



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
TRENCHLESS UTILITY CROSSING OF HIGHWAY 401 EBL AND WBL
AT PITT STREET, CORNWALL, ON
GWP. 4003-14-00
AGREEMENT NUMBER: 4014-E-0014**

GEOCRES NUMBER: 31G-264

SUBMITTED TO

WSP CANADA

LOCATION:

**LATITUDE: 45.05184°
LONGITUDE: -74.75500°**

**APRIL 2018
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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) for the trenchless utility crossing of Highway 401 immediately east of the Pitt Street overpass structures, located within the City of Cornwall, Ontario. Thurber carried out the investigation as a subconsultant to WSP Canada (WSP), under Agreement No. 4014-E-0014.

Utility drawings and base plan mapping were provided by WSP for the preparation of this report.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on this data, provide a borehole location plan, record of boreholes, a stratigraphic profile, laboratory test results and a written description of the subsurface conditions.

2 SITE DESCRIPTION

The Highway 401 overpass structures of Pitt Street (Sites 31-211/1 and 31-211/2) are located approximately 1.4 km east of the Brookdale Avenue (Highway 138) / Highway 401 Interchange in Cornwall, Ontario. The location of the structures and the area of the proposed utility alignment are shown on the inset Key Plan on Drawing No. 1 in Appendix A.

It is noted that for project orientation purposes, Highway 401 will be assumed to be oriented east-west and Pitt Street is assumed to be oriented north-south.

Based on the utility drawings provided, the proposed utility crossing is to be located approximately 30 m east of the centreline of Pitt Street, beyond the existing east abutments for the Highway 401 / Pitt Street overpass structures. The alignment is shown as parallel to Pitt Street (north-south).

At the proposed crossing, Highway 401 is supported on highway fill embankments. The eastbound and westbound lanes are separated by a grassy median ditch. There are steel beam guide rails present along the median and concrete barriers/noise walls on the outside lanes of the highway in both directions.

The existing approach embankments are up to approximately 6.0 m high with side slopes at approximately 2H:1V. The embankment slopes are vegetated with long grasses, and occasional shrubs. The areas beyond the existing embankment footprint at the location of the entry/exit pits and construction staging areas are generally flat and grass covered. There are buried utilities that run parallel to Highway 401 along the MTO right-of-way both north and south, in the general area of the proposed site works.

The site is located within a physiographic region known as the Glengarry till plain which is characterized as lowlands in which the surface is undulating to rolling, consisting of long morainic ridges and a few well-formed drumlins. The till deposit of sand and gravel till is very stony, and contains large near surface boulders.

Storm water drainage in the area is to existing catchbasins and storm sewers.

Site photographs showing the general conditions at the site are presented in Appendix E.

3 SITE INVESTIGATION

3.1 Previous Investigations

Existing Bridge Investigation

A GEOCREST report is available for this bridge site (Report 31G00-128, 1955). This investigation was carried out for the design and construction of the current Pitt Street overpass structures and included three boreholes. A copy of the borehole location plan and the Record of Boreholes from the historical investigation are provided in Appendix C.

The stratigraphy in the area of the bridges is generally characterized as a dense to very dense sandy glacial till with frequent cobbles and boulders. The boreholes were terminated within stoney till material and bedrock was not encountered during the 1955 geotechnical investigation.

2017 Detailed Design Investigation for Bridge Replacement

A foundation investigation was carried out as part of the detailed design assignment for the replacement of the existing overpass structures. During this investigation Boreholes 17-12 and 17-14 were advanced approximately 30 m east of the centerline of Pitt Street in the vicinity of the proposed crossing location for the design of new noise barrier walls. The approximate location of Boreholes 17-12 and 17-14 are illustrated on Drawing No. 1 in Appendix A, and copies of the Record of Boreholes are provided in Appendix B.

It should be noted that Boreholes 17-12 and 17-14 do not meet the MTO design criteria requirement for trenchless crossings that all boreholes be advanced a minimum depth of three times the pipe diameter below the proposed pipe invert elevation and further investigation was warranted.

The soil stratigraphy encountered in Boreholes 17-12 and 17-14 is generally characterized as very loose to very dense embankment fill overlying compact to very dense glacial till. Frequent cobbles and boulders were noted in both the fill and till materials.

3.2 Field Investigation

The field investigation plan was finalized after discussion with the MTO Foundations Section. The field investigation for this site included advancing three boreholes between December 13 and December 19, 2017. The approximate locations and elevations of the boreholes from the current investigation and for Boreholes 17-12 and 17-14 from the adjacent bridge investigation are shown on Drawing No. 1 provided in Appendix A and are summarized in Table 3-1.

Table 3-1: Borehole Summary

Borehole	Location	Latitude (degrees)	Longitude (degrees)	Ground Surface Elevation (m)	Depth (m)
17-101	Exit pit	45.05153	-74.75477	65.0	6.7
17-102	Highway 401 median	45.05184	-74.75500	68.6	9.8
17-103	Entry pit	45.05218	-74.75526	65.0	6.7
17-12	WBL East noise wall	45.05199	-74.75512	68.9	6.4
17-14	EBL East noise wall	45.05164	-74.75485	68.4	6.7

As a component of our standard procedures and due diligence, Thurber contacted Ontario One Call to obtain utility locates/clearances for the intended borehole locations.

The boreholes were advanced with a CME track mounted drill rig equipped with hollow stem augers and NW casing equipment. The subsurface stratigraphy encountered in the boreholes was recorded in the field by Thurber personnel. Split spoon samples were collected at regular depth intervals in the boreholes during the completion of Standard Penetration Tests (SPT), following the methods described in ASTM Standard D1586-11. All soil samples recovered from the boreholes were placed in moisture-proof containers and the samples were transported to Thurber's Ottawa geotechnical laboratory for further examination and testing.

Vibrating wire piezometers were installed, in Boreholes 17-101 through 17-103 to allow for measurement of the groundwater level at the site. The vibrating wire piezometer construction details are detailed on the Record of Borehole sheets provided in Appendix B.

The as-drilled locations of the boreholes and ground surface elevations at the borehole locations were surveyed by WSP relative to the geodetic benchmark (GBM) identified on the plans provided by WSP, located on the southwest wall of the eastbound bridge abutment. The GBM has a geodetic elevation of 68.295 m. The location of the GBM is indicated on Drawing No. 1 in Appendix A.

3.3 Laboratory Testing

Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all soil samples in accordance with the current MTO standards. Grain size distribution analyses and Atterberg Limits testing were carried out on selected samples to MTO and ASTM standards.

The geotechnical laboratory test results are presented on the Record of Borehole sheets in Appendix B and are illustrated on the figures in Appendix D.

Chemical analysis for determination of pH, resistivity, soluble sulphate and chloride concentrations was carried out on three soil samples. Samples were selected to coincide with the proposed invert elevation of the utility crossing. A copy of the chemical analysis results is provided in Appendix D.

4 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 Overview / General

Reference is made to the Record of Borehole sheets in Appendix B for details of the soil stratigraphy encountered in the boreholes. Stratigraphic profiles for the site are presented on Drawing No 1 in Appendix A for illustrative purposes. An overall description of the stratigraphy is given in the following paragraphs; however, the factual data presented in the Record of Boreholes governs any interpretation of the site conditions.

In general, the stratigraphy in the area of the boreholes is characterized by granular fill overlying glacial till, both containing occasional to frequent cobbles and boulders. This stratigraphy is generally consistent with the stratigraphy encountered in the previous investigations.

More detailed descriptions of the individual strata are presented below.

4.2 Topsoil

A layer of topsoil was encountered at the ground surface in Boreholes 17-12 and 17-14. The thickness of this layer ranged from 50 mm to 60 mm at the borehole locations.

4.3 Fill – Silty Clayey Sand to Silty Gravel with Sand

In all boreholes, embankment fill consisting predominantly of brown to grey silty clayey sand to silty gravel with sand was encountered at surface or below any surficial layers. Occasional cobbles and boulders were noted in all boreholes. Trace organics was noted in the fill near the ground surface. The elevation of the top of this layer was Elevation 65.0 m (entry/exit boreholes) and 68.6 m (median borehole). The thickness of this layer ranges from 1.5 m to 4.7 m in Borehole 17-102. The SPT 'N' values ranged from 2 to greater than 100 indicating a very loose to very dense condition, but typically compact to dense.

The moisture content of the samples tested ranged from 9% to 38%. The results of grain size analysis completed on samples of this material indicated a gravel content of 11% to 41%, sand content of 36% to 42%, and fines content (combined silt and clay size particles) of 21% to 49%. The results of the grain size analysis are illustrated on Figure 1 in Appendix D.

The results of Atterberg Limits testing completed on samples of the fines of this material indicated a plastic limit of 18 and 21, a liquid limit of 13, and a plasticity index of 5 and 8, indicating a fines ranging from low plastic to non-plastic. Atterberg Limits analysis results are illustrated on Figure 2 in Appendix D.

4.4 Glacial Till – Sandy Silt (ML) some Gravel to Silty Sand (SM) with Gravel

A stratum of glacial till consisting predominantly of sand and silt with varying amounts of gravel was encountered beneath the fill materials in all boreholes. The top of this layer ranges from Elevation 63.1 m to 64.6 m. All boreholes were terminated within this layer at elevations ranging from Elevation 58.3 m to 58.8 m in the Boreholes 17-101 through 17-103 and 62.5 m to 61.7 m in Boreholes 17-12 and 17-14.

Cobbles and boulders were encountered in the till layer and coring techniques were required to advance the boreholes through the cobbles and boulders at some locations.

The SPT 'N' values ranged from 21 to greater than 100 indicating a compact to very dense condition.

The moisture contents of the samples tested ranged from 9% to 13%. The results of grain size analysis completed on samples of this material indicated a gravel content ranging from 10% to 31%, sand content of 28% to 40%, a silt content ranging 32% to 41% and a clay content ranging from 7% to 10%. The results of the grain size analysis testing are illustrated on Figure 3 in Appendix D.

Based on the results of Atterberg Limits testing the fines content is generally classified as non-plastic silt (ML). The Atterberg Limit results are illustrated on Figure 4 in Appendix C.

4.5 Groundwater Conditions

The groundwater levels were measured at the vibrating wire piezometers installed in Boreholes 17-101 through 17-103 on February 8, 2018 and again on March 6, 2018.

Table 4-1 summarizes the measured water level readings.

Table 4-1: Groundwater Summary

Borehole	Ground Surface Elevation (m)	February 6, 2018		March 6, 2018	
		Depth to Water Level (m)	Water Level Elevation (m)	Depth to Water Level (m)	Water Level Elevation (m)
17-101	65.0	4.6	60.4	4.9	60.1
17-102	68.6	3.7	64.9	3.9	64.7
17-103	65.0	4.2	60.8	4.3	60.7

These observations are considered short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall. The topography and presence of the median ditch may also create localized variation in the groundwater level.

4.6 Analytic Test Results

Three soil samples were submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The analysis was completed 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 buried infrastructure. The analysis results are summarized in the Table 4-2. A copy of the test results is provided in Appendix D.

Table 4-2: Results of Chemical Analysis

Borehole	Sample	Depth (m)	Elevation (m)	pH	Resistivity (Ohm-cm)	Chloride (µg/g)	Sulphate (µg/g)
17-101	SS3	1.8	63.2	7.9	3260	99	29
17-102	SS8	5.6	63.0	7.9	3590	74	19
17-103	SS4	2.6	62.4	8.8	6000	18	86

5 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. WSP surveyed the borehole locations, and determined the ground surface elevations at the borehole locations. George Downing Estate Drilling Ltd. and Forage M3 Drilling Services Inc. both of Hawkesbury, Ontario supplied and operated the drilling equipment to carry out the drilling, sampling, and in-situ testing. Traffic control services were provided Beacon Lite of Ottawa, Ontario. The drilling, and sampling operations in the field were supervised on a full-time basis by Justin Gray or Nick Weil of Thurber. Laboratory testing was carried out by Thurber in its MTO-approved laboratory in Ottawa.

Overall project management and direction of the field program was provided by Paul Carnaffan, P.Eng. Interpretation of the field data and preparation of this report was completed by Kenton Power, P.Eng. The report was reviewed by Paul Carnaffan, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

6 GENERAL

This report presents the interpretation of the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) for the trenchless utility crossing of the Highway 401 immediately east of the overpass structures at Pitt Street, within the City of Cornwall, Ontario. Recommendations are provided to assist the design team in review of possible trenchless crossing alternatives and recommending an appropriate trenchless installation method from a geotechnical engineering perspective.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. Contractors must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

The following sections address geotechnical discussion and recommendations for the selection of an appropriate trenchless installation. The discussions and recommendations presented in this report are based on the information provided about the by WSP and on the factual data obtained during this investigation.

6.1 Applicable Codes and Design Considerations

Trenchless installation should be completed in accordance with the requirements of the Non-Standard Special Provision (NSSP) "Pipe Installation by Trenchless Methods" provided in Appendix G. Amongst the important issues discussed in the NSSP are maintenance of alignment, handling of obstructions, disposal of cuttings and monitoring of the roadway platform during installation.

The geotechnical assessment presented below has been prepared based on the available data regarding the proposed installation, existing ground conditions and in accordance with the Canadian Highway Bridge Design Code, version CSA S6-14 (CHBDC).

In accordance with the CHBDC, the analysis and design of the structures takes into consideration the importance of the structures and the consequence associated with exceeding limit states. The importance category and consequence classification are defined by the Regulatory Authority, which in this case is the Ministry of Transportation, Ontario (MTO).

It is understood that MTO has designated the overpass structures as outlined in Table 6-1. The same classifications have been assumed for the trenchless crossing.

Table 6-1: Bridge Structure Classification

Criteria	Classification	CHBDC Section
Importance Category	Major Route Bridge	4.4.2
Consequence Classification	Typical Consequence	6.5.1

Accordingly, a consequence factor (Ψ) of 1.0, as per Table 6.1 of the CHBDC, has been used in assessing factored geotechnical resistances. If the consequence classification changes, the geotechnical assessment will need to be reviewed and revised.

6.2 Proposed Trenchless Crossing

It is understood that as part of the utility relocations for the replacement of the existing bridge structures, a shared conduit is to be installed beneath both the eastbound and westbound lanes of Highway 401 to the east of the existing structures. It is proposed to install the crossing employing trenchless techniques.

The utility relocation drawings prepared by Planview Utility Services Ltd. identified a 1067 mm outside diameter steel casing pipe with an overall length of 80 m and an invert elevation of approximately 63.1 to 63.2 m. The drawings also indicate that the cover over the pipe under the Highway 401 lanes is 5.0 m though the cover does reduce to 4.5 m in the median between the east and westbound lanes. In either case the cover is greater than three times the proposed pipe diameter.

The location of the alignment for the proposed crossing is illustrated on Drawing No. 1 in Appendix A.

6.3 Geotechnical Assessment

Key elevations (approximate) are as follows:

- Proposed pipe invert: 63.1 m to 63.2 m
- Existing ground surface at entry/exit pits (Borehole 17-103 / 17-101): 65.0 m
- Existing ground surface at median (Borehole 17-102): 68.6 m
- Groundwater Elevation at entry/exit pits (Borehole 17-103 / 17-101): 60.1 m to 60.7 m
- Groundwater Elevation at median (Borehole 17-102): 64.7 m to 64.9 m
- Embankment fill / glacial till interface: 63.1 m to 64.6 m

Based on the results of the field and laboratory investigation and the information provided by WSP with regards to the proposed project requirements, the geotechnical foundation design considerations for this trenchless crossing include the following.

- The boreholes indicate soil conditions consisting of fill over glacial till. Both the fill and till contained cobbles and boulders. The presence of these potential obstructions will limit the effectiveness of some tunneling techniques. The trenchless method employed will need to be able to handle the obstructions while maintaining the required alignment and invert elevation. Suggested wording for an NSSP to alert the contractor

that obstructions are likely to be encountered during tunneling is provided in Appendix H.

- The interface between the fill and the till ranges from Elevation 63.1 to 64.6 m. The proposed profile of the conduit is between approximately Elevation 63 and 64 m and would therefore be along the interface between the fill and the till. Although the gradation of the fill and till are similar, the fill above the proposed crossing includes some loose to very loose material. A mixed material excavation face is not preferred from a risk management perspective. To provide a more consistent soil profile along the alignment and to reduce the challenge of a mixed excavation face, consideration should be given to lowering the conduit invert one full pipe diameter to approximately Elevation 61.5 m. At this elevation the conduit invert would be completely within the till material.
- Excavations for the entry/exit pits through the fill and the till will likely encounter boulders and cobbles. Suggested wording for an NSSP to alert the contractor of these obstructions and that the Contractor shall be prepared to dislodge and remove these obstructions is provided in Appendix H.
- Depending on the final pipe profile, excavation for the entry/exit pits could extend below the groundwater level measured at the site. An adequate and effective surface water management and dewatering plan must be implemented to construct entry/exit pits and preparation of the foundations for trenchless installation equipment in a dry and stable excavation. Also, possible perched water was measured in the embankment borehole. The trenchless method selected by the Contractor must be able to install the proposed pipe under saturated conditions.
- The results of the utility locates carried out prior to commencement of the field work indicate that there are existing utility alignments located along the MTO right-of-way to the north and south of the project limits. These utilities must not be damaged due to the trenchless installation. The protection of these utilities should be a critical consideration by the Contractor when planning excavating activities at the site. The exact location of the existing utility alignments will need to be determined prior to commencing excavation works.
- Access to the area of the entry/exit pits and staging areas can be accessed from Pitt Street. However, it should be noted that overhead utilities and buried infrastructure (i.e. catchbasins, storm and water lines) are present along east side of Pitt Street. The Contractor will need to protect this infrastructure from damage while accessing these areas with heavy construction equipment.
- The native glacial till and fill deposits can provide moderate thrust resistance.
- The frost penetration depth at this site is 1.7 m as per OPSD 3090.101.

