Foundation Investigation and Design Report

Highway 401 Service Crossing
Keele Street Bridge Replacement
Plant Relocation to Station 14+780
City of Toronto

Toronto Hydro-Electric System

Project No. 122410755
GeoCress No. 30M11-245

June 2012

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FOUNDATION INVESTIGATION REPORT
For
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1.0 Introduction

Stantec Consulting Ltd. (Stantec) was retained by Toronto Hydro-Electric System (Toronto Hydro) to undertake a geotechnical investigation for the proposed utility plant service crossing of Highway 401 east of the Keele Street bridge. The installation is to be conducted using trenchless technologies with a preferred option of Jack & Bore.

The utility plant relocation is part of the Keele Street bridge replacement project which forms part of a larger infrastructure improvement program along Highway 401 between Jane Street and Avenue Road.

The alignment of the planned service installation crosses Highway 401, approximately 80 m east of the Keele Street bridge over the highway, at Station 14+780.

This Foundation Investigation Report has been prepared specifically and solely for the Toronto Hydro underground utility service installation described above.

2.0 Site Description and Geology

Site Location

The site of the planned service crossing of Highway 401 is shown on the Key Plan inset to Drawing No. 1, provided in Appendix A.

It is noted that for purposes of project orientation, Highway 401 is assumed to be oriented east-west, with the MTO station chainage increasing from east to west. The Keele Street underpass is located at kilometre marker 362.

General Site Description

Photographs 1, 2, and 3, in Appendix A, show the general area of the planned crossing of Highway 401, to the immediate east of the Keele Street bridge.

At the planned crossing location, the highway has 14 lanes (eastbound express – 4 lanes; westbound express – 4 lanes; eastbound collectors – 3 lanes with on-ramp; and westbound collectors 3 lanes with on-ramp) with an approximate pavement width of 3.66 m and paved shoulders. (Photo Nos. 1, 2 and 3 in Appendix A). The ground surface at the location of the planned crossing is at approximately Elevation 174.2 m on Highway 401 and at approximately Elevation 177.7 m at the Keele Street ramp to eastbound collectors.

Highway 401 is constructed in a cut at the location of the Keele Street bridge.

The planned alignment for the crossing will traverse the existing ramp from Keele Street north to the eastbound collectors. The ramp is approximately 4 m higher than the adjacent Highway and there is a 2.9:1 (Horizontal to Vertical) slope at the location of the planned crossing. Photo No. 2 in Appendix A provides a view of this condition. The surface of the slope is vegetated with grass.

The slope was visually inspected for the presence of tension cracks, active surface or toe erosion, or evidence of previous slope failures. None of these features were observed at the time of the visual assessment. No evidence of erosion or creep was observed.

It is noted that there are underground utilities in the area. It is understood that a Subsurface Utility Mapping (SUM) has been completed by multiVIEW Inc. (multiview) which provides a full site verification of the existing buried infrastructure, the mapping has been incorporated into the design. It is further understood that the Mapping has been considered in the design process. Notwithstanding this, the Contractor shall be responsible for obtaining and confirming all underground utility locates prior to the start of construction.

At the time of the geotechnical investigation, a road contractor was on site reconstructing the pavement in the shoulder lanes on the east and westbound collectors which is understood to be preliminary works for the bridge replacement project.

Physiographic Description

The Physiography of Southern Ontario by Chapman and Putnam (1984) indicates that the site is situated within a physiographic region identified as the Peel Plain.

The Peel Plain is characterized as a level to undulating tract of clayey soils covering approximately 800 square kilometers across central portions of the Regional Municipalities of York, Peel, and Halton. There is a gradual and relatively uniform slope towards Lake Ontario. In general, the Peel Plain consists of a glacial till containing shale and limestone fragments.

The overburden soils in this area consist of till deposits, which generally follow the surface topography, have been identified as the Halton Till. The till is typically comprised of clayey silt to silty clay, with occasional sand to silt zones. Shallow, localized deposits of loose sand and silt and/or soft clay can overlie the uppermost till sheet. The uppermost till deposits and shallow, localized deposits of loose sand and silt and clay in this area overlie and are interstratified with stratified deposits of sand, silt and clay.

Background Geotechnical Information

GOLDER ASSOCIATES
FOUNDATION INVESTIGATION REPORT – JUNE 2011

The following geotechnical report relevant to the Site was provided to Stantec for consideration in the context of preparing our original proposal for this investigation. It is noted that the report was provided 'For Information Only', without benefit of reliance:

- Foundation Investigation Report
  Keele Street Underpass
  Highway 401 Eastbound Collector Rehabilitation from Jane Street to Avenue Road,
  Toronto, Ontario
  G.W.P. 2368-09-00
  Submitted to: URS Canada Inc.
  Prepared by: Golder Associates
  Report Date: June 2011
  Geocres No.: 30M11-237
  Report Number: 09-1111-6007

The Report addresses the widening and rehabilitation of the Keele Street Underpass associated with the Phase 2 Foundation Investigation. The investigation included four (4) boreholes, and two standpipe piezometers installations to permit long term groundwater level monitoring.

The subsurface stratigraphy encountered in the boreholes consisted of a relatively thin layer of fill overlying a deposit of stiff to hard clayey silt till, underlain by a deposit of silt and sand to sandy silt to silt. In two boreholes, a deposit of clayey silt to silty clay was encountered underlying the cohesionless deposit. The clayey silt till contains a varying quantity of sand and a trace to some gravel, and at some locations had the plasticity of a silty clay. Silty sand to sand seams were encountered within the deposit at various depths. The thickness of the glacial till deposit ranged from 23.3 m to 32.9 m. A deposit of sand and silt to sandy silt to silt was encountered underlying the clayey silt till deposit in all of the boreholes. The sand and silt to sandy silt to silt deposit contains trace to some clay and trace of gravel. The surface of the deposit was encountered at depths between 23.9 m to 34.4 m below the ground surface. A clayey silt to clay deposit was encountered underlying the sand and silt to sandy silt to silt deposit in two of the boreholes at a depth of 27.0 m and 42.7 m below the ground surface.

The report indicated that stabilized groundwater levels at the site ranged from Elevation 151 m to 154 m in June 2011. Golder also noted that immediately upon completion of drilling, higher water levels, as close as 5.6 m to ground surface, were observed. High water levels measured during or shortly after drilling were attributed to perched groundwater conditions above and within the upper portion of the clayey silt till deposit which contains sand seams and interlayers.

The report summarizes that the water levels at the bridge site should be expected to fluctuate seasonally in response to changes in precipitation and snow melt, and should be expected to be higher during the spring season or during any period of precipitation.

Adjacent Structures

The location of the planned crossing is 80 m east of the Keele Street interchange.

The location of the planned crossing is 10 m east of the MTO signage board spanning the westbound express lanes.

Based upon background information provided for the Keele Street underpass, the abutment and piers are supported on spread footings and the signage board is supported on caissons.

The location of the crossing has been chosen, in part, to avoid potential interference or damage to the existing infrastructure.

3.0 Method of Investigation

3.1 DRILLING INVESTIGATION

The field investigation consisted of advancing four (4) boreholes. The boreholes were advanced at each end of the tunnel crossing, at the center median and on the Keele Street ramp to the eastbound collectors. The boreholes were designated BH11-1 to BH11-4. The locations are shown on the Borehole Location Plan, Drawing No.1 in Appendix A.

Prior to carrying out the investigation, Stantec contacted the public utility authorities to clear the borehole locations of public utilities.

Traffic protection and signage was provided during all field work in accordance with the Ontario Traffic Manual Book 7 – Temporary Conditions.

The field drilling program was carried out from November 12, 2011, to November 14, 2011, during restricted night and weekend hours. The boreholes were advanced in the roadway using a CME-75 truck drill rig and a track mount drill rig. Standard Penetration Tests were conducted at regular intervals in all the boreholes, in accordance with the methods described in ASTM D1586-99.

The subsurface stratigraphy encountered in each borehole was recorded in the field by personnel from Stantec.

All samples recovered from the boreholes were returned to our Markham laboratory for detailed classification and testing.

The boreholes were backfilled with a mixture of granular bentonite and auger spoils and topped with cold patch asphalt tamped in place in accordance with the requirements of the Ontario Ministry of the Environment Regulation 903.

3.2 CONSTRUCTION MONITORING SETTLEMENT POINT INSTALLATION

At the time of the geotechnical investigation, the drilling subcontractor installed six (6) in-ground settlement monitoring points. These points were installed as a component of the required construction monitoring program.

One array of three (3) monitoring points was installed on the north shoulder of Highway 401 and one array of three (3) monitoring points was installed on the south shoulder of Highway 401. The center point of the array was placed directly over the centerline of the proposed Jack and Bore alignment; the other two points in each array were established a maximum distance of 1.5 m on either side of the centerline of the proposed alignment. The in-ground monitoring points were installed to depths in the range of 2.7 m to 3.0 m below grade, using 100 mm diameter, hollow stem augers.

The monitoring rods, 10 mm in diameter will have a survey prism mounted on the top and a 50 mm diameter PVC casing sleeve for protection. The monitoring rods are encompassed by temporary fencing with flagging to protect them from inadvertent damage caused by construction equipment, snow plows, vehicles, etc.

3.3 SURVEYING

The borehole locations were established relative to the existing site features, including the existing bridge, the Highway 401 median, the MTO signage board and other site features. The ground surface elevations at the boreholes were established using the Digital Terrain Model for the site prepared by URS Canada Inc.

The borehole locations including MTM NAD83 northing and easting coordinates and ground surface elevations referenced to geodetic datum are summarized below in Table 3.1 and are shown on the Borehole Location and Soil Strata drawing contained in the Report.

Table 3.1: Borehole Location and Elevation Summary

	Boreholes			
	BH11-1	**BH11-2**	**BH11-3**	**BH11-4**
MTM NAD83 Zone 10 Northing Easting	 4 842 600.00 306 381.00	 4 842 552.70 306 397.10	 4 842 511.10 306 411.30	 4 842 487.60 306 419.20
Station	14+780	14+780	14+780	14+780
Offset	47.8 m Rt CL	1.5 m Lt CL	45.4 m Lt CL	64.5 m Lt CL
Ground Surface Elevation (m)	174.1	174.2	174.1	177.7
Depth Drilled (m)	9.6	9.6	9.6	18.7
End of Borehole Elevation (m)	164.5	164.6	164.5	159.0
Depth Augered (m)	9.6	9.6	9.6	18.7
Number of Soil Samples	9	9	9	15
Depth Cored (m)	0	0	0	0

The offset centerline has been defined as the concrete center median separating the east and westbound express lanes.

3.4 LABORATORY TESTING

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

Samples were selected for analysis that included the following:

- Atterberg Limits - 5 samples
- Gradation Analysis - 10 samples
- Moisture Content - 41 samples

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

4.0 Subsurface Conditions

4.1 SUBSURFACE PROFILE

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

In general, the subsurface stratigraphy consists of surficial layers of pavement or grass and topsoil, underlain by deposit of clayey silt till. Bedrock was not encountered to the termination depth of the boreholes. Free groundwater was not observed in the open boreholes on completion of drilling.

