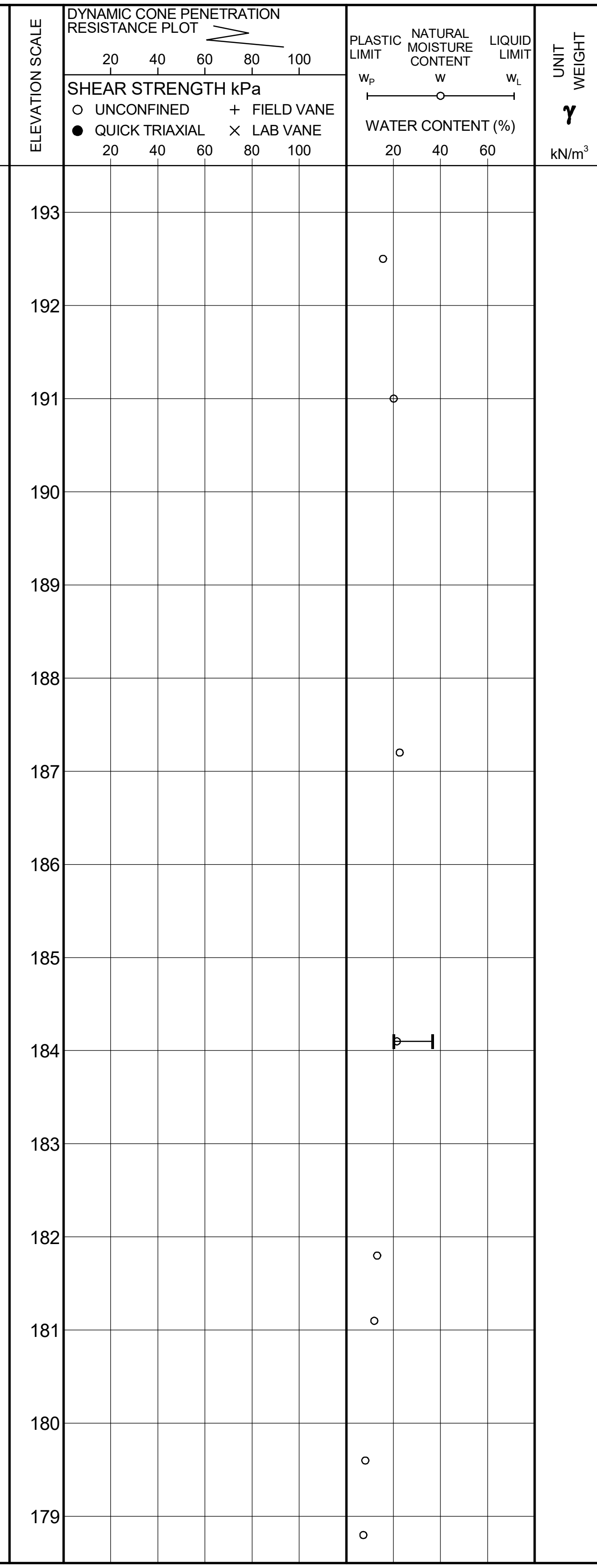
RECORD OF BOREHOLE No BH05

METRIC

W.P.		LOCATION	Coords: E315241.9 N4856275.8
DIST Central	HWY 404	BOREHOLE TYPE	Solid Stem Auger
DATUM Geodetic		DATE 2024.03.17 - 2024.03.18	LATITUDE 43.846378 LONGITUDE -79.370133

ORIGINATED BY AS
COMPILED BY GZ
CHECKED BY RA

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
193.5	Ground Surface					
0.0	**FILL**: clayey silt to silty clay, sandy to trace sand, trace gravel, trace asphalt, trace wood pieces, very stiff to hard, brown to dark grey, moist	1	SS	19		
		2	SS	20		
		3	SS	16		
		4	SS	18		
		5	SS	100/ 80mm		
		6	SS	31		
		7	SS	23		
187.9 / 5.6	**SANDY SILT to SILT**, trace sand, trace clay, trace gravel, compact, brown, moist to wet				▽	
		8	SS	29		1 7 86 6
		9	SS	34		
184.9 / 8.6	**SILTY CLAY to CLAYEY SILT**, trace sand to sandy, trace gravel, very stiff to hard, grey, moist (GLACIAL TILL)					
		10	SS	25		0 8 38 54
		11	SS	44		
		12	SS	32		
		13	SS	48		
		14	SS	100/ 250mm		
		15	SS	100/ 250mm		
		16	SS	61		



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

ONTARIO MTO 121625347_GINT LOGS_20240511.GPJ ONTARIO MTO.GDT 6/24/24

Ministry of Transportation Ontario

RECORD OF BOREHOLE No BH05

METRIC

W.P. ______ LOCATION Coords: E315241.9 N4856275.8 ORIGINATED BY AS

DIST Central HWY 404 BOREHOLE TYPE Solid Stem Auger COMPILED BY GZ

DATUM Geodetic DATE 2024.03.17 - 2024.03.18 LATITUDE 43.846378 LONGITUDE -79.370133 CHECKED BY RA

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 (○ 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SILTY CLAY to CLAYEY SILT, trace sand to sandy, trace gravel, very stiff to hard, grey, moist (GLACIAL TILL) *(continued)*		17	SS	41		178				6 16 45 33
							177				
176.3			18	SS	46						
17.2	**End of Borehole** Unstabilized water level measured at 6.1 m below ground surface; borehole caved at 6.7 m below ground surface upon completion of drilling.										

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

Ministry of Transportation Ontario

Foundation Design

RECORD OF BOREHOLE No BH06

METRIC

W.P.	LOCATION Coords: E315285.2 N4856296.9		ORIGINATED BY AS
DIST Central HWY 404	BOREHOLE TYPE Solid Stem Auger		COMPILED BY GZ
DATUM Geodetic	DATE 2024.03.14 - 2024.03.15	LATITUDE 43.846567 LONGITUDE -79.369594	CHECKED BY RA

Soil Profile

ELEV / DEPTH	DESCRIPTION
190.4	Ground Surface
190.3 / 0.1	75mm TOPSOIL
	FILL: clayey silt to silty clay, trace to some sand, trace gravel, trace rock fragments, trace rootlets, firm to hard, brown to black, moist
187.5 / 2.9	**SANDY SILT to SILTY SAND**, trace to some clay, compact to dense, brown, moist to wet
183.3 / 7.1	**SILTY CLAY to CLAYEY SILT**, sandy to some sand, trace gravel, hard, grey, moist (GLACIAL TILL)
176.2 / 14.2	**End of Borehole** Unstabilized water level measured at 3.7 m below ground surface;

Continued Next Page

Samples

NUMBER	TYPE	"N" VALUES	Remarks & Grain Size Distribution (%) GR SA SI CL
1	SS	4	
2	SS	15	
3	SS	40	
4	SS	30	
5	SS	35	
6	SS	21	1 64 30 5
7	SS	33	
8	SS	30	6 43 39 12
9	SS	63	
10	SS	87	
11	SS	75	
12	SS	50	4 32 44 20
13	SS	46	
14	SS	100/50mm	
15	SS	42	
16	SS	54	

Ground water conditions: water level symbol at approx. elev. 186.7.

Elevation scale: 190, 189, 188, 187, 186, 185, 184, 183, 182, 181, 180, 179, 178, 177

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 (%) 20 40 60

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

ONTARIO MTO 121625347_GINT LOGS_20240511.GPJ ONTARIO MTO.GDT 6/24/24

RECORD OF BOREHOLE No BH06

METRIC

W.P.		LOCATION	Coords: E315285.2 N4856296.9	ORIGINATED BY	AS
DIST	Central HWY 404	BOREHOLE TYPE	Solid Stem Auger	COMPILED BY	GZ
DATUM	Geodetic	DATE	2024.03.14 - 2024.03.15 LATITUDE 43.846567 LONGITUDE -79.369594	CHECKED BY	RA

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 (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	borehole caved at 4.6 m below ground surface upon completion of drilling.										

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

RECORD OF BOREHOLE No BH07

METRIC

W.P.		LOCATION	Coords: E315333.9 N4856309.9
DIST	Central	HWY	404
BOREHOLE TYPE	Solid Stem Auger		
DATUM	Geodetic	DATE	2024.03.13 - 2024.03.14
LATITUDE	43.846683	LONGITUDE	-79.368989
ORIGINATED BY	AS	COMPILED BY	GZ
CHECKED BY	RA		

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
189.5	Ground Surface				
189.4 / 0.1	100mm TOPSOIL				
	FILL: clayey silt, trace to some sand, trace gravel, trace rootlets, stiff, brown to black, moist	1	SS	12	
		2	SS	35	
188.1 / 1.4	**SANDY SILT to SILTY SAND**, trace clay, very dense, light brown, moist	3	SS	52	
187.4 / 2.1	**CLAYEY SILT**, sandy to trace sand, trace gravel, hard, grey, moist (GLACIAL TILL)	4	SS	49	7 41 38 14
		5	SS	33	
185.8 / 3.7	**SANDY SILT to SILTY SAND**, trace to some clay, trace to some gravel, very dense, grey, moist (GLACIAL TILL)	6	SS	100/ 280mm	Resistance to augering from 3.7 m to 6.1 m
		7	SS	100/ 280mm	
		8	SS	100/ 130mm	
		9	SS	73	12 44 31 13
182.0 / 7.5	**SILTY CLAY to CLAYEY SILT**, sandy to trace sand, trace gravel, hard, grey, moist (GLACIAL TILL)	10	SS	45	6 33 38 23
		11	SS	45	
		12	SS	75	
		13	SS	84	0 0 66 34
		14	SS	54	
		15	SS	100/ 250mm	
176.4 / 13.1	**End of Borehole**	16	SS	100/ 130mm	

Piezometer installation consists of a 50 mm diameter PVC pipe with a 3 m slotted screen from 7.6m to 10.6m.

Water Level Readings

Date	Depth (m)	Ele. (m)
04/18/24	3.6	185.9
06/11/24	3.9	185.6

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 (%): 20 40 60
UNIT WEIGHT γ kN/m³
ELEVATION SCALE: 189, 188, 187, 186, 185, 184, 183, 182, 181, 180, 179, 178, 177

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

Ministry of Transportation
Ontario

Foundation Design

RECORD OF BOREHOLE No BH08

METRIC

W.P.		LOCATION	Coords: E315401.3 N4856335.0	ORIGINATED BY	AS
DIST Central	HWY 404	BOREHOLE TYPE	Solid Stem Auger	COMPILED BY	GZ
DATUM	Geodetic	DATE	2024.03.12 - 2024.03.13	LATITUDE 43.846908 / LONGITUDE -79.36815	CHECKED BY RA

Soil Profile

ELEV / DEPTH	DESCRIPTION
191.1	Ground Surface
191.0 / 0.1	100mm TOPSOIL
	FILL: clayey silt to silty clay, trace to some sand, trace grave, trace rootlets, firm to stiff, brown, moist
189.5 / 1.6	**SANDY SILT to SILTY SAND**, trace clay, compact to dense, brown, moist to wet
188.2 / 2.9	**CLAYEY SILT**, sandy to some sand, trace gravel, hard, brown, moist (GLACIAL TILL)
187.4 / 3.7	**SILTY SAND to SANDY SILT**, trace to some clay, trace gravel, very dense, grey, moist (GLACIAL TILL)
182.9 / 8.2	**SILTY CLAY to CLAYEY SILT**, sandy to tace sand, trace gravel, hard, grey, moist (GLACIAL TILL)
178.5 / 12.6	**End of Borehole** Unstabilized water level measured at 5.5 m below ground surface; borehole caved at 5.8 m below ground surface upon completion of drilling.

