REPORT

Foundation Investigation and Design Proposed Culvert Rehabilitation

Unnamed Creek, Highway 417 - Site No. 3-763/C
Ottawa, Ontario

G.W.P. No. 4099-11-00
W.P. No. 4326-13-01

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by WSP Canada Group Limited (WSP) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations associated with numerous bridge and structural culvert rehabilitations and/or replacements on Highway 417 between the Aviation Parkway and Ramsayville Road as well as the widening of Highway 417 from Ottawa Regional Road 174 (OR 174) to Hunt Club Road in Ottawa, Ontario (Assignment number 4016-E-0008, G.W.P. 4099-11-00 and W.P. 4326-13-01).

This report presents the results of the foundation investigation carried out to provide foundation design recommendations for the proposed rehabilitation and associated water diversion for the Unnamed Creek Culvert (Site No. 3-763/C) located beneath the westbound lane (WBL) of Highway 417 in Ottawa, Ontario.
The rehabilitation of the existing structure is to be carried out in accordance with the current version of the Canadian Highway Bridge Design Code (CHBDC, S6-14).

The terms of reference and scope of work for the foundation investigation are outlined in the MTO’s Request for Proposal (RFP), dated May 2016, and subsequent addenda. Golder’s scope of work for foundation engineering services associated with the Highway 417 Unnamed Creek Culvert is contained in Table 17.8.3 of WSP’s Technical Proposal for this assignment. The work has been carried out in accordance with Golder’s Quality Control Plan for foundation engineering services for this project, dated March 13, 2017.

2.0 SITE DESCRIPTION AND GEOLOGY

2.1 General

The Unnamed Creek Culvert (Site No. 3-763/C) is located approximately 125 m north of Cyrville Road in Ottawa, Ontario. At this location, Highway 417 is a divided highway with two travel lanes in the east direction and three in the west direction, separated by a 40 m wide green area. A third lane extending over the existing culvert in the west direction is the continuation of the E-417W Innes Road on-ramp lane, with the westbound lanes as part of a rural cross section with paved shoulders, ditches, and a median grass area.

The existing Unnamed Creek Culvert was constructed in 1973 and consists of a cast-in-place rigid frame concrete box culvert, with a width of 3.7 m, height of 1.5 m and length of 57 m. The Unnamed Creek flows from northwest to southeast, with the culvert invert at approximately Elevation 63.15 m at the inlet and at approximately Elevation 63.10 m at the outlet based on a survey carried out by WSP. Based on the original contract drawings provided by WSP, the stream bed is about 0.3 m above the culvert invert. Based on the original RFP, there is approximately 1.5 m of fill cover on the existing culvert.

The existing embankments were observed during field work and were showing no signs of erosion or instability and are considered to be performing in good condition.

The existing culvert requires rehabilitation, including removal of sediment buildup within the culvert barrel; concrete repairs to inlet and outlet portals, soffit and interior wall; and application of waterproofing membrane and protection board. A temporary flow passage system and temporary protection systems will be required to support the rehabilitation works.

2.2 Regional Geology

As delineated in *The Physiography of Southern Ontario*[1], this section of Highway 417 lies on the boundary of the minor physiographic regions known as the Ottawa Valley Clay Plain and the Russell and Prescott Sand plain, which lies within the major physiographic region of the Ottawa-St. Lawrence Lowland.

The Ottawa Valley Clay Plain region is characterized by relatively thick deposits of sensitive marine clay, silt and silty clay that were deposited within the Champlain Sea basin. These deposits, known as the Champlain Sea clay or Leda clay, overlie relatively thin, commonly reworked glacial till and glaciofluvial deposits, that in turn overlie bedrock[2]. The Russell and Prescott Sand Plains are generally characterized by a sand mantle about 3 to 5 m thick overlying an extensive deposit of sensitive marine clay deposited within the Champlain Sea basin, underlain by glacial till and shale bedrock.

The Bedrock Geology mapping indicates that the bedrock consists of black shale of the Billings Formation of the Ordovician period. It should be noted that the Billings Formation shale is susceptible to swelling if allowed to weather in the presence of oxygen.

The site falls within the Western Québec (WQ) seismic zone according to the Geological Survey of Canada. The WQ zone constitutes a large area which encompasses the urban areas of Montreal, Ottawa-Hull and Cornwall. Within the WQ zone recent seismic activity has been concentrated in two subzones; one along the Ottawa River and another more active subzone along the Montreal-Maniwaki axis. The two major earthquakes in the WQ zone includes the 1935 Témiscaming event which had a magnitude (i.e., a measure of the intensity of the earthquake) of 6.2, and the 1944 Cornwall-Massena event which had a magnitude of 5.6.

3.0 INVESTIGATION PROCEDURES

The subsurface investigation for the culvert rehabilitation was carried out between July 25 and August 15, 2018. During that time, three boreholes (designated as Boreholes 18-3201 to 18-3203) were advanced along in close proximity to the existing culvert structure. Borehole 18-3202 was advanced through the Highway 417 WBL road grade, while Boreholes 18-3201 and 18-3203 were advanced in close proximity to the culvert outlet and inlet, respectively. The borehole locations are shown on Drawing 1.

Boreholes 18-3201 and 18-3203 were advanced using portable rotary drill equipment, supplied and operated by Ohlmann Geotechnical Services Inc (OGS). The boreholes were advanced to a depth of 4.0 m below ground surface, including coring of bedrock for core lengths of 2.8 m and 2.6 m in Boreholes 18-3201 and 18-3203, respectively. Bedrock core samples were obtained using an ‘NQ’ size rock core barrel.

Borehole 18-3202 was advanced using 108 mm inside diameter (200 mm outside diameter) continuous flight hollow stem augers on track mounted drill rigs, supplied and operated by George Downing Estate Drilling Ltd. The borehole was advanced to a depth of 5.1 m below ground surface, including coring of bedrock for a core length of 3.4 m. Bedrock core samples were obtained using an ‘NQ’ size rock core barrel.

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[1] Chapman, L. J. and Putnam, D. F., 1984. *The Physiography of Southern Ontario*, Ontario Geological Survey. Special Volume 2, Third Edition. Accompanied by Map P.2715, Scale 1:600,000. Ontario Ministry of Natural Resources.

[2] Belanger, J.R. “Urban Geology of Canada’s National Capital Area”, in *Urban Geology of Canadian Cities*, Geological Association of Canada Special Paper 42, Ed. P.F. Karrow and O.L. White, 1998.

Soil samples were obtained at vertical intervals of about 0.6 m to 0.76 m, using a 50 mm outer diameter split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586)[3]. A water truck was on site to supply the drill rigs with water for advancing the casing in the overburden (portable drill rig) and for coring of the bedrock. Traffic control required to allow the water truck and support vehicles to park adjacent to the site was supplied by Beacon Lite Ltd. of Ottawa, Ontario. Borehole 18-3202 was advanced in the left shoulder and required the closure of the left lane.

A monitoring well was installed in Borehole 18-3202 to monitor the groundwater level at the site. The monitoring wells consisted of 32 mm outside diameter PVC tubing with a 1.5 m long screen. The groundwater level was measured in the monitoring well on June 23, 3019. The monitoring well was subsequently decommissioned on January 8, 2020 by backfilling the monitoring well with bentonite, removing the top section of the monitoring well, and the asphalt patched upon completion, as per MOE Regulation 903.

The remainder of the boreholes were backfilled with bentonite mixed with soil cuttings in accordance with Ontario Regulation 903, Wells (as amended) and Borehole 18-3202 was sealed to the roadway surface with cold patch asphalt upon completion. The site conditions were restored following completion of the field work.

The field work was supervised on a full-time basis by members of Golder's staff who located the boreholes in the field, directed the drilling, sampling, and in situ testing operations, and logged the boreholes. The soil and bedrock samples were identified in the field, placed in labelled containers, and transported to Golder's laboratory in Ottawa for further visual examination and to Golder's laboratories in Ottawa and Mississauga for geotechnical laboratory testing on selected samples. Index and classification tests consisting of water content determinations and grain size distribution analyses were carried out on selected soil samples at the Golder Ottawa laboratory.
The laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate.

Rock quality (i.e., Total Core Recovery (TCR), Solid Core Recovery (SCR), Rock Quality Designation (RQD), weathering and strength index), discontinuity characteristics and classification data were recorded in the field based on visual inspection of the recovered rock cores upon extraction from the core barrel. The bedrock was sequentially photographed, packed and transported to Golder's Ottawa laboratory for further visual examination. An unconfined compressive strength test was carried out on one selected rock core sample in the Golder Mississauga laboratory. The remainder of the bedrock core samples were placed in wooden core boxes and kept in storage.

Classification of the rock mass quality of the bedrock with respect to the RQD is described based on Table 3.10 of the Canadian Foundation Engineering Manual (CFEM, 2006)[4] while the strength of the bedrock core samples is based on Table 3.5 of CFEM, (2006)[4]. The degree of weathering of the bedrock core samples and the strength classification of the intact rock mass based on field identification are described in accordance with Table B.3 and Table B.6, respectively of the International Society of Rock Mechanics (ISRM, 1985)[5] standard classification system.

One soil sample from Borehole 18-3203 was submitted to Eurofins Environment Testing (Eurofins) for chemical analysis related to potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack).

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

[4] Canadian Foundation Engineering Manual. 2006. Fourth Edition, Canadian Geotechnical Society: Richmond, British Columbia.

[5] International Society for Rock Mechanics Commission on test Methods. 1985. Int. J. Rock Mech. Min. Sci & Geomech. Abstr. Vol 22, No. 2, pp.51-60.

In addition to the borehole investigation, shear wave velocity profiling was completed at the Cyrville Road Overpass site, located about 130 m south of the Unnamed Creek Culvert, using the Multichannel Analysis of Surface Waves (MASW) technique. Two tests were conducted on June 26, 2018 by personnel from the Golder Associates' Mississauga office. A series of 24 low frequency (4.5 Hz) geophones were laid out at 3 m intervals. A 9.9 kg sledge hammer and 45 kg weight drop were used as the seismic source. The source locations were offset at distances of 5, 10, and 15 m off the end and collinear with the geophone array.

The as-drilled borehole locations and elevations were surveyed by Golder using a Trimble R8 GPS unit, to an accuracy of 2 cm in the horizontal and 3 cm in the vertical directions. The locations given in the Record of Borehole sheets and shown on Drawing 1 are positioned relative to MTM NAD83 (Zone 9) northing and easting coordinates and the ground surface elevations are referenced to geodetic datum (CGVD28). The borehole locations, the ground surface elevations and borehole drilled depths are summarized below.

Table 1: Summary of Borehole Locations

Borehole Number	Borehole Location	MTM NAD83 Zone 9 Northing (m)	MTM NAD83 Zone 9 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
18-3201	Near culvert outlet	5031459.7	374193.4	66.7	4.0
18-3202	Highway 417 left / west shoulder	5031468.0	374170.0	66.5	5.1
18-3203	Near culvert inlet	5031481.5	374150.6	65.8	4.0

4.0 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 General Site Stratigraphy

The subsurface soil, bedrock and groundwater conditions encountered in the boreholes and the results of in-situ and laboratory testing are given on the Record of Borehole sheets presented in Appendix A. Photographs of the bedrock core are provided on Figures A1 to A3 contained in Appendix A. The results of geotechnical laboratory testing are presented on Figures B1 to B3 and are contained in Appendix B. The results of the chemical testing performed on one soil sample are provided in Appendix C.

An interpreted stratigraphic profile projected along the Unnamed Creek culvert structure is shown on Drawing 1. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile are inferred from observations of drilling progress and noncontinuous- sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

The MASW test results and technical memorandum are presented in Appendix D and include the calculated shear wave velocity profile measured from the field testing and a graphical representation of the shear wave velocity profile with depth.

Photographs of the site are shown in Appendix E (to be provided by WSP).

In general, the subsurface conditions at the borehole locations consist of topsoil and asphaltic concrete over embankment fill extending down to depths of about 1.2 m to 1.4 m (Elevations 64.6 m to 65.5 m).
The embankment fill is underlain by a discontinuous deposit of glacial till/weathered shale bedrock extending to

depths of about 1.4 m to 1.7 m (Elevations 64.4 m to 64.8 m) and the shale bedrock. Shale bedrock was indicated to be present at depths of about 1.2 to 1.7 m (Elevations 64.4 to 65.5 m). The groundwater level was encountered at a depth of about1.6 m (Elevation 64.9 m).

A detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2 Topsoil

A layer of topsoil was encountered at the ground surface in Boreholes 18-3201 and 18-3203 with a thickness of about 200 mm.

4.3 Pavement Structure and Embankment Fill

Borehole 18-3202 was advanced through the pavement structure of the Highway 417 WBL left shoulder. The pavement structure consists of 400 mm of asphaltic concrete over a 200 mm base layer consisting of gravel and sand fill.

The pavement structure and topsoil, where encountered, are underlain by a 0.8 m to 1.0 m thick layer of embankment fill consisting of sand and gravel to gravelly sand with varying amounts of silt, clay and shale fragments. The embankment fill generally extends to depths ranging between 1.2 m to 1.4 m below the existing ground surface, to about Elevations 65.5 m to 64.4 m.

The Standard Penetration Test (SPT) “N”-values measured in the embankment fill range from 8 to 94 blows per 0.3 m of penetration, indicating a very loose to very dense state of compactness. The higher SPT “N”-values likely reflect the presence of the bedrock surface, rather than the state of compactness of the soil matrix.

The results of grain size distribution testing carried out on three selected samples of the gravel and sand base material are shown on Figure B1 in Appendix B. The results of grain size distribution testing carried out on one selected sample of the embankment fill material are shown on Figure B2 in Appendix B. The measured natural water content of six samples of the fill range from about 2 to 6 per cent.

4.4 Till/Highly Weathered Shale

A deposit of till/highly weathered shale was encountered underlying the embankment fill in Boreholes 18-3202 and 18-3203. The surface of the till / highly weathered shale deposit was encountered at depths of 1.4 m and 1.2 m, corresponding to Elevations 65.2 m and 64.6 m in Boreholes 18-3202 and 18-3203, respectively. The transitional glacial till/highly weathered shale generally consists of silty sand, some gravel to gravelly, containing shale fragments. The till/highly weathered shale extends to depths of about 1.7 m and 1.4 m below the existing ground surface, with a thickness ranging from about 0.3 m and 0.2 m, in Boreholes 18-3202 and 18-3203, respectively.

The SPT “N”-values measured within the till / highly weathered shale deposit 50 blows per 0.15 m of penetration and 50 blows per 0.05 m of penetration, indicating a very dense state of compactness.

4.5 Bedrock

Bedrock was encountered underlying the embankment fill in Borehole 18-3201 and underlying the till / highly weathered shale deposit in Boreholes 18-3202 and 18-3203, at depths ranging from 1.2 m to 1.7 m below the existing ground surface (Elevations 65.5 m to 64.4 m). The upper 0.2 to 0.3 m of the bedrock encountered in Boreholes 18-3202 and 18-3203 was described as highly weathered (see Section 4.4 above) and was drilled and sampled using the augers and/or SPT sampler. The underlying sound bedrock was cored between about 2.6 m and 3.4 m depth using NQ sized coring equipment.

The following table summarizes the sound (i.e., required coring) bedrock surface depths and elevations as encountered at the borehole locations.