A borehole location plan and stratigraphic section of the soils encountered within the boreholes are provided on Drawing No. 1 in Appendix A. The Record of Borehole No. 1 and No. 2 from a previous (MTO) 1963 investigation for the Keele Street bridge are presented in Appendix G.

4.1.1 Ground Surface Cover

Topsoil

Approximately 400 mm of clayey silt with organics (topsoil) was encountered at the ground surface at the location of Borehole BH 11-1.

Asphalt Pavement

Asphalt pavement was present at the locations of Boreholes BH11-2 and BH11-4. The pavement structure consisted of 140 mm and 320 mm of asphalt overlying 360 mm to 780 mm of gravelly sand and silty sand fill materials. As noted above, a road contractor was rehabilitating the existing shoulders; therefore the thickness of the granular material in Borehole BH11-3 does not reflect the pavement design.

Grain size analysis and moisture content testing on three samples of the granular materials yielded the following results:

- 8%, 19% and 29% Gravel
- 57%, 58% and 62% Sand
- 13%, 24% and 30% Fines (silt and clay size particles)
- Moisture Content 7%, 8% and 10%

This fill material can be classified as ranging from silty sand with trace to some gravel, to gravelly sand with some silt.

The grain size distribution curve illustrating the results of the tests is included as Figure 1 in Appendix C.

4.1.2 Silty Sand Fill Material

In Borehole BH11-1, a layer of fill material was encountered underlying the surficial topsoil. The fill consisted of silty sand, some gravel, and some clay. The thickness of this fill layer was approximately 1.1 m.

A gradation test was completed for one sample of the fill deposit as well as moisture content testing on one sample. The test results are summarized as follows.

- 10% Gravel
- 56% Sand
- 34% Fines (silt and clay size particles)
- Moisture Content 9%

The results of the gradation analyses indicate that the fill material can be classified as silty sand with some gravel. The grain size distribution curves are shown on Figure 1 in Appendix C.

4.1.3 Sandy Silty Clay Fill Material

In Borehole BH11-3, a layer of fill material was encountered underlying the pavement structure (asphalt and granular fill materials). The fill consisted of sandy silty clay, with trace gravel. The thickness of this fill layer was approximately 0.9 m. The fill appears to be backfill material for the existing storm pipe that runs parallel with the highway shoulder at this location.

A gradation test was completed for one sample of the fill deposit as well as moisture content testing on one sample. The test results are summarized as follows.

- 8% Gravel
- 28% Sand
- 64% Fines (silt and clay size particles)
- Moisture Content 11%

The results of the gradation analysis indicate that the fill material can be classified as sandy silty clay with some gravel. The grain size distribution curves are shown on Figure 1 in Appendix C.

4.1.4 Clayey Silt Till

A deposit of clayey silt till soil was encountered in all the boreholes, underlying the surficial materials and fill materials as described above. All the boreholes terminated in the clayey silt till soil at depths ranging from 9.6 m to 18.7 m below grade (Elevations between 159.0 m and 164.6 m).

The till consists predominantly of clayey silt, though layers of slightly more plastic soil were encountered. The till contained a varying quantity of sand and typically trace gravel. Silty sand and sand seams were also encountered within the deposit at various depths.

The clayey silt till was observed to be generally stiff to hard based on the results of the SPT tests conducted (N-values ranged from 7 to 48 blows per 300 mm).

Grain size analysis tests were completed on five samples. The test results are summarized as follows.

- 2% and 4% Gravel
- 26%, 30% and 33% Sand
- 64%, 66%, 68% and 69% Fines (silt and clay size particles)

Atterberg Limits tests were also conducted on a portion of the same samples referenced above. The results of the tests were as follows:

- 19 to 21 Liquid Limit
- 12 to 13 Plastic Limit
- Moisture content: 9% to 15%

Based on the results of the grain size and Atterberg Limits tests, the till can generally be classified as a clayey silt of low plasticity.

The grain size distribution curves and Atterberg Limits are shown on Figure 1 and 2 in Appendix C.

Four samples of the clayey silt were submitted to Testmark Laboratories Ltd., in Garson, Ontario, for analysis of pH, water soluble sulphate and resistivity. The analysis results are provided in Table 4.1.

Table 4.1: Results of Chemical Analysis

Borehole No	Sample No.	Depth (m)	pH	Sulphate (µg/g)	Resistivity (Ohm-m)
BH11-1	SS6	4.6 – 5.0	7.6	81	11.44
BH11-2	SS5	3.1 – 3.5	7.6	74	23.1
BH11-3	SS5	3.1 – 3.5	7.6	77	17.5
BH11-4	SS7	6.1 – 6.5	7.6	75	10.8

4.2 BEDROCK

Bedrock was not encountered within the depth of exploration during this investigation.

4.3 GROUNDWATER

All the boreholes were dry on completion of drilling.

5.0 Miscellaneous

The field work was carried out under the supervision of Mr. Maged Abdel-Mesih, B.Sc., P. Eng, Geotechnical Engineer, under the direction of John J. Brisbois, M.Sc.Eng., P.Eng., Senior Geotechnical Engineer.

The truck mounted drill rig was supplied and operated by Strong Soil Search Inc. of Claremont, Ontario and DBW Drilling Ltd. of Toronto, Ontario.

Geotechnical laboratory testing was carried out at the Stantec Markham laboratory. Chemical testing on soil samples was carried out by Testmark Laboratories Ltd. in Garson.

This report was prepared by Mr. John J. Brisbois, M.Sc.Eng., P.Eng., with the assistance of Mr. Eric Fron, Civ.Tech., and reviewed by Mr. Raymond Haché, M.Sc., P.Eng., MTO Designated Principal Contact.

6.0 Closure

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

Respectively Submitted;

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FOUNDATION DESIGN REPORT
For
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Keele Street Bridge Replacement
Plant Relocation to Station 14+780
City of Toronto

7.0 Discussion

7.1 PROJECT DESCRIPTION & BACKGROUND

Project Purpose/Justification

Stantec Consulting Ltd. (Stantec) was retained by Toronto Hydro-Electric System (Toronto Hydro) to undertake the geotechnical investigation for the underground utility plant relocation required as a part of Ministry of Transportation, Ontario G.W.P. 2368-09-00. The installation is to be conducted using trenchless technologies with a preferred option of Jack & Bore.

The alignment of the planned service installation crosses Highway 401, approximately 80 m east of the Keele Street bridge, at Station 14+780.

At the location of the crossing, the highway is a freeway, with a tall wall center median; seven westbound lanes (collector and express) and seven eastbound lanes (collector and express). There are on-ramps from Keele Street to the eastbound collector lanes and westbound collector lanes.

Proposed Structure

The proposed utility plant service installation will be a smooth wall pipe with a diameter of 1050 mm and a length of 107 m between the sending and receiving pits.

Key elevations associated with the installation are as follows:

Pavement Elevation (Highway 401)	174.2 m (approximate)
Pavement Elevation (Keele Street ramp)	177.7 m (approximate)
Obvert Elevation	168.75 m North End 168.75 m South End
Ground Water Elevation	Dry upon completion at the time of drilling

The obvert elevation is approximately 5 m below the pavement surface.

Although groundwater was not encountered in the Investigation, the Golder report submitted for the Keele Street bridge indicated the groundwater was encountered in the boreholes at depths of 5.6 m to 27.2 m below existing ground surface upon completion of the drilling and in the piezometers. The report indicated the water levels measured upon completion of drilling are not representative of the stabilized groundwater level at the site which ranges from Elevation 151 m to 154 m in June 2011. The report indicated the high water levels measured during or shortly after drilling suggests that perched groundwater conditions exist above and within the upper portion of the clayey silt till deposit which contains sand seams and interlayers.

Construction Staging & Detours

The existing platform consists of a 14 lane, 115 m wide, paved highway with express and collector lanes, paved shoulders and center medians with on and off ramps at the Keele Street interchange.

The scope of the work has been planned to accommodate maintaining the traffic flow on the 401 without disruption. The work will take place outside of the traffic lanes with the protection of jersey barriers.

7.2 SOIL SUMMARY

The soil stratigraphy at the location of the planned crossing generally consists of existing asphalt pavement (or grass and topsoil beyond the paved portion of the highway) underlain by localized and limited fill materials, underlain by native clayey silt glacial till soil.

For design purposes, the soil profile shown below in Table 7.1 can be used:

Table 7.1: Geotechnical Soil Stratigraphic Model

Elevation (m)		Soil Type	Design Properties
From	To		
174.1	173.7	Pavement Structure/Topsoil	Not Applicable
173.7	172.6	Silty Sand to gravelly sand, to sandy silty clay: (Mixed FILL)	Total Unit Weight = 21.0 kN/m^3 Friction Angle, ϕ = 28°
172.6	159.0	Clayey SILT, (TILL) With Sand, trace to some gravel	Total Unit Weight = 22.0 kN/m^3 Undrained Shear Strength = 100 kPa

For design purposes, the groundwater elevation will be set at Elevation 151 m to 154 m.

7.3 SEISMIC DESIGN CONSIDERATIONS

Based on the soil conditions identified during the geotechnical investigation, the recommended site classification for seismic site response for this site is Site Class D in accordance with Table 4.1.8.4. A copy of the NBC Seismic Hazard Calculation Data sheet is provided in Appendix E for reference.

The seismic site classification is based on an average STP N = 14 calculated using the following soil profile:

- Layer 1: Thickness = 18.7 m (61 ft) Average STP N = 28 (Native Clayey Silt Till Soil)

It should be noted that the maximum depth of the boreholes for the current investigation was 18.7 m. (61 ft) Therefore, the soil profile was interpreted based on the soil conditions encountered in the boreholes, supplemented by the conditions described on the geological maps, as discussed previously in this report.

Table A3.1.1 of the CHBDC indicates that the Zonal Acceleration Ratio for Toronto is 0.05.

Seismically induced lateral earth pressures are not considered applicable for this project.

Liquefaction of the foundation soils is not a concern for this project as there are stiff to hard soil conditions and a very low Zonal Acceleration Ratio.

8.0 Trenchless Technology Installation

8.1 JACK & BORE APPROACH

8.1.1 Statement of Preferred Approach

Based on the available project information and the subsurface soil and groundwater conditions encountered at the crossing site, the preferred trenchless technology approach of the proponent is Jack and Bore.

Jack and Bore typically involves the simultaneous advancement of a continuous flight auger and conduit pipe. The auger is used to excavate soil in advance of the casing and transport cuttings back to the receiving pit where they are removed. Rotary power to auger and pushing force is provided by a drill rig located within the jacking or sending pit. Jack and Bore is a common method of trenchless installation and in appropriate site and soil conditions may be preferable from a cost perspective.

For this application, the Jack and Bore method will require installing a 1050 mm diameter steel pipe. On completion of the Jack and Bore process, a double wall full complement bore spacer with fifteen (15) 100 mm EPC40 PVC conduits will be inserted into the tunnel liner, and the annulus grouted.

8.1.2 Suitability of Preferred Approach

The following bullets provide a brief review of the suitability of the Jack and Bore approach for this project.

- The work is to be carried out within the MTO Right-of-Way. Open cut excavation in the MTO Right-of-Way is not permitted, necessitating the adoption of a trenchless technology approach.