7 TRENCHLESS TECHNIQUES – ALTERNATIVES

7.1 Evaluation

Given the soil stratigraphy encountered and the requirements of the proposed crossing provided by WSP, the following trenchless techniques were considered for utility installation:

1. Micro-Tunneling (MTBM);
2. Horizontal Directional Drilling (HDD);
3. Jack and Bore (JB); and
4. Pipe Ramming (PR).

These alternatives have been evaluated from a geotechnical perspective in terms of their respective advantages, disadvantages, risks and consequences. The evaluation is summarized in the tables provided in Appendix F.

The application of Alternative 2, HDD has been ruled out as the technique is unable to advance the pipe-train through the anticipated oversized obstructions. Alternative 3, JB has also been ruled out as it also unable to handle the anticipated oversized obstructions and has limited steering and alignment control. Pipe ramming, Alternative 4 has also been ruled out as it has limited installation range, requires workers to access the tunnel for removal of obstructions and has limited steering and alignment control.

7.2 Preferred Alternative

Based on the results of the investigation, the pipe size and invert elevation and soil stratigraphy encountered Alternative 1, MTBM is the recommended trenchless installation method from a geotechnical perspective. MTBM method has a high level of horizontal and vertical alignment control and can advance the pipe-train through the anticipated obstructions while maintaining full-face excavation support during tunneling.

The anticipated settlement for this utility installation using the preferred MTBM method is less than 25 mm. Further Discussions on surface settlements and their causes are provided in Section 8.7.

7.3 Liners

The use of either a steel or concrete liner is feasible for this crossing as they are likely to be able to withstand the overburden pressure of up to 5.0 m of cover material over the proposed pipe crossing. The use of a steel liner is preferred over concrete as the overall excavation diameter would be less with a steel pipe due to a reduce wall thickness of a steel pipe over that of a concrete pipe to achieve similar inner diameters.

The current utility relocation drawings prepared by Planview Utility Services Ltd. identified a 1067 mm outside diameter for the liner. Consideration should be given to indicating a range of diameters instead of restricting to one boring size. Tunneling machines come in standard sizes. Providing a sizing range will allow the Contractor to select an appropriate diameter boring machine to limit over excavation. Consultation with the utility companies would be required to determine the appropriate pipe inner diameter range required.

8 TRENCHLESS INSTALLATION RECOMMENDATIONS

8.1 General

Trenchless installation should be completed in accordance with the requirements of the Special Provision (SP) "Pipe Installation by Trenchless Methods" provided in Appendix G. Amongst the important issues discussed in the SP are maintenance of alignment, handling of obstructions, excavating and site restoration of the entry/exit pits, disposal of cuttings and monitoring of the roadway surface during and after installation. Further discussion on these points are provided in the following sections.

The experience of the Contractor is of primary importance for trenchless installation. The Contractor must submit a detailed work plan in accordance with the SP in Appendix G including

but not limited to the proposed methodology and equipment, maintenance of alignment, and disposal of cuttings.

It is recommended that the Contractor be alerted to the groundwater conditions at the site, the need to maintain stability of the tunnel face, and the need to avoid settlement and loss of ground over the tunnel.

The Contractor must also anticipate encountering cobbles and boulders within the fill and till deposit when selecting the tunnelling methodology. The Contractor should be equipped to handle such obstructions at the tunnel face as required.

The design of safe and stable entry/exit pits for the trenchless installation is the responsibility of the Contractor. Entry/exit pits shall be excavated with side slopes that follow the recommendations provided in Section 8.2 or if deemed necessary, temporary protection systems may be required to support the excavations. The support system should be designed and constructed as outlined in Section 8.3. Dewatering and surface water control must be employed as necessary to keep the entry/exit pits in a dry and stable condition as discussed further in Section 8.4. Available geotechnical bearing resistances at the base of entry/exit pits and passive resistance of the sidewalls should follow recommendations and values provided in Section 8.5.

Monitoring of the roadway surface will be required during all stages of the trenchless installation including a pre-condition survey and monitoring during and after installation and is the responsibility of the Contractor. The pre-condition survey and settlement monitoring program should follow Section 8 of the SP provided in Appendix G. Further discussion of settlement monitoring is provided in Section 8.7 below.

8.2 Excavations and Site Restoration

It is anticipated that temporary excavations in the order of 3 m deep will be required for their construction. Where pit excavations are located at the toe of the embankment slopes, the loading associated with the embankment fill must be considered in assessing the stability of the pit excavations.

All excavations must be conducted in accordance with the requirements of the Occupational Health & Safety Act & Regulations (OHSA) for Construction Projects. In accordance with OHSA the fill material at the site should be classified as Type 3 while the till material if dewatered should be classified as Type 2. However, as indicated in the OHSA, if an excavation contains more than one type of soil, the soil type for the excavation shall be classified as the type with the highest number among the soil types present within the excavation.

The contractor should provide silt fences and erosion control blankets, as required, throughout the duration of the construction to prevent silt/sediments from running off the site as per OPSS 805.

The management of excess materials from the excavations should be in accordance with OPSS.PROV 180.

Selection of the equipment and methodology to excavate and prepare the founding surface within the entry/exit pits is the responsibility of the Contractor. As cobbles and boulders were observed in the boreholes recommended wording for an NSSP alerting bidders to their presence has been provided in Appendix H. Where boulders are encountered at the subgrade elevation, the boulders

should be removed and replaced with granular material meeting the specification of OPSS.PROV 1010 Granular A.

Site restoration shall be in accordance with OPSS.PROV 492. Excavated material or new imported material conforming to OPSS.PROV 1010 Select Subgrade Material (SSM) may be used as backfill material. Compaction of backfill materials should be carried out in accordance with OPSS.PROV 501. A vegetation cover should be established on all exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804.

8.2.1 Entry/Exit Pits

The footprint size for the entry/exits pits will depend on the diameter and size of the tunneling machine selected, operator access requirements and the length of pipe sections selected. In general, unsupported excavations ranging from 15 to 30 m long and between 9 and 12 m wide are anticipated for the micro-tunnelling alternative. The excavation depth will depend on the final invert elevation of the conduit. The use of the temporary protection systems would reduce overall excavation footprint size required.

8.3 Temporary Protection Systems

Should the space/property constraints restrict the size of the entry and/or exit pits, temporary protection systems may be installed to support the excavations. Temporary protection systems should be provided in accordance with OPSS.PROV 539 and designed for Performance Level 2.

The base of the excavations for the entry and exist pits is expected to be within compact to very dense glacial till. The groundwater level in the area of the pits was measured to be in the range of elevation 60.1 to 60.8 m. The proposed pipe invert is at approximately elevation 63 m, above the measured groundwater levels. Depending on the depth of pits and groundwater level at the time of the work, the base of the pits may extend a limited depth below the groundwater level, however, basal heave/stability is not considered a design issue at this site. Softening of the base could occur and protection of the base of the excavations for the entry/exit pits can be achieved with the inclusion of a well compacted gravel pad or a concrete working slab as outlined in Section 8.5. Suggested wording for an NSSP to alert the Contractor to the requirements of the working slab is provided in Appendix H.

The design of protection systems is the responsibility of the Contractor. All shoring should be designed by a licensed professional engineer experienced in such designs. Lateral earth pressure coefficients for the use in the design are provided in Table 8-1. The designer of the temporary protection system must ensure the penetration depth is sufficient to provide base fixity, lateral stability and incorporate traffic loading and surcharge loading due to construction equipment and their operations and shall consider the slope of embankments above the top of the protection system and location of existing utilities and trenches.

Increased difficulty with the installation of protection systems should be anticipated due to the presence of cobbles and boulders within the native glacial till. Sheet piles systems are not considered suitable within the glacial till. One option is to use soldier piles and timber lagging with the piles installed in holes predrilled through and set in the till.

Table 8-1: Static Lateral Earth Pressure Parameters for Horizontal Backfill

Parameter	Existing Fill	Native Till
Soil Unit Weight, kN/m^3 , γ	20.0	21.0
Angle of Internal Friction, ϕ	30°	35°
Coefficient of at Rest Earth Pressure, K_o (Restrained Wall)	0.50	0.43
Coefficient of Active Earth Pressure, K_a (Unrestrained Wall)	0.33	0.27
Coefficient of Passive Earth Pressure, K_p	3.00	3.70

If there is a sloped embankment or backfill above the protection system, the earth pressure parameters must be revised accordingly.

8.4 Dewatering

All excavations for entry/exit pits must be dewatered prior to subgrade preparation and the placement of the tunneling equipment, as per OPSS.PROV 402.

The Contractor must be prepared to control the groundwater and surface water flow at the site to permit the excavations for the entry/exit pits and preparation of the foundations for trenchless installation equipment in a dry and stable excavation. Water from either surface flow and/or groundwater must be diverted away from the excavation at all times. Groundwater perched within the embankment fill and, surface runoff will tend to seep into, and accumulate in proposed excavations.

Due to the compact to very dense state of the glacial till and its non-cohesive nature, additional ground settlement due to groundwater level lowering from shaft dewatering is not anticipated. Basal heave is also not anticipated at the site. Protection of the base of the excavations can be achieved by placing a concrete working slab over the exposed subgrade prior to installing tunneling equipment.

Dewatering and surface water diversion must remain operational and effective until the trenchless installation is completed and the entry/exit temporary excavations are backfilled.

The design of any dewatering system that may be required is the responsibility of the Contractor. The Contract Documents must alert them to this responsibility and to design the system in accordance with SP No. FOUN0003.

The Dewatering Systems Designer Fill-in information for SP No. FOUN0003 are as follows:

Design Storm Return Period	Preconstruction Survey Distance
*	**
Where required, fill-in information will be provided in the Hydraulic Report	From 150 m north of the Highway 401 WBL Overpass structure to 150 m south of the Highway 401 EBL Structure

In accordance with SP FOUN0003, the dewatering system is to be designed in accordance with OPSS.PROV 517 and SP 517F01; Amendment to OPSS 517, July 2017.

The Table A Fill-ins for SP 517F01 are as follows:

IDF Curve Location		Latitude: 45.05184°		Longitude: -74.75500°		
Temporary Flow Passage Systems						
Site Name / Station Reference	Minimum Return Period (Years)	Return Period Flow Estimates (m³/s)				Design Engineer Requirements (Note 1)
		2 Year	5 Year	10 Year	25 Year	
**	***	****	****	****	****	*****
	N/A					
Dewatering Systems						
Site Name / Station Reference	Preconstruction Survey Distance (Note 2) (m)				Design Engineer Requirements (Note 1)	
**	*****				*****	
Trenchless Utility Crossing of Highway 401 EBL and WBL at Pitt Street, Cornwall, ON; GWP. 4003-14-00. Approximate Highway 401 Station 23+240	From 150 m north of the Highway 401 WBL Overpass structure to 150 m south of the Highway 401 EBL Structure				Yes	
Note:						
1. “Yes” means the design Engineer and design-checking Engineer shall have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work. “No” means a minimum experience level is not required for the design Engineer and design-checking Engineer.						
2. “N/A” indicates a preconstruction survey is not required.						

Due to the shallow excavation depths being considered and the depth to groundwater at the site it is anticipated that conventional sump and pump techniques should be sufficient.

8.5 Equipment Foundations and Hydraulic Jacking System

Geotechnical Bearing Resistances

Foundations for the hydraulic jacking systems can be founded directly on undisturbed native glacial till. Consideration should be given to placing a well compacted gravel pad or a concrete working slab over the exposed subgrade promptly after excavation and inspection to provide a working platform for equipment and operators.

For preliminary assessment, a maximum width of 4.5 m has been assumed for the base of the hydraulic jacking system for the Micro-Tunneling system. Based on the proposed invert elevation indicated on the current Utility Drawings of approximately 63.1 to 63.2 m, a foundation elevation of between 63.0 and 62.0 m is anticipated. At this elevation the equipment foundation would be founded on undisturbed native glacial till.

Foundations constructed as outlined above may be designed based on the following factored geotechnical resistances:

- Factored geotechnical resistance at ULS 525 kPa
- Factored geotechnical resistance at SLS 350 kPa

The factored geotechnical resistances include the following factors:

- Consequence factor (Ψ) of 1.0
- Geotechnical resistance factors (CHBDC Table 6.2):
 - $\phi_{gu} = 0.5$ (static analysis; typical degree of understanding)
 - $\phi_{gs} = 0.8$ (static analysis; typical degree of understanding)

The factored geotechnical resistance at SLS corresponds to a total settlement of 25 mm.

The geotechnical resistances are for vertical concentric loading and will need to be adjusted for the effects of inclined or eccentric loading, if applicable. The geotechnical resistance should be calculated as illustrated in the CHBDC Clause 6.10.3 and Clause 6.10.4.

Jacking Thrust Resistance

During the installation the MTBM technique relies on hydraulic jacking forces to push the pipe-train along the alignment while the cutterhead augers through the soil.

The thrust resistance provided by the entry pit wall can be computed by the expression:

$$P_p = \frac{1}{2} \gamma H^2 K_p$$

Where: P_p = resultant of the passive pressures in front of the thrust wall
 γ = unit weight of the trench wall soil (kN/m³) (Table 8.1)
 H = exposed height of the trench wall
 K_p = Coefficient of Passive Earth Pressure (Table 8.1)

Thrust resistance of the side wall of the excavation depends on whether the thrust wall is on the fill layer or till layer or a combination of both. The parameters for use in the calculation of the thrust resistance are provided in Table 8-1.

The thrust wall should be designed using an unfactored modulus of sub-grade reaction of 40 MPa/m for the trench wall.

8.6 Cement Type and Corrosion Potential

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment.

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 sulphate results in Table 4-2 were compared with Table 3 of Canadian Standards Association Standards A23.1-14 (CSA A23.1) and generally indicate a low degree of sulphate attack potential on concrete structures at this site. Accordingly, GU could be specified for concrete in below grade applications.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The test results provided in Table 4-2 were compared with Table 3.2 of the MTO Gravity Pipe Design Guideline and generally indicate a low to moderate corrosive environment. The test results provided in Table 4-2 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

8.7 Subsidence / Heave

The potential for settlement of the highway pavement is a key concern for trenchless installations. Settlements associated with trenchless installations include two types: large settlements and systematic settlements.

Large settlements occur primarily due to over-excavation along the pipe alignment. Though some over excavation is required to reduce friction on the pipe-train during installation large ground losses can lead to the creation of voids above the installed pipe. Large settlements are usually the result of using inappropriate methods, improper operation or sudden, unexpected changes in ground conditions, leaving the tunnel excavation unsupported, and/or selecting a pipe material that is unable to withstand the overburden pressure of the embankment it traverses. The risk of large settlements can be minimized, by selecting the proper tunneling technique, following proper installation methods, and having highly skilled experienced operators.

Systematic settlements associated with trenchless construction are primarily caused by the collapse of the space between the new pipe and the excavation known as the over-cut. An overcut is a necessary component that reduces friction loads on the pipe-train, to allow the injection of lubricant, and to facilitate steering.

If the overcut space is left open during or after micro-tunneling, the soil surrounding the circumference of the excavation may collapse onto the pipe, filling the void. The soil collapse continues upward until the void appears at the surface as a trough. These systematic settlements can be controlled by reducing the over-cut, by keeping the overcut space between the pipe and the excavation wall filled with the bentonite slurry during tunneling, and potentially by grouting the space after pipe installation is complete.

The magnitude of the systematic settlements decreases as:

- The cover over the centerline of the pipe increases (greater than 2.5 to 3.5 times the pipe diameter).
- The diameter of the overcut decreases; and
- When tunneling is carried out in dense soils.

The anticipated settlement for this utility installation is less than 25 mm based on the following.

- Micro-tunneling machines provide full face support of the excavation while advancing, thereby protecting the tunnel from collapse during installation.
- Improper tunneling techniques and loss of face pressure would increase settlements beyond the estimated settlement value provided
- The cover over the pipe invert is greater than 4.0 m or approximately 4 times the pipe diameter.
- The anticipated material along the pipe invert is non-cohesive and in a dense state.
- As the material is non-cohesive no pore water pressures will develop during installation which could dissipate over time and cause long-term settlement.
- The requirement in tunneling SP to grout the over-cut void after installation.
- Micro-tunneling machine's ability to core through obstructions instead of displacing them.

A geotechnical instrumentation and monitoring program will be required to monitor settlement during and after tunnelling operations have been completed. The Contractor is required to submit

a contingency plan to the CA prior to commencing the installation (in accordance with the tunnelling SP provided in Appendix G) that outlines the measures that will be implemented in the event of excessive settlement/heave.

The settlement monitoring equipment and program should follow the requirements of Section 8 of the SP in Appendix G. A drawing showing the location of settlement monitoring instruments is also provided in Appendix G.

8.7.1 Conduit Alignment and Profile

Based on the current Utility Drawings the proposed profile of the conduit is between approximately Elevations 63 and 64 m. The results of the investigation indicate that the interface between the fill and the till layers is between approximate Elevation 63.1 m and 64.6 m and therefore the conduit invert would be along the interface between the fill and the till. Although the gradation of the fill and till are similar, the fill above the proposed crossing includes some loose to very loose material.