Table 2: Summary of Observed Bedrock Depth and Elevation

Borehole Number	Existing Ground Surface Elevation (m)	Depth to Bedrock Surface (m)	Bedrock Surface/ Refusal Elevation (m)
18-3201	66.7	1.2	65.5
18-3202	66.5	1.7	64.8
18-3203	65.8	1.4	64.4

The sound bedrock encountered below the transitional glacial till / highly weathered bedrock consist of fresh, thinly to medium bedded, black to dark grey, fine grained, porous shale. The Rock Quality Designation (RQD) values measured on recovered bedrock core samples ranged from about 74 to 100 percent, indicating a fair to excellent quality rock.

Photos of the bedrock core are shown on Figures A1 to A3 in Appendix A.

The result of the unconfined compressive strength test carried out on one bedrock core sample is presented on Figure B3. Based on the measured unconfined compressive strength of 60.5 MPa, the shale bedrock is classified as relatively strong.

4.6 Groundwater Conditions

A groundwater monitoring well was installed in Borehole 18-3102 to monitor the groundwater level at the site. The water levels were measured in the monitoring well on June 23, 2019 and are summarized in the table below.

Table 3: Summary of Observed Groundwater Conditions

Borehole	Ground Surface Elevation (m)	Screened Interval Material	Water Level Depth (m)	Water Level Elevation (m)	Date of Reading
18-3102	66.5	Bedrock	1.6	64.9	June 23, 2019

It is expected that these water levels will be subject to fluctuations both seasonally and as a result of precipitation events.

4.7 Corrosion and Sulphate Attack Potential

One soil sample from Borehole 18-3202 was submitted to Eurofins for chemical analysis related to potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack). The results of the testing are attached in Appendix C and are summarized in the table below.

Table 4: Results of Chemical Analysis

Borehole No.	Sample Depth (m)	Sample Type	Chloride Soil (%)	pH	Electrical Conductivity Soil (mS/cm)	Resistivity (ohm-cm)	Sulphate Soil (%)
18-3202	0.61 – 1.22	Soil	0.005	8.09	0.69	1450	0.05

5.0 CLOSURE

This report was prepared by Mr. Alex Meacoe, P.Eng. and Ms. Nikol Kochmanová, P.Eng., and reviewed by Mr. Michael Snow P.Eng., a senior geotechnical engineer and Principal with Golder. Mr. Fintan Heffernan, P.Eng., a Senior Consultant with Golder and the Designated MTO Foundations Contact, conducted an independent quality control review of this report.

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PART B

Foundation Design
Proposed Culvert Rehabilitation
Unnamed Creek, Highway 417 - Site No. 3-763/C
Ottawa, Ontario

G.W.P. No. 4099-11-00

W.P. No. 4326-13-01

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

The following sections of the report provides foundation design recommendations for the rehabilitation and associated water diversion of the existing Unnamed Creek Culvert (Site No. 3-763/C), located beneath the westbound lanes of Highway 417 in Ottawa, Ontario. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current subsurface investigation as well as the available information from GEOCRES No. 31G05-114 and 31G05-263 for the site.

The foundation design report, discussion, and recommendations are intended for the use of the Ministry of Transportation, Ontario (MTO) and shall not be used or relied upon for any other purpose or by any other parties, including the construction contractor. The contractor must make their own interpretation based on the factual data in Part A (Foundation Investigation) of the report. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.2 Site and Project Overview

The existing Unnamed Creek Culvert was constructed in 1973 and consists of a cast-in-place rigid frame concrete box culvert, with a width of 3.7 m, height of 1.5 m and length of 57 m. The Unnamed Creek flows from northwest to south east, with the culvert invert at approximately Elevation 63.15 m at the inlet and at approximately Elevation 63.10 m at the outlet based on a survey carried out by WSP. Based on the original contract drawings provided by WSP, the stream bed is about 0.3 m above the culvert invert. Based on the original RFP, there is approximately 1.5 m of fill cover on the existing culvert.

The existing pavement grade at the culvert location is at approximate Elevation 66.5 m at the westbound lanes of Highway 417. Highway 417 at this location has two through lanes in each direction consisting of a rural cross section with partially paved shoulders and ditches.

The existing embankments were observed during field work and were showing no signs of erosion or instability and are considered to be performing in good condition.

The existing culvert requires rehabilitation, including removal of sediment buildup within the culvert barrel; concrete repairs to inlet and outlet portals, soffit and interior wall; and application of waterproofing membrane and protection board. A temporary flow passage system and temporary protection systems will be required to support the rehabilitation works.

6.3 Culvert Rehabilitation Options

It is understood that the rehabilitation of the Unnamed Creek culvert will include installation of a temporary flow passage system / diversion system along an alignment adjacent to and parallel to the existing culvert, with the preferred installation method consisting of a trenchless construction to minimize traffic disruption along Highway 417. The new diversion pipe, if required, can provide temporary water diversion from the existing culvert during rehabilitation and can become a component of the final culvert design. It is assumed that the diversion pipe will be up to about 2.5 m in diameter and will be installed at a similar invert elevation as the existing culvert (approximately Elevation 63.1 m). Section 6.4 below provides more information on the feasibility of trenchless technologies at this site.

6.3.1 Trenchless Technologies

The Contractor should be responsible for choosing the method and equipment for the crossing installations, unless specific methods are otherwise prohibited. Ground behaviour will be, in part, dependent on the installation method adopted and this report provides guidance on the influence of ground behaviour on possible installation methods. It should not be construed that the Contractor is restricted to the particular methods considered herein, and in the event that alternative methods are considered, the Contractor must make their own interpretation of the anticipated ground behaviour, based on the factual information from the investigations undertaken at this site.

Common trenchless construction methods include horizontal directional drilling, pipe jacking and horizontal auger boring, pipe ramming, micro-tunneling, pilot tube micro-tunneling, tunnel boring machine (TBM) and tunnel digging machine (TDM - i.e., open face shield tunnelling). A brief description of each method is included below. Further requirements on the various trenchless methods are outlined in the MTO's Pipe Installation by Trenchless Method Special Provision provided in Appendix F. A discussion on which method(s) are considered feasible for the proposed temporary diversion pipe installation is included in Section 6.4.

- **Horizontal Directional Drilling (HDD):** HDD involves the drilling of a pilot hole using a steerable drill bit on a flexible string of drill rods while the bore is supported using a bentonite slurry. Once the pilot hole is complete, the bore would be reamed in one or more passes to a larger diameter, and then the pipe would be pulled through the bore (using the drill rods to pull the pipe into place). HDD equipment is available for drilling in both bedrock and overburden but is very challenging in bouldery ground. Deep entrance and exit pits are generally not required, however, larger laydown areas are required to install the product pipe, and the crossing typically needs to be longer to accommodate the shallow entry and exit angles for the drilling equipment. Bores are typically limited to less than 1,200 millimetres in diameter.

- **Pipe Jacking and Horizontal Auger Boring:** A pipe jacking operation involves pushing an oversized liner pipe (casing) horizontally into the ground by jacking. The spoil is generally removed from within the casing using an auger boring machine. The cutting head is driven by, and is positioned at, the leading end of an auger string that is established within the casing pipe. The profile needs to be approximately horizontal. Jacking and receiving pits are required. There can be limited ability to steer the casing during jacking. This method is only applicable to construction in the overburden and may not be feasible in bouldery soils (e.g., glacial till). This method is also not feasible in flowing ground. If used in mixed face condition, this method can be adopted with a small boring unit (SBU) head which can advance through soil/bedrock mixed face condition and offers some steering ability.

- **Pipe Ramming:** Pipe ramming is a trenchless method that uses a pneumatic tool to hammer a steel pipe or casing into the ground. The pipe is almost always driven 'open' to thereby direct the soil into the pipe interior instead of compacting it outside the pipe. The leading edge of the pipe typically has a small overcut to reduce friction between the carrier pipe and soil and to improve the load conditions on the pipe. Soil/pipe friction reduction can also be achieved with lubrication, and different types of bentonite and/or polymers can be used for this purpose. Depending on the length of the installation, the soils inside the pipe can be removed either during or after the installation by augering, compressed air or water jetting. This method is not considered feasible in mixed face conditions including sound bedrock.

- **Micro-tunnelling**: Micro-tunnelling is a method of installing pipes in bores ranging from 0.6 to greater than 3 metres in diameter behind a steerable remote-controlled shield that is pressurized with a bentonitic fluid to minimize ground losses. The process is essentially remote-controlled pipe jacking where all operations are controlled from the surface, cuttings are removed by the circulating slurry, and the necessity for personnel to enter the bore is eliminated. Micro-tunnelling equipment is generally more suited to drilling in overburden. Availability of this equipment locally is limited.

- **Pilot Tube Micro-tunneling (PTMT):** PTMT, also known as guided auger boring, employs augers for excavation and soil removal and a jacking system for advancing the drill pipes, casings and product pipes. The guidance system comprises a target with LEDs mounted in the steering head of the equipment that is monitored through a TV monitor. The PTMT operation includes pilot boring and reaming and, since this technique is used for smaller size pipes, the equipment and space required for this operation is smaller than what is normally required for pipe jacking or microtunnelling. PTMT can obtain an accuracy of 10 mm per 100 m of pipe length; however, the accuracy depends on the ground conditions, the accuracy of the guidance system and the operator's skill. The "pilot tube" is advanced in a similar fashion to horizontal directional drilling with a guidance system used to control alignment and grade.
- **Tunnel Boring Machine (TBM):** TBM tunnelling operations involve the advance of a steerable machine with a rotating cutter head horizontally into the ground with successive sections of either an oversized liner pipe or the final product pipe advanced behind the TBM by pipe jacking. The spoil is removed from the tunnel as the TBM is advanced, using augers, conveyor belts or mucking carts. The cutting head is driven and steered by an operator inside the TBM and may be partially open to allow for access to the face. The tunnel profile needs to be approximately horizontal. Jacking and receiving pits are required. Locally, this method is generally used for construction in overburden, and open-faced machines have been used in bouldery soils (e.g., glacial till). Excavations through sandy soils below the water table typically require dewatering to maintain face stability when using open faced machines, specialized earth pressure balance or slurry shield TBMs, which pressurize the face of the excavation and improve face stability, or the use of micro-tunnelling.
- **Tunnel Digging Machine (TDM):** TDM tunnelling, also called open-face shield tunnelling, involves excavating the soils using a hydraulic excavator arm, working within a full-circumference tunnelling shield. Alternatively, hand mining (i.e., manual excavation) within the tunnelling shield could be carried out whereby the soil would be excavated using manual equipment with workers at the face. Typically, the liner (i.e., steel casing) or final pipe would be jacked in sections from the launching shaft. Unlike jack and bore, this method allows personnel to enter the tunnel to allow more control over the operations, such as for removal of obstructions. Similar to jack and bore, however, groundwater lowering is necessary to control cohesionless soils below the groundwater level. Manual or machine-assisted excavation generally requires a tunnel diameter of about 1.2 m or more.

6.4 Assessment of Feasible Installation Methods

The following presents the feasibility of using trenchless installation methods, advantages, disadvantages and geotechnical concerns.

6.4.1 Trenchless Technologies

The ground conditions along the diversion pipe within the assumed tunnel vertical limits (i.e., invert and obvert of the pipe) are likely to consist of embankment fill consisting of sand and gravel with shale fragments, a transitional layer of glacial till/highly weathered shale, as well as sound shale bedrock within the lower portion of the vertical alignment (i.e., mixed-face conditions are expected). The groundwater is anticipated to be above the invert of the pipe; however, groundwater levels may fluctuate both seasonally and with precipitation events and higher groundwater level may be expected.

Based on the ground conditions and the possibility of a relatively large diameter (i.e., up to 2.5 m) of the proposed diversion pipe, in particular the anticipated mixed-face conditions along the tunnel alignment, pipe ramming, HDD and TDM methods are likely not suitable. Auger boring with SBU, micro-tunneling, PTMT or TBM with a pressurized face (e.g. earth pressure balance machine) would likely be the only feasible options in the anticipated ground conditions. Micro-tunneling or TBM with a pressurized face are usually less economical over short distances. The following geotechnical issues/risks associated with trenchless construction methods at the site should be considered and evaluated:

- Most trenchless equipment is suited to construction in rock, or in soil, but not both. A transition from rock to soil or vice-versa can be problematic, particularly if tunnelling/boring through both materials simultaneously (i.e., along the vertical transition between soil and bedrock) as is the case at this location. Mixed-face conditions are a potential issue wherever the soil-rock interface is within the elevation horizon of the proposed bore or where the face conditions are expected to change significantly along the length of the crossing. According to Boreholes 18-3201 to 18-3203, a mixed-face condition consisting of fill, glacial till/ highly weathered shale and shale bedrock (of varying degrees of weathering and strength) will be encountered along the assumed vertical limit of tunnel at this site (see Drawing 1).
- As a general guideline, the required cover above the crown of the tunnel/bore for trenchless installation should preferably be two bore diameters, but at least one tunnel/bore diameter, relative to the ground surface. Lesser amounts of cover could jeopardize the stability of the working face (depending on the method) or lead to excessive ground movements. Highway vibration and surface water infiltrations could increase instability of unsupported tunneling faces. Based on the assumed pipe invert elevation of 63.1 m, water diversion pipe diameter of 2.5 m, and Highway 417 road surface at Elevation 66.5 m, the cover above the tunnel face crown will be less than one bore diameter, and less than 1 m.

Based on the above conditions of the proposed culvert installation, a risk matrix summarizing each trenchless method and mitigation measures, where applicable, has been provided below in Table 5:

Table 5: Summary of Risk Register Associated with Trenchless Technologies

Risks	Trenchless Method	Risk (L/M/H)	Mitigation	Mitigated Risk (L/M/H)
Loss of alignment due to mixed face conditions	1)HDD	L	-N/A (Large Diameter)	N/A
	2)Auger Boring	H	-Limited SBU and Pilot Tube	M
	3)Pipe Ramming	H	- Limited SBU and Pilot Tube	H
	4)Micro-Tunnelling	L to M	-Limited	L to M
	5)PTMT	L to M	-N/A	L to M
	6)TBM	L to M	- Pressurized Face	L
	7)TDM	H	-N/A	N/A
Instability of working face, insufficient crown cover, excessive ground movements	1) HDD	L	-N/A	N/A
	2)Auger Boring	M to H	- Use head with reduced openings, monitor advances and soil volume removal	M
	3)Pipe Ramming	M to H	-N/A	M to H
	4)Micro-Tunnelling	L to M	- Use partial face shield	L
	5)PTMT	L to M	- Use partial face shield	L to M
	6)TBM	L to M	- Pressurized Face	L
	7)TDM	H	-Limited	N/A

As mentioned above, due to the anticipated challenges and potential risks associated with the installation of a diversion pipe given the anticipated ground conditions and limited cover above the pipe, in addition to cost-effectiveness considerations of a short drive (about 60 m), consideration may be given to alternative installation methods. Open cut methods could be considered, although they will result in significant disturbance at the ground surface and impacts to traffic circulation. Consideration could also be given to the installation of a twin or triple diversion pipe (i.e., two or three pipes of smaller diameter) instead of one large diameter pipe to increase the cover above the pipes and reduce risks associated with trenchless installation in limited cover conditions. Sufficient separation would need to be maintained between the pipes, generally a minimum of one to two bore diameters. Consideration could also be given to installing water diversion pipes within the existing culvert structure to the extent that this does not constrain the rehabilitation efforts.

A discussion aiding in the selection of diversion pipe material is provided in Section 6.9.2.