- The fill materials encountered in the boreholes are generally non-cohesive (although sandy silty clay was encountered in one of the boreholes advanced for the investigation). Given that these fill materials are present at shallow depth, of limited thickness, are inferred to be in a compact to dense state, and are above the water table level, penetration of these materials is not anticipated to be a concern.
- The native soils encountered in the boreholes consist predominantly of clayey silt till (sandy with trace gravel). Penetration of this soil via Jack and Bore is not anticipated to be a concern.
- It is anticipated that cobbles will be encountered during construction. It is presumed that the drilling contractor will employ augering equipment capable of extracting cobbles, without impediment to disrupting the alignment and mitigating the potential to incur settlement during the drilling process.
- The presence of boulders was not inferred, based on the conditions observed and encountered at the time of drilling of the investigation boreholes. If boulders larger than approximately 300 mm (or 40% of the auger diameter) were to be encountered in the fill, such material would likely require chipping from within the pipe or a review of the installation method.

8.1.3 Constraints to the Preferred Approach

The following bullets provide a brief review of the constraints of the Jack and Bore approach for this project.

- The location of the planned crossing is 80 m east of the Keele Street interchange and is 10 m east of the MTO signage board spanning the westbound express lanes. Based upon background information provided for the Keele Street underpass, the abutment and piers are supported on spread footings and the signage board is supported on caissons. The location of the crossing has been selected, in part, to avoid potential interference or damage to the existing infrastructure and therefore there no issues are foreseen in this respect.
- It is noted that there are below grade utilities in the area that will need to be protected during the work. The Subsurface Utility Mapping (SUM) should be reviewed to locate the existing buried infrastructure and locates be initiated with the public utility authorities prior to the start of the work. However, the Contractor is responsible for obtaining and confirming all underground utility locates prior to start of construction.
- With the predominant soil type along the bore path being the cohesive glacial till, and given the likely presence of cobbles, the pipe jacking should immediately follow the boring operation. The boring auger should be kept inside the pipe with extrusions limited to 5 mm.
- At the end of a work day it is suggested that the liner be jacked into the silty clay till to form a soil plug (measured from the advancing end of the casing); the length of the soil plug should be proposed by the boring contractor in advance of commencement of the work. This will mitigate potential ground loss during the installation process.
- The amount of settlement which would occur above the Jack and Bore alignment will depend to a large extent, on the contractor's work methods and equipment used. Given that there will be more than 4.7 m of cover over the obvert and that the installation would be above the water table, it is anticipated that the contractor would likely be able to limit the surface settlement to less than 10 mm by limiting the amount that the augers are advanced ahead of the liner. Typically, this limited amount of settlement is achieved by limiting the auger advancement ahead of the liner to about 5 mm.

8.1.4 Entry and Exit Pits

It is understood that the entry pit will have plan dimension of approximately 12 m x 3.6 m. The exit pit plan dimensions will be approximately 6 m x 9 m.

The pits will extend to a depth approximately 0.3 m below the invert of the Jack and Bore tunnel. This depth corresponds approximately to elevation 167.4 m at the south end of the alignment (based on the assumption that the Jack and Bore tunnel liner would have an obvert elevation of 168.75 m at that location). This translates to a depth of approximately 6 m below existing grade on the north side of the highway and 9.7 m below existing grade on the south side of the Highway.

Based on the depths noted above, shoring of the pits will be required. It is understood that the shoring design will be conducted by the Shoring Contractor who employs a Professional Engineer, licensed to practice in the Province of Ontario, and that signed and sealed drawings will be available prior to commencement of the jack and bore operations.

For design purposes, the groundwater elevation will be set at Elevation 151 m to 154 m.

The observed ground water level is below the anticipated tunnel invert and the anticipated access pit elevation. As indicated previously, the high water levels measured during or shortly after drilling suggests that perched groundwater conditions exist above and within the upper portion of the clayey silt till deposit which contains sand seams and interlayers. Control of surface flow and perched groundwater may require sump and pumps in the access pits.

8.2 RECOMMENDATIONS

The tender for the proposed utility plant relocation service installation should include the document titled “Pipe Installation by Trenchless Method, Non Standard Special Provision (NSSP)”, dated February 2009; a copy of this document is provided in Appendix F.

The NSSP includes the general requirements relating to the installation of pipes by trenchless methods including specifications for Jack and Bore and instrumentation monitoring.

The contractor should provide a complete submission consistent with the requirements of the NSSP.

9.0 Construction Considerations

9.1 UNWATERING

The underside of the proposed Jack and Bore tunnel is above the measured groundwater levels. Seasonal fluctuations or flows from perched water within granular seams are to be expected.

It should be practical to undertake any unwatering required in the entry and exit pits using conventional sump and pump techniques. Reference is given to OPSS 517 and OPSS 518 for further requirements in this respect.

Construction stage unwatering is expected to have a negligible impact on existing infrastructure, provided the existing infrastructure is founded on competent soils.

9.2 SITE PREPARATION

Given the existing conditions in the area of the site, clearing and grubbing should not be required as a component of site preparation activities.

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

9.3 CONSTRUCTION MONITORING

Typically, the most common type of distress for trenchless technology applications is settlement caused by loss of ground around the tunnel. Heave of the ground surface and or inadvertent drilling fluid returns are also possible depending on the type of installation. Distortions of this nature would be a serious safety concern and could lead to serviceability issues of the highway.

Distress at the ground surface is generally prevented or minimized by proper planning and good construction practices. The preparation of an installation plan that includes appropriate mitigation measures and contingencies is typically required for these applications. To lay the groundwork for the contractor to prepare a suitable installation plan, the following measures are set forth.

A condition survey of the pavement will be carried out prior to the commencement of construction and documented for the purpose of requirement of restoration, if necessary. A condition survey of each lane will be carried out by a geotechnical engineer with experience in pavement assessments and similar surveys. The condition survey will be completed during the installation of the In-ground monitoring points and on completion of the jack and bore installation. Interim surveys will be required should movement be detected in the in-ground monitoring points.

As indicated in Subsection 3.2, at the time of the geotechnical investigation, the drilling subcontractor installed six (6) in-ground settlement monitoring points as a component of the construction monitoring program.

A high precision surveyor will be engaged for the purposes of monitoring the in-ground and surface monitoring points during construction. The surveying will be undertaken using a Lieca TS30 total station with precision levels. This equipment can obtain reflectorless readings, eliminating the need to install surface settlement points on the travel lanes of the freeway. Instrument accuracy is in the 1 mm range, however; adverse weather conditions typically decrease the accuracy of the readings to a range of ± 1 mm to 1.5 mm in these conditions. Surface monitoring points will be identified and located at 5.0 m intervals along the tunnel alignment and with 5.0 m offsets to the right and left at each interval, consistent with the requirements of the NSSP.

Consistent with the requirements of the NSSP, the surveyor will complete the following:

- Three (3) sets of readings prior to construction to establish “base-line” data.
- One (1) set of readings during each day of construction presuming that movements remain within the anticipated limits. If movements are recorded, the frequency of monitoring will be adjusted consistent with the NSSP.
- Weekly after completion of the work for one month, or until a time when all parties agree that further movement has stopped.

The NSSP referenced above include specifics on: in-ground monitoring points; surface monitoring points; reading frequency; and criteria for assessment, and specify a maximum acceptable surface settlement (or heave) of 25 mm.

The baseline reading, alert level, and review level are described as follows:

- Baseline Reading – The baseline readings will be reviewed by the surveyor and Stantec to confirm consistency and reliability in the initial readings. The readings will be conveyed to all parties for the record, prior to commencement of the work.
- Review Level – A movement of 10 mm relative to the baseline readings will be established for this purpose. If this level is reached, the Contractor will be advised accordingly and changes to the installation method, rate/progress of installation, or sequence of construction, will be required for implementation to mitigate further ground displacement.
- Alert Level – A movement of 15 mm relative to the baseline readings will be established for this purpose. If this level is reached, the Contractor shall cease construction operations and execute pre-planned measures to secure the site, to mitigate further displacement, to assure public safety, and to maintain traffic flow on the Highway.

The reporting process for issue of the survey data will be as follows:

- If the surveyed displacement is below the Review Level, the data obtained will be forwarded within 24 hours of collection to MTO’s project contact, Stantec’s Project Engineer, the General Contractor’s Project Manager, and the earth boring Contractor’s Representative.
- If the surveyed displacement is above the Review Level, the General Contractor’s Project Manager and the earth boring Contractor’s Representative will be notified immediately to request an adjustment to the construction process (see comments provided above), and the survey data will be forwarded within 1 hour of collection to MTO’s project contact, Stantec’s Project Engineer, the General Contractor’s Project Manager, and the Earth Boring Contractor’s Representative.
- If the surveyed displacement is above the Alert Level, the General Contractor’s Project Manager and the earth boring Contractor’s Representative will be notified immediately to stop work and implement contingencies to mitigate any displacements and/or damages incurred. The survey data will be forwarded within 1 hour of collection to MTO’s project contact, Stantec’s Project Engineer, the General Contractor’s Project Manager, and the earth boring Contractor’s Representative, and a site meeting scheduled to review the data and the conditions observed to discuss the nature of the Alert Level, with a view to revising the construction approach and to coordinate the requirement for design and implementation of the remedial measures.

A data distribution list, identifying all parties with the appropriate contact information, will be established prior to commencement of the work.

9.4 EXCAVATION

Temporary excavations must be carried out in accordance with the latest edition of the Occupational Health and Safety Act (OHSA).

All fill materials encountered in this investigation should be classified as Type 3 soils. The maximum excavation side slope for a Type 3 soil is 1:1 (Horizontal: Vertical) in accordance with the OHSA regulation.

The stiff to hard clayey silt till can be classified as a Type 2 soil. The maximum excavation side slope for a Type 2 soil is 1:1 (Horizontal: Vertical) in accordance with the OHSA regulation, with a maximum vertical cut of 1.2 m at the base of the excavation, in accordance with the regulation.

In order to prevent overstressing of the shoring structure, the excavated spoil should be placed away from the edge of the pit at a distance equal to 2 times the depth of the pit. Due to space constraints at the Keele Street ramp (Ramp #3) to the eastbound collector, it is suggested the excavated spoil be removed. These soils must be stockpiled and appropriate chemical analysis be conducted to permit off-site removal to an approved facility.

9.5 SHORING REQUIREMENTS

It is understood that shoring will be used at the locations of the entry and exit pits.

The bracing system may be designed using a rectangular stress distribution shoring system in accordance with the methods described in the Canadian Foundation Engineering Manual (2006 Edition). The soil parameters estimated to be applicable for this design are provided below in Table 9-1.

Table 9.1: Soil Parameters

Material	K_o (at rest)	K_a (active)	K_p (passive)	c (cohesion)	ϕ (friction angle)	Unit Weight
Fill Materials	0.36	0.35	3.0	N/A	28	21 kN/m^3
Clayey Silt Till	0.44	0.28	3.5	5 kPa	34	22 kN/m^3

The design of the shoring and anchorage system should be carried out by a professional engineer specialized in shoring design. The design should consider load effects from the adjacent embankment, existing structures, and construction equipment.