To provide a more consistent soil profile along the alignment and to reduce the challenge of a mixed excavation face, it is recommended that the conduit invert should be lowered one full pipe diameter to approximately Elevation 62.0 m. At this elevation the conduit invert would be completely within the till material. The drawback of lowering the invert elevation is that the depth of excavation for the entry/exit pits would also need to be lowered to align the tunnelling machine with the new invert. However, the overall cover over the pipe will be increased and a more stable excavation face would be encountered during tunneling, decreasing the likelihood of systematic settlements over the pipe.

To ensure that during tunneling there is no interference with existing boreholes at the site the alignment for the trenchless crossing should be located 2.0 m east of the alignment of the existing boreholes.

9 CONSTRUCTION CONCERNS

The planned construction methodology includes the trenchless installation of a new utility crossing.

Potential construction concerns include, but are not necessarily limited to, the following.

- The selection of the correct trenchless method to suit site conditions is critical to the successful installation. Micro-tunneling is the preferred alternative at this site from a geotechnical perspective as it can advance through obstructions, has full face excavation support which minimizes post installation subsidence, and offers highly accurate alignment control both horizontally and vertically.
- The risk of large settlements can be minimized, by following proper means and installation methods, and by the contractor using highly skilled and experienced operators during the installation. Proper inspections by a qualified and experienced inspector will also be required during installation.
- Settlement monitoring of the surface above the pipe alignment is critical. An emergency response plan must be developed for if settlements exceed the Review and Alert levels indicated in the SP "Pipe Installation by Trenchless Method" provided in Appendix G.

- Overcutting during tunneling is to be kept a minimum to reduce the likelihood of systematic settlements. The selection of the appropriate diameter boring machine to closely match the proposed pipe diameter will be critical.
- The tunnel should not be left unsupported during installation to avoid large voids under the embankment and road platform settlements
- Boulders may be encountered in the subgrade surface at the base of the entry/exit pits and may require localized sub-excavation and replacement.
- Cobbles and boulders may be encountered during tunneling operations, the Contractor must have appropriate equipment on site to advance through these ground conditions.
- Increased difficulty in installing protection systems should be anticipated due to the presence of cobbles and boulders in the fill and glacial till materials.

The successful performance of the construction of this structure will depend largely upon good workmanship and quality control during construction. Observation of the excavation, tunnelling and backfilling operations will be required by the owner's Foundations Engineering Specialist retained by the Contract Administrator to confirm that the foundation recommendations are correctly implemented and material specifications are met.

10 CLOSURE

Overall project management and direction of the field program was provided by Paul Carnaffan, P.Eng. Interpretation of the field data and preparation of this report was completed by Kenton Power, P.Eng. The report was reviewed by Paul Carnaffan, P.Eng. and Dr. P.K. Chatterji, P.Eng., the Designated Principal Contact for MTO Foundations Projects.



Kenton C. Power, P.Eng.
Geotechnical Engineer



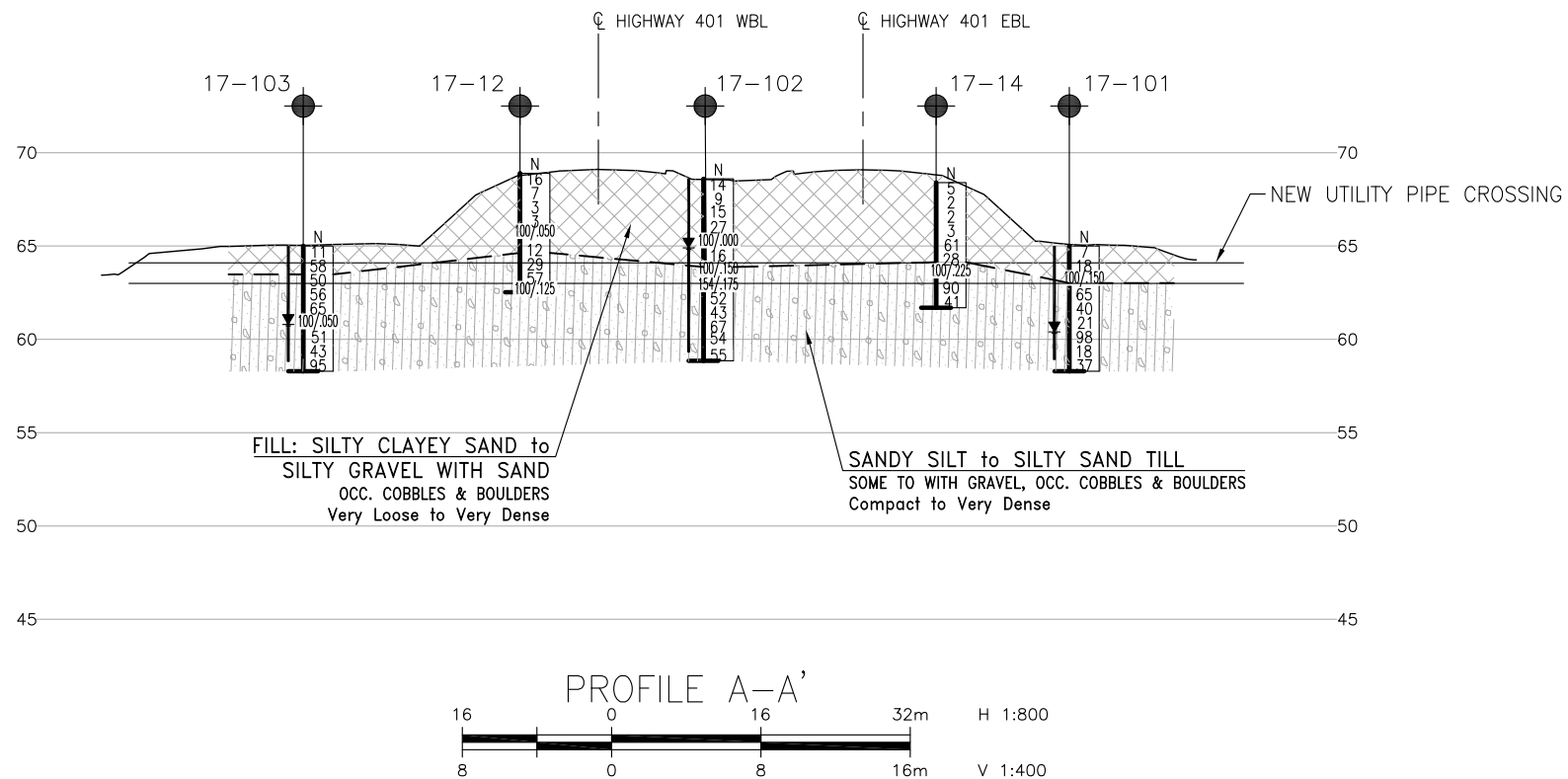
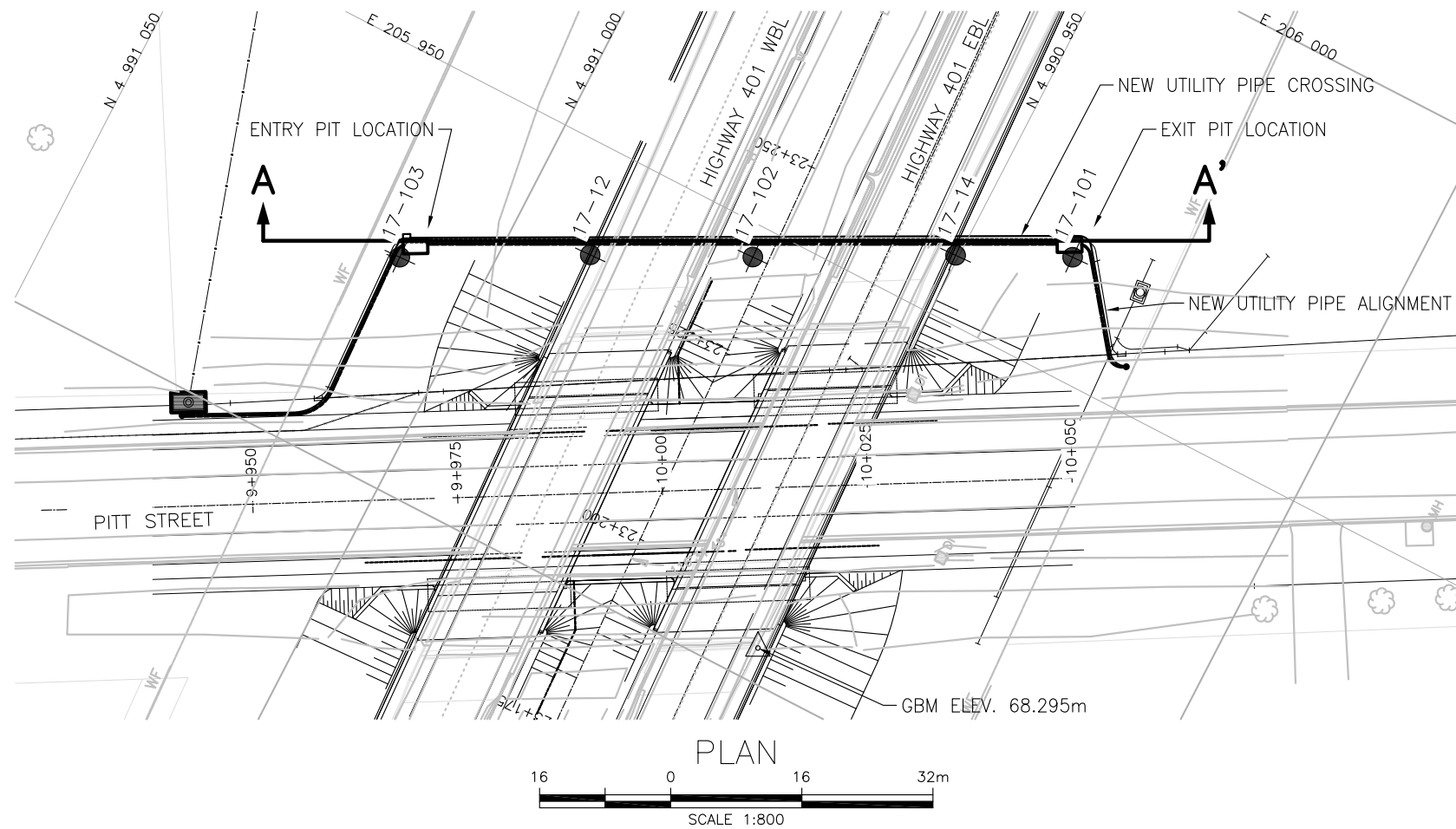
Paul Carnaffan, P.Eng.
Principal, Senior Geotechnical Engineer



P.K. Chatterji, P.Eng.
Review Principal, Designated MTO Contact

APPENDIX A

BOREHOLE LOCATIONS AND SOIL STRATA DRAWINGS – 2017 INVESTIGATION



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

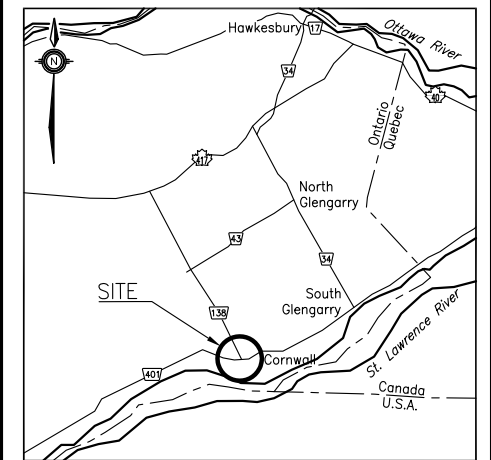


CONT No 2018-4007
GWP No 4003-14-01

HIGHWAY 401
TRENCHLESS UTILITY INSTALLATION
AT PITT STREET
BOREHOLE LOCATIONS AND SOIL STRATA

WSP

THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

●	Borehole (Present Investigation)
○	Borehole (Previous Investigation)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
⌵	Head Artesian Water
⌵	Vibrating Wire Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
17-101	65.0	4 990 937.6	205 964.1
17-102	68.6	4 990 972.3	205 946.2
17-103	65.0	4 991 010.6	205 926.4
17-12	68.9	4 990 990.0	205 937.3
17-14	68.4	4 990 950.4	205 957.7

-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Borehole locations are shown in MTM Zone 8 coordinates.

GEOCRES No. 31G-264

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	JG	CHK	KP
DRAWN	MFA	CHK	JG
CODE		LOAD	
SITE		STRUCT	
DWG	1		
DATE	APR 2018		

APPENDIX B

SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS RECORD OF BOREHOLE SHEETS – 2017 INVESTIGATIONS



SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

Topsoil	mixture of soil and humus capable of supporting vegetative growth
Peat	mixture of fragments of decayed organic matter
Till	unstratified glacial deposit which may include particles ranging in sizes from clay to boulder
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 materials, shrinkage cracks, etc.
Fissured	having cracks, and hence a blocky structure
Varved	composed of 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

RECOVERY:

For soil samples, the recovery is recorded as the length of the soil sample recovered.

N-VALUE:

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented, the number of blows are reported over the sampler penetration in millimetres (e.g. 50/75).

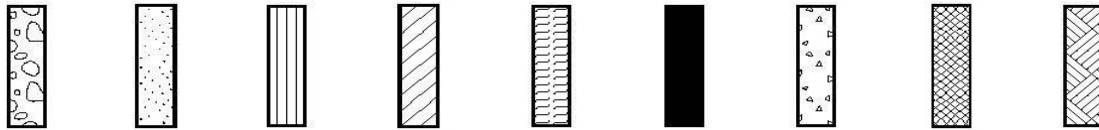
DYNAMIC CONE PENETRATION TEST (DCPT):

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an "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 0.3 m into the soil. The DCPT is used as a probe to assess soil variability.



STRATA PLOT:

Strata plots symbolize the soil and 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 Bedrock

TEXTURING CLASSIFICATION OF SOILS

Classification	Particle Size
Boulders	Greater than 200 mm
Cobbles	75 – 200 mm
Gravel	4.75 – 75 mm
Sand	0.075 – 4.75 mm
Silt	0.002 – 0.075 mm
Clay	Less than 0.002 mm

TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

Descriptive Term	Undrained Shear Strength (kPa)
Very Soft	12 or less
Soft	12 – 25
Firm	25 – 50
Stiff	50 – 100
Very Stiff	100 – 200
Hard	Greater than 200

NOTE: Clay sensitivity is defined as the ratio of the undisturbed strength over the remolded strength.

SAMPLE TYPES

SS	Split spoon samples
ST	Shelby tube or thin wall tube
DP	Direct push sample
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ etc.	Rock core sample obtained with the use of standard size diamond coring equipment

TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

Descriptive Term	SPT "N" Value
Very Loose	Less than 4
Loose	4 – 10
Compact	10 – 30
Dense	30 – 50
Very Dense	Greater than 50

MODIFIED UNIFIED SOIL CLASSIFICATION

Major Divisions		Group Symbol	Typical Description
COARSE GRAINED SOIL	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILT AND CLAY SOILS $W_L < 35\%$	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		OL	Organic silts and organic silty-clays of low plasticity.
	SILT AND CLAY SOILS $35\% < W_L < 50\%$	MI	Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts.
		CI	Inorganic clays of medium plasticity, silty clays.
		OI	Organic silty clays of medium plasticity.
	SILT AND CLAY SOILS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other organic soils.

Note - W_L = Liquid Limit



EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock materials.
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structures are preserved.

TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1 m in length or larger, as a percentage of total core length
Unconfined Compressive Strength: (UCS)	Axial stress required to break the specimen.
Fracture Index: (FI)	Frequency of natural fractures per 0.3 m of core run.

DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 to 2 m
Medium bedded	0.2 to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 to 60 mm
Laminated	6 to 20 mm
Thinly laminated	Less than 6 mm

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)
Extremely Strong	Greater than 250
Very Strong	100 – 250
Strong	50 – 100
Medium Strong	25 – 50
Weak	5 – 25
Very Weak	1 – 5
Extremely Weak	0.25 – 1

RECORD OF BOREHOLE No 17-101

1 OF 1

METRIC

GWP# 4003-14-00 LOCATION Trenchless Utility Crossing, MTM Zone 8: N 4 990 937.6 E 205 964.1 ORIGINATED BY NW
HWY 401 BOREHOLE TYPE NW Casing COMPILED BY KCP
DATUM Geodetic DATE 2017.12.13 - 2017.12.13 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								20 40 60 80 100								
65.0																
0.0	Silt with sand trace organics Loose Compact Brown FILL		1	SS	7											
64.3																
0.8	Silty clayey sand with gravel - occasional cobbles Compact to very dense Brown FILL		2	SS	18		64									19 36 33 12
63.1	- cobbles cored		3	SS	100/ 150mm		63									
2.0	SILTY SAND (SM) with gravel TILL - occasional cobbles and boulders Compact to very dense Grey - cobbles cored		4	SS	65		62									
			5	SS	40		61									
			6	SS	21		60									18 35 38 9
	- boulders cored		7	SS	98		59									
			8	SS	18											
			9	SS	37											
58.3	End of Borehole VWP installed with tip at 6.1 m BGS. Groundwater was measured at 4.6 m BGS (elev. 60.5 m) on February 8, 2018.															
6.7																

ONTMT4S 31-211-1&2 PITT ST BH LOGS.GPJ 2012TEMPLATE(MTO).GDT 2/4/18

RECORD OF BOREHOLE No 17-102

1 OF 2

METRIC

GWP# 4003-14-00 LOCATION Trenchless Utility Crossing, MTM Zone 8: N 4 990 972.3 E 205 946.2 ORIGINATED BY NW
HWY 401 BOREHOLE TYPE NW Casing COMPILED BY KCP
DATUM Geodetic DATE 2017.12.14 - 2017.12.19 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa												
68.6								20	40	60	80	100								
0.0	Silt with sand trace organics Loose to compact Brown FILL		1	SS	14															
67.8																				
0.8	Silty clayey sand with gravel - occasional cobbles Loose to compact Brown FILL - cored 2 - 150 mm cobbles at 1.2 m		2	SS	9															
			3	SS	15															
66.3																				
2.3	Silty sand some gravel - occasional cobbles and boulders Loose to compact Brown FILL - cored 100 mm cobble at 2.7 m - cored 270 mm boulder at 3.0 m - cored 80 mm cobble at 3.4 m		4	SS	27															
			5	SS	100/ 0mm															
			6	SS	16															
63.8	- cobbles cored		7	SS	100/ 150mm															
4.7	SANDY SILT (ML) with gravel TILL - occasional cobbles Compact to very dense Grey - cored 2 - 120 mm cobbles at 5.6 m		8	SS	154/ 175mm															
			9	SS	52															
	- cored 60 mm cobble at 6.7 m		10	SS	43															
	- cored 170 mm cobble at 7.3 m		11	SS	67															
			12	SS	54															
			13	SS	55															
58.8																				
9.8																				

Continued Next Page

+³ ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

ONTMT4S 31-211-1&2 PITT ST BH LOGS.GPJ 2012TEMPLATE(MTO).GDT 2/4/18

RECORD OF BOREHOLE No 17-102

2 OF 2

METRIC

GWP# 4003-14-00 LOCATION Trenchless Utility Crossing, MTM Zone 8: N 4 990 972.3 E 205 946.2 ORIGINATED BY NW
 HWY 401 BOREHOLE TYPE NW Casing COMPILED BY KCP
 DATUM Geodetic DATE 2017.12.14 - 2017.12.19 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	W P	W	W L	20 40 60					
	Continued From Previous Page																
	End of Borehole VWP installed with tip at 9.3 m BGS. Groundwater was measured at 3.7 m BGS (elev. 64.9 m) on February 8, 2018.																

ONTMT4S 31-211-1&2 PITT ST BH LOGS.GPJ 2012TEMPLATE(MTO).GDT 2/4/18

RECORD OF BOREHOLE No 17-103

1 OF 1

METRIC

GWP# 4003-14-00 LOCATION Trenchless Utility Crossing, MTM Zone 8: N 4 991 010.6 E 205 926.4 ORIGINATED BY NW
 HWY 401 BOREHOLE TYPE NW Casing COMPILED BY KCP
 DATUM Geodetic DATE 2017.12.15 - 2017.12.15 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
65.0														
0.0	Silt with sand trace organics - occasional cobbles Compact to very dense Brown FILL		1	SS	11									
	- cobbles cored		2	SS	110/ 250mm		64							
63.5														
1.5	SILTY SAND (SM) with gravel TILL - occasional cobbles and boulders Dense to very dense Brown		3	SS	50		63							31 30 32 7 Non-plastic
			4	SS	56		62							
			5	SS	65									
	- cored 200 mm boulder at 4.0 m		6	SS	100/ 50mm		61							
	- cored 2 - 80 mm cobbles at 4.4 m		7	SS	51		60							23 28 41 8 Non-plastic
			8	SS	43		59							
			9	SS	95									
58.3														
6.7	End of Borehole VWP installed with tip at 6.2 m BGS. Groundwater was measured at 4.2 m BGS (elev. 60.8 m) on February 8, 2018.													

ONTMT4S 31-211-1&2 PITT ST BH LOGS.GPJ 2012TEMPLATE(MTO).GDT 2/4/18

RECORD OF BOREHOLE No 17-12

1 OF 1

METRIC

GWP# 4003-14-00 LOCATION Pitt Street, MTM Zone 8: N 4 990 990.0 E 205 937.3 ORIGINATED BY JG
 HWY 401 BOREHOLE TYPE NW Casing COMPILED BY CM
 DATUM Geodetic DATE 2016.05.16 - 2016.05.16 CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa													
								20 40 60 80 100													
							<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>					<div><div>PLASTIC LIMIT</div><div>NATURAL MOISTURE CONTENT</div><div>LIQUID LIMIT</div></div> <div><div>W_P</div><div>W</div><div>W_L</div></div> <div>WATER CONTENT (%)</div> <div>20 40 60</div>									
							<div>○ UNCONFINED + FIELD VANE</div> <div>● QUICK TRIAXIAL × LAB VANE</div>														
68.9																					
0.1	50mm Topsoil		1	SS	16									41 38 21 (SH+CL)							
	Silty sand with gravel, to silty gravel with sand - Occasional cobbles Very loose to very dense Brown FILL		2	SS	7																
			3	SS	3																
			4	SS	3																
	- cored 220 mm Boulder at 3.3 m		5	SS	100/ 50mm																
	- cored 130 mm Cobble at 3.7 m		6	SS	12																
64.6			7	SS	29																
4.3	Sandy SILT (ML) some gravel TILL - Occasional cobbles and boulders Compact to very dense Grey		8	SS	57									10 40 40 10							
	- boulder		9	SS	100/ 125mm																
62.5																					
6.4	End of Borehole																				

ONTMT4S 31-211-1&2 PITT ST BH LOGS.GPJ 2012TEMPLATE(MTO) GDT 2/4/18

RECORD OF BOREHOLE No 17-14

1 OF 1

METRIC

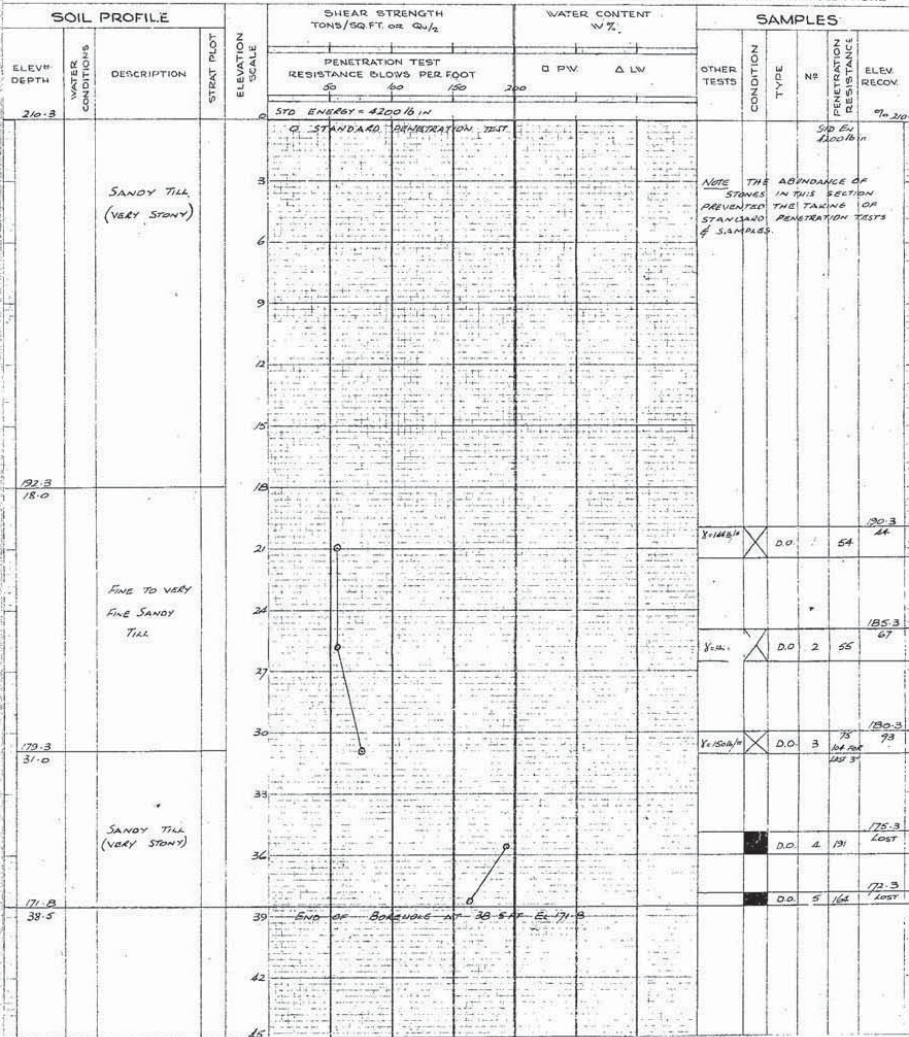
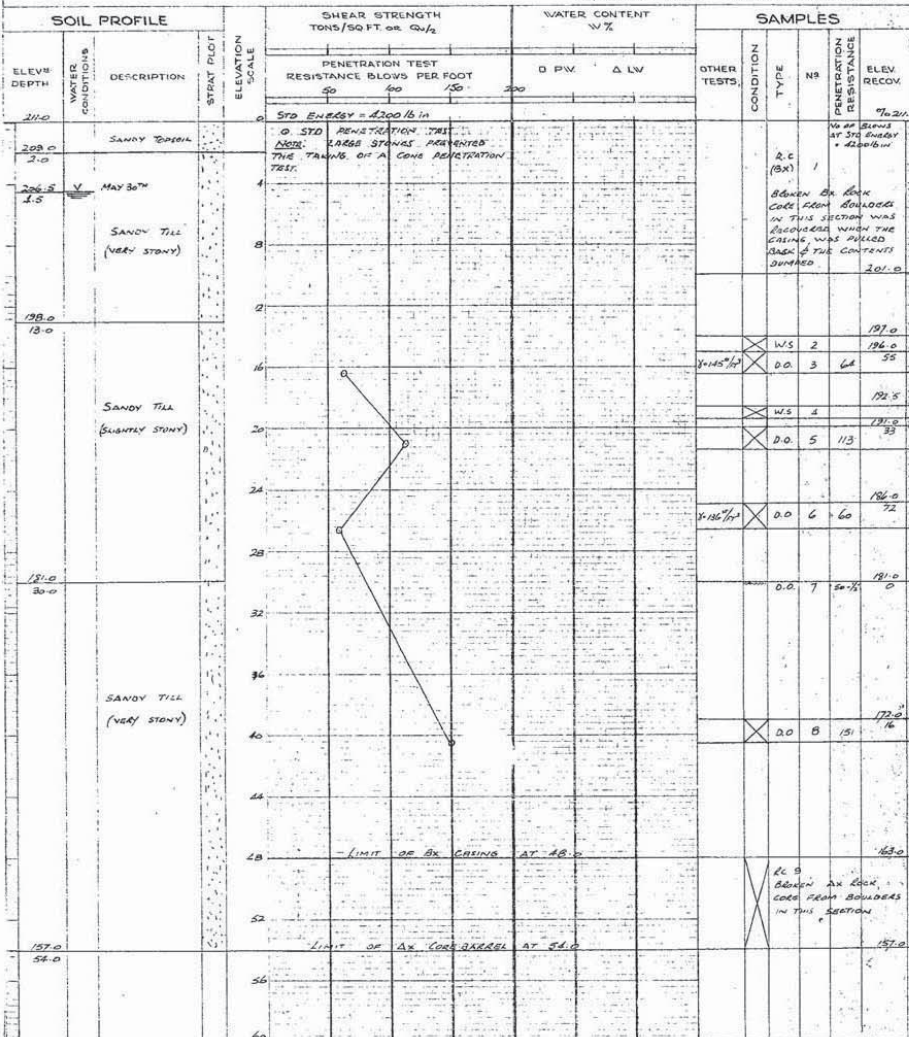
GWP# 4003-14-00 LOCATION Pitt Street, MTM Zone 8: N 4 990 950.4 E 205 957.7 ORIGINATED BY JG
 HWY 401 BOREHOLE TYPE NW Casing COMPILED BY CM
 DATUM Geodetic DATE 2017.05.16 - 2016.05.16 CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)								
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					W P W W L								
68.4								20	40	60	80	100									
0.9	60mm Topsoil		1	SS	5		68							○							
	Silty sand with gravel, occasional cobbles Very loose to very dense Brown FILL		2	SS	2		67							○							
			3	SS	2		66							○					18 42 40 (SH+CL)		
			4	SS	3		65							○							
	- cobbles		5	SS	61		64							○							
64.1			6	SS	28		63							○							
4.3	Sandy SILT (ML) some gravel TILL - Occasional cobbles Dense to very dense Grey - cobbles		7	SS	100/ 225mm		62							○							
			8	SS	90		61							○					11 39 40 10 Non-plastic		
			9	SS	41		60							○							
61.7																					
6.7	End of Borehole																				

ONTMT4S 31-211-1&2 PITT ST BH LOGS.GPJ 2012TEMPLATE(MTO).GDT 2/4/18

APPENDIX C

HISTORICAL BOREHOLE LOCATIONS AND SOIL STRATA DRAWINGS HISTORICAL RECORD OF BOREHOLE SHEETS



TA 113
51-90

MATERIALS LABORATORY - DEPARTMENT OF HIGHWAYS - ONTARIO

OFFICE REPORT ON SOIL EXPLORATION

DRILL RIG: 1000 J-1
CASING: 3X STANDARD
SAMPLER HAMMER WT: 250

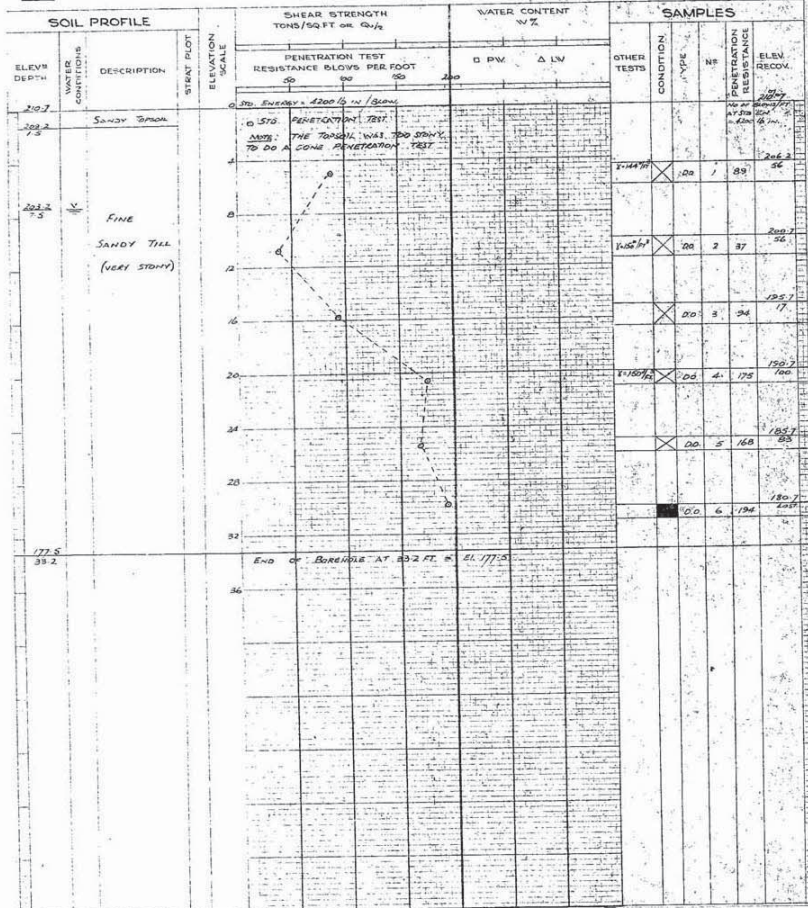
JOB: 35' F. 13 CORNWALL
DATUM: 31A 389+67.2
COMPILED BY: B.A. CHECKED BY:

BORING NO: 3
DATE REPORT: BORING DATE: June 19, 1958

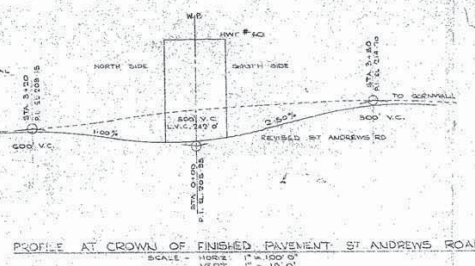
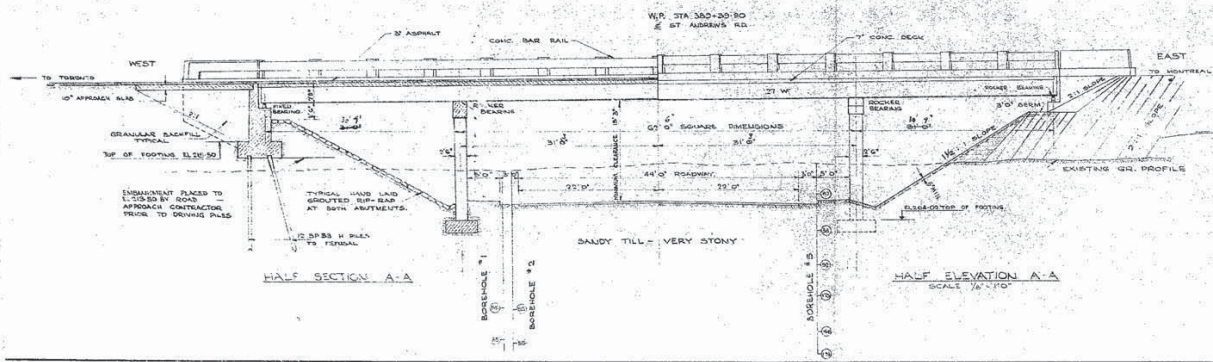
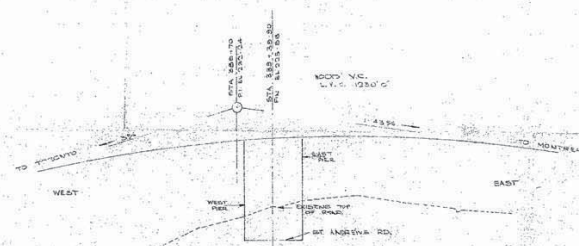
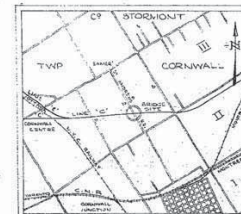
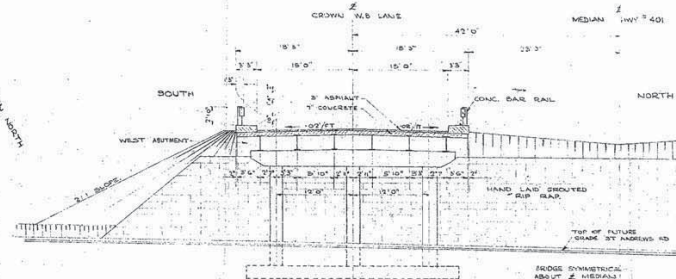
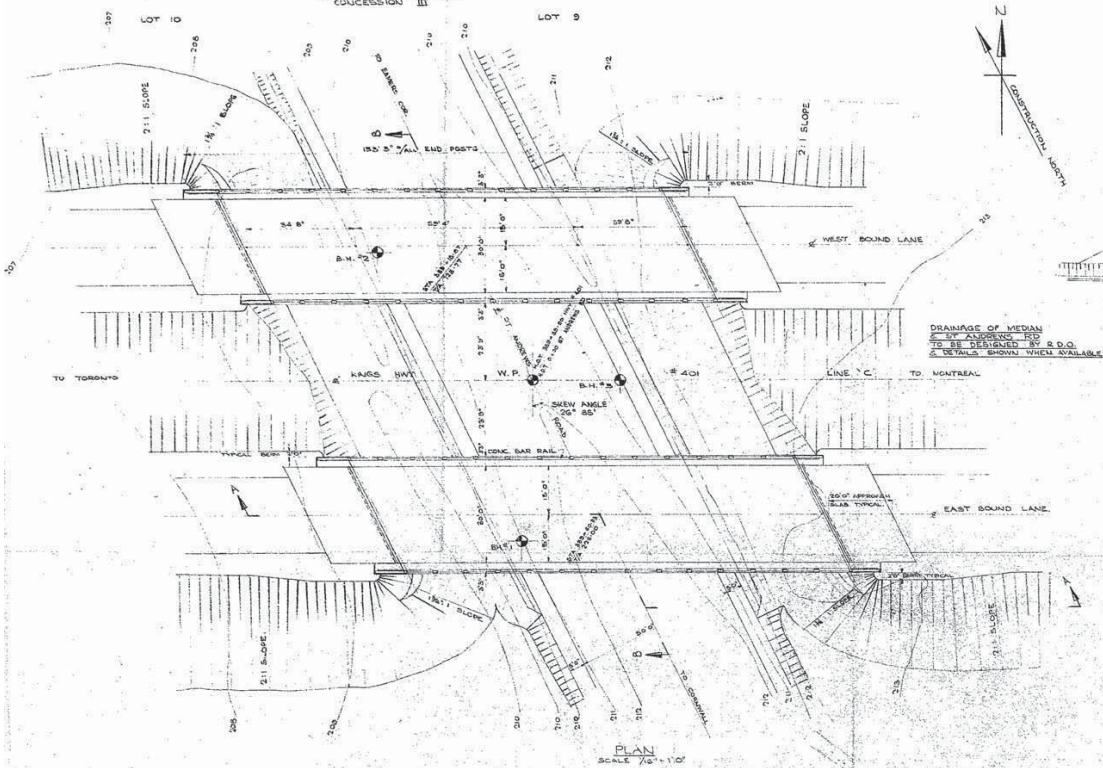
SAMPLE CONDITION
DISTURBED
GOOD
LOST

SAMPLE TYPES
C5 - CHURK
D5 - DRIVE OPEN
D7 - DRIVE FOOT VALVE
TO - THIN WALLED OPEN
W5 - WASHED SAMPLE
RC - ROCK CORE

ABBREVIATIONS
V - VISU VANE SHEAR TEST
M - MECHANICAL ANALYSIS
U - UNCONFINED COMPRESSION
Q - TRIAXIAL CONSOLIDATED QUICK
Q - TRIAXIAL QUICK
S - TRIAXIAL SLOW
X - UNIT WEIGHT
K - PERMEABILITY
C - CONSOLIDATION
CA - CASING
WL - WATER LEVEL IN CASING
WT - WATER TABLE IN SOIL



COUNTY OF STORMONT
TOWNSHIP OF CORNWALL
CONCESSION III



APPROVED
MAY 13 1960

BRIDGE ENGINEER
DESIGN ENGINEER

THE KING'S HIGHWAY NO. 401
DIST. NO. 9

CORNWALL TOWNSHIP
BRIDGE NO. 14
OVER ST ANDREWS RD.

PRELIMINARY GENERAL ARRANGEMENT

DATE MAY 1960

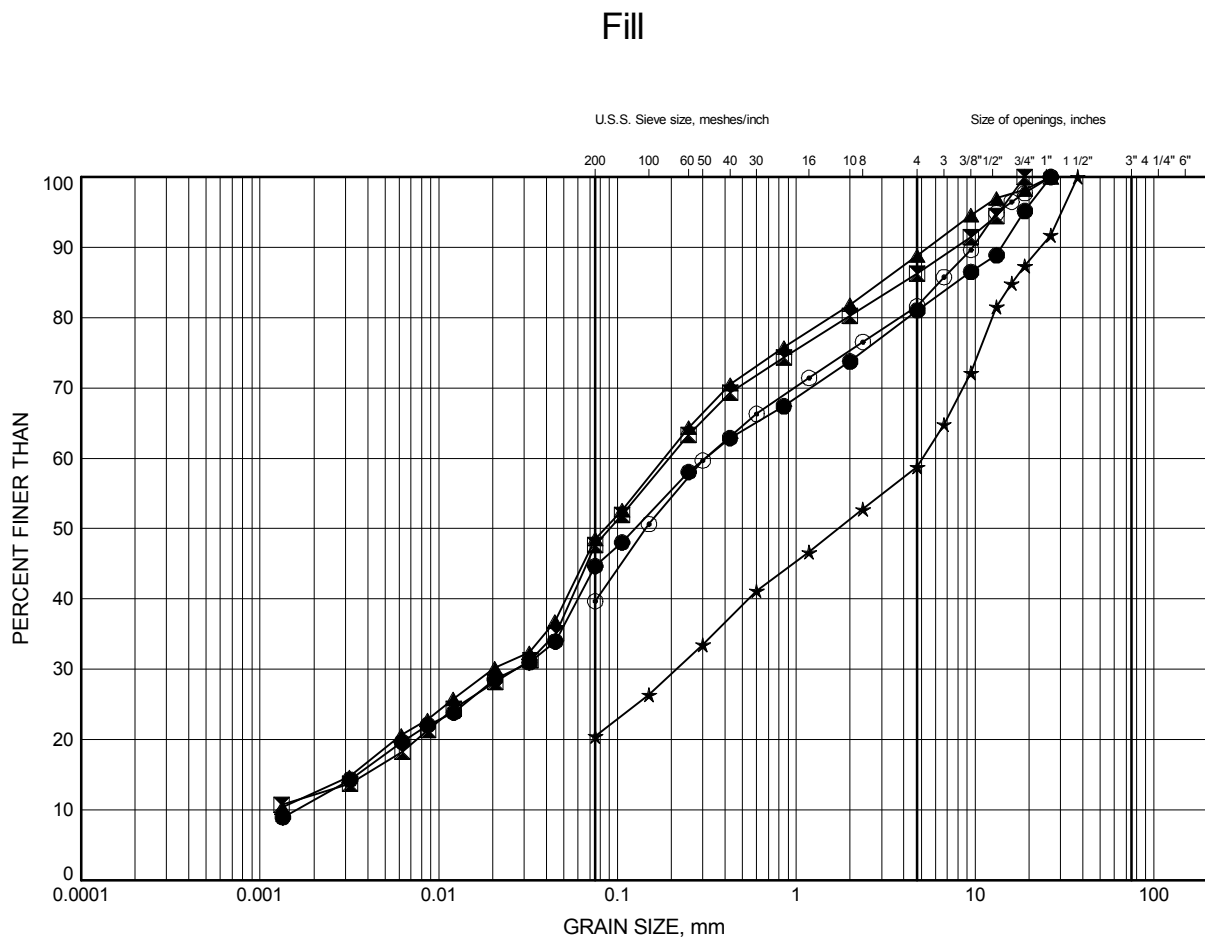
REVISIONS

NO.	BY	DESCRIPTION
1	AF	DESIGN
2	AF	DESIGN
3	AF	DESIGN
4	AF	DESIGN
5	AF	DESIGN
6	AF	DESIGN
7	AF	DESIGN
8	AF	DESIGN
9	AF	DESIGN
10	AF	DESIGN

APPENDIX D

LABORATORY TEST RESULTS – 2017 INVESTIGATION

GRAIN SIZE DISTRIBUTION



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-101	1.07	63.97
⊠	17-102	1.83	66.73
▲	17-102	4.11	64.45
★	17-12	0.30	68.56
⊙	17-14	1.83	66.57

Date February 2018

GWP# 4003-14-00



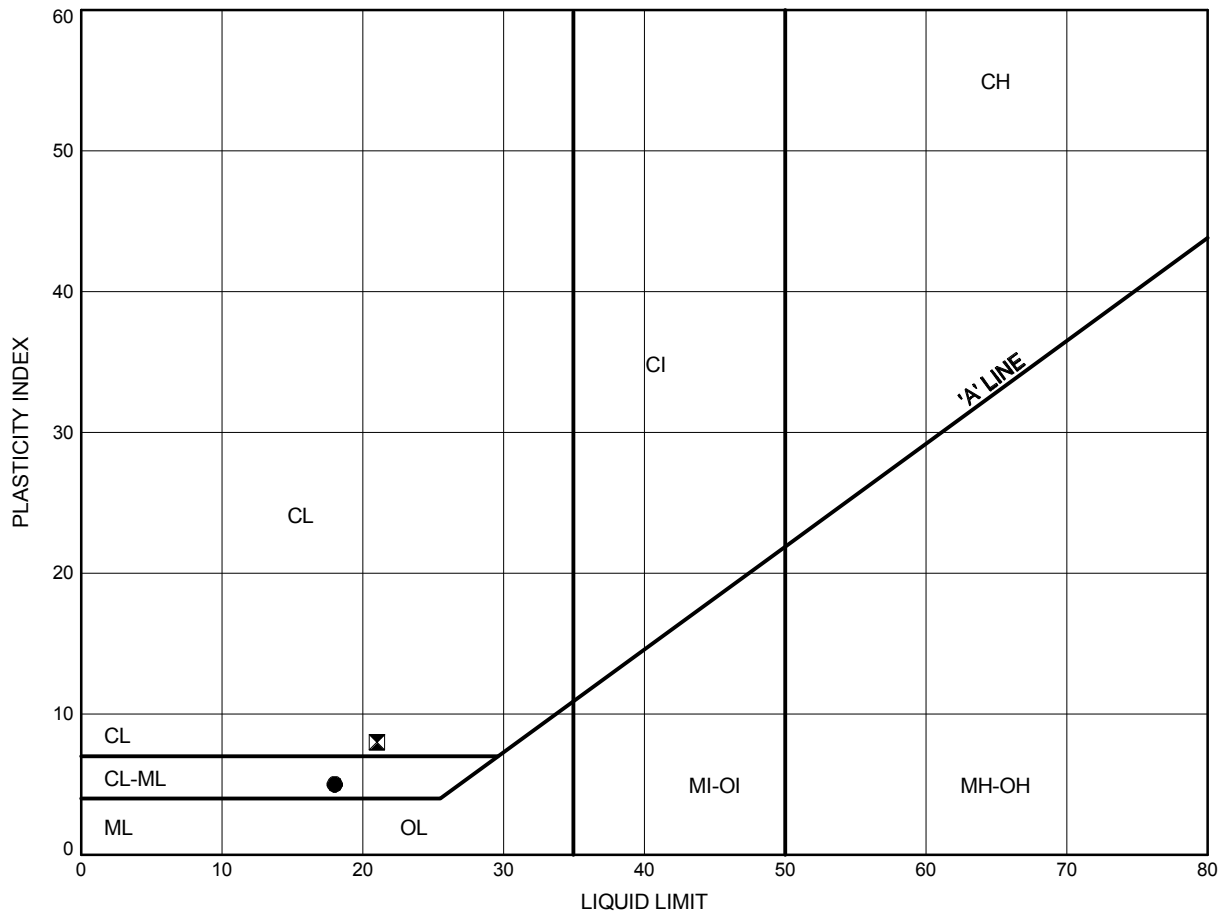
Prep'd KCP

Chkd. PC

Trenchless Utility Installation Highway 401 at Pitt Street

ATTERBERG LIMITS TEST RESULTS

FIGURE 2



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-101	1.07	63.97
⊠	17-102	1.83	66.73

Date February 2018

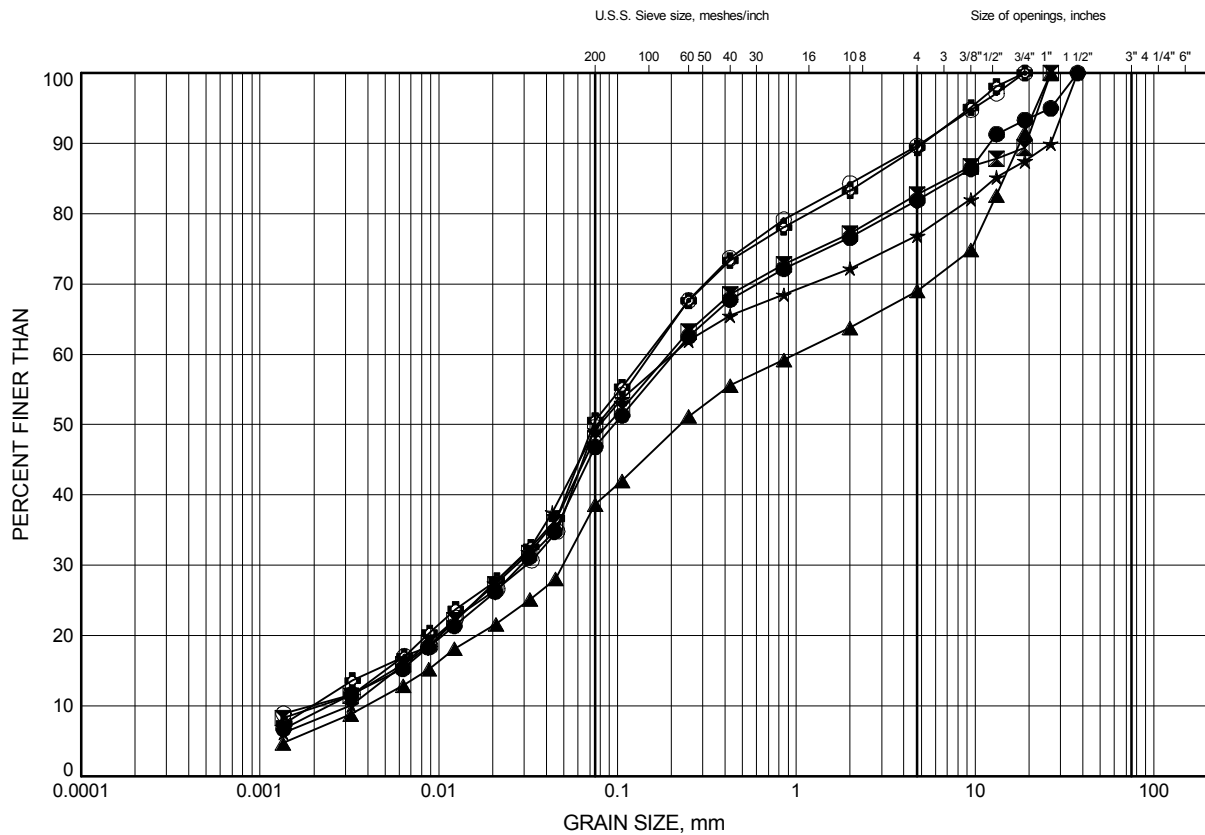
GWP# 4003-14-00



Prep'd KCP

Chkd. PC

Till - Sandy Silt some Gravel to Silty Sand with Gravel



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-101	4.88	60.16
⊠	17-102	7.16	61.40
▲	17-103	1.83	63.15
★	17-103	4.88	60.10
⊙	17-12	5.61	63.25
⊕	17-14	5.64	62.76