6.4.2 Open Cut Installation

Based on the existing ground conditions and proposed rehabilitation plan it is considered feasible to install a diversion pipe using open cut excavation construction methods.

The assumed invert elevation is approximately 1.3 m to 2.4 m below the bedrock surface, which would require excavations through the embankment fill, till / weathered shale bedrock and into the fresh shale bedrock. There are no geotechnical concerns with using open cut excavation methods to install the diversion pipe, should it be required. Excavation work may encounter shale fragments within the embankment fill and till deposits, as well as potentially cobbles within the embankment fill.

From a geotechnical standpoint, open-cut methods are the preferred method of installation of a larger diameter diversion pipe, over trenchless technologies given the limited amount of soil cover. However, open-cut methods would likely require the construction of median cross-overs and possibly closing of the on/off ramps during construction.

Frost tapers should conform to OPSD 205 and 803 series and are detailed in Section 6.6.1.

6.5 Recommendations and Considerations for Trenchless Replacement

Pipe installation by trenchless methods, if retained, should follow guidelines and specifications detailed in MTO's Special Provision – Pipe Installation by Trenchless Methods provided in Appendix F.

6.5.1 Ground Settlements

As mentioned above, the limited cover above the pipe could lead to excessive settlements at the road surface and the trenchless installation of a 2.5 m diameter pipe is not recommended. If the cover above the pipe is increased to a minimum of two pipe diameters, negligible surface settlements are anticipated for a well executed installation. For a cover depth equivalent to two bore diameters, a pipe diameter of 1.1 m or smaller would be required; for a cover depth of one bore diameter, a pipe diameter of 1.7 m or smaller would be required.

Careful installation will be required. The magnitude of anticipated settlement will be dependent upon the final equipment selection (e.g. overcut resulting from the equipment size selection) and methodology. Should a trenchless installation be selected for the proposed diversion pipe installation, settlement estimates and settlement mitigation measures should be furthered evaluated when the equipment and methodology is selected.

As required by Section 7.07 of the Pipe Installation by Trenchless Method NSSP (see Appendix F) for this project, and in accordance with MTO's "Guidelines for Foundation Engineering – Tunnelling Specialty for Corridor Encroachment Permit Application", a settlement monitoring program will need to be implemented, if a trenchless approach is retained. That settlement monitoring and will serve to:

- Document the effects of tunnelling;
- Obtain prior warning of ground movements that could occur due to the construction methods; and,
- Allow adjustments to be made to the trenchless construction method such that the settlement limits established are not exceeded, recognizing however that there is typically some delay between the trenchless construction and the full manifestation of the ground surface settlements.

6.5.2 Temporary Excavations, Shoring, and Groundwater Control

Excavations for the entry and exit pits/shafts would be made through the existing highway embankment fill materials, glacial till / weathered shale bedrock and into the fresh shale bedrock. It is anticipated that excavations of about 4 m to 4.5 m below the road surface (i.e., depth of about 0.5 to 1 m below the invert of the diversion pipe) will be required, depending on the rehabilitation works to be undertaken at this site.

Excavation works must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act and Regulations for Construction Projects (OHSA). The existing fill materials are classified as Type 3 soils, while the native very dense till / weathered shale bedrock deposit is generally classified as Type 2 soils, according to the OHSA. Temporary excavations (i.e., those that are open for a relatively short time period of time) should be made with side slopes no steeper than 1H:1V. Any fill which extends below the water table would be classified as Type 4 soil and excavations in these materials should be sloped no steeper than 3H:1V. As indicated in 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.

However, due to the proximity of the existing highway, the excavations would most likely be carried out within supported (i.e., shored) excavations for worker safety and road embankment support. The excavation support may also need to be designed to act as a backstop for the jacking forces and boring operations. A conventional shoring system for these conditions could consist of soldier piling and lagging. This support system shall be designed and constructed by the contractor in accordance with the Ontario Provincial Standard Specification (OPSS) OPSS.PROV 539 (*Temporary Protection Systems)* with amendments as per Special Provision (SP) 105S19. The lateral movement of the temporary shoring system shall meet Performance Level 2 as specified in OPSS.PROV 539 (*Temporary Protection Systems)* with amendments as per SP105S19.

Bedrock is anticipated within the depth of excavation along the culvert profile. The bedrock surface encountered at the site is at about Elevation 65.5 m to 64.4 m metres, which is at about 1.3 m to 2.4 m above the existing culvert invert elevation. Both highly weathered and fresh bedrock was encountered within the upper 1.5 m to 2.6 m of the bedrock at the borehole locations. The amount of bedrock removal required for this project will depend on the design invert elevations and size of the diversion pipe.

It is anticipated that the overburden soils can be excavated using conventional excavating equipment. Shallow excavation of the bedrock could be carried out using mechanical methods. It is likely that the highly weathered bedrock can be excavated using conventional excavation equipment (similar to overburden soils), however the fresh bedrock may required methods such as hoe ramming. Where thicker and more competent beds are present, and/or where greater than 1 m of bedrock must be removed, hoe ramming in conjunction with tightly spaced line drilling or blasting may be required. The fresh bedrock encountered during this investigation generally consists of shale bedrock. Due to the expansive potential of the Billings shale bedrock at this site, all exposed final bedrock surfaces should be covered by a mud slab or shotcrete within 48 hours of being exposed to limit long-term expansion of the exposed shale.

Near vertical trench walls in the bedrock should stand unsupported for the construction period. Loose rock should be removed from the sidewalls during excavation. Where the bedrock is in poor to very poor condition and is more than 1.2 metres in height, some form of additional worker protection (e.g., steel plates, or draped mesh) may be required to protect against rockfall.

Based on the measured groundwater levels, it is anticipated that the groundwater table will be encountered above the base of the entry and exit pits/shafts. Groundwater inflow is expected to be generally originating from the upper portion of the bedrock or glacial till and is expected to be low. Groundwater control requirements will largely be dictated by the method of excavation support. If groundwater flow is encountered, pumping from sumps in the excavations would probably be adequate to handle the inflow to the pits/shafts. However, given that the pits/shaft will be adjacent to, and extend about 1 m below the creek, appropriate measures will need to be implemented to avoid inflow of creek water into the temporary excavations/shafts/pits. Dewatering can be carried out as per OPSS.PROV 517 (*Dewatering*), as modified by Special Provision (SP) 517F01 for trenchless replacement and provided in Appendix F. As the groundwater inflow from the excavations is anticipated to be relatively low, no significant impact on the highway is anticipated from the dewatering operations. Further recommendations on dewatering, groundwater control, design parameters and temporary water diversion systems are provided in Section 6.9.1.

6.6 Recommendations and Considerations for Open-Cut Installation and Rehabilitation Works

6.6.1 Culvert Bedding, Backfill and Erosion Protection

If the diversion pipe is installed at the same invert elevation as the existing Unnamed Creek Culvert, the diversion pipe will be installed within the shale bedrock and the pipe embedment should be in accordance with Ontario Provincial Standard Drawing OPSD 802.013 (*Flexible Pipe Embedment and Backfill, Rock Excavation*). If the size and proposed invert elevation for the diversion pipe is revised and the diversion pipe is installed within the embankment fill, which contains potential for shale fragments and/or shale cobbles, the pipe embedment should be in accordance with OPSD 802.014 (Flexible Pipe Embedment in Embankment, Original Ground: Earth or Rock). An NSSP for excavations with obstructions is provided in Appendix F.

Due to the limited soil cover present for a single barrel large diameter diversion pipe, open-cut replacement or multiple smaller diversions pipes is the preferred installation method from a geotechnical perspective. It is expected that cobbles and shale fragments within the embankment fill, if encountered, should not hinder the progression of the excavation. The pipe embedment material should consist of OPSS.PROV 1010 (*Aggregates*) Granular A, fully encapsulated in non-woven geotextile. The granular material placed in the haunch area should be compacted to at least 95 per cent of the material’s Standard Proctor Maximum Dry Density (SPMDD) using suitable vibratory equipment prior to placing and compacting the remainder of the embedment material.

For a diversion pipe installation, the bedding levelling pad and backfill requirements should be in accordance with OPSS.PROV 421 (*Pipe Culvert Installation in Open Cut*). The bedding and cover material should be placed in maximum 200 mm thick lifts and should be compacted to at least 95 per cent of its SPMDD. The backfill should be placed in maximum 300 mm thick lifts and should be compacted to at least 95 per cent the material’s SPMDD. The backfill should extend vertically up to at least 1.5 m above the pipe to match existing grade. The fill depth during placement should be maintained equal on both sides of the diversion pipe and culvert, with one side not exceeding the other by more than 200 mm in height. To limit compaction induced stresses in the culvert, heavy equipment should not be allowed within 1 m of the diversion pipe or culvert during compaction of the backfill.

Based on the results of the investigations, the existing embankment fill consists of gravel and sand to gravelly sand with varying amounts of silt. In accordance with the MTO Pavement Design Manual, the fill is classified to have a low to moderate susceptibility of frost heave and therefore frost tapers are considered necessary for the new diversion pipe and backfill for the existing culvert after rehabilitation works are completed.

As per OPSD 3090.101 (*Foundation Frost Penetration Depths for Southern Ontario*), the frost penetration depth at the site is 1.8 m below the existing ground surface. This depth should be utilized when designing frost tapers in accordance with OPSD 205 and OPSD 803 series.

The diversion pipe installation should be designed for the full overburden pressure and live loads, assuming an embankment fill unit weight of 22 kN/m^3.

6.6.2 Temporary Excavations, Shoring and Temporary Roadway Protection

Temporary excavations for the installation of the diversion pipe and for rehabilitation works for the existing culvert will be made through the existing pavement structure, embankment fill, glacial till / highly weathered bedrock and into the shale bedrock. No unusual problems are anticipated with trenching in the overburden materials using conventional hydraulic excavating equipment, although cobble/shale fragment removal could be required within the embankment fill.

Excavation works must be carried out in accordance with the guidelines outlined OHSA. The existing fill materials are classified as Type 3 soils, while the native very dense till / weathered shale bedrock deposit is generally classified as Type 2 soils, according to the OHSA. Temporary excavations (i.e., those that are open for a relatively short time period of time) should be made with side slopes no steeper than 1H:1V. Any fill which extends below the water table would be classified as Type 4 soil and excavations in these materials should be sloped no steeper than 3H:1V. As indicated in 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.

If the required safe side slopes for the open cut excavations cannot be accommodated, then temporary roadway protection (i.e., excavation shoring) will be required. Where shoring is required, the support system shall be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems)* with amendments as per SP105S19. The lateral movement of the temporary shoring system shall meet Performance Level 2 as specified in OPSS.PROV 539 (*Temporary Protection Systems)* with amendments as per SP105S19.

6.7 Seismic Considerations

The site is located in an area where there exists a history of earthquake activity. A seismic Site Class needs to be assigned to this site, for use by the structural designer.

The CHBDC states that the seismic hazard values associated with the design earthquakes should be those established for the National Building Code of Canada (NBCC) by the Geological Survey of Canada (GSC).
The current seismic hazard maps (referred to as the 5th generation seismic hazard maps) were developed by the GSC and were made available for public use in December 2015.

Multichannel Analysis of Surface Waves (MASW) geophysical testing was carried out within the Highway 417 shoulder at the Cyrville Road overpass located about 250 m south of the Unnamed Creek Culvert to evaluate the average shear wave velocity of the upper 30 m of soil/bedrock at the site. The shear wave velocities measured at the site are presented in a technical memorandum (see results in Appendix D) and indicate that the average shear wave velocity in the upper 30 m of the subsurface stratigraphy at the two MASW locations were 863 m/s and 969 m/s.

Based on the results of the MASW testing and the depth to bedrock encountered at the borehole locations, the shear wave velocity in the upper 30 metres of bedrock at the site is on the order of 1,100 to 1,200 m/s. Based on these values, it is considered that a Site Class B designation would be applicable for the spread footings at the culvert founded directly on the bedrock.

6.8 Shallow Foundations

6.8.1 Bearing Resistance

The spread footings founded directly on the bedrock for the culvert, the static factored geotechnical resistance at Ultimate Limit States (ULS) was calculated based on the compressive strength and condition of the bedrock using the methodology outlined in the Canadian Foundation Engineering Manual (2006), and may be considered to be 1,900 kPa for the structural assessment. Serviceability Limit States (SLS) resistances do not apply to the footings on the bedrock, because the SLS resistance for 25 mm of settlement is greater than the factored geotechnical bearing resistance at ULS.

The factored geotechnical resistances provided above are given for loads that will be applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the footing, inclination of the load should be taken into account in accordance with Section 6.10.4 of the CHBDC.

6.8.2 Sliding Resistance

The parameter values in the following table may be used to calculate the lateral resistance to sliding/shearing at the foundation-soil interface:

Table 6: Sliding Resistance Design Parameters

Interface Condition	Effective Friction Angle (degrees)	Effective Cohesion (kPa)
Cast-in-Place Concrete – Shale Bedrock	25	0
Pre-Cast Concrete – Shale Bedrock	20	0

These values are unfactored; in accordance with the CHBDC, a factor of 0.8 is to be applied in calculating the horizontal resistance.

6.9 Design and Construction Considerations

6.9.1 Temporary Water Diversion Systems

Control of the creek flow, surface water and groundwater will be necessary for the rehabilitation of the culvert, to allow construction to be carried out in dry conditions.

Depending on the creek flow, surface water flow conditions and the groundwater levels at the time of construction, water flow could be bypassed through either the existing culvert or through the newly installed diversion pipe(s) by diverting the flow toward or pumping from behind a temporary water diversion system. Temporary water diversion systems for these works could consist of either sand bags or glacial till / weathered shale cofferdam advanced to an appropriate depth to control the surface water and groundwater inflow from the creek. Alternatively, an inflatable water diversion system could be used. However, the selection and design of temporary unwatering/dewatering system is the responsibility of the contractor and shall be carried out in accordance with OPSS.PROV 517 *(Dewatering)* with amendments as per SP517F01 *(Dewatering System)*. Given the groundwater and soil conditions at this site, dewatering is expected to be of low complexity, and it is therefore not a requirement to carry out a preconstruction survey or to require a dewatering design engineer for the dewatering system as per Table A of SP 517F01 *(Dewatering System).*

Additionally, excavations and backfilling of the culvert during construction shall conform to NSSP FOUND003 with additional considerations for obstructions with NSSP – Obstructions, provided in Appendix F.

As per OPSD 3090.101 *(Foundation Frost Penetration Depths for Southern Ontario)*, the frost penetration depth at the site is 1.8 m below the existing ground surface.

6.9.1.1 Sheet Pile Cut-Off Wall

Temporary water diversion systems consisting of steel sheet pile cut-off walls driven to found within the native glacial till/highly weathered shale deposits would be feasible at the culvert inlet and outlet locations. These systems should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems)* with amendments as per SP105S19. The lateral movement of the temporary sheet pile cut-off walls should meet Performance Level 3 as specified in OPSS.PROV 539 (*Temporary Protection Systems)* with amendments as per SP105S19. The design of a temporary water diversion system consisting of braced sheet piles should be based on the anticipated unbalanced hydraulic loads and the earth pressure distribution for soft to firm cohesive soils provided in the Canadian Foundations Engineering Manual (CFEM 2006) using the design parameters given in **Error! Reference source not found.** below.