Reference is given to OPSS 538 and OPSS 539 which pertains to excavation support and protection systems. Performance Level 2 should be specified for the bracing system.

Although boulders were not encountered in the boreholes during the field investigation, their presence should be anticipated within the native clayey silt till in addition to the presence of cobbles.

9.6 CEMENT TYPE AND CORROSION PROTECTION

Four samples of the native soil were submitted to Testmark Laboratories Ltd., in Garson, Ontario, for analysis of pH, water soluble sulphate and resistivity. The testing was carried out to determine the potential for degradation of the concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel used in foundations and buried infrastructure. The results are presented in Table 4.1.

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. The soluble sulphate results ranged from 74 to 81 µg/g. Soluble sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. Type GU Portland Cement should therefore be suitable for use in concrete at this site.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The soil pH was 7.6 which is within what is considered the normal range for soil pH of 5.5 to 9.0. The pH levels of the tested soil do not indicate a highly corrosive environment. The test results provided in Table 4.1 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

9.7 REMOVAL OF PROTECTION SYSTEMS

The protection systems should be removed from the right-of-way unless it is specified in the Contract Documents that they remain in place.

For the sheet piles at the receiving pit on the south side of Highway 401, it is understood with MTO Corridor Management approval, the sheet piles may be left in place, with the top being cut 1.5 m below the finished grade upon completion of work.

All disturbed areas should be restored to an equivalent or better condition than prior to the start of construction.

Reference is given to OPSS 538 and OPSS 539 which pertains to excavation support and protection systems.

10.0 Specifications

The following specifications should apply to the content of this report:

Table 10.1: Specifications Referenced in Report

Document	Title
NSSP	Pipe Installation by Trenchless Method, February 2009
OPSS 565	Construction Specification for the Protection of Trees
OPSS 539	Construction Specification for Temporary Protection System
OPSS 538	Construction Specification for Shoring and Bracing
OPSS 518	Construction Specifications for Control of water from Dewatering Operations
OPSS 517	Construction Specification for Dewatering of Pipeline, Utility and Associated Structure Excavation
OPSS 503	Construction Specification for Site Preparation for Pipelines, Utilities, and Associated Structures
OPSS 201	Construction Specification for Clearing, Close Cut Clearing, Grubbing, and Removal of Surface and Piled Boulders

11.0 References

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

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

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

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

CHBDC, 2006. Canadian Highway Bridge Design Code. Canadian Standards Association, Mississauga, Ontario.

Ministry of Labour. Occupational Health and Safety Act and Regulations for Construction Projects. Toronto, Ontario: Publications Ontario, 2002.

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

MTO LS-701: Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.

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

12.0 Closure

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

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

This report has been prepared by Eric Fron, Civ. Tech. with the assistance of John J. Brisbois, M.Sc.Eng., P.Eng., and Raymond Haché, M.Sc., P.Eng.

Respectfully submitted,

STANTEC CONSULTING LTD.

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APPENDIX A

Statement of General Conditions

STATEMENT OF GENERAL CONDITIONS

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

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

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

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

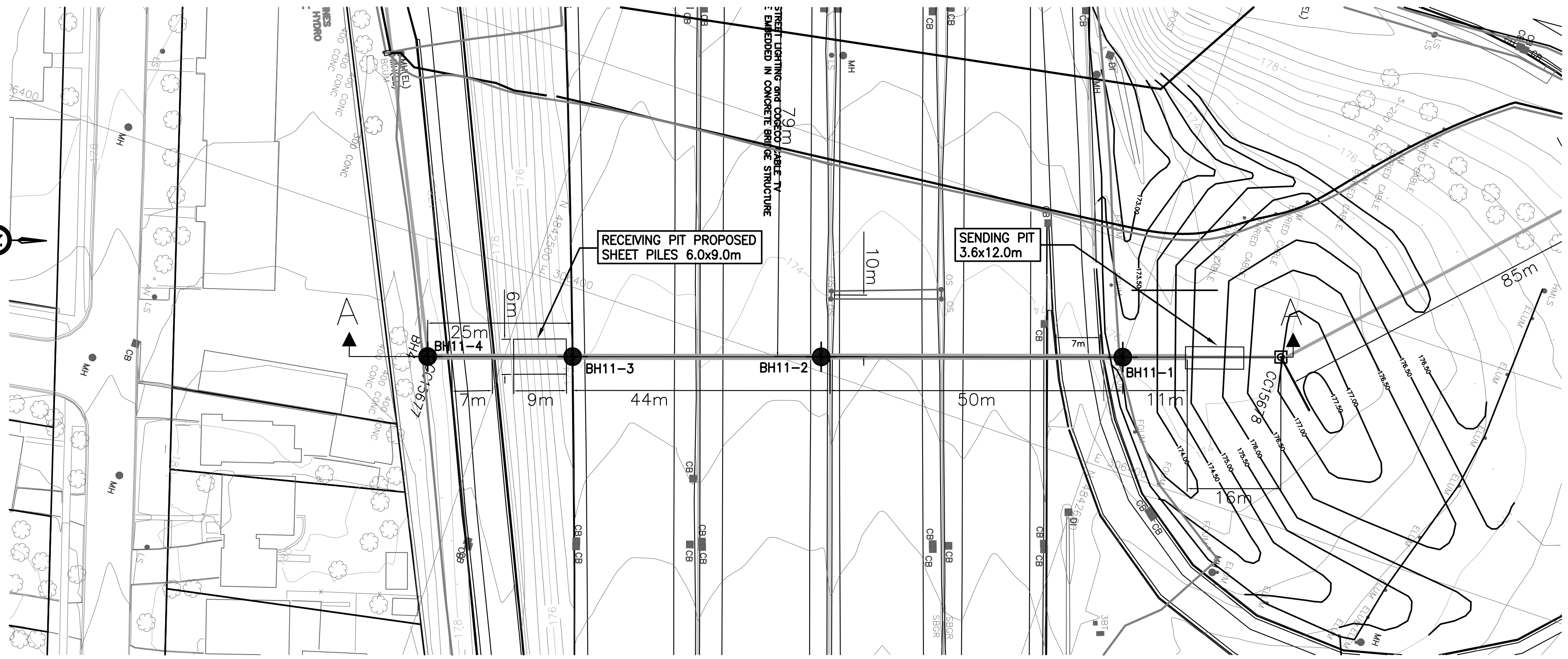
VARYING OR UNEXPECTED CONDITIONS: Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Stantec Consulting Ltd. must be notified immediately to assess if the varying or unexpected conditions are substantial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

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

APPENDIX B

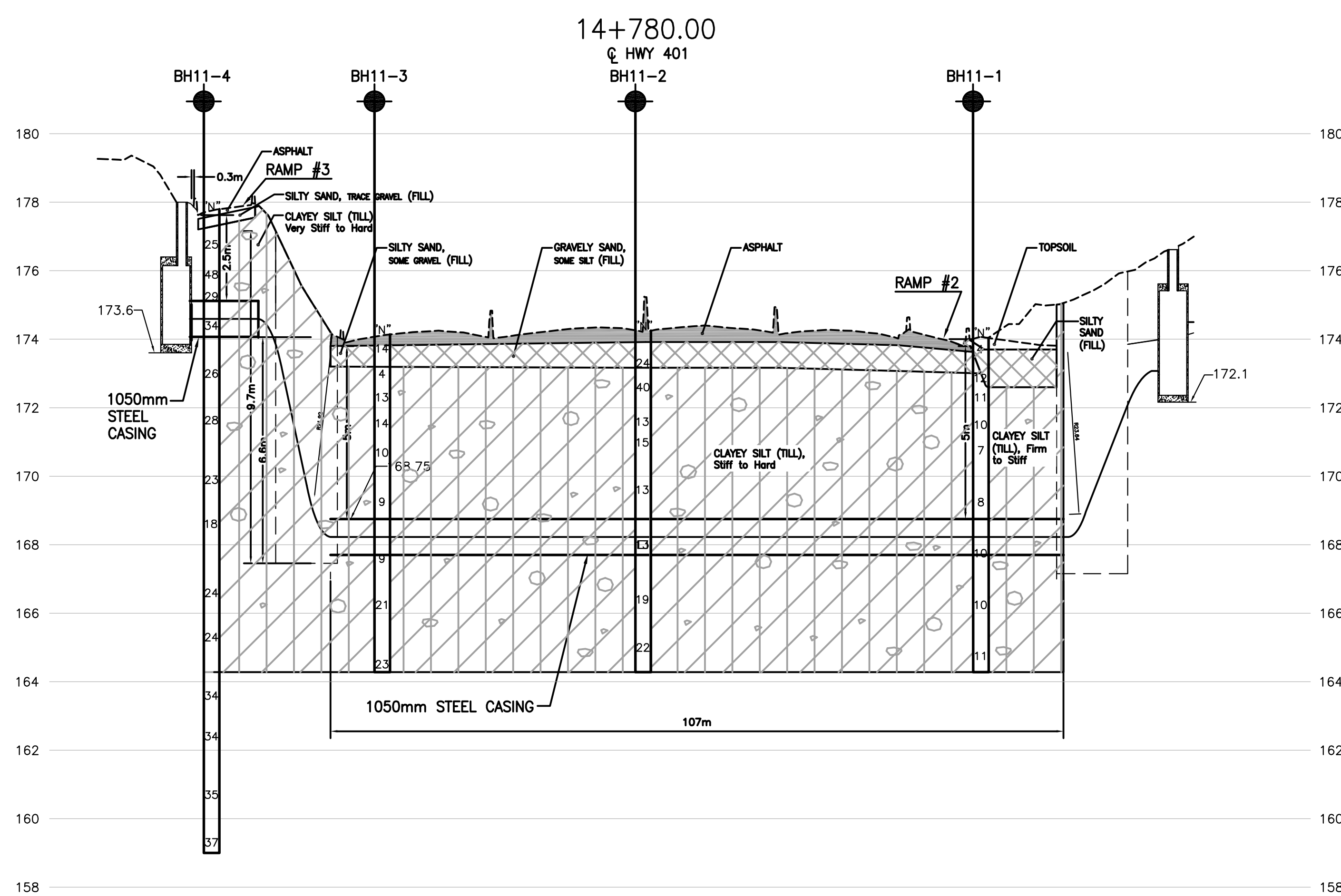
Drawing No. 1 – Borehole Location Plan and Soil Strata

Site Photos



PLAN

SCALE: 1:500



SECTION A–A ALONG PROPOSED TUNNEL ALIGNMENT

SCALE: VERT: 1:100 HORZ: 1:500

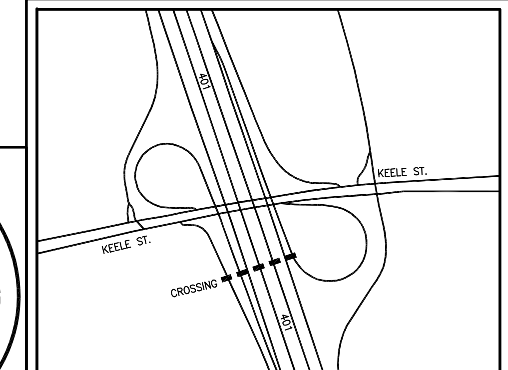
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

PLATE No
CONT
WP 2368–09–00

HIGHWAY 401 KEELE STREET BRIDGE – PHASE 2
REPLACEMENT PLANT RELOCATION, TORONTO, ONTARIO
BOREHOLE LOCATION PLAN AND SOIL STRATA

SHEET
1

Stantec



KEY PLAN
SCALE: N.T.S.