Date February 2018

GWP# 4003-14-00

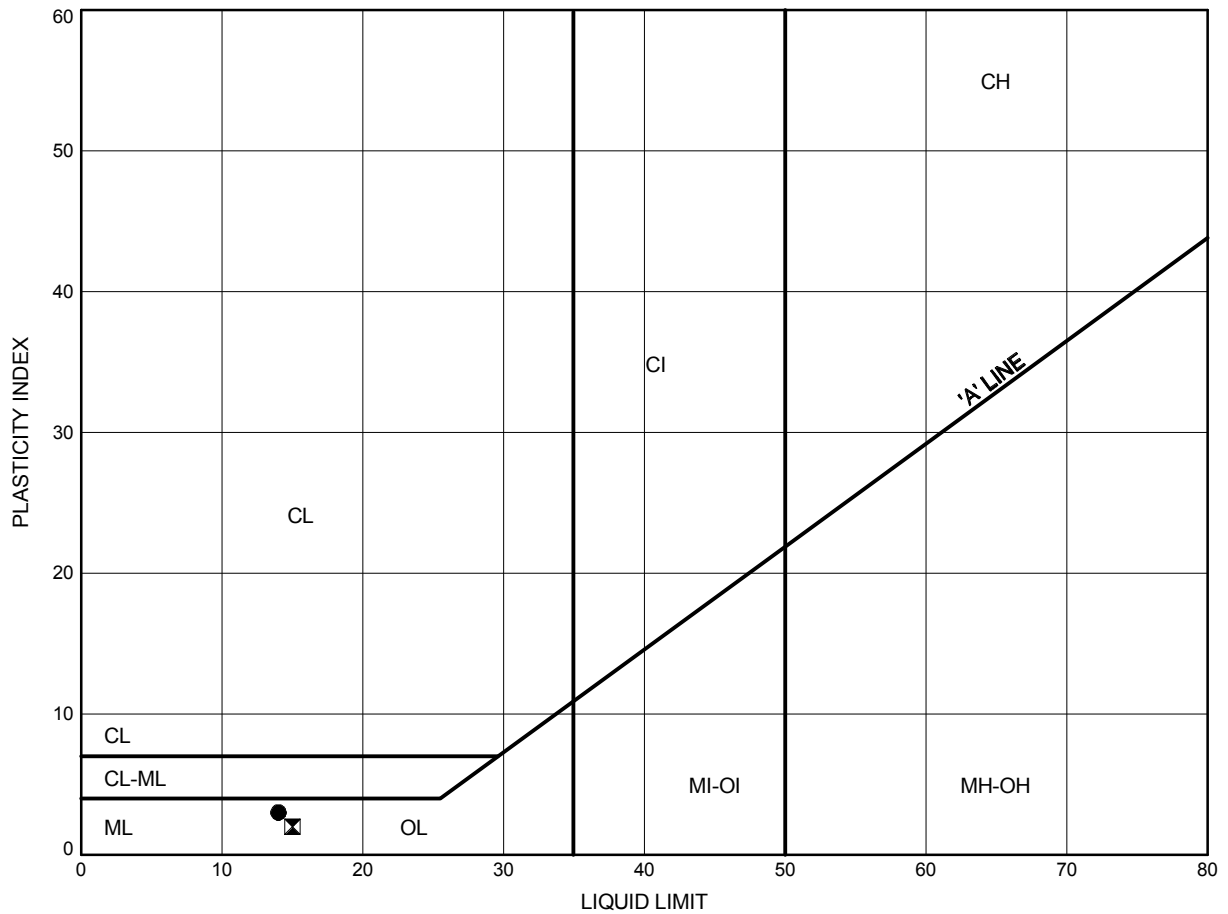


Prep'd KCP

Chkd. PC

Trenchless Utility Installation Highway 401 at Pitt Street
ATTERBERG LIMITS TEST RESULTS

FIGURE 4



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-101	4.88	60.16
⊠	17-12	5.61	63.25

Date February 2018

GWP# 4003-14-00



Prep'd KCP

Chkd. PC

Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Unit 107
Ottawa, ON K1B4S5
Attn: Kenton Power

Client PO:

Project: Pitt St. Utility Gossy 19-5161-263

Custody: 109421

Report Date: 5-Jan-2018

Order Date: 3-Jan-2018

Order #: 1801096

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

Paracel ID

1801096-01

1801096-02

1801096-03

Client ID

BH17-101 SS3 5-7'

BH17-102 SS8 17'6"-19'6"

BH17-103 SS4 7'6"-9'6"

Approved By:



Dale Robertson, BSc
Laboratory Director

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO:

Report Date: 05-Jan-2018

Order Date: 3-Jan-2018

Project Description: Pitt St. Utility Gossy 19-5161-263

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	4-Jan-18	4-Jan-18
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	3-Jan-18	4-Jan-18
Resistivity	EPA 120.1 - probe, water extraction	4-Jan-18	4-Jan-18
Solids, %	Gravimetric, calculation	3-Jan-18	4-Jan-18

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO:

Report Date: 05-Jan-2018

Order Date: 3-Jan-2018

Project Description: Pitt St. Utility Gossy 19-5161-263

Client ID:	BH17-101 SS3 5-7'	BH17-102 SS8 17'6"-19'6"	BH17-103 SS4 7'6"-9'6"	-
Sample Date:	13-Dec-17	14-Dec-17	15-Dec-17	-
Sample ID:	1801096-01	1801096-02	1801096-03	-
MDL/Units	Soil	Soil	Soil	-

Physical Characteristics

% Solids	0.1 % by Wt.	87.1	88.6	92.0	-
----------	--------------	------	------	------	---

General Inorganics

pH	0.05 pH Units	7.91	7.85	8.78	-
Resistivity	0.10 Ohm.m	32.6	35.9	60.0	-

Anions

Chloride	5 ug/g dry	99	74	18	-
Sulphate	5 ug/g dry	29	19	86	-

Certificate of Analysis
 Client: Thurber Engineering Ltd.
 Client PO:

Report Date: 05-Jan-2018

Order Date: 3-Jan-2018

Project Description: Pitt St. Utility Gossy 19-5161-263

Method Quality Control: Blank

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	ND	5	ug/g						
Sulphate	ND	5	ug/g						
General Inorganics									
Resistivity	ND	0.10	Ohm.m						

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO:

Report Date: 05-Jan-2018

Order Date: 3-Jan-2018

Project Description: Pitt St. Utility Gossy 19-5161-263

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	99.1	5	ug/g dry	98.6			0.5	20	
Sulphate	ND	5	ug/g dry	28.8			0.0	20	
General Inorganics									
pH	7.95	0.05	pH Units	7.91			0.5	10	
Resistivity	32.6	0.10	Ohm.m	32.6			0.2	20	
Physical Characteristics									
% Solids	81.0	0.1	% by Wt.	80.7			0.3	25	

Certificate of Analysis
 Client: Thurber Engineering Ltd.
 Client PO:

Report Date: 05-Jan-2018

Order Date: 3-Jan-2018

Project Description: Pitt St. Utility Gossy 19-5161-263

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	194	5	ug/g	98.6	95.6	78-113			
Sulphate	128	5	ug/g	28.8	99.5	78-111			

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO:

Report Date: 05-Jan-2018

Order Date: 3-Jan-2018

Project Description: Pitt St. Utility Gossy 19-5161-263

Qualifier Notes:

None

Sample Data Revisions

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable

ND: Not Detected

MDL: Method Detection Limit

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

%REC: Percent recovery.

RPD: Relative percent difference.

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.

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

APPENDIX E
SITE PHOTOGRAPHS



Photograph 1 : Exit pit location (south end of alignment) looking east.



Photograph 2: Exit pit location (south end of alignment) looking north towards Highway 401 embankment



Photograph 3: Looking east towards Borehole 17-102 along Highway 401 median



Photograph 4: Entry pit location (north end of alignment) looking east

APPENDIX F

COMPARISON OF TRENCHLESS INSTALLATION METHODS

Comparison of Trenchless Installation Methods

Micro-Tunneling (MTBM)	
Description	Micro-tunneling is a trenchless technique based on the pipejacking principle that uses a boring machine for excavation that provides continuous excavation face support during tunneling. A remote control boring machine with a cutterhead is advanced by a hydraulic jacking system mounted and aligned in the entry pit. As the boring machine advances pipe segments are attached and are hauled behind the boring machine in a “pipe-train”. Soils spoils are mixed with a slurry of clean water and bentonite and mixture is pumped to a separation system to allow slurry recycling and recirculating.
Advantages	<p>Using the cutterhead the tunneling machine can advance through obstructions up to 30% of the diameter size of the tunneling machine.</p> <p>Boring machine provides full face excavation support during tunneling</p> <p>Personnel are not required to enter the excavation for spoil removal etc.</p> <p>High precision in alignment control can be achieved</p> <p>Can be used above and below groundwater table</p>
Disadvantages	<p>MTBM requires significant ground excavation to construct the entry/exit points.</p> <p>The base of the pits needs to be at a slightly lower elevation than the proposed pipe invert to allow the construction of the hydraulic jacking system foundation which increases the excavation depths.</p> <p>Space is required for the separation system and storage of slurry mixture on site prior to disposal</p> <p>High operator skill required</p>
Risks / Consequences	Unforeseen oversized obstruction may slow progress / new alignment may be required and/or a second shaft may be required if the obstruction cannot be overcome
Relative Cost	High
Conclusion	Recommended for this site. MTBM method has a high level of horizontal and vertical alignment control can advance the pipe-train through the anticipated obstructions while maintaining full-face excavation support during tunneling.

Horizontal Directional Drilling	
Description	Three phase drilling process where the tunnel diameter is increased with each pass. Boring is achieved from surface without the use of launching or receiving pits. During Phase 1 a pilot hole is advanced, Phase 2 the tunnel is enlarged using a reaming tool and last phase the pipe is pulled back through the reamed tunnel. A drilling fluid is used to suspend and remove soil cuttings.
Advantages	Limited requirement for launching or receiving pits Moderate precision in alignment control can be achieved
Disadvantages	Unable to advance through obstructions greater than gravel size particles Space is required for the drilling fluid mixture on site prior to disposal High operator skill required Accuracy decreases with increased tunnel length Cannot be used below the groundwater level in non-cohesive soils
Risks / Consequences	Unforeseen oversized obstructions encountered / new alignment may be required if the obstruction cannot be avoided.
Relative Cost	Moderate
Conclusion	Not recommended as this method is unable to advance through oversized obstructions

Jack and Bore	
Description	Pipe sections are advanced by a hydraulic jacking system mounted and aligned in the launching shaft.
Advantages	Pipe sizes up to 2.0 m in diameter can be bored Readily available equipment
Disadvantages	Requires significant ground excavation to construct launching and receiving shafts at the entry/exit points. The base of the shafts need to be slightly lower elevation than the proposed pipe invert to allow the construction of the hydraulic jacking system. Unable to advance through obstructions greater than gravel size particles Prone to misalignment with limited horizontal steering control.
Risks / Consequences	Unforeseen oversized obstructions encountered / new alignment may be required if the obstruction cannot be avoided.
Relative Cost	Moderate
Conclusion	Not recommended as this method is unable to advance through oversized obstructions and has limited steering and alignment control

Pipe Ramming	
Description	Pipe jacking is a trenchless technology method similar in principle to micro-tunneling. The method uses a horizontal jacking force to advance the pipe. Unlike micro-tunneling, pipe jacking requires personnel entry inside the pipe to carry out excavation and spoil removal. The method is best suited to large-diameter pipes to provide adequate space for spoil removal and ventilation for workers.
Advantages	Advancement past obstruction is possible by manual removal at the tunnel face
Disadvantages	<p>Requires significant ground excavation to construct launching and receiving shafts at the entry/exit points. The base of the shafts need to be slightly lower elevation than the proposed pipe invert to allow the construction of the hydraulic jacking system.</p> <p>High risk for workers that need to access the tunnel face</p> <p>Tunnel face instability is likely with the removal of larger obstructions and could cause settlement of the road surface</p> <p>Maximum length is approximately 60 m which is less than the proposed alignment</p> <p>Prone to misalignment when obstructions are encountered</p> <p>The method has limited horizontal steering control.</p>
Risks / Consequences	Unforeseen oversized obstructions encountered / new alignment may be required if the obstruction cannot be avoided.
Relative Cost	Moderate
Conclusion	Not recommended as this method has a limited effective installation range, requires manual removal of obstructions requiring workers to access the tunnel, unable to advance through oversized obstructions they must be manually removed and has limited steering and alignment control

APPENDIX G

SPECIAL PROVISION PIPE INSTALLATION BY TRENCHLESS METHOD SETTLEMENT INSTRUMENT LOCATION PLAN

Special Provision

This specification covers the requirements for the installation of pipes by trenchless method utilizing Microtunnelling. This construction method involves jacking a pipe behind a micro-tunnel boring machine (MTBM).

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

OPSS 180 Management and Disposal of Excess Material

OPSS 401	Trenching, Backfilling, and Compaction
OPSS 402	Excavation, Backfilling and Compaction for Maintenance Holes, Catch Basins, Ditch Inlets and Valve Chambers
OPSS 403	Rock Excavation for Pipelines, Utilities and Associated Structures in Open Cut
OPSS 404	Support Systems
OPSS 491	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures in Open Cut
OPSS 517	Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS 539	Temporary Protection Systems

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

OPSS 1820 Material Specification for Circular Concrete Pipe

ASTM A252-93 Welding and Seamless Steel Pipe Piles

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:

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

Casing means a pipe to support a bore.

Cased Bore means a bore in which a pipe is inserted simultaneously with the boring operation.

Conditioning Agents means bentonite, polymers, surfactants, foam and soda ash, or other additives used as an aid in performing the microtunnelling excavation.

Contact Grouting means grouting of the overcut.

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.

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

Earth Pressure Balance Shield means a shield on a microtunnel boring machine that uses the excavated soil to provide continuous face support that counteracts the soil and groundwater pressure at the tunnel face.

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

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

Fill means 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.

Foundation Investigation Report means a report providing information on the anticipated geotechnical subsurface conditions. May be a geotechnical data report or a geotechnical interpretive report. May or may not be a contract document.

Grouting means the process of filling voids or modifying/improving ground conditions. Grouting materials may be cementitious, chemical, or other mixtures. In microtunnelling, grouting may be used to fill voids around the pipe or shaft, or to improve ground conditions.

Intermediate Jacking Station means a fabricated steel cylinder fitted with hydraulic jacks that is incorporated into a pipeline between two pipe segments. Its function is to distribute the jacking load over the pipe string on long drives.

Jacking Pipes means pipes designed to be installed using pipe jacking techniques. May be casing and/or product pipe.

Launch/Exit Seal means a mechanical seal, usually composed of a rubber flange that is mounted to the wall of the drive shaft. The flange seal is distended by the MTBM as it passes through, creating a seal to prevent water or lubrication inflow into the shaft during tunnelling operations.

Lubricant means a mixture of water and additives designed to reduce friction in the bore.

Microtunnelling means a trenchless construction method for installing pipelines that includes the following features: (1) Remote Controlled, (2) Guided, (3) Pipe Jacked, (4) Continuously Supported.

Microtunnel Boring Machine (MTBM) means mechanized excavating component of the microtunnelling system including cutter head, machine can, and any trailing cans.

Microtunnelling Methodology means a written description, together with supporting documentation that defines the Contractor's plans and procedures for microtunnelling operations.

Obstruction means any object or feature that lies completely or partially within the cross-section of the microtunnel and prevents continued forward progress.

Overcut means the annular space between the excavated hole and the outside diameter of the jacking pipe.

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

Portal means entrance (start) and exit (end) of the microtunnel drive. Also referred to as the tunnel eye.

Product Pipe means a pipe used for conveyance of water, gas, sewage, and other products and services.

Quality Verification Engineer (QVE) means 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.

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

Shaft means vertically sided excavation from which the microtunnelling operation is initiated or directed.

Slurry means a fluid, normally water, used in a closed loop system for the removal of spoil and for the balance of groundwater pressure during microtunnelling.

Slurry Separation means a process in which excavated material is separated from the circulation slurry.

Soil means 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.

Spoil means earth, rock and other materials removed during installation.

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

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

Work means the total construction and related services required by the Contract Documents.

4. DESIGN AND SUBMISSION REQUIREMENTS

4.01 General

The Contractor's documentation, submission requirements and installation methods shall specifically consider and address any subsurface conditions at the pipe crossing that may be identified in the borehole logs included in the Contract Drawings. If the Contractor requires additional foundation information than what is provided in the Contract Documents, it is the Contractor's responsibility to obtain this information at no additional cost the Contract.

The Contractor shall be fully responsible for the design of the shapes, wall thicknesses, sizes and types of the casing and shafts required to facilitate the work.

4.02 Qualifications

The Tunnelling Contractor shall have demonstrated expertise for the work. The Tunnelling Contractor shall have a minimum of 10 years' experience in microtunnelling trenchless crossings of similar nature and scope to the required work.

The Design Engineer shall have demonstrated expertise for the work. The design Engineer shall have a minimum of 10 years' experience in designing trenchless crossings of similar nature and scope to the required work.

The Design-Checking Engineer shall have demonstrated expertise for the work. The design-checking Engineer shall have a minimum of 10 years' experience in designing trenchless crossings of similar nature and scope to the required work.

One person shall not perform both the Design Engineer and Design-Checking Engineer roles.

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

4.03 Submission Requirements

The Contractor shall submit 3 sets of Working Drawings, including all required details and procedures to the Contract Administrator at least 14 Days prior to commencement of construction for installation of the

trenchless crossing, for information purposes only. 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, details and procedures at the site during construction.