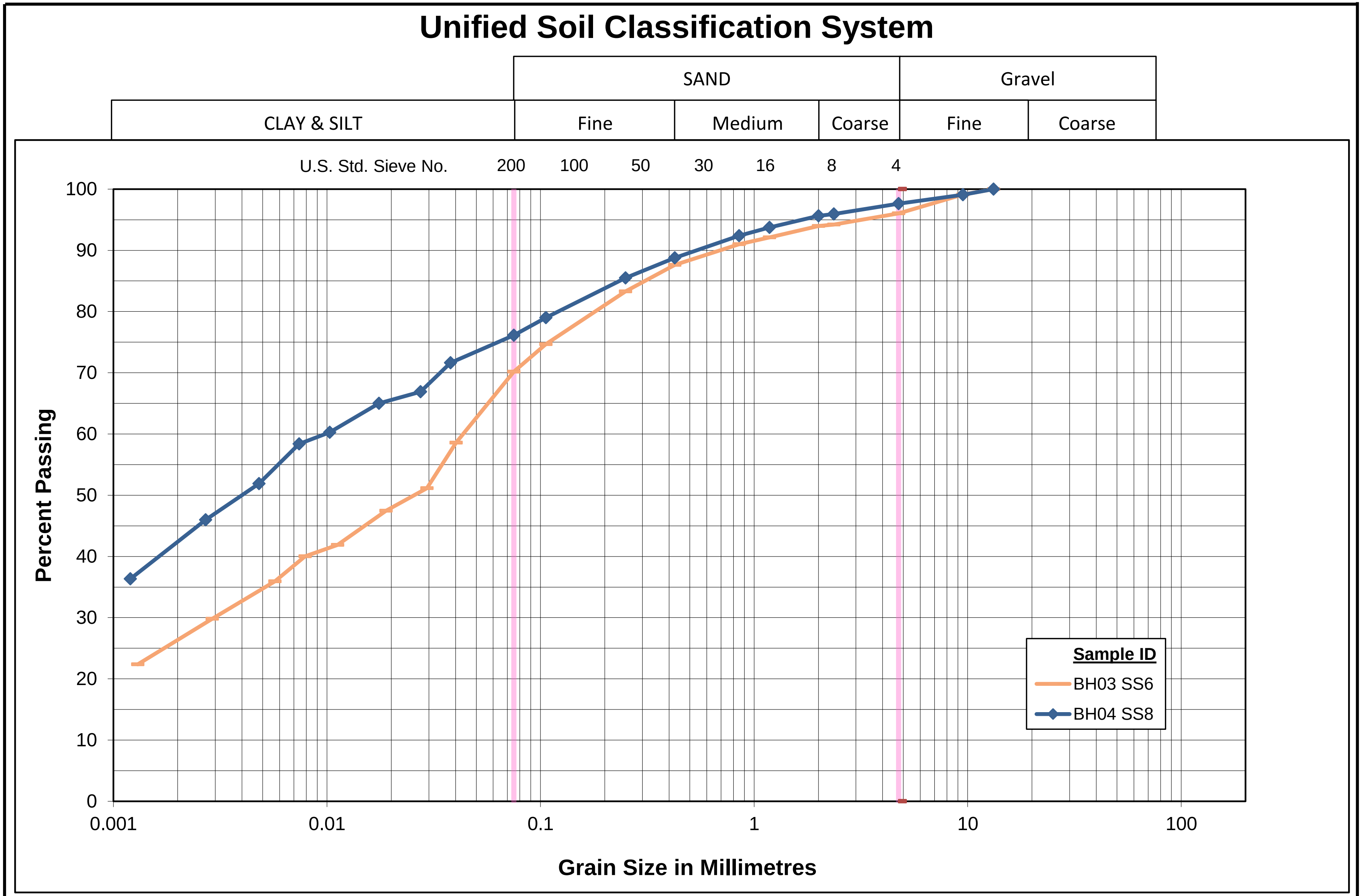
Samples

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	10	
2	SS	6	
3	SS	21	
4	SS	42	7 48 37 8
5	SS	33	
6	SS	100/ 280mm	
7	SS	95	
8	SS	100/ 280mm	1 76 19 4
9	SS	57	
10	SS	100/ 250mm	
11	SS	100/ 250mm	
12	SS	45	5 15 50 30
13	SS	100/ 250mm	
14	SS	100/ 280mm	0 5 41 54
15	SS	75	

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (191 – 179); 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 (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