For cantilever walls or where the support to the wall is provided by anchors, the wall design shall be based on a triangular earth pressure distribution using the design parameters given below. The supports must be designed to accommodate the loads applied from earth pressures and surcharge pressures from area, line or point loads as may be imposed by construction equipment and materials, as well as the impact of sloping ground behind the system.

The temporary cut-off wall design should be assessed for both the drained and undrained cases, based on the more conservative earth pressure conditions. The earth pressure coefficients noted in **Error! Reference source not found.** are based on a horizontal surface adjacent to the excavation. If sloped surfaces are present, the coefficient of earth pressure should be adjusted accordingly.

6.9.1.2 Sand Bags or Glacial Till Cofferdam

Alternatively, the water diversion system could consist of a sand bag embankment or temporary earth embankment with a clay core. For both options, the base of the temporary water diversion system should be excavated to the surface of the fresh shale bedrock to create a continuous cut off between the native soil and the temporary embankments. Further comments with regards to temporary excavations are provided in Section 6.6.2.

Where a clay core is used, it should be covered with an approximately 0.5 m thick layer of OPSS.PROV 1010 (*Aggregates*) Granular B Type II to reduce the potential for erosion of the embankment side slopes.

6.9.1.3 *Inflatable Water Diversion System*

Consideration could also be given to the use of an inflatable water diversion system. These systems typically consist of vinyl coated polyester water-inflated bladders with internal baffle systems. Various barrier heights are available, with a standard maximum height of about 2.5 m. However, the height of barrier should typically maintain a minimum of at least 25 percent of freeboard above the static water level. Inflatable systems also rely on surface friction in order to stabilize when exposed to uneven water pressure. An anchoring system at the creek bank may also be required depending on the water flow in the creek at the time of construction. The design parameters provided in **Error! Reference source not found.** can be used for the design of an inflatable water diversion system; however, it should be noted that these types of systems are proprietary to individual suppliers and may require additional investigation and/or input for design.

Table 7: Design Parameter - Inflatable Water Diversion System

Soil Type	Internal Angle of Friction (ϕ, degrees)	Unit Weight (γ, kN/m^3)	Coefficients of Earth Pressure		
			Active, Ka	At-Rest, Ko	Passive, Kp
Embankment Fill	28	20	0.61	0.53	2.70
Till/Highly Weathered Bedrock	30	22	0.57	0.50	3.00

6.9.2 Cement Type and Steel Corrosion Potential

One soil sample from Borehole 18-3202 was submitted to Eurofins for chemical analysis related to potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack).

The results indicate a low potential for concrete degradation due to the presence of sulphates, and that concrete made with Type GU Portland cement should be acceptable for substructures. The results also indicate a very high potential for corrosion of exposed ferrous metal which should be considered in the design.

The test results provided in Section 4.7 and attached in Appendix C can be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

6.9.3 Erosion Protection

The need for (and design of) erosion protection at the culvert inlet and outlet (including the slopes and sides of the channel) will depend on the anticipated hydrologic/hydraulic conditions. Typically, rip-rap protection should be provided over these areas. The rip-rap layer should cover all surfaces on the embankment slopes against which creek water is likely to be in contact. If needed, rip-rap treatment should be consistent with the OPSD 810.010 (*Rip-Rap Treatment for Sewer and Culvert Outlets*).

7.0 CLOSURE

This report was prepared by Ms. Nikol Kochmanová, P.Eng. and was reviewed by Mr. Michael Snow, P.Eng., a senior geotechnical engineer and Principal of Golder. Mr. Fintan Heffernan, P.Eng., a Senior Consultant with Golder and the Designated MTO Foundations Contact for this project, conducted an independent quality control review of this report.

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WAM/NK/MSS/FJH/hdw
https://golderassociates.sharepoint.com/sites/11263g/shared documents/01_foundations/6 - reports/1320 unamed creek 417/final/1662565-1320-001-r-rev0-unnamed creek culvert-2706_19 fidr.docx

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Chapman, L.J. and Putnam, D.F. 1984. *The Physiography of Southern Ontario, Ontario Geological Survey*, Special Volume 2, Third Edition. Accompanied by Map P.2715, Scale 1:600,000.

International Society for Rock Mechanics Commission on Test Methods, 1985. Int. J. Rock Mech.Min. Sci. & Geomech. Abstr. Vol 22, No. 2, pp. 51-60.

ASTM International Standards:

ASTM D1586	Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

Ontario Provisional Standard Drawings:

OPSD 802.013	Flexible Pipe, Embedment and Backfill, Rock Excavation
OPSD 802.014	Flexible Pipe, Embedment in Embankment, Original Ground: Earth or Rock
OPSD 810.010	General Rip-Rap Layout for Sewer And Culvert Outlets
OPSD 3090.101	Foundation Frost Penetration Depths for Southern Ontario

Ontario Provincial Standard Specification:

OPSS.PROV 421	Construction Specification for Pipe Culvert Installation in Open Cut
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Special Provision (SP)

SP105S19	Amendment to OPSS 539, November 2014
SP517F01	Temporary Flow Passage System - Amendment to OPSS 517, November 2016

Ontario Water Resources Act:

Ontario Regulation 903	Wells (as amended)

Ontario Occupational Health and Safety Act:

Ontario Regulation 213/91	Construction Projects (as amended)

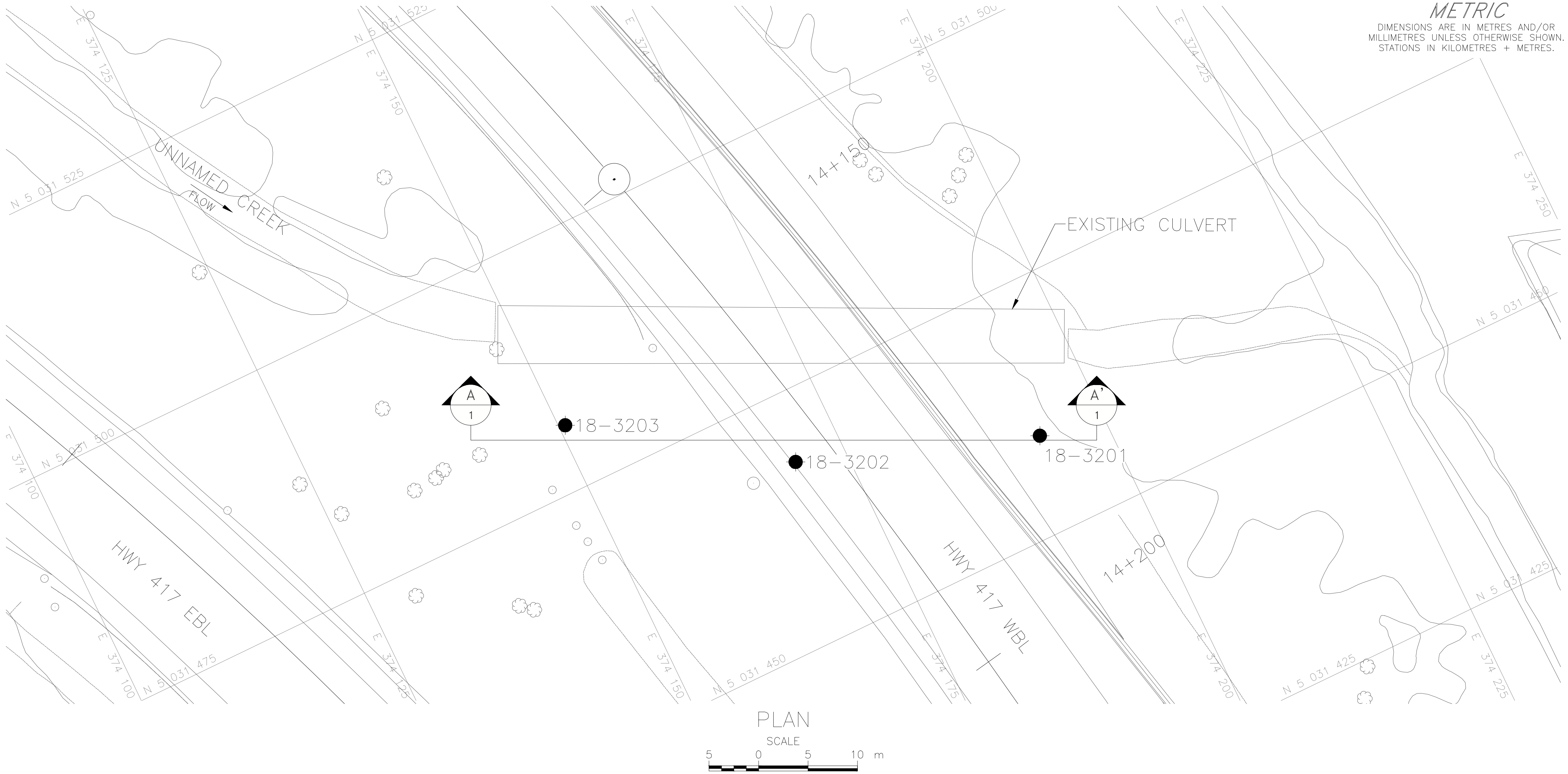
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 4099-11-00

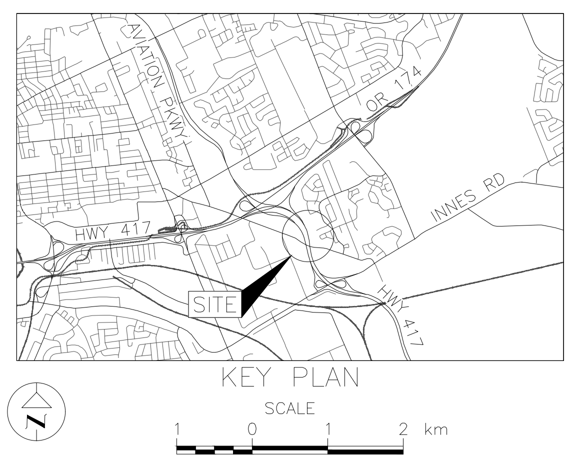
SHEET

UNNAMED CREEK CULVERT
HIGHWAY 417
BOREHOLE LOCATIONS AND SOIL STRATA
LAT. 45.419734 LONG. -75.613476

GOLDER



PLAN



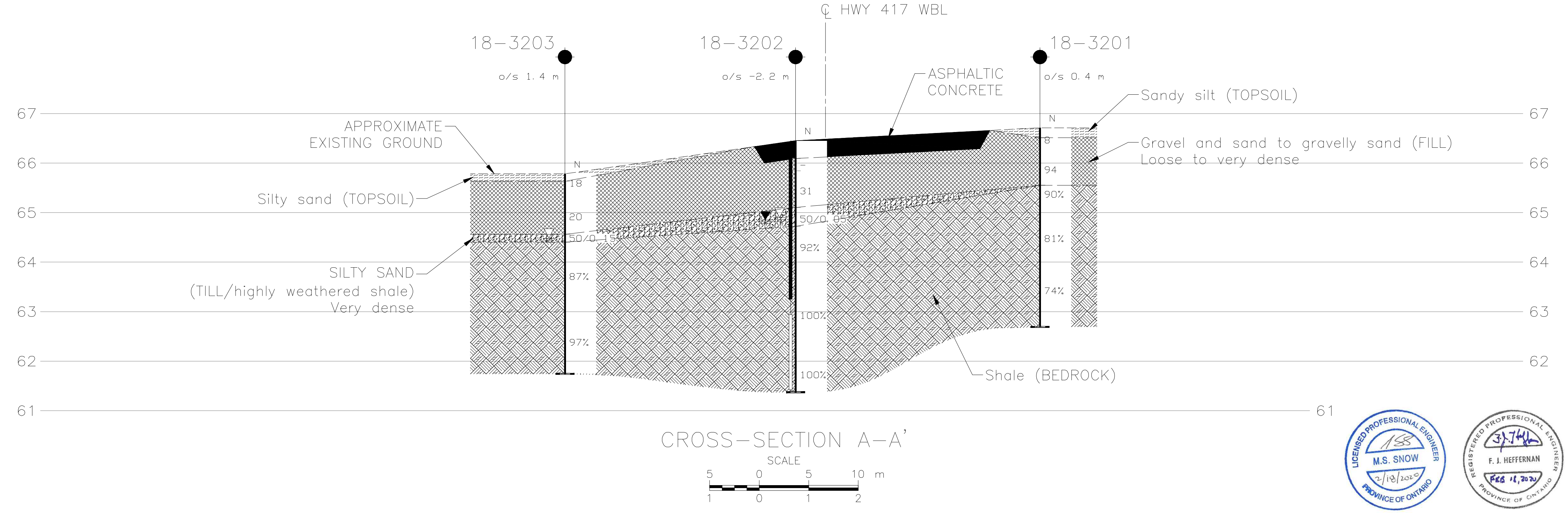
KEY PLAN

LEGEND

●	Borehole – Current Investigation
▮	Seal
▯	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
▼	WL in piezometer, measured on JUNE 23, 2019
▽	WL upon completion of drilling

BOREHOLE CO-ORDINATES NAD 83 (CSRS)/MTM ZONE 9

No.	ELEVATION	NORTHING	EASTING
18-3201	66.7	5031459.7	374193.4
18-3202	66.5	5031468.0	374170.0
18-3203	65.8	5031481.5	374150.6



CROSS-SECTION A-A'

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

REFERENCE

Base plans provided in digital format by WSP, drawing file nos. XA1-NAD 83.dwg and XB1-NAD 83 (CSRS).dwg, received APR. 19, 2017.

M.S. SNOW
2/18/2020

F. J. HEFFERNAN
FEB 18, 2020

NO.	DATE	BY	REVISION

Geocres No. 31G5-311

HWY. 417	PROJECT NO. 1662565		DIST. EASTERN
SUBM'D. WAM	CHKD. WAM	DATE: 2/19/2020	SITE: 3-763/C
DRAWN: JM	CHKD. MSS	APPD. FJH	DWG. 1

PLOT DATE: February 19, 2020
FILENAME: N:\Active\Spatial_IM\MTO\Hwy417Rehab&Widening\99_PROJ\1662565_MTO_Hwy417Replacements\40_PROD\0018_UnnamedCreekCulvert_417\1662565-0018-BG-0001.dwg

APPENDIX A

Borehole and Drillhole Records, Current Investigation

Lists of Abbreviations and Symbols

Lithological and Geotechnical Rock Description Terminology

Records of Boreholes 18-3201 to 18-3203

Bedrock Core Photographs, Figures A1 to A3

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\ \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan \delta$
c′	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p′	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes:

1 $\tau = c' + \sigma' \tan \phi'$

2 shear strength = (compressive strength)/2

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d:

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60º cone attached to “A” size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

Compactness Condition	**N** **Blows/300 mm or Blows/ft**
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils

Consistency	**kPa**	**psf**
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	100 to 200	1,000 to 2,000
Very stiff	over 200	over 4,000
Hard		

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	**Modifier**	**Example**
0 to 10	Trace	Trace sand
10 to 20	Some	Some sand
20 to 35	(ey) or (y)	Sandy
over 35	And	Sand and Gravel

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERINGS STATE

Fresh: no visible sign of weathering

Faintly weathered: weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.

Completely weathered: rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

BEDDING THICKNESS

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

JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

Term	Size*
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: * Grains greater than 60 microns diameter are visible to the naked eye.

CORE CONDITION

Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, as measured along the centerline axis of the core, relative to the length of the total core run. RQD varies from 0% for completely broken core to 100% for core in solid segments.