As a minimum, Working Drawings and details and procedures 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, site and equipment layout plan, work area layout, methods and schedule to be used to execute the work.
- Project utility/site servicing details.
- Traffic management plan, including emergency access/egress.
- Ground control/dewatering details, as applicable, describing the proposed method for control, handling, treatment, and disposal of water. Working Drawings for the dewatering system shall be submitted according to OPSS 517. The requirements outlined in subsection 517.04.03 'Preconstruction Survey' shall to adjacent properties, buildings, underground structures, water wells, Utilities, and structures, within a distance of 150 metres from the groundwater control system.
- Environmental erosion and sediment control plan.
- Excavated materials disposal plan.

b) Construction Shafts

- Drawings and calculations for work shafts, entry and exit pits and required protection systems.
- Shaft construction details including access/egress, launch/reception seals and thrust wall.

c) Methodology

- Microtunnelling method statement, including pre-launch and MTBM reception procedures and a site specific construction program.
- Estimated jacking force calculations, including identifying the need for any intermediate jacking stations.
- Calculations demonstrating that the soils behind the thrust block are capable of sustaining the maximum anticipated jacking forces with a minimum factor of safety of 2.0.
- Casing pipe details, including any intermediate jacking stations and pipe specials. Casing pipe design must demonstrate that the pipe is capable of sustaining all anticipated loads including loads imposed during jacking. Also, to include potential larger jacking forces required to advance the pipeline following stoppages.
- Calculated volume of lubrication.
- Contingency plans as specified in the Contract Documents.
- Microtunnelling guidance system details.
- Spoil disposal plan.
- Casing contact grouting plan.

d) Equipment

- MTBM and jacking frame details.
- MTBM Guidance system
- Slurry management and separation system details.
- Lubrication system details.

- Ventilation system details.
- Atmosphere monitoring systems and alert protocols.
- Communication system plan.

e) 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.

f) Health and Safety Plan

- Response plan to hazardous atmosphere detection.
- Confined space entry plan, if required to enter the tunnel.
- Emergency microtunnel and shaft evacuation and rescue plans, to encompass injury, fire, flooding, and security breach.

g) Environmental Contingency Plans

- Environmental spill response plan.
- Adverse weather plan, if required.

h) Quality Control and As-Built Records

- Survey Control: Verification of jacking frame alignment and elevation.
- Monitoring data (settlement, vibration, noise, building, groundwater, etc.) as specified in the Contract Documents.
- Calibration and certification records as specified in the Contract Documents.
- Details of MTBM data logging and daily record sheets.
- Vertical and horizontal alignment survey of jacked pipe and/or final product pipe.

i) Contingency Plan

- Machine unable to advance:
 - Possible obstruction.
 - Insufficient jacking capacity.
 - Machine malfunction.
- Slurry separation problems:
 - Cuttings do not settle out using the Contractor's on-site slurry separation plant.
 - Cuttings settle out in the slurry lines before reaching the separation plant.
- Strong hydrocarbon smell is detected in the slurry return lines or in the jacking or receiving shaft.
- Laser distorted by heat, humidity, or physical disturbance.
- Jacking forces:
 - Jacking forces increase dramatically or suddenly.
 - Jacking forces reach design capacity of pipe, jacking frame, or thrust wall (treat these scenarios as separate incidents).
- Settlement/Heave:
 - Survey measurements indicate that ground movement exceeds allowable limits.
 - Excavated volumes exceed pipe volume plus overcut volume.
 - Slurry face pressures and/or torque on head decrease suddenly and/or significantly.
- Slurry Returns to Ground Surface:

- Describe procedures for preventing slurry losses or spills to, or on, the ground surface. The plan shall also address changes that may be required to the Contractor's operations to avoid recurrences.
- Groundwater inflow to shaft increases significantly and/or transports soils into shaft in measurable quantities.
- Steering difficulties result in line and grade tolerances and/or allowable steering corrections being exceeded (onshore drive).
- Steering difficulties result in line and grade tolerances and/or allowable steering corrections being exceeded (offshore drive).
- Pipe damaged or found to be out of compliance with specifications.
 - Before installation.
 - During or after installation.
- Thrust block deforms excessively (causing misalignment of the jacking frame or failure of the shoring wall) under jacking loads, or provides insufficient capacity to advance pipe.
- Severe storms or flooding predicted; shaft flooding possible.
- Voids are created by inadvertent over excavation.
- Control signal is lost. Cannot monitor position, torque, thrust, steering jack position or other MTBM performance parameters.

4.04 Site Survey

Prior to commencing the work, the Contractor shall, at each pipe location, layout the alignment and install settlement monitoring points and benchmarks as per the monitoring plan outlined in Section 8.

4.05 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 and Design-Checking 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 4.04)
 Excavation for pits including dewatering of excavation
 Jacking and installation of Casing/Liner
 Excavation and Dewatering
 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.

5.0 MATERIALS

5.01 Casing / Pipe Materials

The casing and product pipe shall be reinforced concrete or steel.

5.01.01 Concrete Pipe

Concrete pipe shall conform to OPSS 1820.

The Contractor shall select the pipe class to withstand grouting pressure, installation forces and final configuration. The Contractor shall identify these forces within the submission requirements.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used. Pipe joints shall be fully gasketed and sealed.

5.01.02 Steel Pipe

Steel pipe shall be according to ASTM A 252, 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 and anticipated installation forces for selected pipe and driven pipe lengths. The wall thickness shall be increased as required to ensure the casing is not damaged during handling and installation. The pipe minimum wall thickness shall be as per Table 1 of OPSS 1802.

Pipe segments shall be determined by the Contractor.

Steel pipe joints shall be pressure fit type or welded.

All steel casing pipe shall be square cut.

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

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

Corrosion protection shall be provided to the steel pipe to suit the existing soil conditions. The Contractor shall refer to analytic test results for the existing soils specified in the Foundation Investigation Report for the Trenchless Utility Crossing of Highway 401 EBL and WBL at Pitt Street, prepared by Thurber Engineering Ltd., 2018.

5.01.02.01 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.

5.02 Lubricant

Lubricants shall be appropriately mixed for the anticipated in situ ground conditions. Only bentonite or additives shall be used as annular lubricants. All additives shall be chemically inert, biodegradable, and non-toxic. No petroleum-based or detergent additives shall be permitted.

5.03 Grout

The Contractor shall submit the proposed grout mix design for grouts to be used 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.

6.0 EQUIPMENT

6.01 Microtunnelling Equipment

6.01.01 General

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

The Contractor shall employ microtunnelling equipment that will be capable of handling the various anticipated ground conditions indicated in the Foundation Investigation Report for the Trenchless Utility Crossing of Highway 401 EBL and WBL at Pitt Street, prepared by Thurber Engineering Ltd., 2018. The MTBM shall also be capable of controlling loss of soil ahead of and around the machine and shall provide continuous pressurized support of the excavated face.

6.01.02 Remote Control System

The MTBM shall include a remote control system that allows for operation of the system without the need for personnel to enter the microtunnel. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.

6.01.03 Active Direction Control

The MTBM shall include an active direction control system that controls line and grade by a guidance system that relates the actual position of the MTBM to a design reference. The MTBM shall have active steering information that shall be monitored and transmitted to the operating console and recorded.

6.02 Shafts

Shafts shall be designed to incorporate the following features:

- The thrust block shall be perpendicular to the pipe alignment and shall be designed to withstand the anticipated jacking force with a factor of safety of a minimum of 2.0. The thrust block shall be designed to transmit the applied jacking forces to the earth behind the shaft excavation shoring without excessive deflection or displacement (causing misalignment of the jacking frame or failure of the shoring wall). The thrust block shall be removed prior to backfilling unless approved in writing by the Contract Administrator.
- The jacking shaft shall be designed with a concrete working slab. The guide rails and the jacking frame shall be securely attached to the concrete working slab with supplementary concrete or grout, if necessary, to prevent movement or shifting during the work.

6.03 Pipe Jacking Equipment

Provide a pipe jacking system with the following features:

- Has sufficient jacking capacity to push the microtunnelling excavation equipment and the string of pipe through the ground.
- Develops a uniform distribution of jacking forces on the end of the casing pipe.
- Provides and maintains a pipe lubrication system at all times to lower the friction developed on the surface of the pipe during jacking.
- Jack Thrust Blocking shall adequately support the jacking pressure developed by the main jacking system.

6.04 Spoil Separation System

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

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

The system shall include the following features:

- A surface separation plant shall be provided that is equipped with screens, centrifuges, cyclones and settling tanks for efficient removal of muck (both coarse and fine-grained fractions) from the slurry at a rate compatible with the anticipated MTBM advance rate.
- The microtunnel system shall include a slurry separation plant that can achieve the rates of spoil separation and slurry cleaning required by the Contractor to achieve planned production rates. The Contractor shall ascertain the use of only gravity separation based on the ground conditions at its own risk. Shaker screens, hydrocyclones and centrifuges are required for efficient separation of tunnel spoils. The Contractor is advised that the separation plant must fit within the allowable work areas indicated on the Contract Drawings and that excavated slurry shafts or ponds are prohibited.
- All tunnel spoils and slurry must be contained in trucks, tanks, or other containers. Dumping of soil or slurry on the ground or into lagoons, discharge into sewers, or discharge in shafts will not be permitted. The Contractor shall transport and dispose of all spoils and waste slurry off-site at a MOE approved disposal facility.

6.05 Electrical Equipment, Fixtures and Systems

Electrical equipment shall be suitably insulated for noise reduction. Noise produced by electrical equipment must comply with local municipal noise by-laws. Electrical systems shall conform to requirements of the Canadian Electrical Code – CSA C22.1.

6.06 Air Quality

Provide equipment to maintain proper air quality in shafts and in any manned microtunnel intervention during construction in accordance with OSHA requirements.

7. CONSTRUCTION

7.01 General

The Contractor shall notify the Contract Administrator and any other authorities identified in the contract documents at least 72 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.

For microtunnelling the following tolerances shall be:

- Maximum Departure from Established Grade: 300 mm.
- Maximum Departure from Established Line: 750 mm.
- Return to line and grade (i.e.: maximum steering correction): 25 mm over 7.5 m drive length

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

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.

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 construction entrances. The fence shall be removed on completion of the Work.

7.01.03 Protection Systems

The construction of all protection systems, if required, 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 may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works.

7.01.04 Settlement or Heave

Any settlement or heave at the ground surface as a result of the pipe installation, that exceeds the limits specified in the contract documents, shall be immediately corrected by the Contractor at no additional cost.

7.01.05 Stability of Excavation

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

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

7.01.06 Preservation and Protection of Existing Facilities

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

Buried utilities are present on the north and south sides of the proposed tunnel installation at approximate locations detailed elsewhere in the Contract Documents. Existing underground facilities shall be exposed to verify its horizontal and vertical locations at the entry and exit pits. 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 shafts or other locations along the pipe path shall be according to OPSS 401, 402 and 403.

7.01.09 Dewatering

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

The dewatering system shall be according to OPSS 517.

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.

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.

The Contractor shall maintain shift logs of construction events and observations. The Contract Administrator shall have access to the Contractor's logs with regard to the following information:

- Location of MTBM by station and progress of microtunnel drive during shift.
- Hours worked per shift on microtunnelling operations.
- Completed field forms for checking line and grade of the microtunnelling operation, showing achieved tolerance relative to design alignment. Steering control logs will generally be acceptable.
- Maximum pipe jacking forces per drive.
- Location, elevation and brief soil descriptions of soil strata.
- Groundwater control operations and groundwater levels.
- Observation of any lost ground or other ground movement.
- Any unusual conditions or events.
- Reasons for operational shutdown in the event a drive is halted.
- Pressure at the face of the tunnel.
- Lubrication records.
- Slurry flow rates and pressures.

7.01.12 Testing

Testing of the product installation shall consist of verifying the specified grade between the two ends of the

pipe.

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

Once the tunnel installation is completed, the Contractor shall cap each end of the tunnel with a removable watertight seal that can also permit backfilling of the entry and exit pits. The Contractor shall install a delineator at each end of the tunnel to identify the precise location of the tunnel entry and exit. The selection and installation of the delineator shall be to the satisfaction of the Contract Administrator.

The remainder of the site restoration shall be according to OPSS 492.

7.02 Microtunneling Installation

7.02.01 General

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

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

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

The Contractor shall maintain clean working conditions at all times.

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

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

7.02.02 Method Installation

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

- 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 subsurface conditions within the tunnel alignment.
- Perform microtunnelling operations in a manner that will minimize the movement of the ground in front of and surrounding the tunnel in conformance with the limits listed in the Contract Documents.

- Prevent damage to structures and utilities above and in the vicinity of the microtunnelling operations.
- Excavated diameter should be the minimum size required to permit pipe installation by jacking.
- Whenever there is a condition encountered which could endanger the microtunnel excavation or adjacent structures if tunnelling operations cease, continue to operate without intermission including 24-hour working days, weekends and holidays, until the condition no longer exists.
- Maintain an envelope of lubricant around the exterior of the pipe during the jacking and excavation operation to reduce the exterior soil/pipe friction and possibility of the pipe seizing in place.
- In the event a section of pipe is damaged during the jacking operation or a joint failure occurs, as evidenced by inspection, visible ground water inflow or other observations, the Contractor shall submit for approval his methods for repair or replacement of the pipe.

7.02.03 Casing Installation

Casing must withstand the jacking forces determined by the Contractor.

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

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

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

7.03 Monitoring

The Contractor shall monitor, record, and submit records for the monitoring of settlement and ground stability at the trenchless installation site as specified in Section 8.0 and Contract Drawings.

8. SETTLEMENT INSTRUMENTATION AND MONITORING

8.01 General

The work specified in this Section includes furnishing, installing monitoring of the instruments for monitoring of settlement and ground stability at the trenchless installation site.

Surface Monitoring Points (SP) and Settlement Monitoring Points (SM) 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.

The purpose of the SPs is to monitor settlement of asphalt paved surface. The ground movement readings shall assist in assessing the tunnelling performance and any need to modify the installation methodology as required. Settlement is measured by level surveying the SPs with reference to stable, non-settling benchmarks.

The purpose of the SMs is to monitor the settlement of the ground and highway embankments along the proposed tunnel alignment. The settlement readings shall assist in assessing the tunnelling performance and

any need to modify the installation methodology as required. Settlement is measured by surveying the top of the rod with reference to stable, non-settling benchmarks.

The Contractor shall supply all materials and equipment required for the installation of the SPs and SMs.

The Contractor shall install all SPs and SMs a minimum of two (2) weeks prior to the start of work and complete baseline readings as specified in the Contract Documents.

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

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.

The number of monitoring points that will be installed at the trenchless installation are as follows:

- Surface Monitoring Points (SP) Fourteen (14)
- Settlement Monitoring Point (SM) Five (5)

The locations of SPs and SMs are shown on the Contract Drawings.

8.02 Surface Monitoring Point (SP) - Supply & Installation

8.02.01 General Procedure

SPs shall be rigidly affixed so as not to move relative to the asphalt pavement surface to which they are attached.

The locations of SPs are shown on the Contract Drawings.

8.02.02 Surface Monitoring Point Materials - Steel Markers

The Contractor shall supply hardened steel markers with an exposed convex head treated or coated to resist corrosion, similar to surveyor's PK nails. The steel markers shall have a minimum diameter of 12 mm and have sufficient length for anchoring in the pavement and to withstand the weather conditions and effects of traffic. The exposed nail head shall be equipped with reflective paint or reflective tape to allow for measurements with total-station equipment.

8.02.03 Surface Monitoring Point Installation

During installation traffic shall be managed by the Contractor using short term lane closures in accordance with the Ontario Traffic Manual (OTM), Book 7.

The SPs in the shoulders of the highway should be installed in an array of three points perpendicular to the alignment, with a maximum center-to-center spacing of 2.5 m. The spacing between the two outside SPs in an array should not exceed 5.0 m. Additional single SPs shall be installed along the alignment at the centerline of Highway 401 eastbound and westbound.

8.02.04 Documentation

Relevant installation details shall be recorded and documented. These include, but are not limited to:

- SP's location, easting, northing and elevation;
- Dates of installation; and
- Installation notes / sketches / pictures.

8.03 Settlement Monitoring Point (SM) - Supply & Installation

8.03.01 General Procedure

In general, the SMs shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe used as a friction reducing sleeve, set to a depth of 1.7 m below ground surface.

The assembly shall be placed in a drilled hole and backfilled with anchor grout and clean washed sand as shown on Settlement Monitoring Point Detail on the Contract Drawings.

The locations of SMs are shown on the Contract Drawings.

8.03.02 Settlement Monitoring Point Materials

Rod

The Contractor shall supply 12 to 18 mm diameter steel rebars in the required lengths in order to complete this installation.

The top end of each rod shall be equipped with reflective paint or reflective tape to allow for measurements with total-station equipment.

Anchor

The Contractor shall supply concrete for anchoring the lower end of the steel rebar. The concrete shall be prepared in accordance with OPSS 1350 with a minimum compressive strength of 10 MPa.

Sand

The Contractor shall supply clean washed sand. The sand will be Sakcrete washed general purpose sand, or equal.

Friction Reducing Sleeve

The Contractor shall supply a friction reducing sleeve consisting of Schedule 40, 50 mm O.D. PVC pipe cut perpendicular to the axis of the pipe.

Protective Casing

The Contractor shall supply protective steel casings installed flush with the ground surface where the SMs are installed in shoulders that can be travelled by vehicles.

8.03.03 Settlement Monitoring Point Installation

The Contractor shall install SMs as per Settlement Monitoring Point Detail on the Contract Drawings in addition to what is stated or emphasized below.

During installation traffic shall be managed by the Contractor using short term lane closures in accordance with the Ontario Traffic Manual (OTM), Book 7 as required.