APPENDIX B
Laboratory Test Results



Stantec

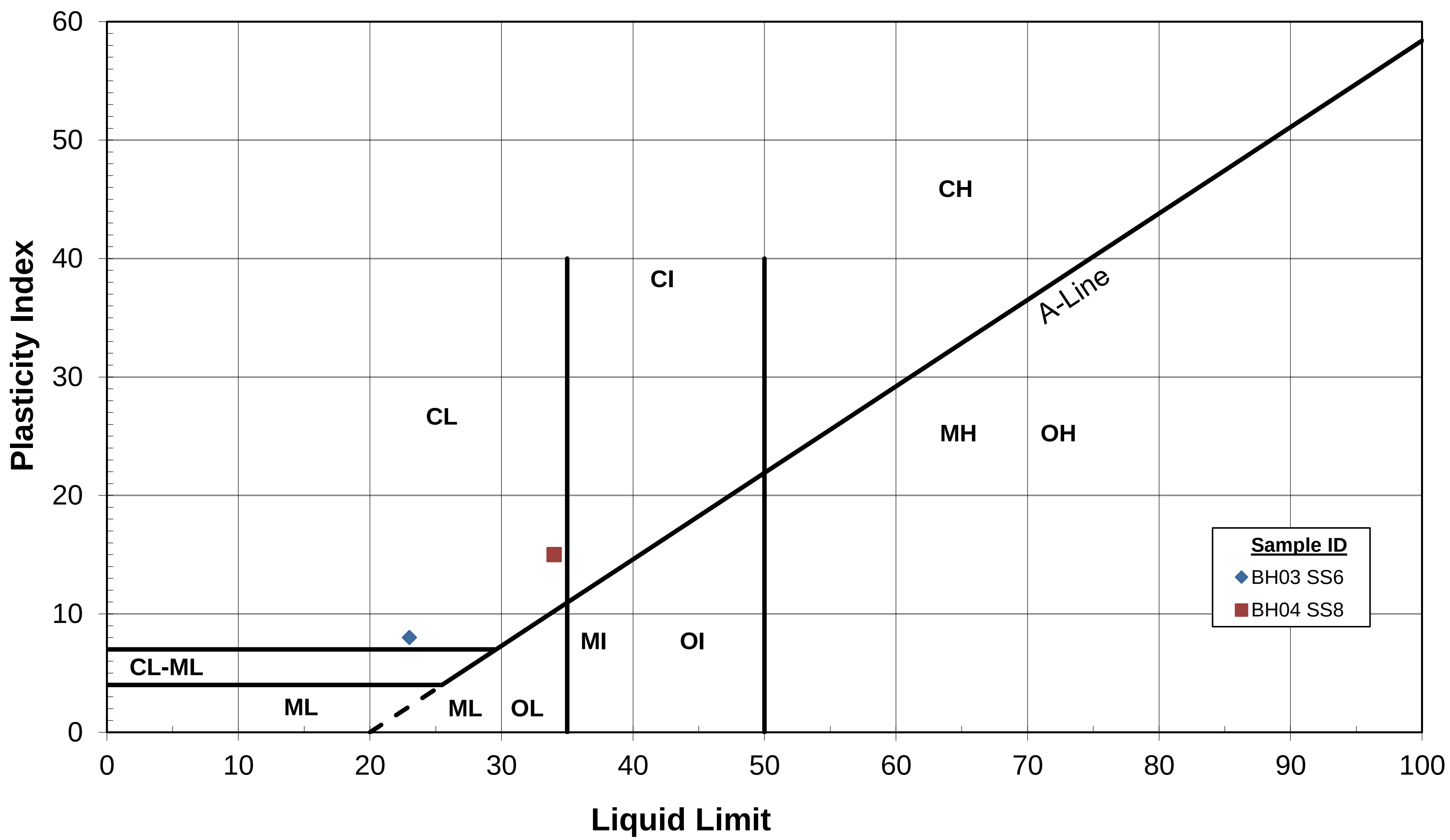
GRAIN SIZE DISTRIBUTION

FILL: CLAYEY SILT TO SILTY CLAY

HWY 404 Crossing

Figure No. B1

Project No. 121625347



Stantec

PLASTICITY CHART

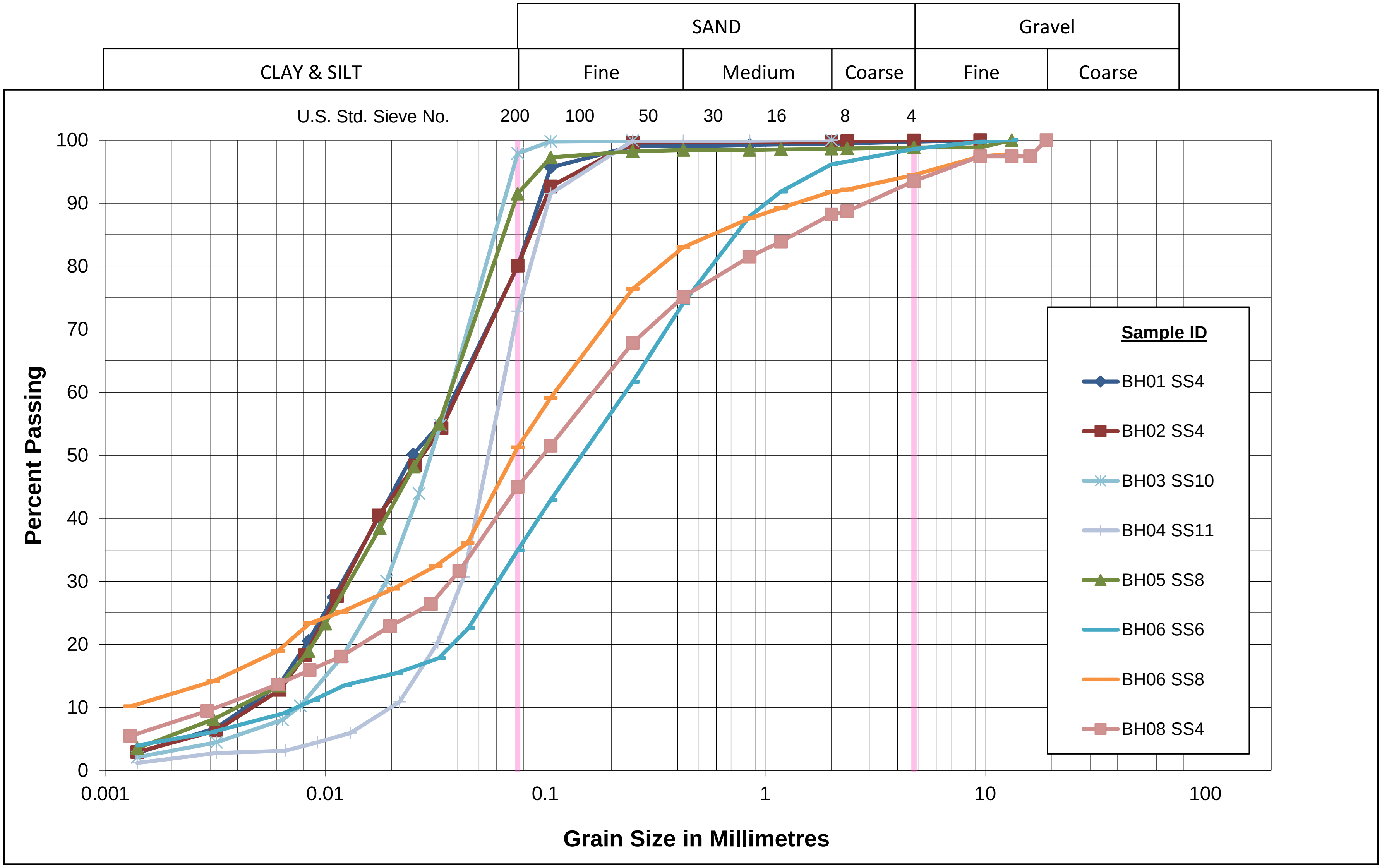
FILL: CLAYEY SILT TO SILTY CLAY

HWY404 Crossing

Figure No. B2

Project No. 121625347

Unified Soil Classification System



Stantec

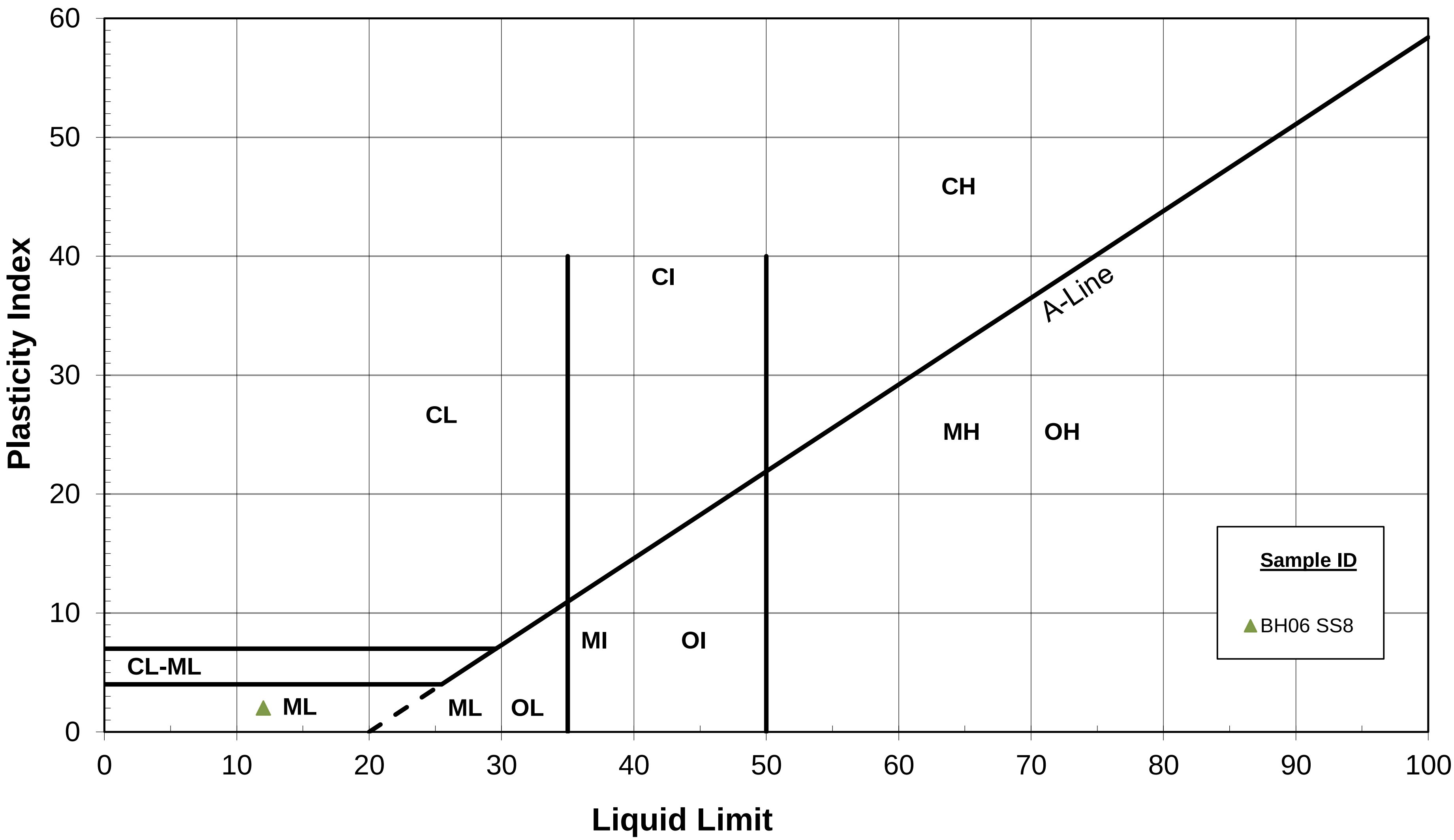
GRAIN SIZE DISTRIBUTION

SANDS AND SILTS

HWY 404 Crossing

Figure No. B3

Project No. 121625347



Stantec

PLASTICITY CHART

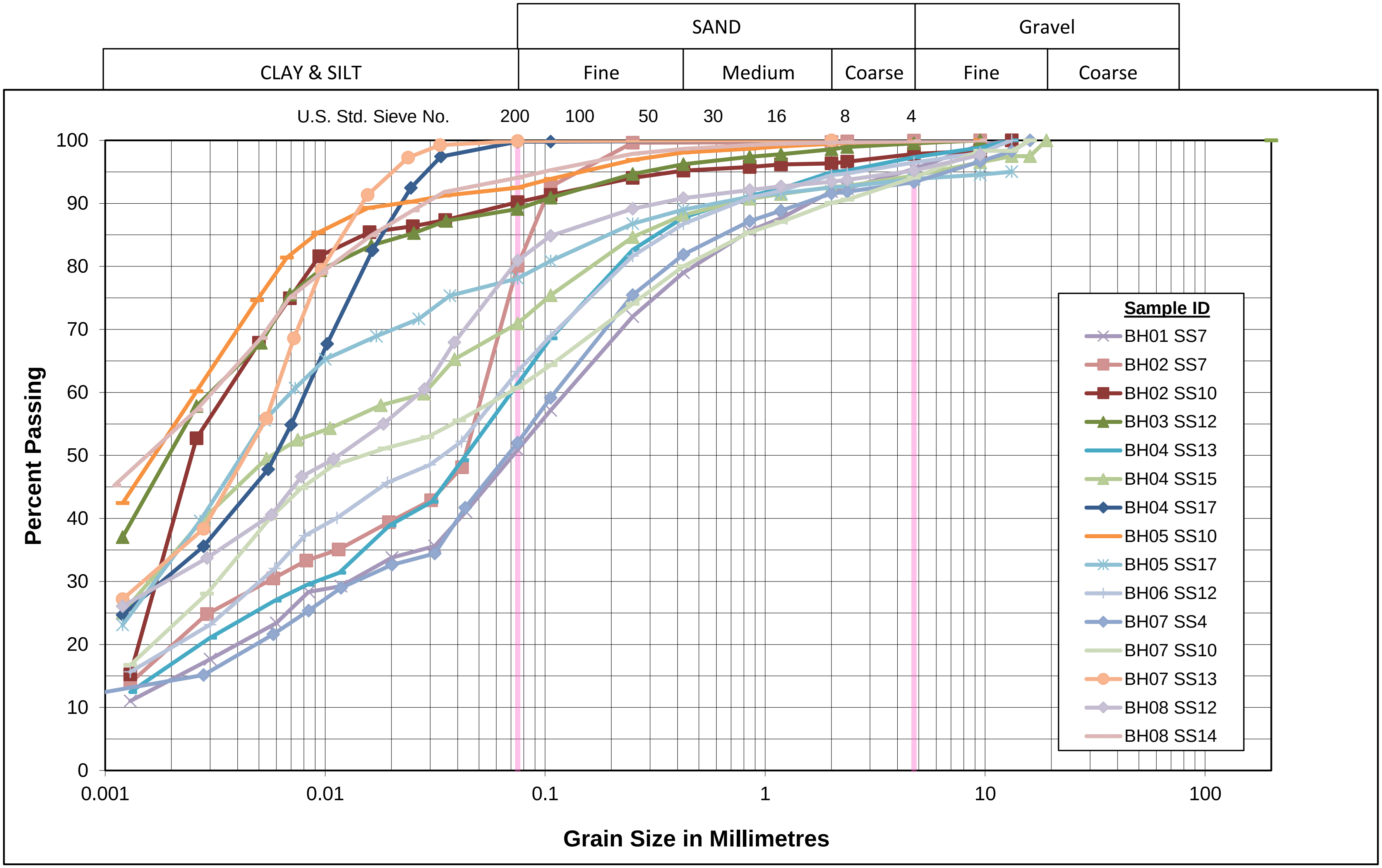
SANDS AND SILTS

HWY404 Crossing

Figure No. B4

Project No. 121625347

Unified Soil Classification System



Stantec

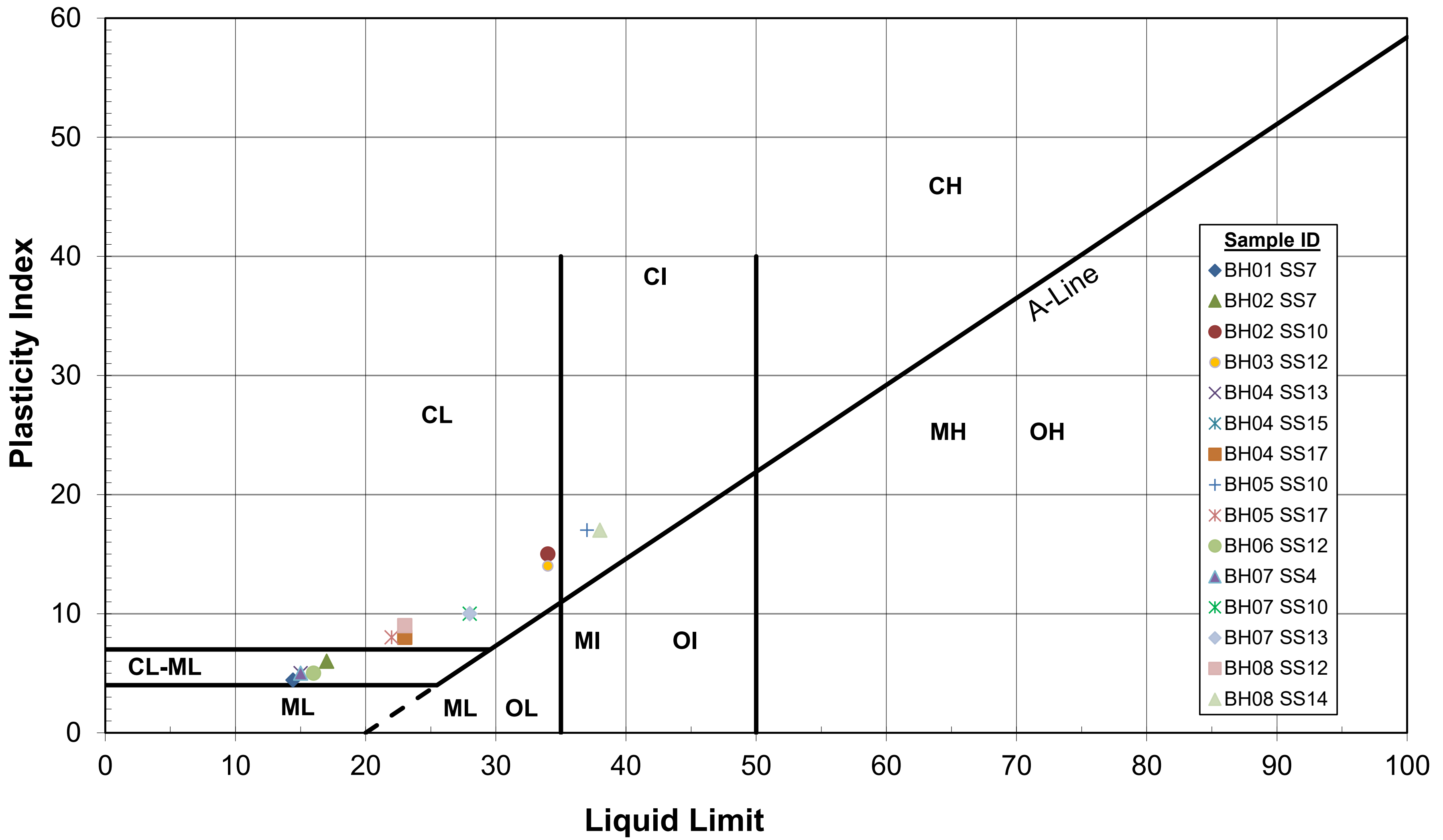
GRAIN SIZE DISTRIBUTION

SILTY CLAY TO CLAYEY SILT TILL

HWY 404 Crossing

Figure No. B5

Project No. 121625347



Stantec

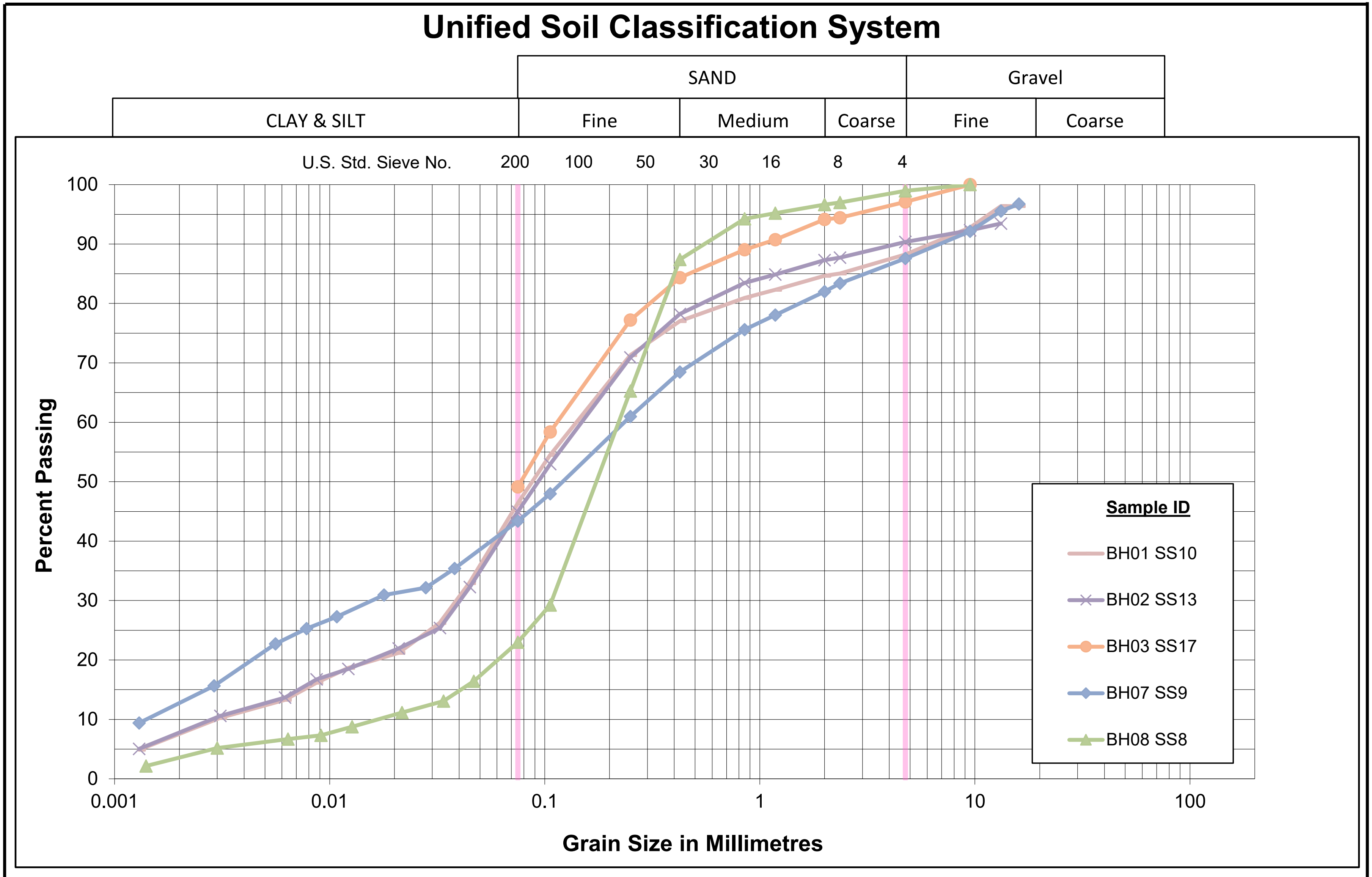
PLASTICITY CHART

SILTY CLAY TO CLAYEY SILT TILL

HWY 404 Crossing

Figure No. B6

Project No. 121625347



Stantec

GRAIN SIZE DISTRIBUTION

SANDY SILT TO SILTY SAND TILL

HWY 404 Crossing

Figure No. B7

Project No. 121625347

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Certificate of Analysis

Stantec Consulting Ltd. (Markham)
300-675 Cochrane Dr West Tower
Markham, ON L3R 0B8
Attn: Gary Zhao

Report Date: 15-May-2024
Order Date: 9-May-2024

Client PO:
Project: 121625347
Custody: 72408

Order #: 2419396

This Certificate of Analysis contains analytical data applicable to the following samples as submitted:

Paracel ID	Client ID
2419396-01	BH2 SS11
2419396-02	BH6 SS12

Approved By: Mark Foto

Mark Foto, M.Sc.
Lab Supervisor

Certificate of Analysis

Report Date: 15-May-2024

Client: **Stantec Consulting Ltd. (Markham)**

Order Date: 9-May-2024

Client PO:

Project Description: 121625347

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	13-May-24	13-May-24
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	15-May-24	15-May-24
Resistivity	EPA 120.1 - probe, water extraction	13-May-24	13-May-24
Solids, %	CWS Tier 1 - Gravimetric	10-May-24	13-May-24

Certificate of Analysis