DISCONTINUITY DATA

Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations

JN	Joint
FLT	Fault
SH	Shear
VN	Vein
FR	Fracture
SY	Stylolite
BD	Bedding
FO	Foliation
CO	Contact
AXJ	Axial Joint
KV	Karstic Void
MB	Mechanical Break
PL	Planar
CU	Curved
UN	Undulating
IR	Irregular
K	Slickensided
PO	Polished
SM	Smooth
SR	Slightly Rough
RO	Rough
VR	Very Rough

RECORD OF BOREHOLE No 18-3201

SHEET 1 OF 2

METRIC

PROJECT 1662565-1320

G.W.P. 4099-11-00

DIST Eastern HWY 417

DATUM Geodetic

LOCATION N 5031459.7; E 374193.4 NAD 83 MTM ZONE 9 (LAT. 45.419630; LONG. -75.613312)

BOREHOLE TYPE Portable Drill, DO Sampler/Rotary Drill, NQ Core

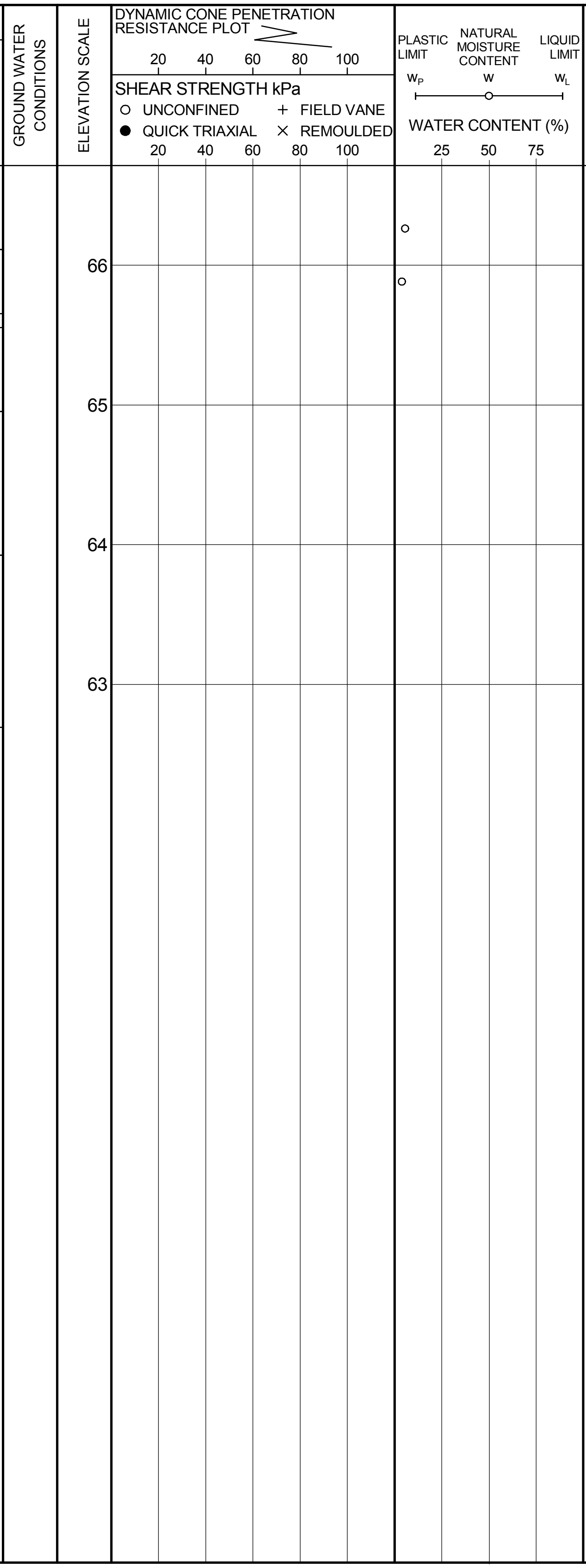
DATE August 7, 2018

ORIGINATED BY DJG

COMPILED BY ZS

CHECKED BY WAM

SOIL PROFILE		SAMPLES			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES		
66.7	GROUND SURFACE					
0.0	(ML) Sandy silt (TOPSOIL) Dark brown Moist					
66.5 0.2	(SW-SM) Sand and gravel, trace to some silt, trace clay (FILL) Loose to very dense Brown Dry	1	SS	8		
		2	SS	94		37 50 11 2
65.5 1.2	Shale (BEDROCK) Bedrock cored from depths 1.2 m to 4.0 m For bedrock coring details refer to Record of Drillhole 18-3201	1	RC	REC 100%		RQD = 90%
		2	RC	REC 100%		RQD = 81%
		3	RC	REC 100%		RQD = 74%
62.7 4.0	END OF BOREHOLE					



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$+^3, \times^3$: Numbers refer to Sensitivity

$\bigcirc^{3\%}$ STRAIN AT FAILURE

PROJECT: 1662565-1320

RECORD OF DRILLHOLE: 18-3201

SHEET 2 OF 2

LOCATION: N 5031459.7 ;E 374193.4

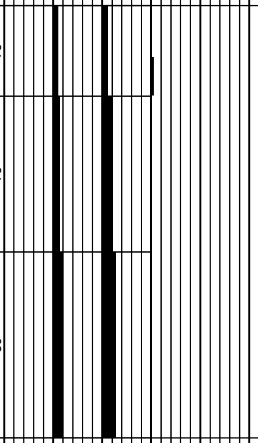
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: August 7, 2018
DRILL RIG: Portable Drill
DRILLING CONTRACTOR: OGS

DATUM: Geodetic

NOTE:
For abbreviations, symbols and descriptions refer to
LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX PER 5 10 15 20	DIP w.r.t. CORE AXIS 0 30 60 90	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-6} 10^{-5} 10^{-4} 10^{-3}	WEATHERING INDEX W1 W2 W3 W4 W5 W6	FEATURES
		BEDROCK SURFACE		65.55													
	Rotary Drill NQ Core	Shale (BEDROCK) Fresh Thinly laminated Black Fine grained Porous Strong	▨	1.16	1	75											
2					2	75											
3					3	80											
4		END OF DRILLHOLE		62.69 4.02													
5																	
6																	
7																	
8																	
9																	
10																	
11																	



DEPTH SCALE
1 : 50

GOLDER

LOGGED: DJG
CHECKED: WAM

RECORD OF BOREHOLE No 18-3202

SHEET 1 OF 2

METRIC

PROJECT 1662565-1320

G.W.P. 4099-11-00

DIST Eastern HWY 417

DATUM Geodetic

LOCATION N 5031468.0; E 374170.0 NAD 83 MTM ZONE 9 (LAT. 45.419708; LONG. -75.613609)

BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)/Rotary Drill, NQ3 Core

DATE August 14-15, 2018

ORIGINATED BY KM

COMPILED BY ZS

CHECKED BY WAM

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa

○ UNCONFINED + FIELD VANE

● QUICK TRIAXIAL × REMOULDED

20 40 60 80 100

PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L

WATER CONTENT (%) 25 50 75

UNIT WEIGHT γ kN/m³

ELEVATION SCALE: 66, 65, 64, 63, 62

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
66.5	GROUND SURFACE				
0.0	ASPHALTIC CONCRETE				
66.1	(GP/GM) Gravel and sand, trace to some silt, trace clay (FILL) Brown Moist	1	GRAB	-	52 35 11 2
65.9 0.6	(SW-SM) Gravelly sand, trace to some silt, trace clay, contains shale fragments (FILL) Dense Brown Moist	2	SS	31	21 69 8 2
65.2 1.4	(SM) SILTY SAND, some gravel and clay, contains shale fragments (TILL/highly weathered shale) Very dense Dark brown to black Moist	3	SS	50/0.05	
64.8 1.7	Shale (BEDROCK) Bedrock cored from depths 1.7 m to 5.1 m For bedrock coring details refer to Record of Drillhole 18-3202	1	RC	REC 97%	RQD = 92%
		2	RC	REC 100%	RQD = 100%
		3	RC	REC 100%	RQD = 100%
61.4 5.1	END OF BOREHOLE				

NOTES:

1. Water level measured upon completion of borehole drilling in open borehole at 1.6 m depth (Elev. 64.9 m) on August 15, 2018.

2. Water level measured in standpipe piezometer at a depth of 1.6 m below ground surface (Elev. 64.9 m) on June 23, 2019.

$+^3, \times^3$: Numbers refer to Sensitivity

$\bigcirc^{3\%}$ STRAIN AT FAILURE

PROJECT: 1662565-1320

RECORD OF DRILLHOLE: 18-3202

SHEET 2 OF 2

LOCATION: N 5031468.0 ;E 374170.0

DRILLING DATE: August 14-15, 2018

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 75

DRILLING CONTRACTOR: Downing Drilling

NOTE:
For abbreviations, symbols and descriptions refer to
LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN
		BEDROCK SURFACE	64.72		
2	Rotary Drill NQ3 Core	Shale (BEDROCK) Fresh Thinly bedded Dark grey Fine grained Porous Strong	1.73	1	10
3				2	0
4					
5			61.37	3	0
		END OF DRILLHOLE	5.08		
6					
7					
8					
9					
10					
11					

RECOVERY: TOTAL CORE % (80 60 40 20), SOLID CORE % (80 60 40 20); R.Q.D. % (80 60 40 20); FRACT. INDEX PER (5 10 15 20); DISCONTINUITY DATA: DIP w.r.t. CORE AXIS (0 30 60 90), TYPE AND SURFACE DESCRIPTION, Jr, Ja; HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WEATHERING INDEX (W1 W2 W3 W4 W5 W6); FEATURES

DEPTH SCALE

1 : 50

GOLDER

LOGGED: KM

CHECKED: WAM

RECORD OF BOREHOLE No 18-3203

SHEET 1 OF 2

METRIC

PROJECT 1662565-1320
G.W.P. 4099-11-00
DIST Eastern HWY 417
DATUM Geodetic

LOCATION N 5031481.5; E 374150.6 NAD 83 MTM ZONE 9 (LAT. 45.419831; LONG. -75.613855)
BOREHOLE TYPE Portable Drill, DO Sampler/Rotary Drill, NQ Core
DATE July 25, 2018

ORIGINATED BY DJG
COMPILED BY ZS
CHECKED BY WAM

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 25 50 75	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				GR	SA	SI	CL
65.8	GROUND SURFACE													
0.0	(SM) Silty sand (TOPSOIL) Brown													
0.2	(GW-GM) Gravel and sand, some silt, trace clay (FILL) Compact Dark brown Moist to wet		1	SS	18				○		53	32	10	5
			2	SS	20		65		○					
64.6														
	(SM) SILTY SAND, some gravel to gravelly, some clay, contains shale fragments(TILL/highly weathered shale) Very dense Black Moist		3	SS	50/0.15	▽								
1.4	Shale (BEDROCK) Bedrock cored from depths 1.4 m to 4.0 m For bedrock coring details refer to Record of Drillhole 18-3203		1	RC	REC 100%		64 63				RQD = 87%			
			2	RC	REC 100%		62				RQD = 97%			
61.8 4.0	END OF BOREHOLE													

NOTES:

1. Water level in open borehole at 1.3 m depth (Elev. 64.6 m), measured during drilling.

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

○ $^{3\%}$ STRAIN AT FAILURE

GTA-MTO 001 N:\ACTIVE\SPATIAL_IM\MTO\HWY417REHAB&WIDENING\02_DATA\GINT\1662565.GPJ GAL-GTA.GDT 10/7/19 ZS

PROJECT: 1662565-1320

RECORD OF DRILLHOLE: 18-3203

SHEET 2 OF 2

LOCATION: N 5031481.5 ;E 374150.6

DRILLING DATE: July 25, 2018

DATUM: Geodetic

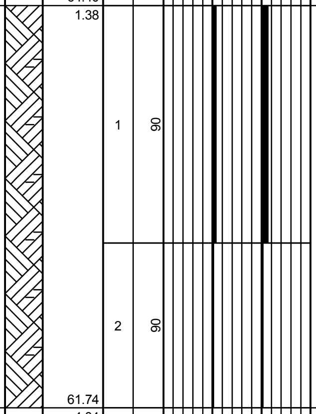
INCLINATION: -90° AZIMUTH: ---

DRILL RIG: Portable Drill

DRILLING CONTRACTOR: OGS

NOTE:
For abbreviations, symbols and descriptions refer to
LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX PER 5 10 15 20	DISCONTINUITY DATA DIP w.r.t. CORE AXIS 0 30 60 90	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-6} 10^{-5} 10^{-4} 10^{-3}	WEATH-ERING INDEX W1 W2 W3 W4 W5 W6	FEATURES
		BEDROCK SURFACE		64.40													
2	Rotary Drill NQ Core	Shale (BEDROCK) Fresh Thinly to medium bedded Grey-black Fine grained Slightly porous Strong		1.38	1	90											
3					2	90											
4		END OF DRILLHOLE		61.74 4.04													
5																	
6																	
7																	
8																	
9																	
10																	
11																	



DEPTH SCALE

1 : 50

GOLDER

LOGGED: DJG

CHECKED: WAM

BH 18-3201

Cored Length of 1.16 to 4.02 metres

Core Box 1 of 1

1.16 m Top of Core

4.02 m EOH

Foundation Investigation

Unnamed Creek North of Cyrville Road

Ottawa, Ontario

Project No.	1662565 / 1320
Drawn:	WAM
Date:	2019-03-19
Checked:	
Review:	