LEGEND

- Bore Hole
- N Blows/0.3m (Std Pen Test, 475 J/blow)

No	ELEVATION	MTM ZONE 10 COORDINATES NORTH	EAST
11–1	174.1	4 842 600.00	306 381.00
11–2	174.2	4 842 552.70	306 397.10
11–3	174.1	4 842 511.10	306 411.30
11–4	177.7	4 842 487.60	306 419.20

=NOTE=
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore holes the boundaries are assumed from geological evidence.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

REVISIONS	DATE	BY	DESCRIPTION

GEOCRES No

HWY No 401			DIST
SUBM'D	CHECKED	DATE 2011-12-20	SITE
DRAWN	CHECKED	APPROVED	DWG 1

DRAWING NAME:
CREATED BY:
MODIFIED:
T:\Autocad\Drawings\Project Drawings\2011\122410755\122410755_prp_rev Dec 20.dwg (Layout1) Printed: Dec 20, 2011

MINISTRY OF TRANSPORTATION, ONTARIO PH-D-707 88-05

Photo 1: Hwy 401 – Proposed Jack & Bore located approximately 10 m east of signboard over westbound express lanes (looking east from Keele Street overpass).

Photo 2: Highway 401 – eastbound collectors with Keele Street on-ramp at extreme right (looking east from Keele Street overpass).

Photo 3: Highway 401 – Keele Street on-ramp to westbound collectors (looking east from Keele Street overpass).

APPENDIX C

Symbols and Terms Used on Borehole Records and Test Pit Records

Borehole Records

SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

SOIL DESCRIPTION

Terminology describing common soil genesis:

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). The classification excludes particles larger than 76 mm (3 inches). 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 76 mm, visible organic matter, 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 N-Value (also known as N-Index). 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	Undrained Shear Strength	
	kips/sq.ft.	kPa
Very Soft	<0.25	<12.5
Soft	0.25 - 0.5	12.5 - 25
Firm	0.5 - 1.0	25 - 50
Stiff	1.0 - 2.0	50 – 100
Very Stiff	2.0 - 4.0	100 - 200
Hard	>4.0	>200

ROCK DESCRIPTION

Terminology describing rock quality:

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

Rock quality classification is based on a modified core recovery percentage (RQD) in which all pieces of sound core over 100 mm long are counted as recovery. The smaller pieces are considered to be due to close shearing, jointing, faulting, or weathering in the rock mass and are not counted. RQD was originally intended to be done on NW core; however, it can be used on different core sizes if the bulk of the fractures caused by drilling stresses are easily distinguishable from *in situ* fractures. The terminology describing rock mass quality based on RQD is subjective and is underlain by the presumption that sound strong rock is of higher engineering value than fractured weak rock.

Terminology describing rock mass:

Spacing (mm)	Joint Classification	Bedding, Laminations, Bands
> 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:

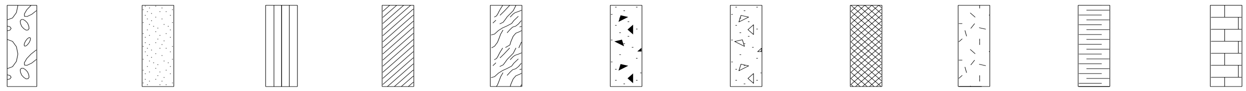
Strength Classification	Unconfined Compressive Strength (MPa)
Extremely Weak	< 1
Very Weak	1 – 5
Weak	5 – 25
Medium Strong	25 – 50
Strong	50 – 100
Very Strong	100 – 250
Extremely Strong	> 250

Terminology describing rock weathering:

Term	Description
Fresh	No visible signs of rock weathering. Slight discolouration along major discontinuities
Slightly Weathered	Discolouration indicates weathering of rock on discontinuity surfaces. All the rock material may be discoloured.
Moderately Weathered	Less than half the rock is decomposed and/or disintegrated into soil.
Highly Weathered	More than half the rock is decomposed and/or disintegrated into soil.
Completely Weathered	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.

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
WS	Wash 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 (64 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (305 mm) into the soil. 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 value 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 (305 mm) into the soil. The DCPT is used as a probe to assess soil variability.

OTHER TESTS

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

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

Stantec

BOREHOLE RECORD

BH11-1

W.P. 2368-09-00

PROJECT No. 122410755

LOCATION Highway 401, east of Keele Street, Toronto, ON, N: 4 842 600 E: 306 381

DATUM Geodetic

DATES: BORING November 13, 2011

WATER LEVEL

TPC ELEV.

DEPTH (m)	ELEVATION (m)	STRATA DESCRIPTION	DEPTH (ft)
0	174.1	400 mm TOPSOIL	0
0.4	173.7	FILL: silty sand, some gravel, some clay - brown	
1.5	172.6	Clayey silt (CL-ML), sandy, trace gravel, TILL - firm to stiff - grey - moist	
9.6	164.5	END OF BOREHOLE	

SAMPLE TYPE	NUMBER	RECOVERY (mm) TCR(%) / SCR(%)	N-VALUE OR RQD(%)	DEPTH (ft)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
SS	1	410/610	4	0–2	
SS	2	410/460	12	2.5–4.5	10 56 24 10
SS	3	410/460	11	5–7	
SS	4	460/460	10	7.5–9.5	
SS	5	410/460	7	10–12	
SS	6	460/460	8	15–17	
SS	7	460/460	10	20–22	
SS	8	460/460	10	25–27	4 26 47 22
SS	9	410/460	11	30–31.5	

UNDRAINED SHEAR STRENGTH (kPa): 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS: W_P W W_L

DYNAMIC CONE PENETRATION TEST, BLOWS/0.3m ▼

STANDARD PENETRATION TEST, BLOWS/0.3m ●

Scale: 10 20 30 40 50 60 70 80 90 100

□ Field Vane Test, kPa

■ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

BOREHOLE RECORD

Stantec

BH11-1 SHEET 2 of 2

W.P. 2368-09-00 PROJECT No. 122410755

LOCATION Highway 401, east of Keele Street, Toronto, ON, N: 4 842 600 E: 306 381 DATUM Geodetic

DATES: BORING November 13, 2011 WATER LEVEL TPC ELEV.

DEPTH (m)	ELEVATION (m)	STRATA DESCRIPTION	STRATA PLOT	WATER LEVEL	DEPTH (ft)	SAMPLES TYPE	NUMBER	RECOVERY (mm) TCR(%) / SCR(%)	N-VALUE OR RQD(%)	UNDRAINED SHEAR STRENGTH (kPa) 50 100 150 200	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
10	164.1	Borehole dry and open upon completion of drilling.			33–65						
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC CONE PENETRATION TEST, BLOWS/0.3m ▼

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90 100

□ Field Vane Test, kPa

■ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

BOREHOLE RECORD

Stantec — BH11-2 — SHEET 1 of 2

W.P. 2368-09-00 — PROJECT No. 122410755

LOCATION Highway 401, east of Keele Street, Toronto, ON, N: 4 842 553 E: 306 397 — DATUM Geodetic

DATES: BORING November 14, 2011 — WATER LEVEL — TPC ELEV.

DEPTH (m)	ELEVATION (m)	STRATA DESCRIPTION	DEPTH (ft)	TYPE	NUMBER	RECOVERY (mm) TCR(%) / SCR(%)	N-VALUE OR RQD(%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
0	174.2		0					
	173.9	320 mm ASPHALT						
		FILL: gravelly sand, some silt - brown	1	AS	1			29 58 13
1	173.1	Clayey silt (CL-ML), sandy, trace gravel, TILL - stiff to hard - grey - moist	3	SS	2	250/460	24	
			5–6	SS	3	250/460	40	
			8	SS	4	300/460	13	
			10–11	SS	5	460/460	15	
			15–16	SS	6	410/460	13	
			20–21	SS	7	410/460	13	
			25–26	SS	8	360/460	19	2 33 47 17
			30–31	SS	9	410/460	22	
	164.6	END OF BOREHOLE	32					
10								

UNDRAINED SHEAR STRENGTH (kPa): 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS (W_P, W, W_L)

DYNAMIC CONE PENETRATION TEST, BLOWS/0.3m ▼

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90 100

□ Field Vane Test, kPa

■ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

BOREHOLE RECORD

Stantec

BH11-2 SHEET 2 of 2

W.P. 2368-09-00 PROJECT No. 122410755

LOCATION Highway 401, east of Keele Street, Toronto, ON, N: 4 842 553 E: 306 397 DATUM Geodetic

DATES: BORING November 14, 2011 WATER LEVEL TPC ELEV.

DEPTH (m)	ELEVATION (m)	STRATA DESCRIPTION	STRATA PLOT	WATER LEVEL	DEPTH (ft)	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm) TCR(%) / SCR(%)	SAMPLES N-VALUE OR RQD(%)	UNDRAINED SHEAR STRENGTH (kPa) 50 100 150 200 / WATER CONTENT & ATTERBERG LIMITS Wp W WL / DYNAMIC CONE PENETRATION TEST, BLOWS/0.3m ▼ / STANDARD PENETRATION TEST, BLOWS/0.3m ● / 10 20 30 40 50 60 70 80 90 100	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
10	164.2	Borehole dry and open upon completion of drilling.			33–65						

□ Field Vane Test, kPa

■ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

Stantec — BOREHOLE RECORD

BH11-3 SHEET 1 of 2

W.P. 2368-09-00 | PROJECT No. 122410755

LOCATION Highway 401, east of Keele Street, Toronto, ON, N: 4 842 511 E: 306 411 | DATUM Geodetic

DATES: BORING November 13, 2011 | WATER LEVEL | TPC ELEV.

DEPTH (m)	ELEVATION (m)	STRATA DESCRIPTION
0	174.1	
0–0.6	173.5	FILL: silty sand, some gravel - brown
0.6–1.5	172.6	FILL: sandy silty clay, trace gravel - brown
1.5–9.6	164.5	Clayey silt (CL-ML), sandy, trace gravel, TILL - stiff to very stiff - grey - moist
9.6		END OF BOREHOLE

SAMPLES

DEPTH (ft)	TYPE	NUMBER	RECOVERY (mm) TCR(%) / SCR(%)	N-VALUE OR RQD(%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
0–2	SS	1	250/610	14	19 57 24
2.5–4.5	SS	2	100/460	4	8 28 47 17
5–6.5	SS	3	360/460	13	
7.5–9	SS	4	410/460	14	2 30 49 19
10–11.5	SS	5	360/460	10	
15–16.5	SS	6	460/460	9	
20–21.5	SS	7	410/460	9	
25–26.5	SS	8	460/460	21	
30–31.5	SS	9	460/460	23	

UNDRAINED SHEAR STRENGTH (kPa) 50 100 150 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC CONE PENETRATION TEST, BLOWS/0.3m ▼

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90 100

□ Field Vane Test, kPa

■ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

BOREHOLE RECORD

Stantec

BH11-3 SHEET 2 of 2

W.P. 2368-09-00 PROJECT No. 122410755

LOCATION Highway 401, east of Keele Street, Toronto, ON, N: 4 842 511 E: 306 411 DATUM Geodetic

DATES: BORING November 13, 2011 WATER LEVEL TPC ELEV.