Report Date: 15-May-2024

Client: **Stantec Consulting Ltd. (Markham)**

Order Date: 9-May-2024

Client PO:

Project Description: 121625347

Client ID:		BH2 SS11	BH6 SS12	-	-		
Sample Date:		08-May-24 16:30	08-May-24 16:30	-	-	-	-
Sample ID:		2419396-01	2419396-02	-	-		
Matrix:		Soil	Soil	-	-		
	MDL/Units						
Physical Characteristics							
% Solids	0.1 % by Wt.	85.2	91.7	-	-	-	-
General Inorganics							
pH	0.05 pH Units	7.40	7.27	-	-	-	-
Resistivity	0.1 Ohm.m	66.3	36.9	-	-	-	-
Anions							
Chloride	10 ug/g	<10	<10	-	-	-	-
Sulphate	10 ug/g	84	139	-	-	-	-

Method Quality Control: Blank

Analyte	Result	Reporting Limit	Units	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions								
Chloride	ND	10	ug/g					
Sulphate	ND	10	ug/g					
General Inorganics								
Resistivity	ND	0.1	Ohm.m					

Certificate of Analysis

Report Date: 15-May-2024

Client: **Stantec Consulting Ltd. (Markham)**

Order Date: 9-May-2024

Client PO:

Project Description: 121625347

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	ND	10	ug/g	ND			NC	35	
Sulphate	82.8	10	ug/g	84.3			1.8	35	
General Inorganics									
pH	7.10	0.05	pH Units	7.11			0.1	2.3	
Resistivity	13.3	0.1	Ohm.m	13.0			1.7	20	
Physical Characteristics									
% Solids	88.4	0.1	% by Wt.	90.0			1.7	25	

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	101	10	ug/g	ND	101	82-118			
Sulphate	181	10	ug/g	84.3	96.3	80-120			

Qualifier Notes:

Sample Data Revisions:

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable

ND: Not Detected

MDL: Method Detection Limit

Source Result: Data used as source for matrix and duplicate samples

%REC: Percent recovery.

RPD: Relative percent difference.

NC: Not Calculated

Soil results are reported on a dry weight basis unlesss otherwise noted.

Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

Any use of these results implies your agreement that our total liabilty in connection with this work, however arising, shall be limited to the amount paid by you for this work, and that our employees or agents shall not under any circumstances be liable to you in connection with this work.

PARACEL LABORATORIES LTD.