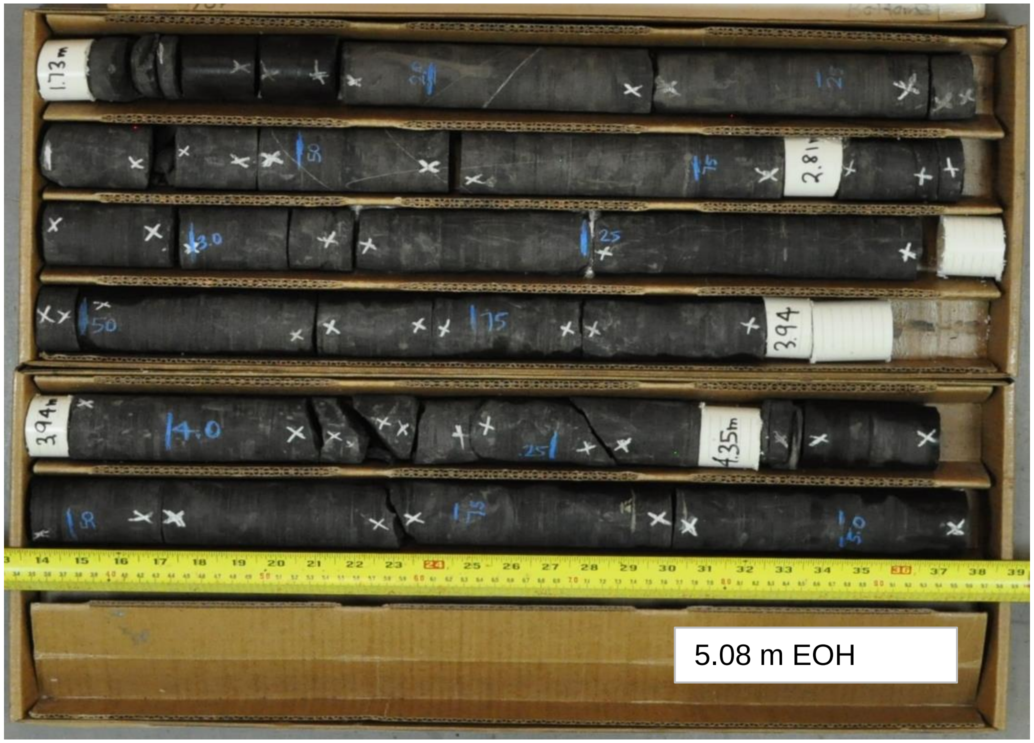
Figure A1

BH 18-3202

Cored Length of 1.73 to 5.08 metres

Core Box 1 and 2 of 2

1.73 m Top of Core



5.08 m EOH

Foundation Investigation

Unnamed Creek North of Cyrville Road

Ottawa, Ontario

Project No.	1662565 / 1320
Drawn:	WAM
Date:	2019-03-19
Checked:	
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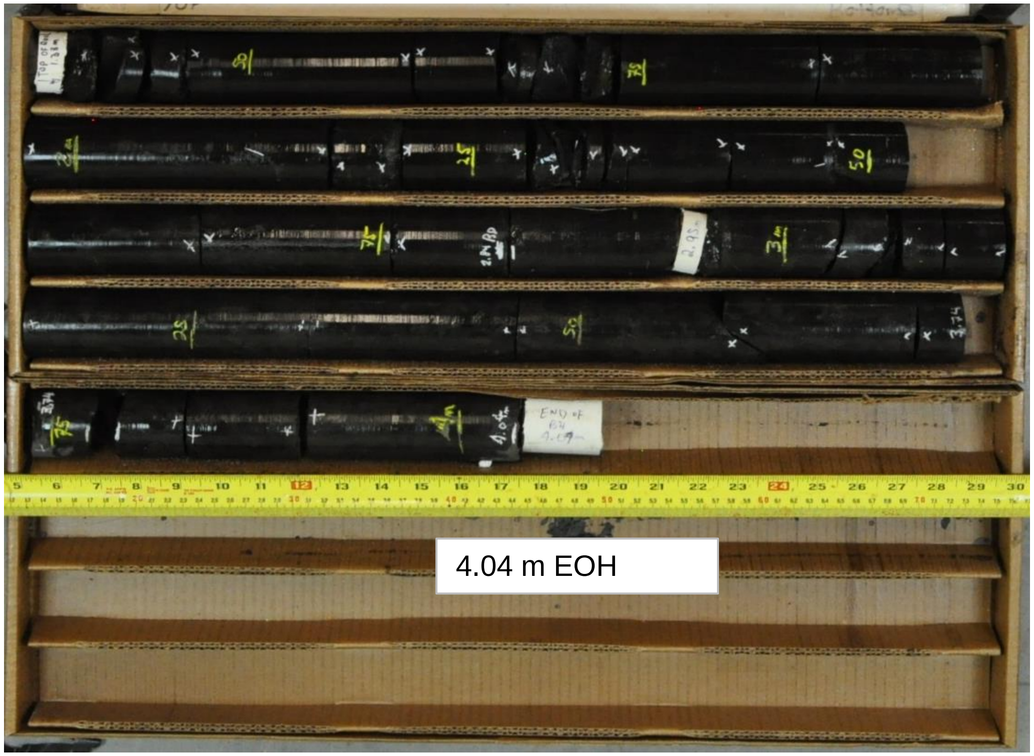
Figure A2

BH 18-3203

Cored Length of 1.38 to 4.04 metres

Core Box 1 and 2 of 2

1.38 m Top of Core



4.04 m EOH

Foundation Investigation

Unnamed Creek North of Cyrville Road

Ottawa, Ontario

GOLDER

Project No.	1662565 / 1320
Drawn:	WAM
Date:	2019-03-19
Checked:	
Review:	

Figure A3

APPENDIX B

Laboratory Test Results, Current Investigation

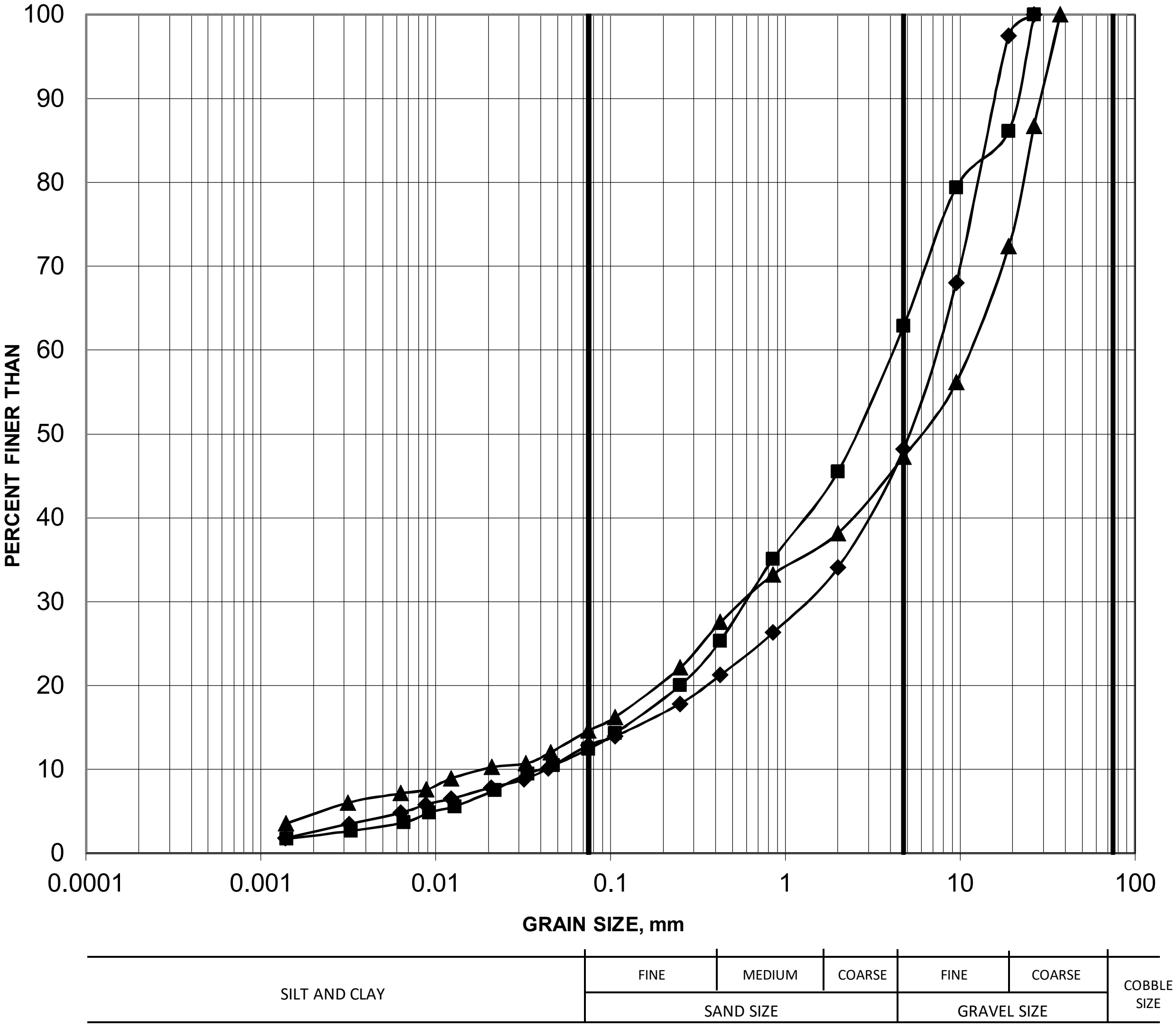
Figure B1 – Grain Size Distribution Test Results – Gravel and Sand (FILL)

Figure B2 – Grain Size Distribution Test Results – Gravelly Sand (FILL)

Figure B3 – Summary of Laboratory Compressive Strength Testing – Unconfined Compression Test

GRAIN SIZE DISTRIBUTION	FIGURE B1

GRAVEL AND SAND (FILL)



Borehole	Sample	Depth (m)
■ 18-3201	2	0.61-1.07
◆ 18-3202	1	0.00-0.61
▲ 18-3203	2	0.61-1.22

Project: 1662565/1320

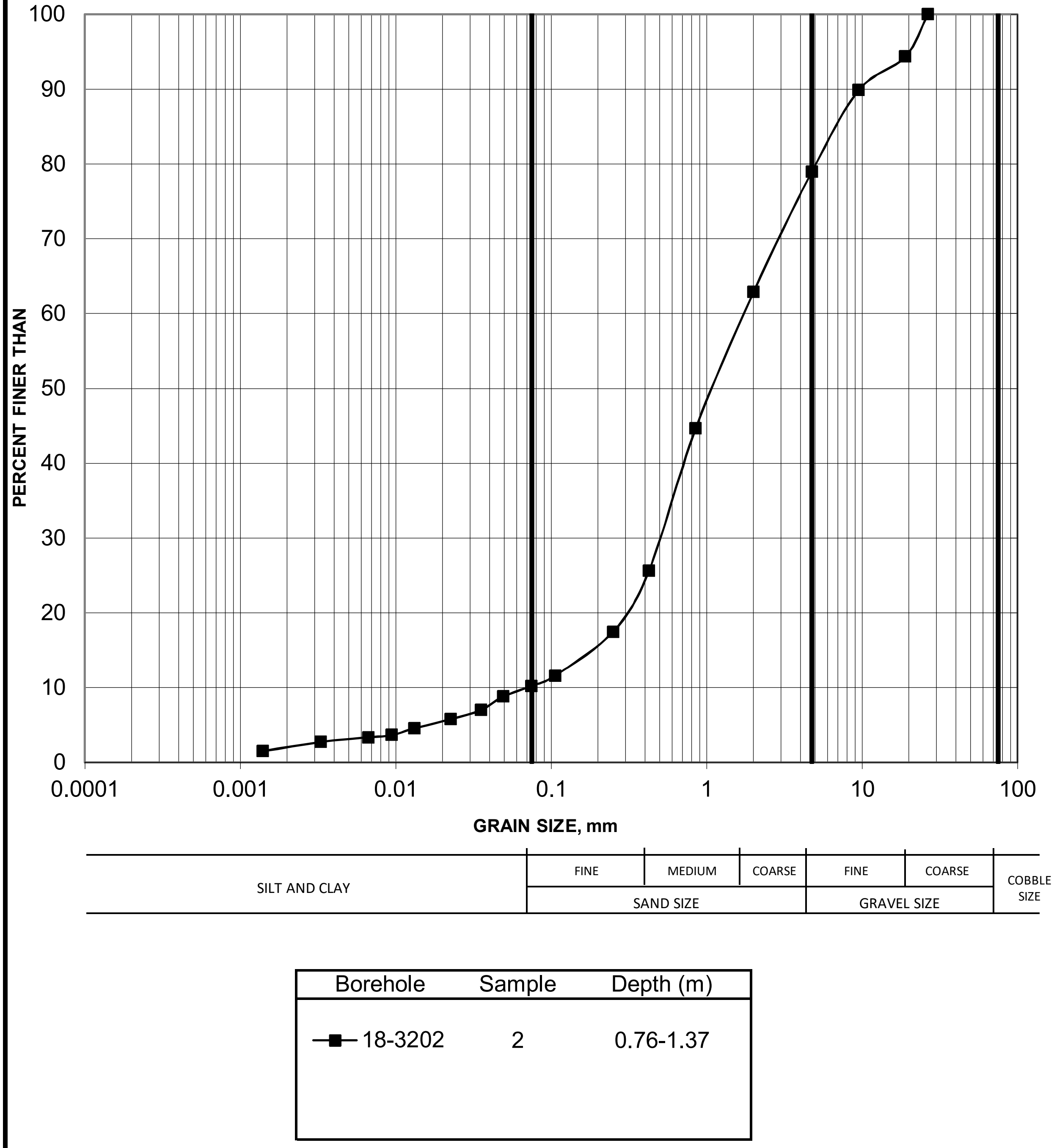
Golder Associates

Created by: CW
Checked by: MI

GRAIN SIZE DISTRIBUTION

FIGURE B2

GRAVELLY SAND (FILL)



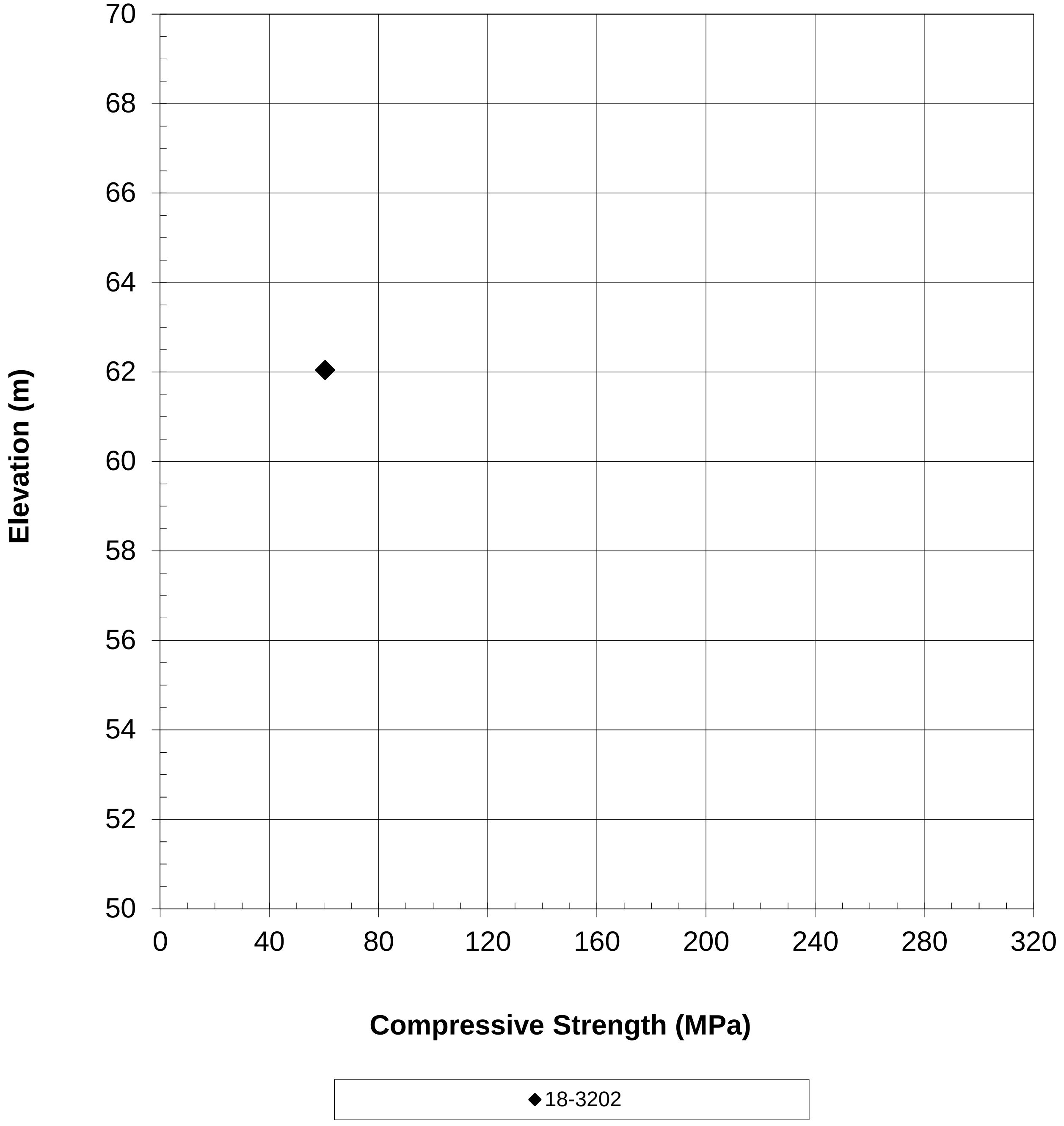
Project: 1662565/1320

Golder Associates

Created by: CW

Checked by: MI

SUMMARY OF LABORATORY COMPRESSIVE STRENGTH UNCONFINED COMPRESSION TESTS	FIGURE B3



Project: 1662565 /1320

GOLDER

Created by: CW
Checked by: MI

APPENDIX C

Basic Chemical Analysis – Eurofins Report Number 1816328

eurofins Environment Testing

Certificate of Analysis

Client: Golder Associates Ltd (Ottawa)
1931 Robertson Road,
Ottawa, Ontario
K2E 7Y1
Attention: Ms. Gabrielle Marcotte
PO#:
Invoice to: Golder Associates Ltd

Report Number:	1816328
Date Submitted:	2018-09-10
Date Reported:	2018-09-13
Project:	1662565/1320
COC #:	835568

				Lab I.D. Sample Matrix Sample Type Sampling Date Sample I.D.	1386360 Soil 2018-07-25 18-3203 SA2/2-4
Group	**Analyte**	**MRL**	**Units**	**Guideline**	
Anions	Cl	0.002	%		0.005
	SO4	0.01	%		0.05
General Chemistry	Electrical Conductivity	0.05	mS/cm		0.69
	pH	2.00			8.09
	Resistivity	1	ohm-cm		1450

Guideline = *** = Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

APPENDIX D

Results of MASW Testing

TECHNICAL MEMORANDUM

DATE July 16, 2018

Project No. 1662565/1240

TO Susan Trickey, Golder Associates Ltd.