DEPTH (m)	ELEVATION (m)	STRATA DESCRIPTION	STRATA PLOT	WATER LEVEL	DEPTH (ft)	SAMPLES TYPE	NUMBER	RECOVERY (mm) TCR(%) / SCR(%)	N-VALUE OR RQD(%)	UNDRAINED SHEAR STRENGTH (kPa)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
10	164.1	Borehole dry and open upon completion of drilling.			33						
11					36						
12					39						
13					43						
14					46						
15					49						
16					52						
17					56						
18					59						
19					62						
20					65						

UNDRAINED SHEAR STRENGTH (kPa): 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS: W_P W W_L

DYNAMIC CONE PENETRATION TEST, BLOWS/0.3m ▼

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90 100

□ Field Vane Test, kPa

■ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

BOREHOLE RECORD

BH11-4 SHEET 1 of 2

W.P. 2368-09-00 PROJECT No. 122410755

LOCATION Highway 401, east of Keele Street, Toronto, ON, N: 4 842 488 E: 306 419 DATUM Geodetic

DATES: BORING November 14, 2011 WATER LEVEL TPC ELEV.

DEPTH (m)	ELEVATION (m)	STRATA DESCRIPTION	DEPTH (ft)	TYPE	NUMBER	RECOVERY (mm) TCR(%) / SCR(%)	N-VALUE OR RQD(%)	Water content / SPT (approx.)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
0	177.7		0						
	177.6	140 mm ASPHALT							
	177.2	FILL: silty sand, trace gravel, brown, moist	1–2	AS	1				8 62 30
1		Clayey silt (CL-ML), sandy, trace gravel, TILL - very stiff to hard - brown to grey - moist	3	SS	2	250/460	25		
2			5–6	SS	3	360/460	48		
			8	SS	4	410/460	29		2 30 50 18
3			10–11	SS	5	410/460	34		
5			15–16	SS	6	410/460	26		4 30 47 19
6			20–21	SS	7	410/460	28		
8			25–26	SS	8	250/460	23		
9			30–31	SS	9	360/460	18		
10			32						

UNDRAINED SHEAR STRENGTH (kPa): 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS (W_P, W, W_L)

DYNAMIC CONE PENETRATION TEST, BLOWS/0.3m ▼

STANDARD PENETRATION TEST, BLOWS/0.3m ●

Scale: 10 20 30 40 50 60 70 80 90 100

□ Field Vane Test, kPa

■ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

BOREHOLE RECORD

Stantec

BH11-4

W.P. 2368-09-00 PROJECT No. 122410755

LOCATION Highway 401, east of Keele Street, Toronto, ON, N: 4 842 488 E: 306 419 DATUM Geodetic

DATES: BORING November 14, 2011 WATER LEVEL TPC ELEV.

UNDRAINED SHEAR STRENGTH (kPa): 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS (W_P, W, W_L)

DYNAMIC CONE PENETRATION TEST, BLOWS/0.3m ▼

STANDARD PENETRATION TEST, BLOWS/0.3m ●

DEPTH (m)	ELEVATION (m)	STRATA DESCRIPTION	DEPTH (ft)	TYPE	NUMBER	RECOVERY (mm) TCR(%) / SCR(%)	N-VALUE OR RQD(%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
10	167.7	Clayey silt (CL-ML), sandy, trace gravel, TILL - very stiff to hard - grey - moist	33					
11			36	SS	10	410/460	24	
12			41	SS	11	360/460	24	
14			46	SS	12	410/460	34	
15			51	SS	13	410/460	34	
17			56	SS	14	150/460	35	
18.7	159.0		61	SS	15	460/460	37	
19		END OF BOREHOLE Borehole dry and open upon completion of drilling.	62–65					
20								

□ Field Vane Test, kPa

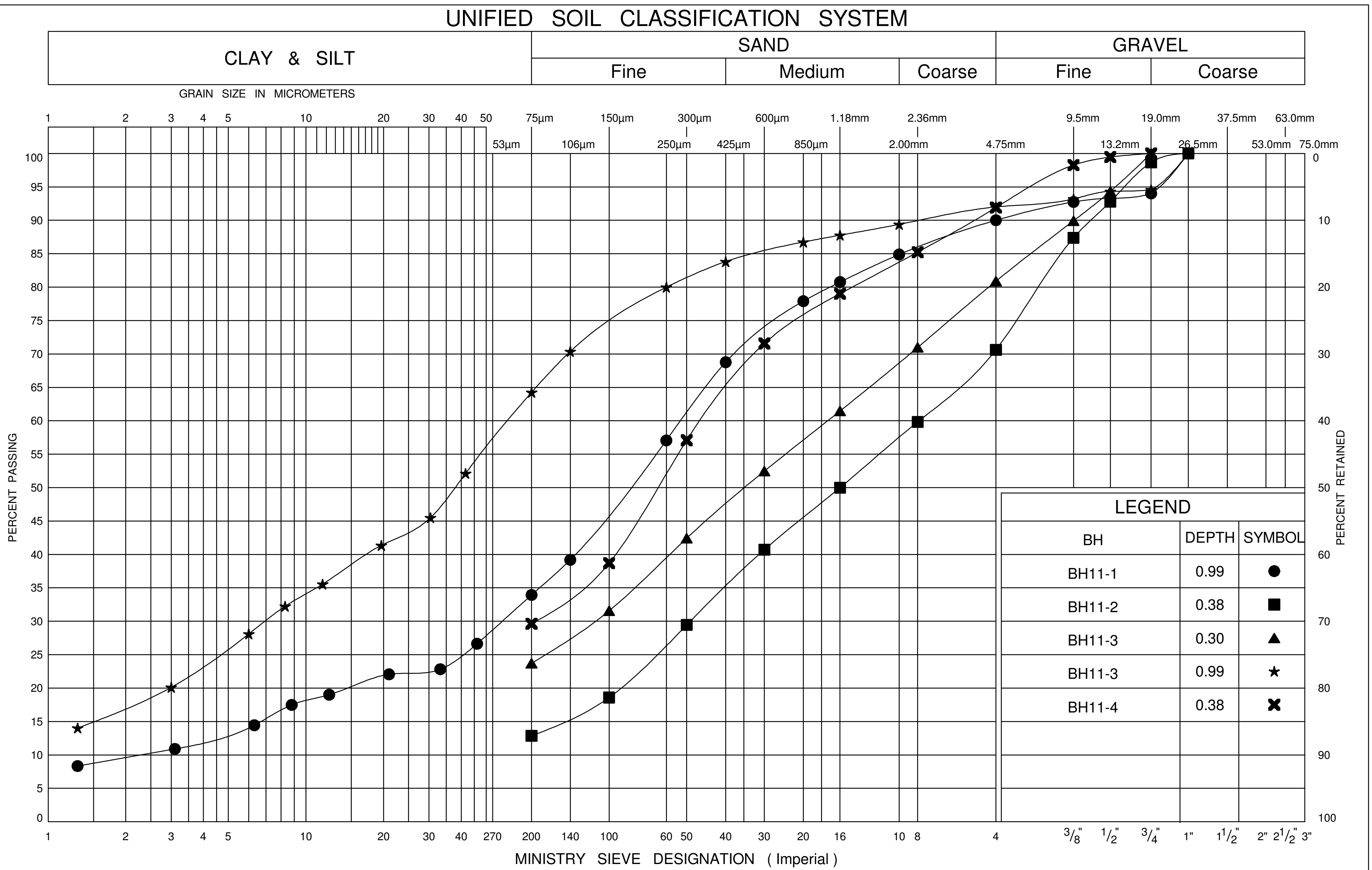
■ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