Paracel ID: 2419396

Paracel Order Number (Lab Use Only): 2419396

Chain Of Custody (Lab Use Only) № 72408

Client Name: Stantec Consulting Ltd	Project Ref: 121625347	Page 1 of 1
Contact Name: Gary Zhao	Quote #:	Turnaround Time
Address: 300W-675 Cochrane drive Markham, ON, L3R 0BW	PO #:	☐ 1 day ☐ 3 day
	E-mail: Gary.Zhao@Stantec.com	☐ 2 day ☒ Regular
Telephone: 647-213-2132		Date Required:

REG 153/04	REG 406/19	Other Regulation
☐ REG 153/04	☐ REG 406/19	
☐ Table 1 ☐ Res/Park	☐ Med/Fine	☐ REG 558 ☐ PWQO
☐ Table 2 ☐ Ind/Comm	☐ Coarse	☐ CCME ☐ MISA
☐ Table 3 ☐ Agri/Other		☐ SU - Sani ☐ SU - Storm
☐ Table ___		Mun:
For RSC: ☐ Yes ☐ No		☐ Other:

Matrix Type: S (Soil/Sed.) GW (Ground Water) SW (Surface Water) SS (Storm/Sanitary Sewer) P (Paint) A (Air) O (Other)

Required Analysis

	Sample ID/Location Name	Matrix	Air Volume	# of Containers	Sample Taken Date	Sample Taken Time	Corrosivity	Redox Potential									
1	BH2 SS11	Soil		2	May 8, 2024	16:30	X	X									
2	BH6 SS12	"		2	"	"	X	X									
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	

Comments:

Method of Delivery: WALK-IN

Relinquished By (Sign): Akshat Shukla	Received at Depot: [signature]	Received at Lab: [signature]	Verified By: [signature]
Relinquished By (Print): [signature]	Date/Time: 09-MAY-24 15:00	Date/Time: May 10, 24 10:35	Date/Time: May 10, 24 10:55
Date/Time: May 9, 2024 15:00	Temperature: 7.0 °C	Temperature: 6.2 °C	pH Verified: ☐ By:

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Subcontracted Analysis

Stantec Consulting Ltd. (Markham)
300-675 Cochrane Dr West Tower
Markham, ON L3R 0B8
Attn: Gary Zhao

Paracel Report No **2419396**
Client Project(s): **121625347**
Client PO:
Reference: **Corrosivity Package**
CoC Number: **72408**

Order Date: 09-May-24
Report Date: 17-May-24

Sample(s) from this project were subcontracted for the listed parameters. A copy of the subcontractor's report is attached

Paracel ID	Client ID	Analysis
2419396-01	BH2 SS11	Redox potential, soil
2419396-02	BH6 SS12	Redox potential, soil

TESTMARK Laboratories Ltd.
Committed to Quality and Service

CERTIFICATE OF ANALYSIS

Client:	Dale Robertson	Work Order Number:	534142
Company:	Paracel Laboratories Ltd. - Ottawa	PO #:	
Address:	300-2319 St. Laurent Blvd. Ottawa, ON, K1G 4J8	Regulation:	Information not provided
		Project #:	2419396
Phone/Fax:	(613) 731-9577 / (613) 731-9064	DWS #:	
Email:	drobertson@paracellabs.com	Sampled By:	
Date Order Received:	5/10/2024	Analysis Started:	5/17/2024
Arrival Temperature:	14 C	Analysis Completed:	5/17/2024

WORK ORDER SUMMARY

ANALYSES WERE PERFORMED ON THE FOLLOWING SAMPLES. THE RESULTS RELATE ONLY TO THE ITEMS TESTED.

Sample Description	Lab ID	Matrix	Type	Comments	Date Collected	Time Collected
BH2 SS11	2003801	Soil	None		5/8/2024	4:30 PM
BH6 SS12	2003802	Soil	None		5/8/2024	4:30 PM

METHODS AND INSTRUMENTATION

THE FOLLOWING METHODS WERE USED FOR YOUR SAMPLE(S):

Method	Lab	Description	Reference
RedOx - Soil (T06)	Mississauga	Determination of RedOx Potential of Soil	Modified from APHA-2580B

This report has been approved by:

Brad Halvorson, B.Sc.
Laboratory Director

TESTMARK Laboratories Ltd.
Committed to Quality and Service

CERTIFICATE OF ANALYSIS

Paracel Laboratories Ltd. - Ottawa

Work Order Number: 534142

WORK ORDER RESULTS

Sample Description	BH2 SS11		BH6 SS12		
Sample Date	5/8/2024 4:30 PM		5/8/2024 4:30 PM		
Lab ID	2003801		2003802		
General Chemistry	Result	MDL	Result	MDL	Units
RedOx (vs. S.H.E.)	323	N/A	319	N/A	mV

LEGEND

Dates: Dates are formatted as mm/dd/year throughout this report.

MDL: Method detection limit or minimum reporting limit.

Organic Soil Analysis: Data reported for organic analysis in soils samples are corrected for moisture content.

Quality Control: All associated Quality Control data is available on request.

LCL: Lower Control Limit.

UCL: Upper Control Limit.

QAQCID: This is a unique reference to the quality control data set used to generate the reported value. Contact our lab for this information, as it is traceable through our LIMS.

Field Data: Reports containing Field Parameters represent data that has been collected and provided by the client. Testmark is not responsible for the validity of this data which may be used in subsequent calculations.

Sample Condition Deviations: A noted sample condition deviation may affect the validity of the result. Results apply to the sample(s) as received.

Reproduction of Report: Report shall not be reproduced, except in full, without the approval of Testmark Laboratories Ltd.

ICPMS Dustfall Insoluble: The ICPMS Dustfall Insoluble Portion method analyzes only the particulate matter from the Dustfall Sampler which is retained on the analysis filter during the Dustfall method.

Regulation Comparisons: Disclaimer: Please note that regulation criteria are provided for comparative purposes, however the onus on ensuring the validity of this comparison rests with the client.

7 Margaret Street, Garson, ON, P3L 1E1
Phone: (705) 693-1121 Fax: (705) 693-1124 Web: www.testmark.ca

CERTIFICATE OF ANALYSIS

Paracel Laboratories Ltd. - Ottawa

Work Order Number: 534142

QUALITY CONTROL DATA

THIS SECTION REPORTS QC RESULTS ASSOCIATED WITH THE TEST BATCH; THESE ARE NOT YOUR SAMPLE RESULTS.
QAQC details include only values where sufficient sample data allowed measurement.

General Chemistry

Positive Control: ORP Control 240 (7)

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
RedOx (vs. S.H.E.)	N/A	mV	220	245	260	20240517.TM-M.A6B

Sample Replicate: % RPD (9)

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
RedOx (vs. S.H.E.)	N/A	%	0	0.6	10	20240517.TM-M.A6B

THIS INDEX SHOWS HOW YOUR SAMPLES ARE ASSOCIATED TO THE CONTROLS INCLUDED IN THE IDENTIFIED BATCHES.

Sample Description	Lab ID	Method	QAQCID	Prep QAQCID
BH2 SS11	2003801	RedOx - Soil (T06)	20240517.TM-M.A6B	
BH6 SS12	2003802	RedOx - Soil (T06)	20240517.TM-M.A6B	

PARACEL LABORATORIES LTD.

Paracel ID: 2419396

Paracel Order Number (Lab Use Only): 2419396

Chain Of Custody (Lab Use Only) № 72408

Client Name: Stantec Consulting Ltd	Project Ref: 121625347		Page 1 of 1
Contact Name: Gary Zhao	Quote #:		Turnaround Time
Address: 300W-675 Cochrane drive Markham, ON, L3R 0BW	PO #:		☐ 1 day ☐ 3 day
	E-mail: Gary.Zhao@Stantec.com		☐ 2 day ☒ Regular
Telephone: 647-213-2132			Date Required:

☐ REG 153/04 ☐ REG 406/19 | Other Regulation

☐ Table 1 ☐ Res/Park ☐ Med/Fine | ☐ REG 558 ☐ PWQO

☐ Table 2 ☐ Ind/Comm ☐ Coarse | ☐ CCME ☐ MISA

☐ Table 3 ☐ Agri/Other | ☐ SU - Sani ☐ SU - Storm

☐ Table ___ | Mun: ___

For RSC: ☐ Yes ☐ No | ☐ Other:

Matrix Type: S (Soil/Sed.) GW (Ground Water) SW (Surface Water) SS (Storm/Sanitary Sewer) P (Paint) A (Air) O (Other)

Required Analysis

	Sample ID/Location Name	Matrix	Air Volume	# of Containers	Sample Taken Date	Sample Taken Time	Corrosivity	Redox Potential										
1	BH2 SS11	Soil		2	May 8, 2024	16:30	X	X										
2	BH6 SS12	"		2	"	"	X	X										
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		

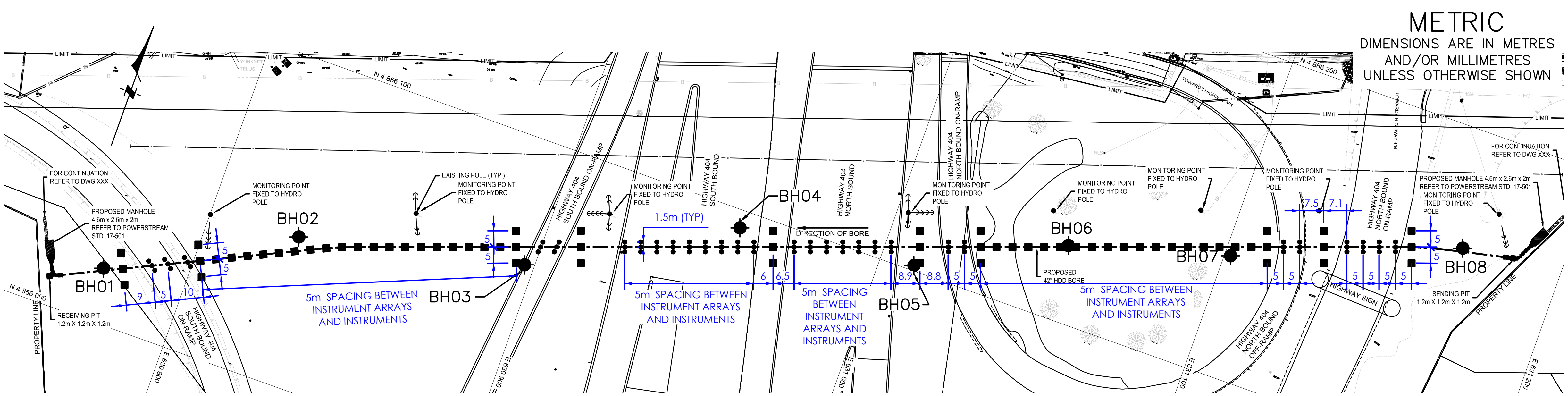
Comments:

Method of Delivery: WALK-IN

Relinquished By (Sign): Akshat Shukla	Received at Depot: [signature]	Received at Lab: [signature]	Verified By: [signature]
Relinquished By (Print): [signature]	Date/Time: 09-MAY-24 15:00	Date/Time: May 10, 24 10:35	Date/Time: May 10, 24 10:35
Date/Time: May 9, 2024 15:00	Temperature: 7.0 °C	Temperature: 6.2 °C	pH Verified: ☐ By:

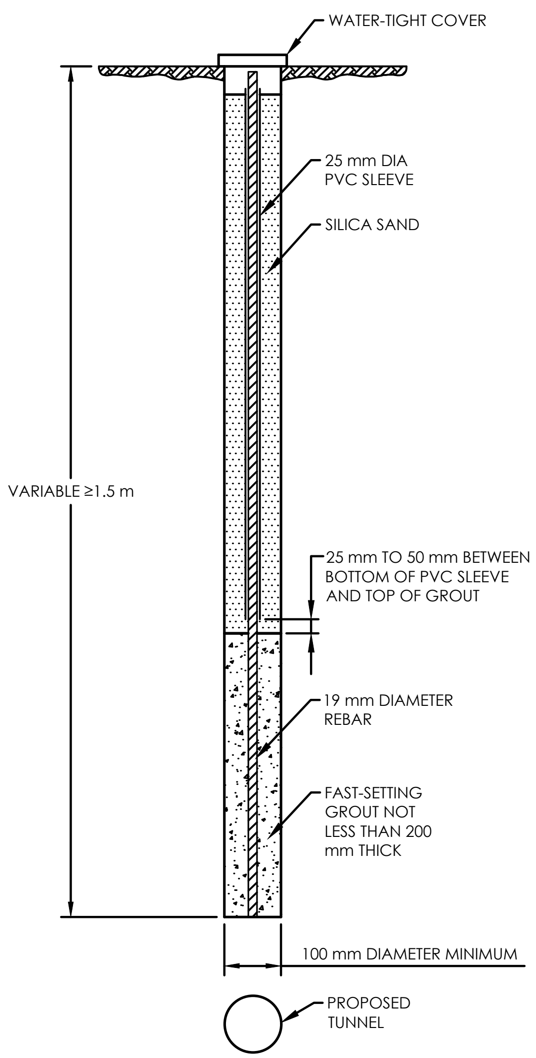
APPENDIX C
Settlement Monitoring Program

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

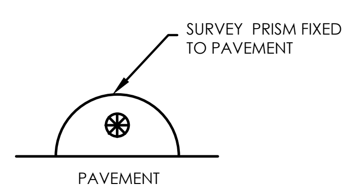


PLAN

15m 0 15 30m



DEEP (IN-GROUND) MONITORING POINT
NOT TO SCALE



SURFACE MONITORING POINT
NOT TO SCALE

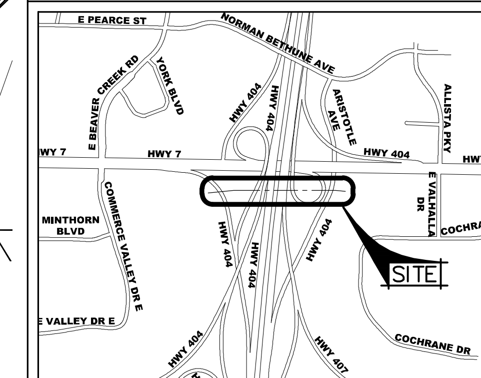
GENERAL NOTES

1. BASE PLAN PROVIDED BY ALECTRA UTILITIES. FILENAME: NBM-H23-0163-AUC - Project Rainbow Site 2 - MTO Crossing Rev B.08-For Geotech.DWG, SHEET 401, ISSUED FOR GEOTECH 05/29/2024.
2. ALL DIMENSIONS IN METERS UNLESS OTHERWISE SPECIFIED.
3. THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH STANTEC FOUNDATION INVESTIGATION AND DESIGN REPORT - ALECTRA UTILITIES INSTALLATION BELOW HIGHWAY 404 AND HIGHWAY 7 INTERCHANGE, NBM-H23-0163-AUC PROJECT RAINBOW SITE 2, MARKHAM, ONTARIO, DATED JUNE 2024.
4. ALL MONITORING LOCATIONS SHOULD BE CONSIDERED APPROXIMATE AND MUST BE CONFIRMED BY THE CONTRACTOR IN CONSULTATION WITH THE CONTRACT ADMINISTRATOR, GEOTECHNICAL ENGINEER, MTO, PRIOR TO INSTALLATION/CONSTRUCTION AND MAY HAVE TO BE ADJUSTED IN THE FIELD TO SUIT LOCAL CONDITIONS/CONSTRAINTS.
5. THE CONSULTANT SHALL RETAIN A SURVEYOR REGISTERED IN ONTARIO AND MTO RAQS FOR ESTABLISHING AND SURVEYING THE MONITORING POINTS FOR THE DURATION OF CONSTRUCTION.
6. ALL MONITORING INSTRUMENTS SHALL BE INSTALLED AT LEAST 14 DAYS PRIOR TO ANY EXCAVATION OR TUNNELLING TAKING PLACE.
7. SHALLOW IN-GROUND MONITORING POINTS SHALL BE FOUNDED AT DEPTH 1.5 m BELOW EXISTING GRADE, TIP ELEVATION OF IN-GROUND MONITOR POINT SHALL BE ADJUSTED BASE ON HDD CONTRACTORS DRILL FLUID PRESSURE TO MITIGATE THE POSSIBILITY OF "FRAC OUT". PAVEMENT MONITORING POINTS SHALL BE INSTALLED IN ACCORDANCE WITH THE MANUFACTURER'S INSTRUCTIONS.
8. THE CONTRACTOR SHALL ESTABLISH TWO TEMPORARY BENCHMARKS OUTSIDE THE AREA OF CONSTRUCTION. THE CONTRACTOR SHALL SUBMIT THE PROPOSED BENCHMARK LOCATIONS TO THE CONTRACT ADMINISTRATOR FOR APPROVAL. PRIOR TO CONSTRUCTION ALL MONITORING POINTS SHALL BE SURVEYED FOR ELEVATION AND LOCATION TO A TOLERANCE OF NOT MORE THAN ±2 mm IN THE VERTICAL AND HORIZONTAL DIRECTION.
9. THE SPECIFIED SETTLEMENT REVIEW LEVEL BELOW HWY 404 IS 10 mm AND THE SPECIFIED SETTLEMENT ALERT LEVEL IS 15 mm RELATIVE TO THE BASELINE READING. THE REQUIRED ACTIONS TO BE TAKEN IF THE REVIEW AND ALERT LEVELS ARE REACHED OR EXCEEDED ARE SPECIFIED IN THE STANTEC REPORT.
10. THE FREQUENCY AT WHICH THE CONTRACTOR IS REQUIRED TO SURVEY THE MONITORING POINTS ARE SPECIFIED IN THE STANTEC REPORT.
11. WITHIN 24 HOURS OF COMPLETION OF ANY MEASUREMENT A COPY OF THE RESULTS SHALL BE MADE AVAILABLE TO THE CONTRACT ADMINISTRATOR, GEOTECHNICAL ENGINEER AND MTO.
12. THE CONTRACTOR SHALL MAKE ALL ARRANGEMENTS FOR TRAFFIC CONTROL IN ACCORDANCE WITH ONTARIO TRAFFIC MANUAL BOOK 7.
13. REMOVE ALL MONITORING POINTS ON COMPLETION OF SURVEY, SUBJECT TO APPROVAL FROM THE CONTRACT ADMINISTRATOR, GEOTECHNICAL ENGINNER AND MTO.

HIGHWAY 404
PROJECT RAINBOW SITE 2
MONITORING & INSTRUMENTATION PLAN

SHEET

Stantec



KEY PLAN
200m 0 200 400m

LEGEND

Borehole
Surface Monitoring Point
In-ground Monitoring Point

No	ELEVATION	MTM ZONE 10 COORDINATES NORTH	EAST
BH01	188.4	4 856 195.3	315 004.4
BH02	188.9	4 856 223.7	315 058.6
BH03	194.7	4 856 237.7	315 127.6
BH04	194.3	4 856 269.8	315 187.2
BH05	193.5	4 856 275.8	315 241.9
BH06	190.4	4 856 296.9	315 285.2
BH07	189.5	4 856 309.9	315 333.9
BH08	191.1	4 856 335.0	315 401.3

NOTES

The proposed structure detail/works if shown are for illustration purposes only and may not be consistent with final design configuration as shown elsewhere in the contract document

REVISIONS

DATE	BY	DESCRIPTION

GEOCRES No 30M14-660

HWY No 404			DIST CENTRAL
SUBM'D GZ	CHECKED	DATE 2024-06-27	SITE
DRAWN GBB	CHECKED GZ	APPROVED RA	DWG 2

DRAWING NAME: 121625347_PMP_240627.dwg
CREATED BY: GBB MODIFIED:
T:\1216XXX\121625347 ONT\From G Zhao\121625347_PMP_240627.dwg (2) Printed: Oct 21, 2024

APPENDIX D
Non-Standard Special Provisions

PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Special Provision June 2021

CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY TRENCHLESS METHOD

1.0 SCOPE

This Special Provision covers the requirements for the installation of pipes by a selected trenchless method.

2.0 REFERENCES

This Special Provision refers to the following standards, specifications, or publications:

Ontario Provincial Standard Specifications, General

OPSS 180 General Specification for the Management of Excess Materials

Ontario Provincial Standard Specifications, Construction

OPSS 182 Environmental Protection for Construction in Waterbodies and On Waterbody Banks
OPSS 401 Trenching, Backfilling, and Compacting
OPSS 402 Excavating, Backfilling, and Compacting for Maintenance Holes, Catch Basins, Ditch Inlets and Valve Chambers
OPSS 403 Rock Excavation for Pipelines, Utilities, and Associated Structures in Open Cut
OPSS 404 Construction Specification for Support Systems
OPSS 409 Closed-Circuit Television (CCTV) Inspection of Pipelines
OPSS 490 Site Preparation for Pipelines, Utilities, and Associated Structures
OPSS 491 Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492 Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 510 Construction Specification for Removal
OPSS 517 Construction Specification for Dewatering
OPSS 539 Construction Specification for Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

OPSS 1004 Material Specification for Aggregates - Miscellaneous
OPSS 1350 Material Specification for Concrete - Materials and Production
OPSS 1440 Steel Reinforcement for Concrete
OPSS 1802 Material Specification for Smooth Walled Steel Pipe
OPSS 1820 Material Specification for Circular and Elliptical Concrete Pipe
OPSS 1840 Material Specification for Non-Pressure Polyethylene (PE) Plastic Pipe Products
OPSS 1841 Material Specification for Non-Pressure Polyvinyl Chloride (PVC) Plastic Pipe Products

CSA Standards

A3000 Cementitious Materials Compendium
B182.6 Profile polyethylene (PE) sewer pipe and fittings for leak-proof sewer applications
B182.8 Profile Polyethylene (PE) Storm Sewer and Drainage Pipe and Fittings

B182.13	Profile Polypropylene (PP) Sewer Pipe and Fittings for Leak-proof Sewer Applications
C22.1	Canadian Electrical Code
W59	Welded Steel Construction

American Society for Testing and Materials (ASTM) International Standards

A 252M-19	Standard Specification for Welded and Seamless Steel Pipe Piles
C-33	Standard Specification for Concrete Aggregates.
C-39	Standard Test method for Compressive Strength of Cylindrical Concrete
D 2657	Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings
D 3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
D6910	Standard Specification for Marsh Funnel Viscosity of Clay Construction Slurries
F 894	Standard Specification for Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

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

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

3.0 DEFINITIONS

For the purpose of this Special Provision, the following definitions apply:

Annular Space means the space between the inside edge of the opening and the outside edge of the penetrating item or inserted pipe.