FROM Stephane Sol, Christopher Phillips

EMAIL ssol@golder.com, cphillips@golder.com

CHBDC SEISMIC SITE CLASS TESTING RESULTS
CYRVILLE ROAD AND HIGHWAY 417, OTTAWA, ONTARIO

This technical memorandum presents the results of two Multichannel Analysis of Surface Waves (MASW) tests performed for the purpose of the Canadian Highway Bridge Design Code (CHBDC 2014) Seismic Site Classification (Figure 1). The tests are located on each side of the interchange between Cyrville Road and Highway 417 in Ottawa. The geophysical testing was performed by Golder Associates Ltd. (Golder) personnel on June 26, 2018.

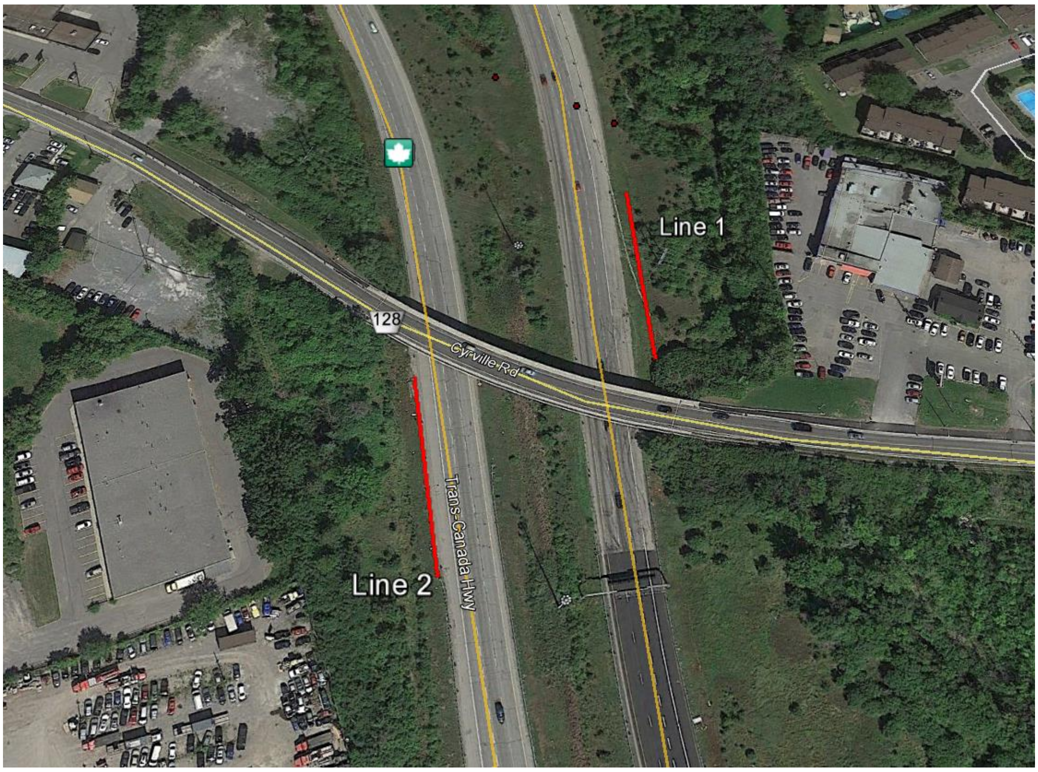


Figure 1: MASW Location Site Map. MASW Lines in red – Line 1 (Northbound) and Line 2 (Southbound).

Golder and the G logo are trademarks of Golder Associates Corporation

Methodology

The MASW method measures variations in surface-wave velocity with increasing distance and wavelength and can be used to infer the rock/soil types, stratigraphy and soil conditions.

A typical MASW survey requires a seismic source, to generate surface waves, and a minimum of two geophone receivers, to measure the ground response at some distance from the source. Surface waves are a special type of seismic wave whose propagation is confined to the near surface medium.

The depth of penetration of a surface wave into a medium is directly proportional to its wavelength. In a non-homogeneous medium, surface waves are dispersive, i.e., each wavelength has a characteristic velocity owing to the subsurface heterogeneities within the depth interval that particular wavelength of surface wave propagates through. The relationship between surface-wave velocity and wavelength is used to obtain the shear-wave velocity and attenuation profile of the medium with increasing depth.

The seismic source used can be either active or passive, depending on the application and location of the survey. Examples of active sources include explosives, weight-drops, sledge hammer and vibrating pads. Examples of passive sources are road traffic, micro-tremors, and water-wave action (in near-shore environments).

The geophone receivers measure the wave-train associated with the surface wave travelling from a seismic source at different distances from the source.

The participation of surface waves with different wavelengths can be determined from the wave-train by transforming the wave-train results into the frequency domain. The surface-wave velocity profile with respect to wavelength (called the ‘dispersion curve’) is determined by the delay in wave propagation measured between the geophone receivers. The dispersion curve is then matched to a theoretical dispersion curve using an iterative forward-modelling procedure. The result is a shear-wave velocity profile of the tested medium with depth, which can be used to estimate the dynamic shear-modulus of the medium as a function of depth.

Field Work

The MASW field work was conducted on June 26, 2018, by personnel from the Golder Mississauga office. For each MASW line, a series of 24 low frequency (4.5 Hz) geophones were laid out at 3 m intervals. Both active and passive readings were recorded along the MASW lines. For the active investigation, a seismic drop of 45 kg and a 9.9 kg sledge hammer were used as seismic sources. Active seismic records were collected with seismic sources located 5, 10, and 15 m from and collinear to the geophone array. A seismic refraction survey was also conducted along both lines to be able to determine the depth to bedrock as well as to estimate the shear wave velocity of the overburden. An example of active seismic records collected at each line are shown in Figures 2 and 3, below.

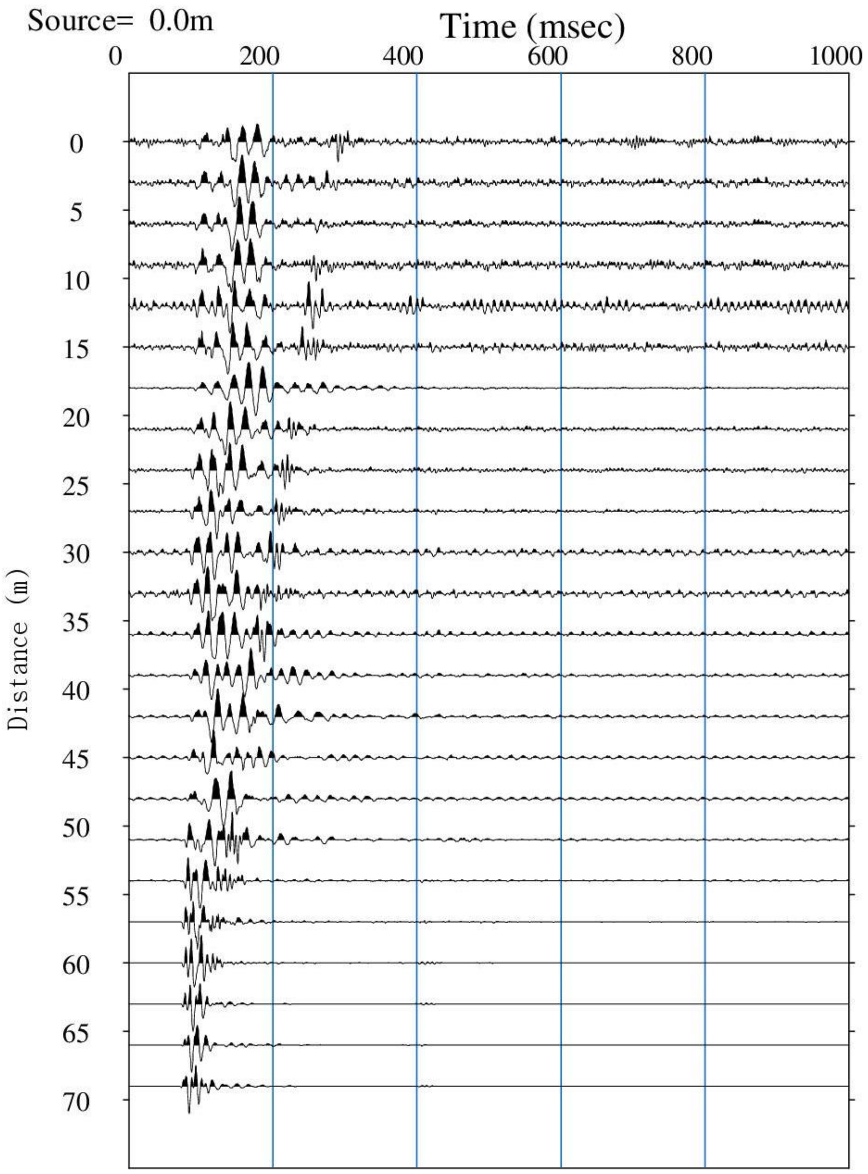


Figure 2: Typical seismic record collected at the site of MASW Line 1.

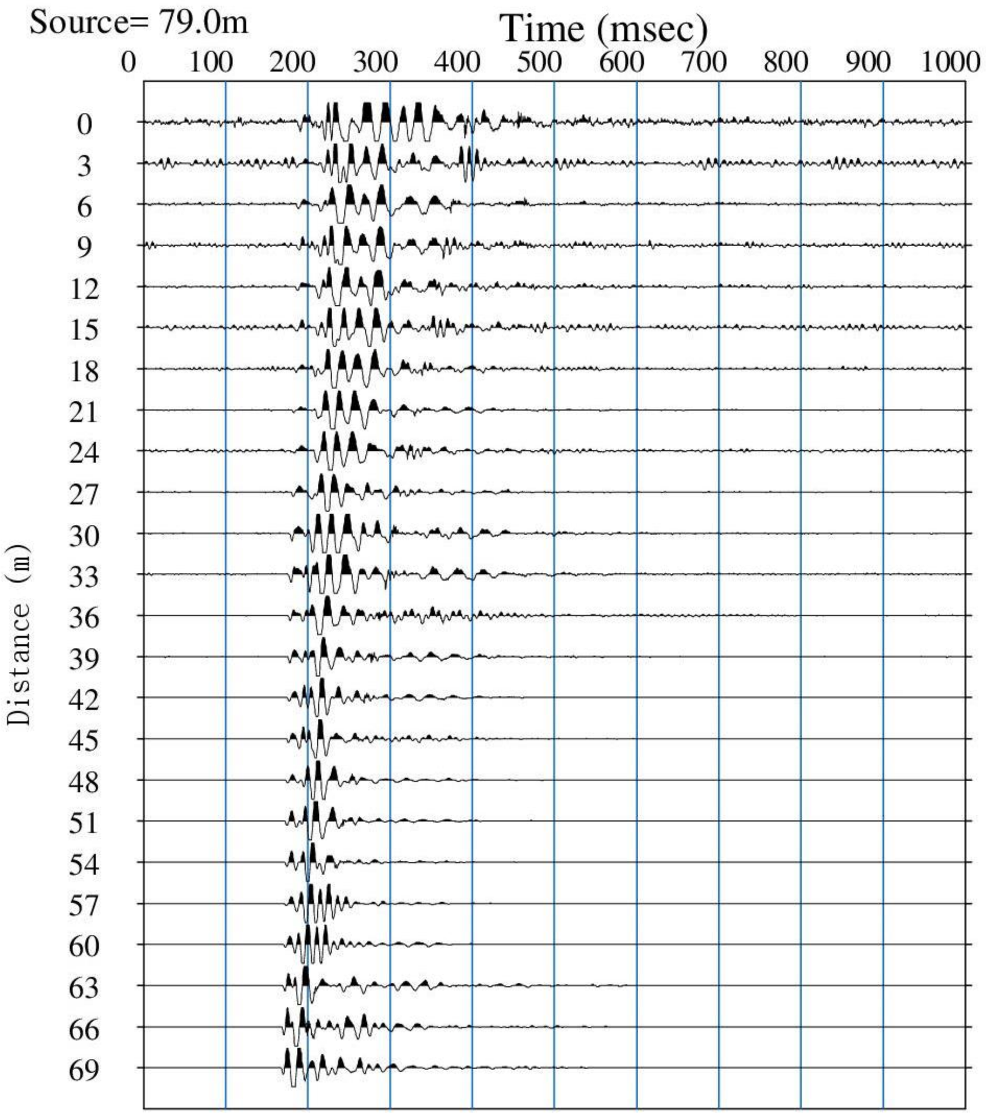


Figure 3: Typical seismic record collected at the site of MASW Line 2.

Data Processing

Processing of the MASW test results consisted of the following main steps:

1) Transformation of the time domain data into the frequency domain using a Fast-Fourier Transform (FFT) for each source location;

2) Calculation of the phase for each frequency component;

3) Linear regression to calculate phase velocity for each frequency component;

4) Filtering of the calculated phase velocities based on the Pearson correlation coefficient (r2) between the data and the linear regression best fit line used to calculate phase velocity;

5) Generation of the dispersion curve by combining calculated phase velocities for each shot location of a single MASW test; and,

6) Generation of the stiffness profile, through forward iterative modelling and matching of model data to the field collected dispersion curve.