The rod shall be centred in the borehole.

The friction reducing sleeve shall extend for the length of the rod above the anchor grout.

8.03.04 Documentation

Relevant installation details shall be recorded and documented. All documentation information shall be provided to the Contract Administrator.

These include, but are not limited to:

- SM's location, easting, northing;
- Elevation of top of rod;
- Dates of installation; and
- Installation notes / sketches / pictures.

8.04 Decommissioning of Instruments

The Contractor shall decommission all SPs and SMs after the completion of the monitoring program as directed by the Contract Administrator.

8.05 Settlement/Heave Monitoring Program

8.05.01 General

The instrumentation monitoring services specified herein apply to all the SPs and SMs for this site.

The requirements include data collection, reporting, data reduction and data transmission.

The Contractor shall carry out the monitoring program for this project. The required tasks include the following:

- Supply materials and equipment required for monitoring;
- Survey the instruments with no interference with the traffic on Hwy 401 and its ramps;
- Compile and reduce the survey data as described in Section 8.05.04.01
- Transmit the settlement data and associated pipe installation / construction activities to Contract Administrator, Contract Administrator's Geotechnical Consultant and MTO;
- Notify Contract Administrator, Contract Administrator's Geotechnical Consultant and MTO of any required modifications to the construction procedures;
- Notify Contract Administrator, Contract Administrator's Geotechnical Consultant and MTO of any modifications of the original site conditions related to pipe installation or otherwise, including appearance of cracks on the pavement and shoulder, concrete barriers etc.;
- Notify immediately Contract Administrator, Contract Administrator's Geotechnical Consultant and MTO if Review or Alert Levels have been reached or exceeded and follow the procedures outlined in Section 8.06.05.

8.05.02 Purpose

The purpose of this program is to monitor settlement of the paved surfaces and embankments at selected locations during the trenchless utility installation.

The rate and/or methodology of trenchless installation may need to be adjusted based on the instrumentation readings.

8.05.03 Reading Schedule and Frequency

The Contractor shall keep a complete record in electronic and hard copy formats of all instrumentation survey and associated data, including the location of the advancing face at the time of each survey.

Monitoring shall commence after the installation of an instrument. Monitoring is to continue as specified in this document and as required by Contract Administrator and Contract Administrator's Geotechnical Consultant.

The minimum monitoring frequencies along with the anticipated number of readings are given in Table 8-1 below. The monitoring frequency is the same for each individual instrument.

Instruments shall be read more frequently as required by Contract Administrator and Contract Administrator's Geotechnical Consultant.

Table 8-1 Minimum Monitoring Frequency

Stage	Frequency	Anticipated No. of Readings Per Instrument (**)
Baseline Readings (*)	3 readings on 3 consecutive days	3
Just prior to start of trenchless installation	Once	1
During trenchless installation	A minimum of three (3) sets of readings be taken daily for all instruments located above a tunnel being installed, if movements are within anticipated limits. Monitoring of movements is also required during work stoppages, such as during non-operation periods (off-shifts) or weekends.	Variable
After trenchless installation	After the end of installation all instruments located above the tunnel shall be read weekly for the first month	4

Notes: (*) Baseline Readings: Instrument elevation readings taken prior to tunnel installation to provide a baseline against which all subsequent readings are compared to assess settlements of the ground.

(**) Number of readings may vary.

8.05.04 Specific Requirements

8.05.04.01 Surveying

The elevations of the instruments shall be surveyed to an accuracy of plus/minus two (± 1) millimetre or better, and shall be reported to the nearest millimetre.

Shoulder and/or lane closures for instrument readings are not permitted.

8.05.04.01 Data Recording and Data Reduction

For every instrument elevation reading the following information shall be recorded electronically in an Excel spreadsheet containing the following information:

- Date and time of the day
- Location of the advancing face (i.e. distance from launching point) at the time of data recording
- Construction activities (e.g. tunnel installation underway; weekend – no construction; boulder encountered at the advancing face of installation, etc.)
- Pavement visual survey (e.g.: No visual pavement distress; 1 mm wide, 3 m long pavement crack parallel to west shoulder and close to instruments No. A, B and C, sketches and photos, etc.)
- Instrument Number
- Settlement Array Number
- Horizontal distance measured along the tunnel alignment between the advancing face of installation and the instrument or array of instruments that contains the instrument being monitored
- Instrument elevation
- Instrument settlement

The settlement data shall be presented in X-Y charts as follows:

- Settlement versus Time for each instrument
- Settlement versus Distance from the advancing face of installation for each instrument
- Settlement profile for different dates along each of the pipe alignment
- Settlement profile for different dates along each of the settlement arrays

Reported information should be supplemented by sketches, diagrams and plots as necessary.

8.05.04.02 Data Transmission

All settlement data obtained on a particular day shall be reported in electronic format to Contract Administrator, Contract Administrator's Geotechnical Consultant and MTO not later than mid-day on the next calendar day.

Any unusual movements deduced from the field data must be reported immediately before leaving the site.

8.06 Criteria for Assessment

The following settlement levels are to be observed:

Review Level: A maximum value of 10 mm relative to the baseline or zero readings.

- If a maximum value of 10 mm relative to the baseline readings is reached, Contractor shall immediately notify Contract Administrator and Contract Administrator's Geotechnical Consultant and MTO, and review and discuss response actions
- The Contractor shall review or modify the method, rate of sequence of construction or ground stabilization measures to mitigate further ground displacement.
- The Contractor shall submit a plan of action to prevent Alert Level from being reached. All construction work shall be continued such that Alert Level is not reached.

Alert Level: A maximum value of 15 mm relative to the baseline or zero readings.

- If the Alert Level is reached or exceeded, or lesser ground settlements cause or threaten to cause damage to utilities or the highway pavement, as indicated by monitoring instruments or direct observation, the Contractor shall cease installation operation immediately and inform Contract Administrator and Contract Administrator's Geotechnical Consultant and MTO 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
 - Contract Administrator, Contract Administrator's Geotechnical Consultant and MTO deem it is safe to proceed.

8.07 Contractor's Responsibility for Restoration

Notwithstanding the monitoring program to assess the adequacy of the tunnel installation method to control potential ground movements and groundwater, the Contractor is responsible for reinstatement (such as surface paving and fill placement) should movements or other surface distress occurs.

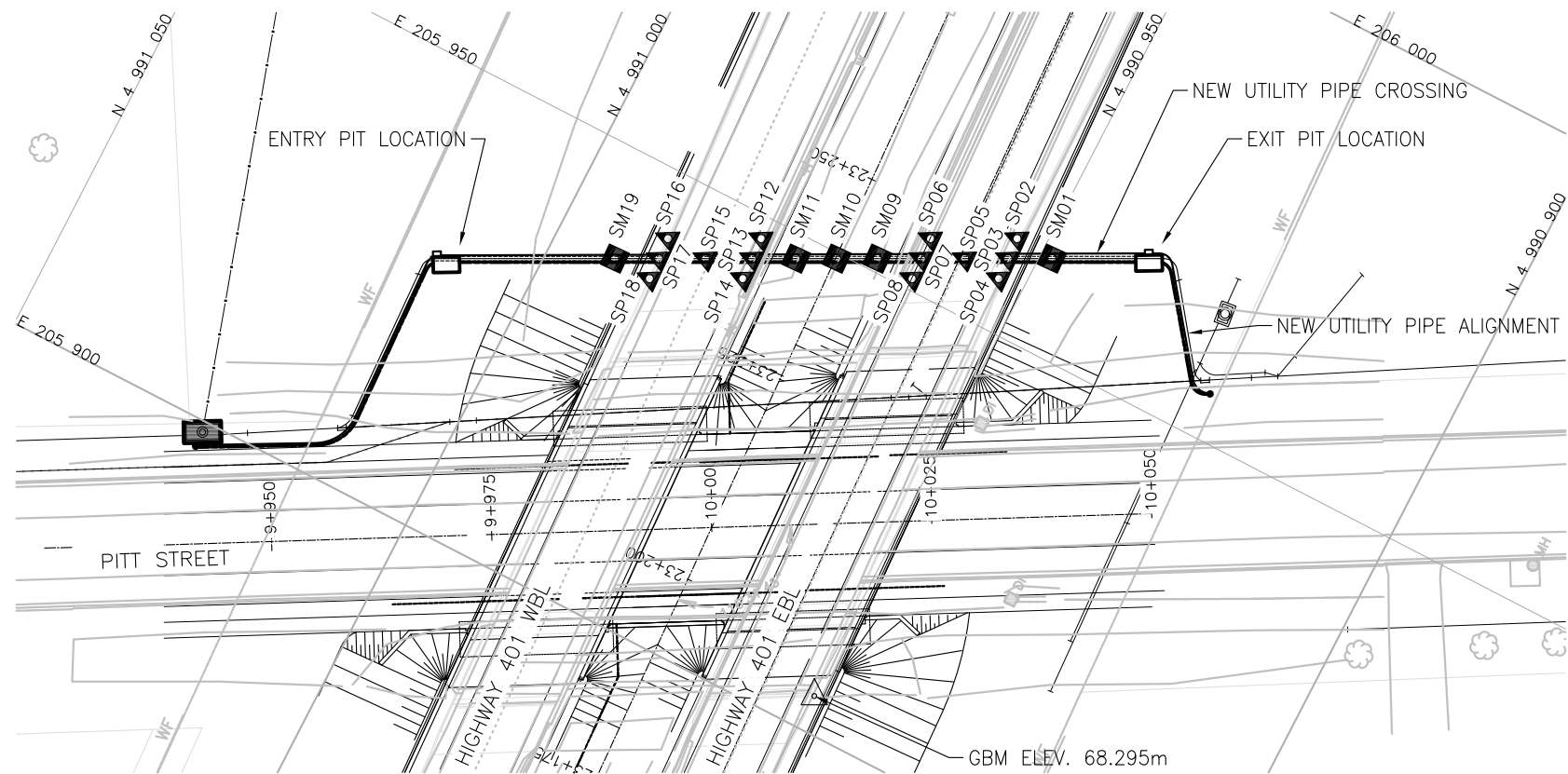
The Contractor shall decommission all SPs and SMs after the completion of the monitoring program as directed by the Contract Administrator.

9. MEASUREMENT FOR PAYMENT

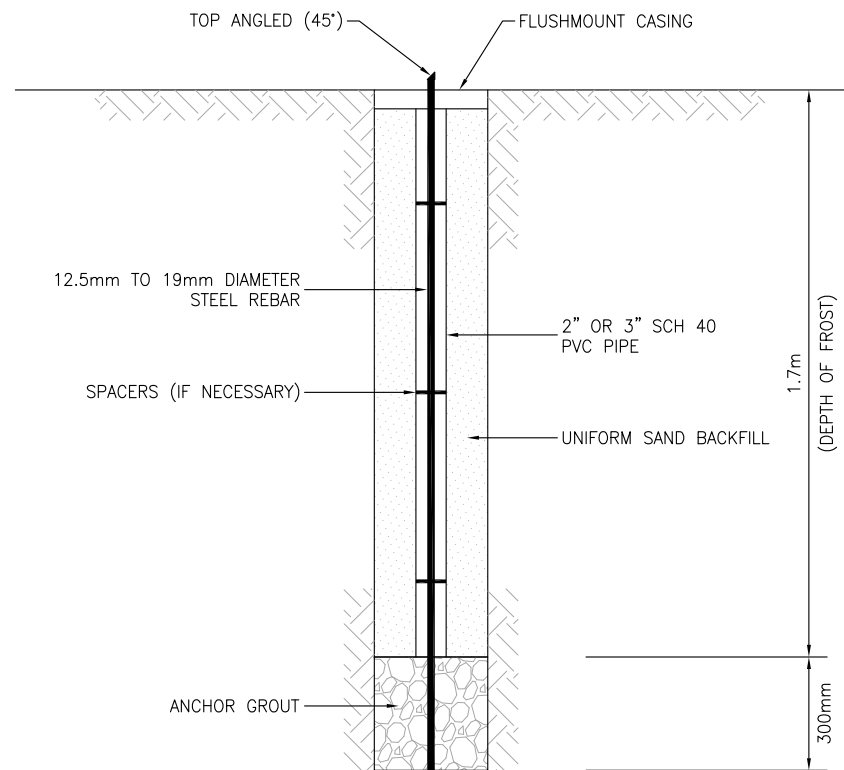
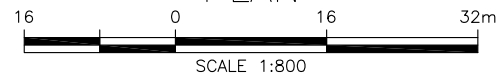
Measurement of tunnel shall be in metres along the centreline of the tunnel to the ends of the tunnel as constructed.

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, protection systems, supply and installation of casing / product pipe, settlement monitoring and instrumentations site restoration and for all other work necessary to complete the installation as specified.



PLAN



SETTLEMENT MONITORING POINT (SM) DETAIL
N.T.S.

METRIC

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

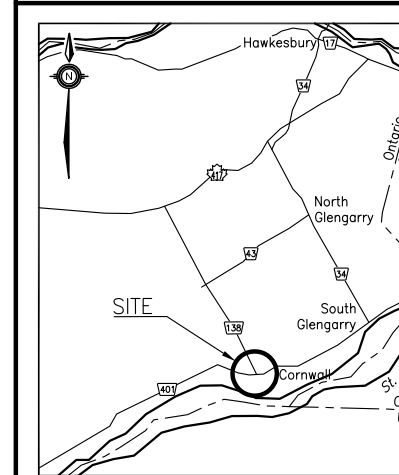


CONT No 2018-4007
GWP No 4003-14-01

HIGHWAY 401
TRENCHLESS UTILITY INSTALLATION
AT PITT STREET
SETTLEMENT MONITORING LOCATION PLAN

wsp

THURBER ENGINEERING LTD.



KEYPLAN

LEGEND



Surface Monitoring Point (SP)
Settlement Monitoring Point (SM)

NO	NORTHING	EASTING
SM01	4990948.656	205960.601
SM09	4990966.279	205951.498
SM10	4990970.381	205949.379
SM11	4990974.483	205947.260
SM19	4990992.776	205937.811
SP02	4990953.213	205960.804
SP03	4990953.099	205958.307
SP04	4990952.985	205955.809
SP05	4990957.468	205956.049
SP06	4990961.952	205956.290
SP07	4990961.838	205953.792
SP08	4990961.724	205951.295
SP12	4990979.040	205947.463
SP13	4990978.926	205944.965
SP14	4990978.812	205942.468
SP15	4990983.631	205942.535
SP16	4990988.449	205942.602
SP17	4990988.335	205940.105
SP18	4990988.221	205937.607

-NOTES-

Monitoring Point locations are shown in MTM Zone 8 coordinates.

GEOCREs No. 31G-264

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	JG	CHK KP	CODE
DRAWN	MFA	CHK JG	SITE
			LOAD
			STRUCT
			DWG SMLP-1
			DATE APR 2018

APPENDIX H

LIST OF REFERENCED SPECIFICATIONS NON-STANDARD SPECIAL PROVISIONS

LIST OF REFERENCED SPECIFICATIONS

OPSD 3090.101	Foundation, Frost Penetration Depths for Southern Ontario
OPSS.PROV 402	Construction Specification for Excavating, Backfilling and Compacting for Maintenance Holes, Catch Basins, Ditch Inlets and Valve Chambers
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 805	Construction Specification for Temporary Erosion and Sediment Control Measures
OPSS.PROV 1010	Material Specification for Aggregates - Base, Subbase, Select Subgrade, and Backfill Material
Special Provision 517F01	Amendment to OPSS 517, July 2017
Special Provision Foun0003	Dewatering Structure Excavations, March 2018

Non-Standard Special Provisions

RECOMMENDED WORDING FOR “NSSP – 402.07.08 Excavation”

Subsection 402.07.08.01 General of OPSS 402 is amended by the addition of the following:

Excavations at the site may be impeded by obstructions within the existing fill and glacial till. The contractor shall be prepared to dislodge and remove these obstructions and extend the excavations to the design depths.

Reference can be made to the following Foundation Investigation Reports prepared by Thurber Engineering Ltd. for further details on likely subsurface conditions at the foundation locations

- Replacement of The Highway 401 EBL And WBL Overpasses at Pitt Street, 2017; and
- Trenchless Utility Crossing of The Highway 401 EBL And WBL Overpasses at Pitt Street, 2018.

RECOMMENDED WORDING FOR “NSSP – TUNNELLING OBSTRUCTIONS”

The new utility crossing will be installed in ground conditions that include fill and glacial till. The Contractor's trenchless method must be capable of penetrating obstructions such as cobbles, boulders or other obstructions within the fill and glacial till.

Reference can be made to the following Foundation Investigation Reports prepared by Thurber Engineering Ltd. for further details on likely subsurface conditions at the foundation locations

- Trenchless Utility Crossing of The Highway 401 EBL And WBL Overpasses at Pitt Street, 2018; and
- Replacement of The Highway 401 EBL And WBL Overpasses at Pitt Street, 2017

RECOMMENDED WORDING FOR “NSSP – A CONCRETE WORKING SLAB”

This Non-standard Special Provision covers the requirements for the supply and placement of a concrete working slab to protect the sand and silt subgrade of the entry/exits pits and provide a proper working surface for the tunnelling equipment.

Excavation for the working slab shall be according to OPSS.PROV 402. Within four hours following inspection and approval of the prepared subgrade, a working slab with a minimum thickness of 100 mm shall be placed on the foundation subgrade as specified in the Contract Documents. Concrete for working slabs shall have a minimum 28 day strength of 20 MPa.