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

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

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

Boulder Number Ratio (BNR) means the number of individual boulders per m^3 of cumulative boulder volume.

Boulder Volume Ratio (BVR) means the ratio between the cumulative volume of boulders and the volume of the material excavated.

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

Design Checking Engineer means the Engineer retained by the Contractor who checks the original design and Working Drawings.

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

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

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

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

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

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

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

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

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

Horizontal Directional Drilling (HDD) means a surface-launched trenchless technology for the installation of pipes, conduits, and cables. HDD creates a pilot bore along the design pathway and reams the pilot bore in one or more passes to a diameter suitable for the product, which is pulled into the prepared bore in the final steps of the process.

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

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

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

MTBM means a microtunnelling boring machine.

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

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

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

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

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

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

Reaming means a process for enlarging the bore path.

Rock means natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a volume of 0.5 m^3 or greater.

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

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

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

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

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

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

TBM means a tunnel boring machine.

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

Trenchless Installation means an underground method of constructing a passage open at both ends that involves installing a pipe product by auger jack & boring, pipe ramming, horizontal directional drilling, or tunnelling.

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

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

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.01 Design

4.01.01 General

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

The trenchless installation method selected for each pipe crossing shall be designed for the subsurface conditions in accordance with the Contract Documents.

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

Auger Jack and Bore, Pipe Ramming and Digger Shield/Hand Mining are not suitable methods.

4.02 Submission Requirements

4.02.01 Qualifications

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

4.02.01.01 Project Superintendent

The Project Superintendent shall have a minimum of five (5) years experience on projects with similar scope and complexity.
During construction, the Project Superintendent shall not be changed without written permission from the Contract Administrator. A proposal to change the Project Superintendent shall be submitted at least one week prior to the actual change in Project Superintendent.

As defined in MTO's Guidelines for Foundation Engineering -Tunnelling Speciality For Corridor Encroachment Permit Application, this project is categorized as High Complexity Tunnelling.

4.02.01.02 Trenchless Contractor

The Trenchless Contractor shall have a minimum of five (5) years experience on projects with similar scope and complexity.

As defined in MTO's Guidelines for Foundation Engineering -Tunnelling Speciality For Corridor Encroachment Permit Application, this project is categorized as High Complexity Tunnelling.

4.02.02 Working Drawings

Three (3) sets of Working Drawings for the selected trenchless installation method, and a Request to Proceed shall be submitted to the Contract Administrator two weeks (2) prior to the commencement of the Work or as per the Contract Documents.

The trenchless installation operation shall not proceed until a Notice to Proceed has been received from the Contract Administrator.

All Working Drawings shall bear the seal and signature of the Design Engineer and Design Checking Engineer.

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

a) Plans and Details:

   i. Plans and profiles defining all horizontal and vertical alignment positions and positions of all utilities and other infrastructure within the zone of influence of the work.
   ii. A work plan outlining the materials, procedures, methods and schedule to be used to execute the Work.
   iii. A list of personnel, including backup personnel, and their qualifications and experience.
   iv. A traffic control plan.
   v. A safety plan including the company safety manual and emergency procedures.
   vi. The Working Area layout.
   vii. An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail.

viii. A contingency plan with specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner.

ix. 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.

x. Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations.

xi. Excavated materials disposal plan.

xii. Locations of protection systems.

xiii. Contingency plans for the following potential conditions:

- Unforeseen obstructions causing stoppage.
- Deviation from required alignment and grade.
- Extended service disruption.
- Damage to the existing Utilities and methods of repair.
- Soil heaving or settlement.
- Contaminated soil or water.
- Alignment passing through buried structures.

b) Designs:

i. Primary Liner/Secondary Liner design (e.g. steel liner plates, steel ribs and wood lagging, and steel casing etc.).

ii. Design assumption and material data when materials other than those specified are proposed for use.

iii. Drill path design, details of alignment and alignment control, maximum curvature and reaming stages.

iv. Minimum depth of cover for trenchless installation appropriate for the highway type and pipe diameter, maximum excavation diameter, maximum annulus, alignment and grade tolerance etc.

v. Detailed subsurface conditions along the proposed path or within the footprint of the trenchless technology equipment or pits/shafts.

c) Materials:

i. Certification from the manufacturer that the product furnished on the contract meets the specifications cited in the manufacturer's product specification and that the materials supplied are suitable for the application.

ii. Manufacturer data sheets for all drilling fluids and additives for use in Earth Pressure Balance (EPB), Slurry Pressure Balance (SPB).

iii. Manufacturer data sheets for drilling systems.

iv. Mix designs, target rheology criteria (e.g., viscosity, density, shear strength, gel time, pressure-filtration – fluid losses under pressure, etc.) and additive dosage rates for all slurries and Earth Pressure Balance (EPB) tunnel boring machine (TBM) and microtunnelling boring machine (MTBM) operations.

v. The proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces.

vi. Compressive strength of concrete pipe products.

vii. Pipe class for all steel pipe products.

viii. Steel for Permanent Casings:

- One copy of a mill test certificate certifying that the steel meets the requirements for the appropriate standards for permanent casings shall be submitted to the Contract Administrator at the time of delivery.
- Where mill test certificates originate from a mill outside Canada or the United States of America, the information on the mill certificates shall be verified by testing by a Canadian laboratory. The laboratory shall be certified by an organization accredited by the Standards Council of Canada to comply with the requirements of ISO/IEC 17025 for the specific tests or type of tests required by the material standard specified on the mill test certificate.
- The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date (i.e., yyyy-mm-dd), and the signature of an authorized officer of the Canadian testing laboratory.

ix. Slurry, drilling fluids, and tunnelling fluids:

- Type, source, and physical and chemical properties of bentonite, polymer or other additives;
- Source of water;
- Method of mixing;
- Water to solids ratio and the mass and volumes of the constituent parts, including any chemical admixtures or physical treatment employed to achieve required physical properties;
- Details of procedure to be used for monitoring physical properties of slurry, drilling fluids and tunneling fluids or EPB spoils; and
- Method of disposal of the slurry, drilling fluids and associated spoil.

d) Upstream/Downstream Portal Installation Procedure:

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

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

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

f) Excavation and Dewatering:

i. Equipment and methods for control, handling, treatment, and disposal of groundwater and water or fluids introduced by the Contractor;

ii. Equipment and methods for maintaining control of ground inflow at the excavation face during excavation;

iii. Equipment and methods for removal of cobbles and boulders;

iv. Manufacturer data sheets for each TBM, shield, tunnelling system or drilling system noting all intermediate and final cut dimensions, and methods and equipment for controlling and measuring drilling fluid, Slurry Pressure Balance (SPB) and Earth Pressure Balance (EPB) pressures;

v. Methods for measuring excavated volumes or weights of earth and rock materials cut from ground on a per meter or per pipe basis up to a maximum of 3 m long intervals per measurement;

vi. Target operating pressures (minimum and maximum) and range of expected pressure variation for slurry or EPB spoil at excavated face or drilling fluids at lead end of drilling equipment and in annular gap between maximum excavated dimensions and outside dimensions of tunnelling equipment, drilling equipment and primary liner systems;

vii. Basis for setting target operating conditions (pressures, flow rates, advance rates) and the relationship of target operating conditions to ground conditions;

viii. Basis for selection of excavation tools (e.g., bits, TBM face tools, MTBM face tools, excavator fittings, etc.) as related to expected ground conditions;

ix. Jacking forces for installation of pipe, for driving of trenchless equipment forward and, in the case of Auger Jack & Bore, for advancing the lead end of the casing ahead of the lead end of the auger cutting tools.

g) Monitoring Method:

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

i. Maintaining the alignment of the installation;

ii. EPB, SPB and drilling fluid pressures at the leading edge of excavation (face), flow rates and volume or weights of spoil;

iii. Jacking forces on pipes, linings and cutting tools;

iv. Torque, total revolutions and revolution rates on rotating equipment such as TBM or MTBM heads, auger flights, drill bits, etc.

v. Grout injection pressures and volumes;

vi. Longitudinal position of all casings and excavation cutting tools (auger flight heads, TBM face, drill bit position, etc.); and

vii. Ground displacements (heave and settlement); and noise and ground vibrations induced by trenchless construction.

4.02.03 As-Built Drawings

As-built drawings shall be submitted to the Contract Administrator in a reproducible format prior to the Contract completion.

The as-built drawings shall be dated and bear the seal and signature of the Design Engineer and Design Checking Engineer.

5.0 MATERIALS

5.01 Pipe

5.01.01 General

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

All joints shall be suitable for jacking operations as specified in the Working Drawings.

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

All fittings shall be designed to be watertight.

5.01.02 Steel Pipe

Steel pipe shall be according to ASTM A252.

All steel casing pipe shall be square cut.

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

5.01.03 High Density Polyethylene Pipe

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

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

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

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

5.01.04 Concrete Pipe

Concrete pipe shall be according to OPSS 1820.

5.02 Concrete

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

5.03 Steel Reinforcement

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

5.04 Wood

Wood shall be according to OPSS 1601.

5.05 Drilling Fluids

Drilling fluid shall be mixed according to the Working Drawings.

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

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

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

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

5.06 Grout

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

6.0 EQUIPMENT

6.01 Auger Jack & Bore

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

Pipe Auger Jack & Bore equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

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

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

6.02 Pipe Ramming

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

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

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

6.03 Horizontal Directional Drilling

6.03.01 General

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

6.03.02 Drilling Rig

The horizontal directional drilling rig shall:

a) Consist of a leak free hydraulically powered boring system to rotate, push, and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head.

b) Have drill rod that is suitable for both the drill and the product pipe installation.

c) Contain a drill head that is steerable, equipped with the necessary cutting surfaces and fluid jets, and be suitable for the anticipated ground conditions.

d) Have adequate reamers and down-bore tooling equipped with the necessary cutting surfaces and fluid jets to facilitate the product installation and be suitable for the anticipated ground conditions.

e) Contain a guidance system to accurately guide boring operations.

f) Be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation.

g) Be grounded during all operations unless otherwise specified by the drilling rig manufacturer.

6.03.03 Drill Head

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

6.03.04 Guidance System

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

6.03.05 Drilling Fluid Mixing System

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

6.03.06 Drilling Fluid Delivery System

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

6.04 Tunnelling

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

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

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

6.05 Microtunnelling Equipment

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

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

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

a) Remote Control System – The Contractor shall provide a MTBM that includes a remote control system with the following features:

i. Allows for operation of the system without the need for personnel to enter the microtunnel.

ii. Has a display available to the operator, at a remote operation console, showing the position of the shield in relation to a design reference together with other information such as face pressure, roll, pitch, steering attitude, valve positions, thrust force cutter head torque, rate of advance and installed length.

iii. Integrates the system of excavation and removal of spoil and its simultaneous replacement by product pipe. As each pipe section is jacked forward, the control system shall synchronize all of the operational functions of the system.

iv. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.

v. The system shall monitor and continuously balance the soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.

vi. The pressure at the excavation face shall be managed by controlling the volume of spoil removal with respect to the advance rate.

vii. The system shall include a separation process designed to provide adequate separation of the spoil from the slurry so that slurry with a sediment content within the limits required for successful microtunnelling, can be returned to the cutting face for reuse. Appropriately contain spoil at the site prior to disposal.

viii. The type of separation process shall be suited to the size of microtunnel being constructed, the soil type being excavated, and the work space available at each work area.

ix. The system shall allow the composition of the slurry to be monitored to maintain the slurry weight and viscosity limits required.

b) Active Direction Control – The Contractor shall provide a MTBM that includes an active direction control system with the following features:

i. Controls line and grade by a guidance system that relates the actual position of the MTBM to a design reference.

ii. Provides active steering information that shall be monitored and transmitted to the operating console and recorded.

iii. Provides positioning and operation information to the operator on the control console.