APPENDIX D

Laboratory Test Results

78 12 M



Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

FILL: silty sand, trace gravel

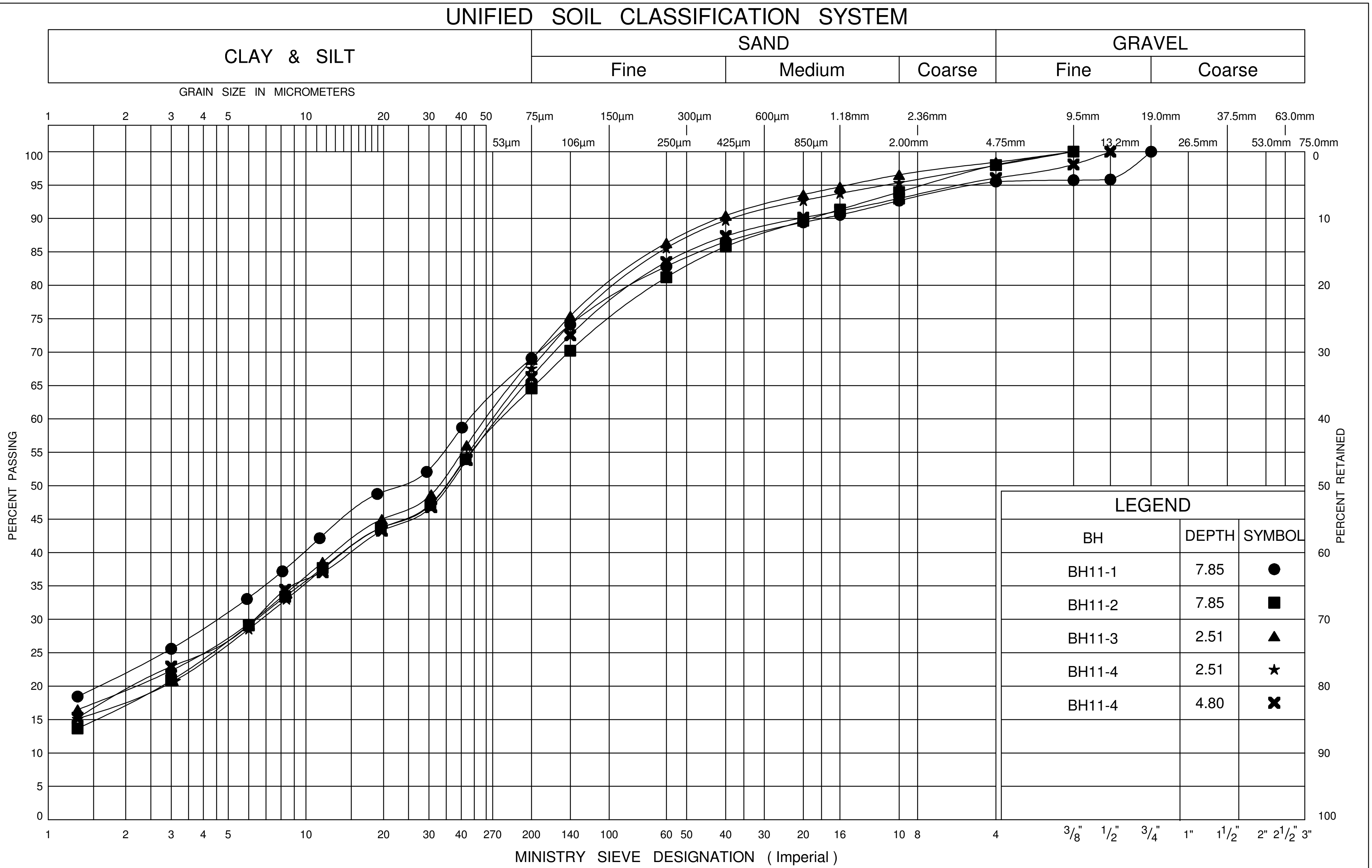
FIG No 1

W P 2368-09-00

Underground Utility Conduits

ONTARIO MOT GRAIN SIZE 122410755.GPJ ONTARIO MOT.GDT 12/20/11

78 12 M



Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

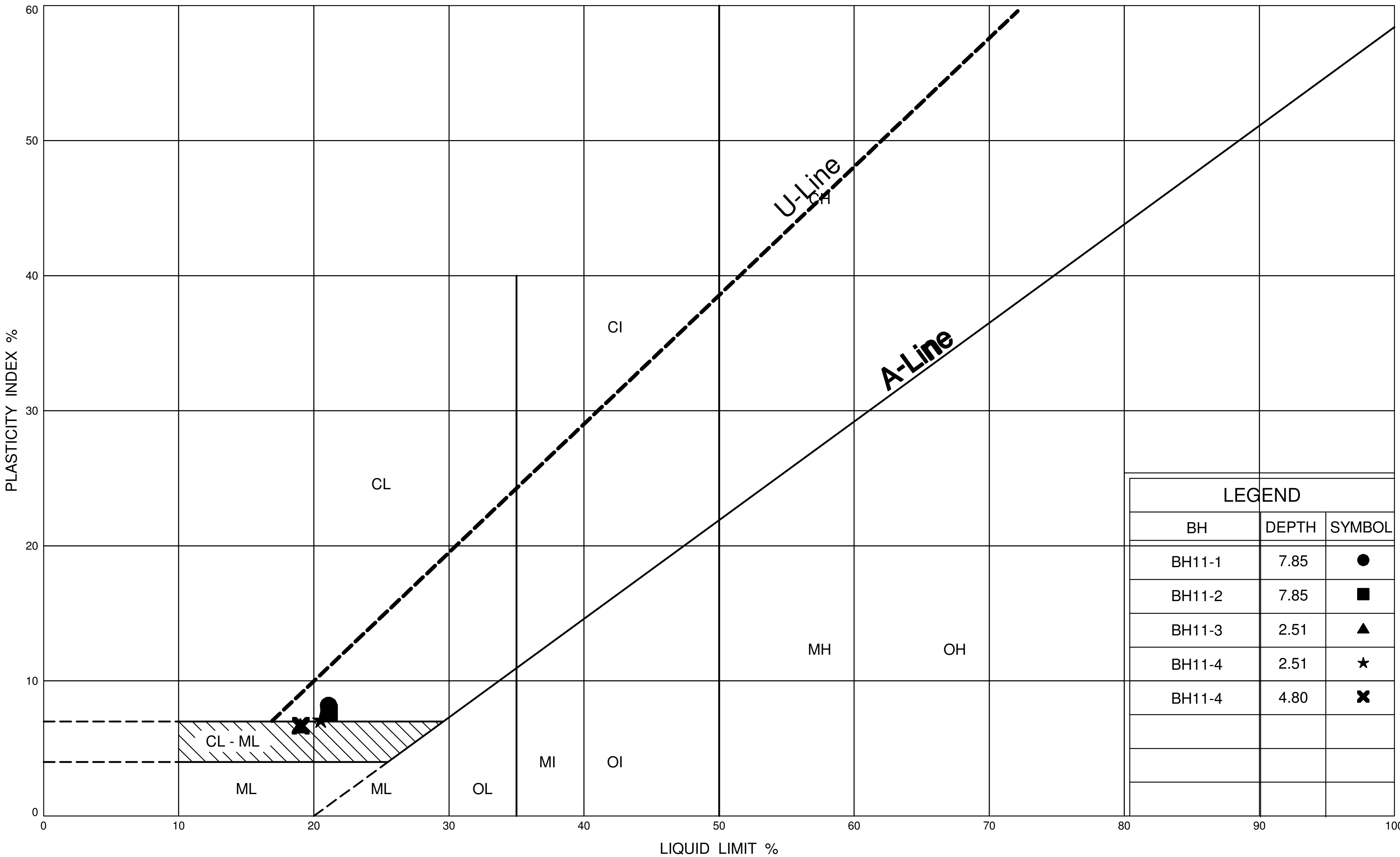
Clayey SILT, sandy, trace gravel TILL

FIG No 2

W P 2368-09-00

Underground Utility Conduits

Oct 75, FF - S - 21



LEGEND

BH	DEPTH	SYMBOL
BH11-1	7.85	●
BH11-2	7.85	■
BH11-3	2.51	▲
BH11-4	2.51	★
BH11-4	4.80	✖

Ministry of Transportation
Ontario

PLASTICITY CHART

Clayey SILT, sandy, trace gravel TILL

FIG No 3

W P 2368-09-00

Underground Utility Conduits

ONTARIO MOT PLASTICITY CHART 122410755.GPJ ONTARIO MOT.GDT 12/20/11

APPENDIX E

National Building Code Seismic Hazard Calculation

2010 National Building Code Seismic Hazard Calculation

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

Requested by: Shae Warren, Stantec Consulting Ltd. December 12, 2011

Site Coordinates: 43.7227 North 79.4806 West

User File Reference: Highway 401 Keele Street Overpass, Toronto, ON.

National Building Code ground motions:
2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.2)	Sa(0.5)	Sa(1.0)	Sa(2.0)	PGA (g)
0.205	**0.118**	**0.066**	**0.021**	**0.095**

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

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.2)	0.027	0.081	0.132
Sa(0.5)	0.016	0.047	0.073
Sa(1.0)	0.008	0.027	0.043
Sa(2.0)	0.003	0.009	0.014
PGA	0.009	0.033	0.053

References

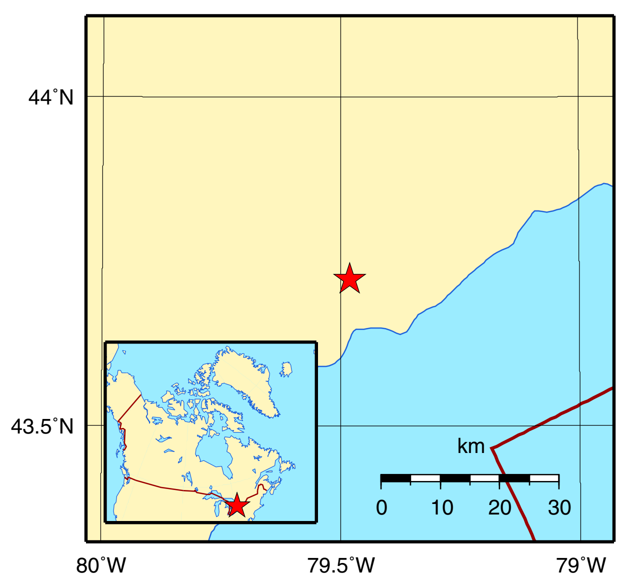
National Building Code of Canada 2010 NRCC no. 53301; sections 4.1.8, 9.20.1.2, 9.23.10.2, 9.31.6.2, and 6.2.1.3
Appendix C: Climatic Information for Building Design in Canada - table in Appendix C starting on page C-11 of Division B, volume 2

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

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

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

Aussi disponible en français



APPENDIX F

NSSP, February 2009 – Pipe Installation by Trenchless Method

PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Non Standard Special Provision February 2009

1. SCOPE

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

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

OPSS 415 (Construction Specification for Pipeline and Utility Installation by Tunnelling), OPSS 416 (Construction Specification for Pipeline and Utility Installation by Jacking and Boring) and OPSS 450 (Construction Specification for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling) shall not be used to do the work for the above tender item.

2. REFERENCES

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

Foundation Investigation Report - identify and reference appropriate reports.

Highway 401 Crossing
Keele Street Bridge Replacement
Forced Relocation to Station 14+633
City of Toronto
Stantec Project No. 122410755
March 2012

Ontario Provincial Standard Specifications, General

OPSS 180	Management and Disposal of Excess Material

Ontario Provincial Standard Specifications, Construction

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

Ontario Provincial Standard Specifications, Material

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

MTO Specifications

OPSS 1820	Material Specification for Circular Concrete Pipe
OPSS 1840	Material Specification for Non-Pressure Polyethylene Plastic Pipe Products

American Society for Testing and Materials (ASTM) International Standards

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

Canadian Standards Association Standards:

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

3. DEFINITIONS

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

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

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

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

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

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

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

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

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

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

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

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

Grouting: injection of grout into voids.

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

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

HDPE: high density polyethylene.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4. DESIGN AND SUBMISSION REQUIREMENTS

4.01 General

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

4.02 Working Drawings

Three copies of stamped working drawings for portal or shaft construction, primary liner, excavation, secondary lining, dewatering and groundwater control and grouting shall be submitted to the Contract Administrator (CA) at least one (1) week prior to the commencement of the work for information purposes. All submissions shall bear the seal and signature of the Design Engineer and Design Checking Engineer. The Contractor shall have a copy of the stamped working drawings at the site during construction.

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

a) Plans, Elevations and Details:

- A work plan outlining the materials, procedures, methods and schedule to be used to execute the work;
- A list of personnel, including backup personnel, and their qualifications and experience;
- A safety plan including the company safety manual and emergency procedures;
- The work area layout;
- An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail;

- A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan detailing emergency procedures in the event that the fluid management plan fails;
- Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations; and
- Excavated materials disposal plan.

b) Design Criteria:

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

c) Materials:

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

d) Upstream/Downstream Portal Installation Procedure:

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

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

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

f) Excavation and Dewatering:

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

g) Monitoring Method

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

4.03 Site Survey

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

4.04 Certificate of Conformance

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

The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer upon completion of each of the following operations and prior to commencement of each subsequent operation for each pipe installation:

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

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

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

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

5. MATERIALS

5.01 Product

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

5.02 Concrete

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

5.03 Concrete Reinforcement

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

5.04 Timber

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

5.05 Grout

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

5.06 Jack & Bore Materials

5.06.01 Pipe Materials

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

Concrete pipe as per OPSS 1820.

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

5.07 Pipe Ramming Materials

5.07.01 Pipe Materials

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

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

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

Pipe wall thickness shall be determined by the Contractor based on static and dynamic loads from traffic loading and anticipated ramming forces for selected pipe and driven pipe lengths. The wall thickness shall be increased as required to ensure the casing is not damaged during handling and installation. A minimum wall thickness of 50 mm and minimum yield strength of 240 MPa is required.

Pipe segments shall be determined by the Contractor.

Steel pipe joints shall be pressure fit type or welded.

All steel casing pipe shall be square cut.