6.05.01 Pipe Jacking Equipment

Provide a pipe jacking system with the following features:

a) Has the main jacks mounted in a jacking frame located in the launch shaft.

b) Has a jacking frame that successively pushes towards a receiving shaft, a string of product pipe that follows the microtunnelling excavation equipment.

c) Has sufficient jacking capacity to push the microtunnelling excavation equipment and the string of pipe through the ground.

d) The main jack station may be complemented with the use of intermediate jacking stations as required.

e) Has a capacity at least 20 % greater than the calculated maximum jacking load.

f) Develops a uniform distribution of jacking forces on the end of the casing pipe.

g) Provides and maintains a pipe lubrication system at all times to lower the friction developed on the surface of the pipe during jacking.

h) Jack Thrust Blocking shall adequately support the jacking pressure developed by the main jacking system.

i) Special care shall be taken when setting the pipe guide rails in the jacking shaft to ensure correctness of the alignment, grade, and stability.

6.05.02 Spoil Separation System

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

6.05.03 Electrical Equipment, Fixtures and Systems

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

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

7.0 CONSTRUCTION

7.01 General

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

The Contractor's Engineer shall supervise the work at all times.

A Request to Proceed shall be submitted to the Contract Administrator upon completion of each of the following operations and prior to commencement of each subsequent operation and no less than 2 weeks prior to the commencement of the trenchless installation.

a. Site Surveying (see Clause 4.02)
b. Excavation for pits including dewatering of excavations.
c. Jacking / Ramming / Directional Drilling of Casing / Liner

d. Installation of the Product
e. Grouting Operations

Operations a) to e) shall not proceed until the Contract Administrator has issued a Notice to Proceed for each proceeding operation.

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 Working Day, and shall monitor and record the alignment and depth readings provided by the tracking system every 2 m.

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

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

7.01.02 Construction Shafts

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

Shafts shall be maintained in a drained condition.

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

7.01.03 Protection Systems

The construction of all protection systems shall be according to OPSS 539.

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

7.01.04 Settlement or Heave

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

7.01.05 Stability of Excavation

The construction methods, plant, procedures, and precautions employed shall ensure that excavations are stable, free from disturbance, and maintained in a drained condition.
The construction methods, plant, procedures, and materials employed shall prevent the migration of soil and/or rock material into the excavation from adjacent ground.

7.01.06 Preservation and Protection of Existing Facilities

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

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

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

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer’s recommendations for transporting, unloading, storing, and handling of materials shall be followed.

7.01.08 Trenching, Backfilling and Compacting

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

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

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

7.01.10 Dewatering

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

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

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

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

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

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Cobbles and Boulders

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

For baseline purposes boulders defined as a detached rock mass with a diameter greater than 300 mm will comprise of 0.25% by total volume of excavated soil. The majority of boulders within the soil deposits are less than 1 m in diameter; however, boulders with maximum dimensions of between 2m and 3 m have been encountered in excavations made in the deposits of Southern Ontario. For baseline purposes, 98% of the boulders will not exceed 1 m in maximum dimension and 2% of the boulders will range from 1 m to 3 m in maximum dimension.

7.01.12 Removal of Obstructions

The Contractor is alerted that obstructions such as, but not limited to wood debris, roots, and construction debris consisting of (broken asphalt, concrete etc.) are expected within the trenchless alignment as identified in the Contract Documents. Accordingly, the Contractor shall address methods for the removal of obstructions in the proposed method of construction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered and the Contractor’s expected method of and schedule for removal.

Known obstructions include cobbles and boulders.

7.01.13 Management of Excess Material

Management of excess material shall be according to OPSS 180.

Satisfactory re-usable excavated material required for backfill shall be separated from unsuitable excavated material.

7.01.14 Site Restoration

Site restoration shall be according to OPSS 492.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

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

a) Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.

b) A suitably padded jacking head or collar shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.

c) The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.

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

7.02.02 Pipe Installation

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

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

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

7.03 Pipe Ramming Installation

For Pipe Ramming installation the following requirements apply:

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

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

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

iv. 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.

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

vi. Following installation of the liner pipe, all material shall be removed from the pipe to the satisfaction of the Contract Administrator.

vii. Any voids remaining between the pipe and the excavation wall shall be grouted as soon as the pipe is rammed.

viii. The annular space between the liner pipe and the product shall be fully grouted with a watertight, expandable, and stable grout.

7.04 Horizontal Directional Drilling Installation

7.04.01 General

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

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

7.04.02 Site Preparation

Site preparation shall be according to OPSS 490 and as specified herein.
The work site shall be graded or filled to provide a level working area for the drilling rig. No alterations beyond what is required for HDD operations are to be made. All activities shall be confined to designated Working Areas.

7.04.03 Pilot Bore

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

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

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

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

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

7.04.04 Drilling Fluid Losses to Surface ("Frac-Out")

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

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

7.04.05 Reaming

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

7.04.06 Product Installation

7.04.06.01 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 contravened.

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

7.04.06.02 Pullback and Grouting

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

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

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

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

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

7. 05 Tunnelling Installation

7.05.01 General

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

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

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

The Contractor shall provide ventilation and lighting in accordance with OHSA requirements for the entire length of the tunnel installed as tunneling progresses.

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

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

If excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation and make the excavation face secure. The Contractor shall then evaluate methods of construction and revise as necessary to ensure the safe continuation of the Work.

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

7.05.02 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.

7.05.03 Primary Liner (Support System)

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

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

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

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

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

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

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

7.05.04 Secondary Liner

7.05.04.01 Placing of Grout

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

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

7.06 Microtunnelling

7.06.01 General

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

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

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

The Contractor shall maintain clean working conditions at all times.

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

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

7.06.02 Method of Installation

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

a) The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.

b) Selection of the excavation method and jacking equipment shall take into consideration the subsurface conditions within the tunnel alignment.

c) Perform microtunnelling operations in a manner that will minimize the movement of the ground in front of and surrounding the tunnel in conformance with the limits listed in the Contract Documents.

d) Prevent damage to structures and utilities above and in the vicinity of the microtunnelling operations.

e) Excavated diameter should be the minimum size required to permit pipe installation by jacking.

f) Whenever there is a condition encountered which could endanger the microtunnel excavation or adjacent structures if tunnelling operations cease, continue to operate without intermission including 24-hour Working Days, weekends and holidays, until the condition no longer exists.

g) Maintain an envelope of lubricant around the exterior of the pipe during the jacking and excavation operation to reduce the exterior soil/pipe friction and possibility of the pipe seizing in place.

h) In the event a section of pipe is damaged during the jacking operation or a joint failure occurs, as evidenced by inspection, visible ground water inflow or other observations, the Contractor shall submit for approval his methods for repair or replacement of the pipe.

7.06.03 Casing Installation

Casing must withstand the jacking forces determined by the Contractor.

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

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

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

7.07 Instrumentation and Monitoring

The Instrumentation and Monitoring program shall be project specific. The work specified in this section includes furnishing and installing instruments for monitoring of settlement (and heave) and ground stability.

7.07.01 General

The Contractor shall furnish, install and monitor Surface Monitoring Points (SMP) and In-Ground Monitoring Points at the locations shown on the Contract Drawings.
The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within a repeatability (combined accuracy and precision of equipment and methods) ± 2 mm of the actual elevation.

7.07.02 Surface Settlement Monitoring Points

Surface settlement monitoring points shall be installed on the traffic lanes and shoulders to monitor settlement and stability. The surface settlement monitoring points shall be installed centred on the tunnel alignment as arrays of three points at intervals of 5 m or less and off-set a lateral distance of 1.5 m on either side of the tunnel centerline.

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

7.07.03 In-Ground Settlement Monitoring Points

In-ground settlement monitoring points shall be installed beyond the traffic lanes and shoulders to monitor settlement and stability of the ground surface between the surface settlement monitoring points and the entry and exit portals. In-ground settlement monitoring points shall be located at intervals of 5 m or less along the tunnel alignment.

In-ground settlement monitoring points shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe, set to a depth of 1.5 m below ground surface or below frost penetration depth, whichever is greater. The assembly shall be placed in a drill hole, backfilled with uniform sand and provided with protective covers suitable for high vehicular traffic areas.

7.07.04 Installation, Replacement and Abandonment

The Contractor shall install all settlement monitoring points a minimum of two (2) weeks prior to the start of works to permit baseline surveying to be completed. The settlement monitoring points shall be clearly labelled for easy field identification. The Contractor shall submit to the Contract Administrator a site plan showing the locations of the monitoring points, a geodetic survey of the settlement monitoring points including station, offset and elevation. Instruments damaged by the Contractor’s operations or other causes shall be replaced and surveyed at the time of installation within 24 hours at no additional cost. At the completion of the job, the Contractor shall abandon all instrumentations installed during the course of the Work and restore the surface at instrument locations.

7.07.05 Monitoring and Reporting Frequency

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

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

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

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

7.07.06 Benchmarks

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

7.08 Criteria for Assessment of Roadway Subsidence/Heave

Project specific Review and Alert Levels are 10 mm and 15 mm respectively.

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

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

i. The cause of the settlement has been identified.
ii. The Contractor submits a corrective/preventive plan complete with a Request to Proceed.
iii. Any approved corrective and/or preventive measure deemed necessary by the Contractor is implemented.

iv. Operations shall not proceed until the Contract Administrator has issued a Notice to Proceed for each corrective/preventive plan.

7.09 Certificate of Conformance

A Certificate of Conformance shall be submitted to the Contract Administrator upon completion of the installation of the pipe at each location. In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a final Quality Control Certificate sealed and signed by the Design Engineer and the Design Checking Engineer. The Certificate shall state that the pipe has been installed in general conformance with the Contractor's Submission and Design Requirements, sealed Working Drawings and Contract Documents.

8.0 QUALITY ASSURANCE – Not Used

9.0 MEASUREMENT FOR PAYMENT

Measurement shall be by Plan Quantity Payment as may be revised by Adjusted Plan Quantity Payment in metres, following along the centreline 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.

10.0 BASIS OF PAYMENT

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

If a pipe is installed inside the pipe liner, payment for the pipe 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 removal of boulders exceeding Boulder Volume Ratio (BVR) and Boulder Number Ratio (BNR) shall be by Time and Material