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

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

5.07.02 Mill Certificates

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

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

5.08 Directional Drilling Materials

5.08.01 Drilling Fluids

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

5.08.02 Pipe Materials

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

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

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

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

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

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

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

5.09 Tunnelling Materials

5.09.01 Primary Liner

Tunnelling methods will require installation of a primary liner to provide support and stability to the excavation.

5.09.02 Secondary Liner

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

5.09.02.01 Concrete Pipe

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

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

5.09.02.02 High Density Polyethylene (HDPE)

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

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

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

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

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

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

6. EQUIPMENT

6.01 Jack & Bore Equipment

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

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

6.02 Pipe Ramming Equipment

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

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

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

6.03 Directional Drilling Equipment

6.03.01 General

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

6.03.02 Drilling Rig

The directional drilling rig shall:

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

6.03.03 Drill Head

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

6.03.04 Guidance System

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

6.03.05 Drilling Fluid Mixing System

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

6.03.06 Drilling Fluid Delivery System

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

6.04 Tunnelling Equipment

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

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

7. CONSTRUCTION

7.01 General

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

7.01.01 Layout, Alignment and Depth Control

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

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

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

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

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

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

7.01.02 Shafts

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

Shafts shall be maintained in a drained condition.

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

7.01.03 Protection Systems

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

7.01.04 Settlement or Heave

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

7.01.05 Stability of Excavation

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

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

7.01.06 Preservation and Protection of Existing Facilities

Preservation and protection of existing facilities shall be according to OPSS 504.

Existing underground facilities shall be exposed to verify its horizontal and vertical locations when the outlet pipe path comes within 1.0 m horizontally or vertically of the existing facility. Existing facilities shall be exposed by non-destructive methods.

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer’s handling and storage recommendations shall be followed.

7.01.08 Trenching, Backfilling and Compacting

Trenching, backfilling, and compacting for entry and exit points or other locations along the pipe path shall be according to OPSS 514.

7.01.09 Dewatering

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

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

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

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

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

Dewatering shall be according to OPSS 517.

7.01.10 Removal of Boulders

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

7.01.11 Record Keeping

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

7.01.12 Testing

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

7.01.13 Management and Disposal of Excess Material

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

7.01.14 Site Restoration

Site restoration shall be according to OPSS 507.

7.01.15 Supervision

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

7.02 Jack & Bore Installation

7.02.01 Method of Installation Procedure

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

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

7.02.02 Pipe Installation

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

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

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

7.03 Pipe Ramming Installation

For pipe ramming installation the following requirements apply:

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

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

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

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

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

7.04 Directional Drilling Installation

7.04.01 General

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

7.04.02 Site Preparation

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

7.04.03 Pilot Bore

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

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

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

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

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

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

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

7.04.04 Drilling Fluid Fracture (Frac-Out)

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

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

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

7.04.05 Reaming

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

7.04.06 Product Installation

7.04.06.01 General

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

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

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

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

7.04.06.02 Pullback and Grouting

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

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

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

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

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

7. 05 Tunnelling Installation

7.05.01 General

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

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

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

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

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

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

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

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

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

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

7.05.01 Tunnelling Method

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

7.05.02 Primary Liner (Support System)

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

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

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

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

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

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

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

7.05.03 Secondary Liner

7.05.03.01 Placing of Grout

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

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

7.06 Instrumentation Monitoring

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

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

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

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

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

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

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

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

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

7.07 Criteria for Assessment of Roadway Subsidence/Heave

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

- Review Level: If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate of sequence of construction or ground stabilization measures to mitigate further ground displacement.

  If the Review Level is exceeded, the Contractor shall immediately notify the CA and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.

- Alert Level: If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic.

  No construction shall take place until all the following conditions are satisfied:

  - The cause of the settlement has been identified.
  - The Contractor submits a corrective/preventive plan.
  - Any corrective and/or preventive measure deemed necessary by the Contractor is implemented.
  - The CA deems it is safe to proceed.

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

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

9. MEASUREMENT FOR PAYMENT

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

10. BASIS OF PAYMENT

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

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

Where a protection system is made necessary because of the Contractor’s operations (e.g. choice of trenchless installation method), the cost shall be included in this item and shall be full compensation for all labour, equipment and materials required to carry out the work including subsequently removing the temporary protection system and performing any necessary restoration work.

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

(a) Where such drains and service connections are shown on the contract drawings the cost of connections shall be included in the contract price for pipe installation.

(b) Where such drains and service connections are not shown on the contract drawings, the cost of connections will be considered an allowable extra to the contract.

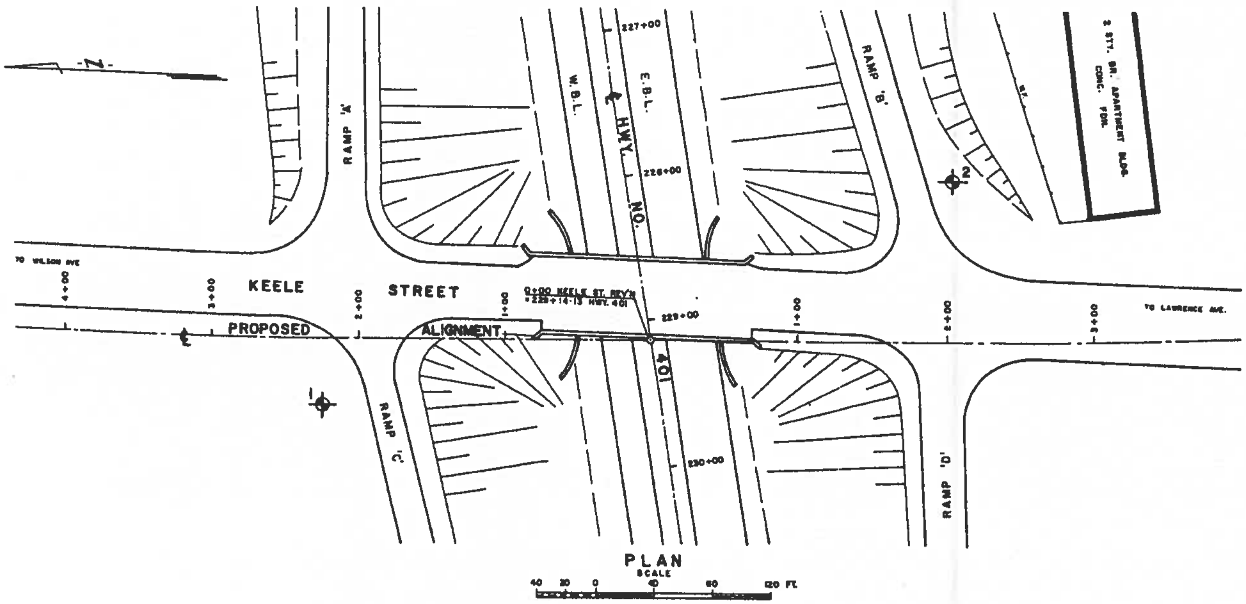
Payment for removal of boulders/obstructions greater than an equivalent 0.3 m in diameter shall be on a time and materials basis. The Contractor shall inform the Contract Administrator when boulders/obstructions are encountered and prior to removal to allow for proper and accurate tracking of time and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

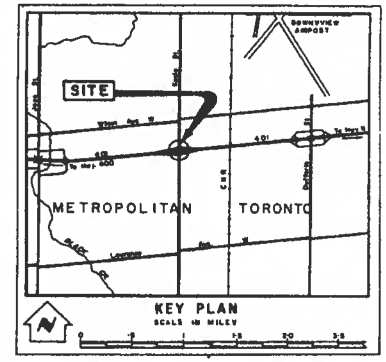
Notes to Designer:

- *Under Section 7.01.06, minimum horizontal and vertical clearances to existing facilities shall be identified in the Contract Documents. Clearances shall be measured from the nearest edge of the largest cut diameter required to the nearest edge of the facility being paralleled or crossed. The number of exposures required to monitor work progress shall be specified in the Contract Documents.*

APPENDIX G

(MTO) 1963 Record of Boreholes for Keele Street Bridge





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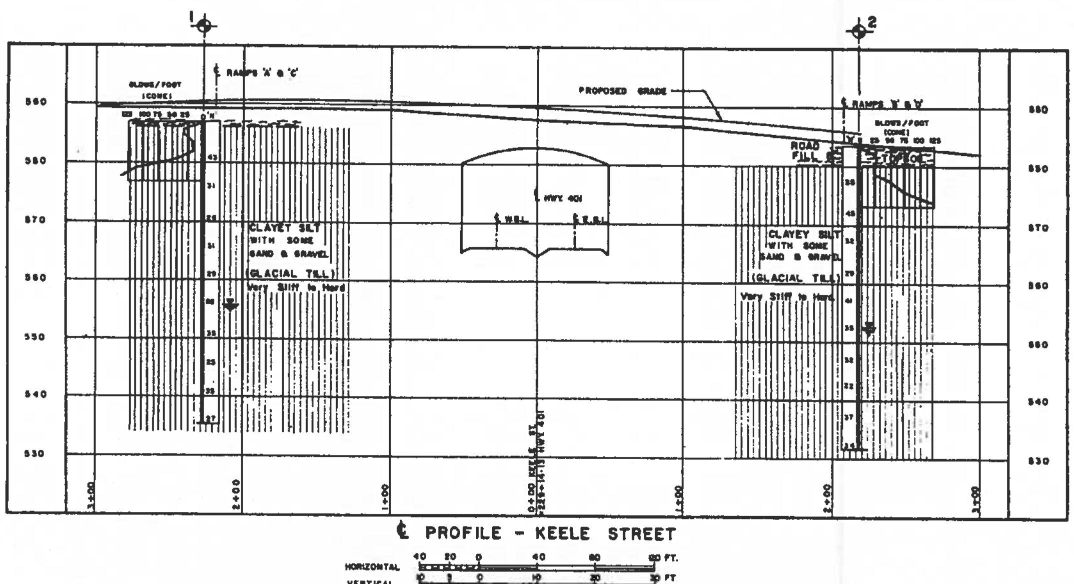
LEGEND

- Bore Hole
- Cone Penetration Hole
- Bore & Cone Penetration Hole
- Water Levels established at time of field investigation. Aug. 14, 1963.

NO.	ELEVATION	STATION HWY. NO. 401	OFFSET
1	566·7	228+23	227'RT.
2	563·3	228+40	219'LT.



℄ PROFILE - KEELE STREET

SECOND PRINTING OCT. 1964

- NOTE -

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence and may be subject to considerable error.

REVISIONS — DATE | BY | DESCRIPTION

CAZALY ASSOCIATES

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & RESEARCH DIVISION - FOUNDATION SECTION

KEELE STREET

KING'S HIGHWAY NO. 401 DIST NO. 6

CO. METROPOLITAN TORONTO

TWP. NORTH YORK LOT CON.

BORE HOLE LOCATIONS & SOIL STRATA

SUBM'D B.G.	CHECKED	WP NO 231-60	M&R DRAWING NO 63-F-87A
DRAWN	CHECKED	JOB NO 63-F-87	
DATE AUG. 22, 1963		SITE NO	BRIDGE DRAWING Nº
APPROVED		CONT NO	D 52