Processing of the MASW data was completed using the SeisImager/SW software package (Geometrics Inc.). The calculated phase velocities for a seismic shot point were combined and the dispersion curve generated by choosing the minimum phase velocity calculated for each frequency component as shown on Figure 4 for Line 1 and Figure 5 for Line 2. Shear wave velocity profiles were generated through inverse modelling to best fit the calculated dispersion curves. The active survey of Line 1 provided a dispersion curve with a suitable frequency range (9-31 Hz). The active survey of Line 2 provided a dispersion curve with a suitable frequency range (9-81 Hz). The minimum measured surface wave frequency with sufficient signal-to-noise ratio to accurately measure phase velocity was approximately 9 Hz at Lines 1 and 2.

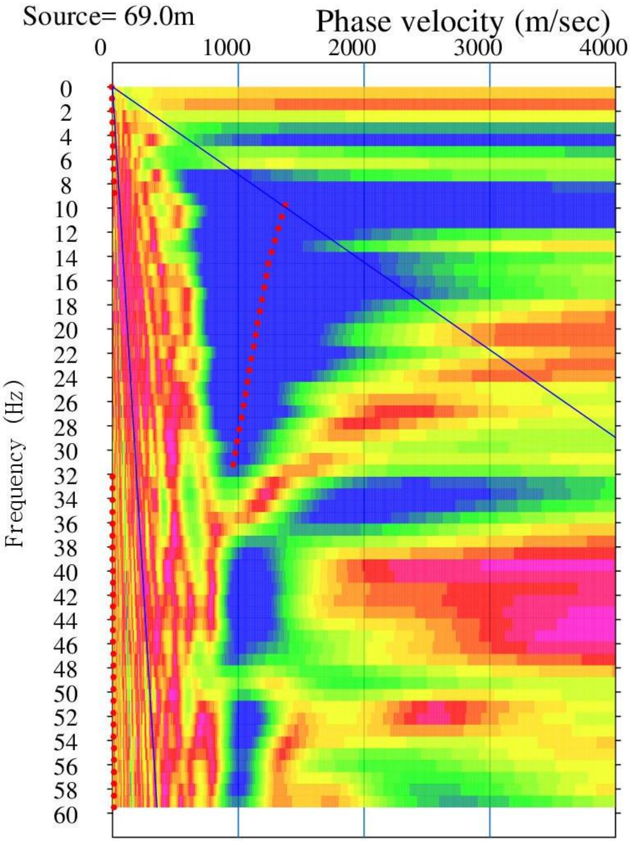


Figure 4: Active MASW Dispersion Curve Picks (red dots) along MASW Line 1

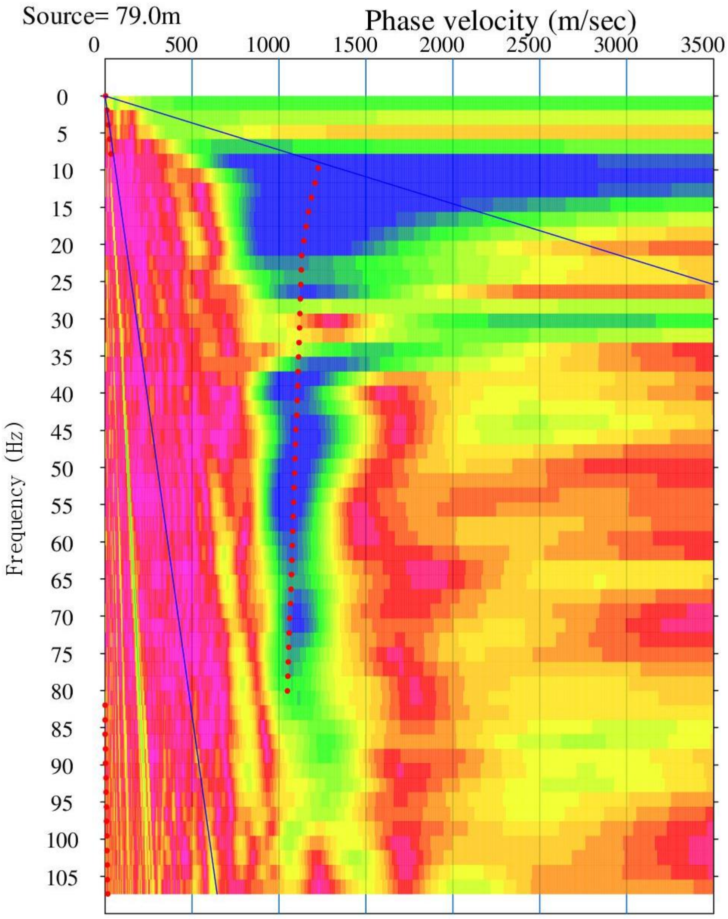


Figure 5: Active MASW Dispersion Curve Picks (red dots) along MASW Line 2

Results

The MASW test results are presented in Figures 6 and 7, which present the calculated shear wave velocity profile derived from the field testing along MASW Lines 1 and 2, respectively. The results along MASW Line 1 have been calculated using a weight-drop located 5 m from the last geophone. The results along MASW Line 2 have also been calculated using a weight-drop located 5 m from the last geophone. The field collected dispersion curves are compared with the model generated dispersion curves on Figures 8 and 9 for MASW Lines 1 and 2, respectively. There is a satisfactory correlation between the field collected and model calculated dispersion curves, with a root mean squared error of less than 1% along both lines.

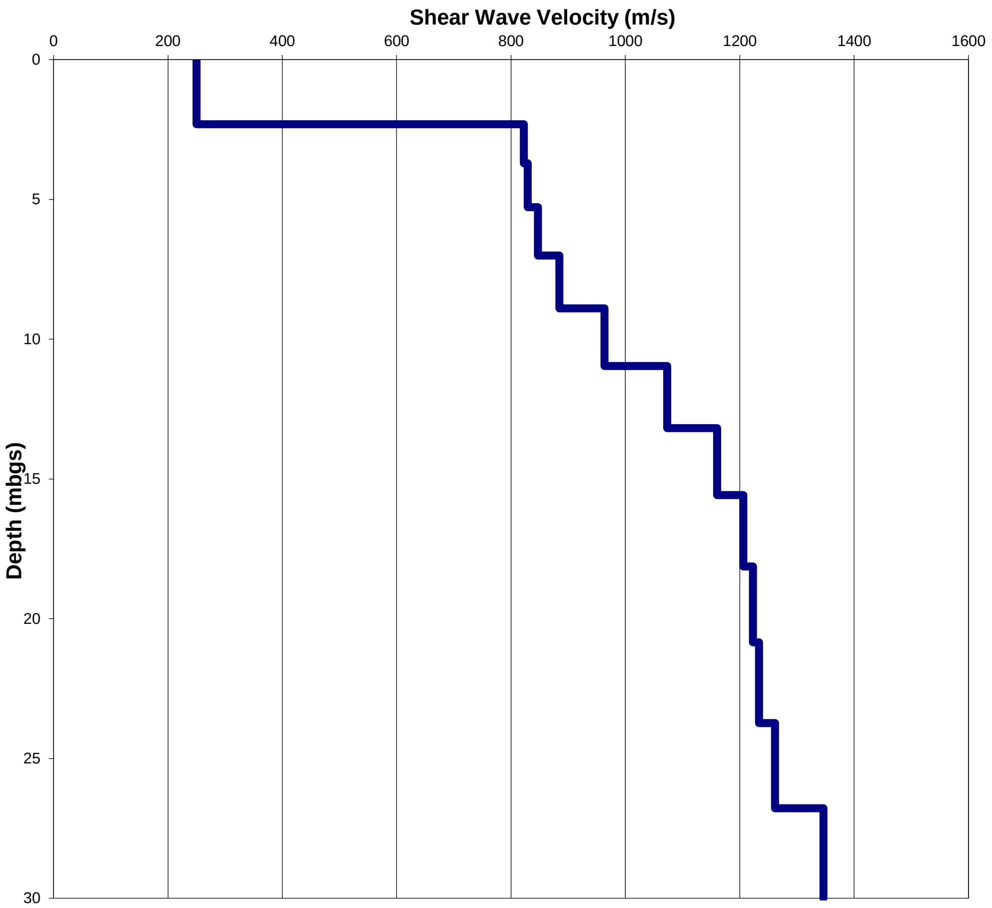


Figure 6: MASW Modelled Shear-Wave Velocity Depth profile along MASW Line 1

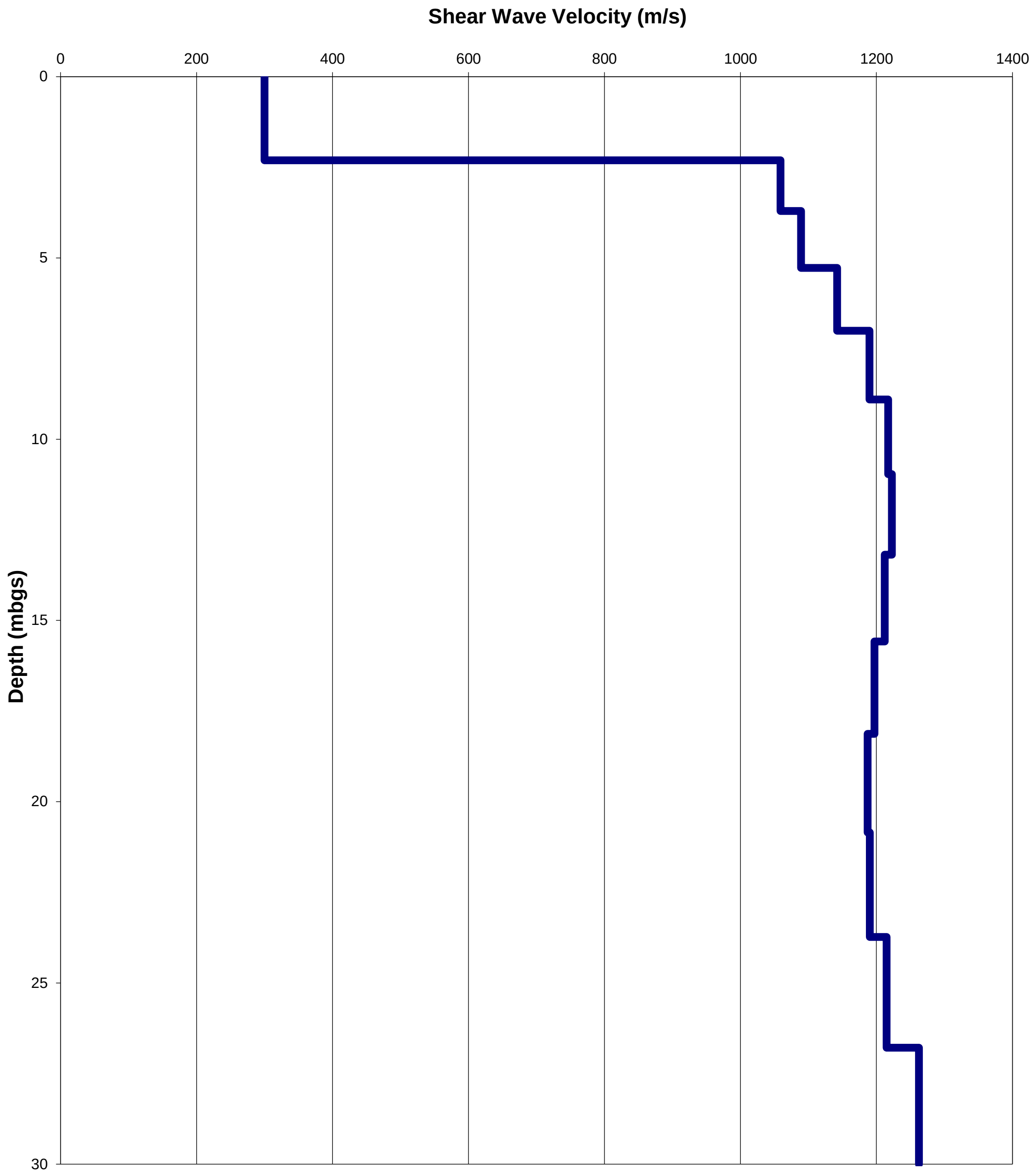


Figure 7: MASW Modelled Shear-Wave Velocity Depth profile along MASW Line 2

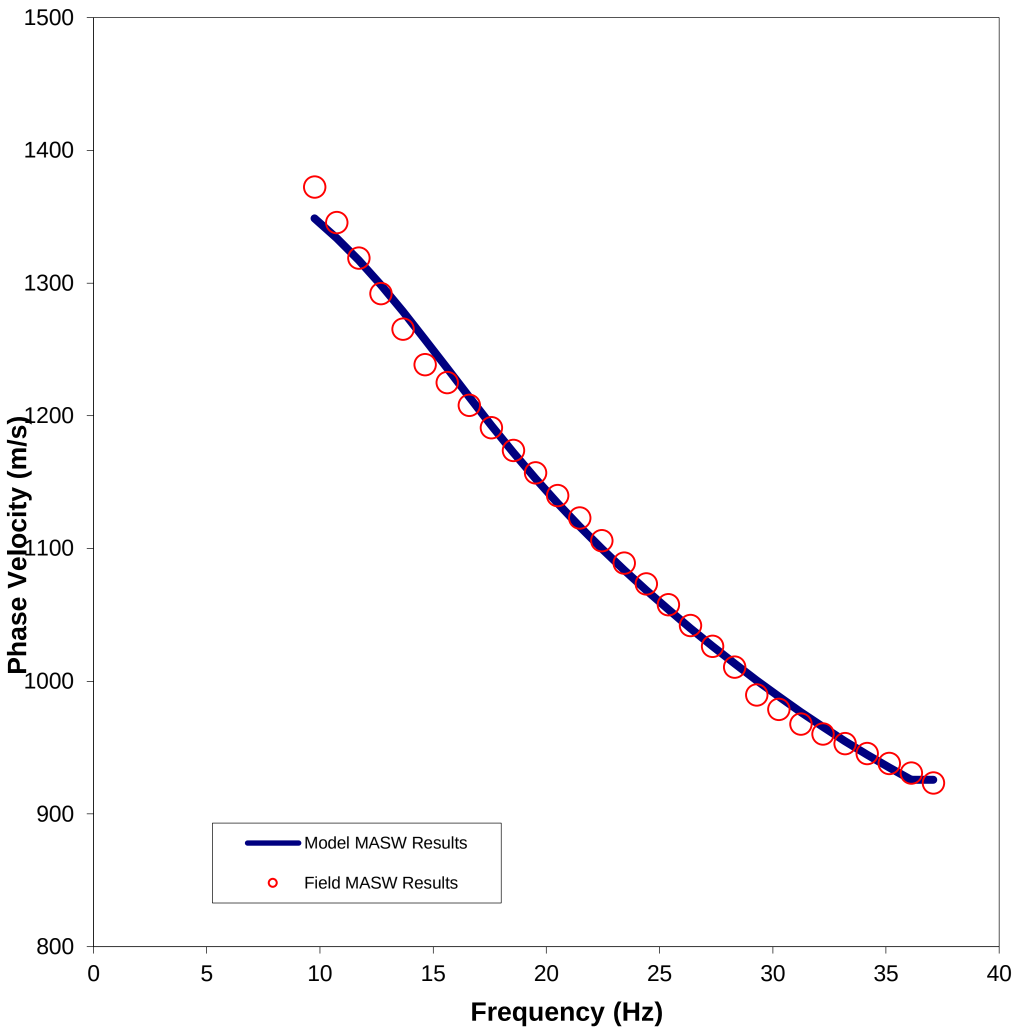


Figure 8: Comparison of Field (red dots) vs. Modelled Data (blue line) along MASW Line 1

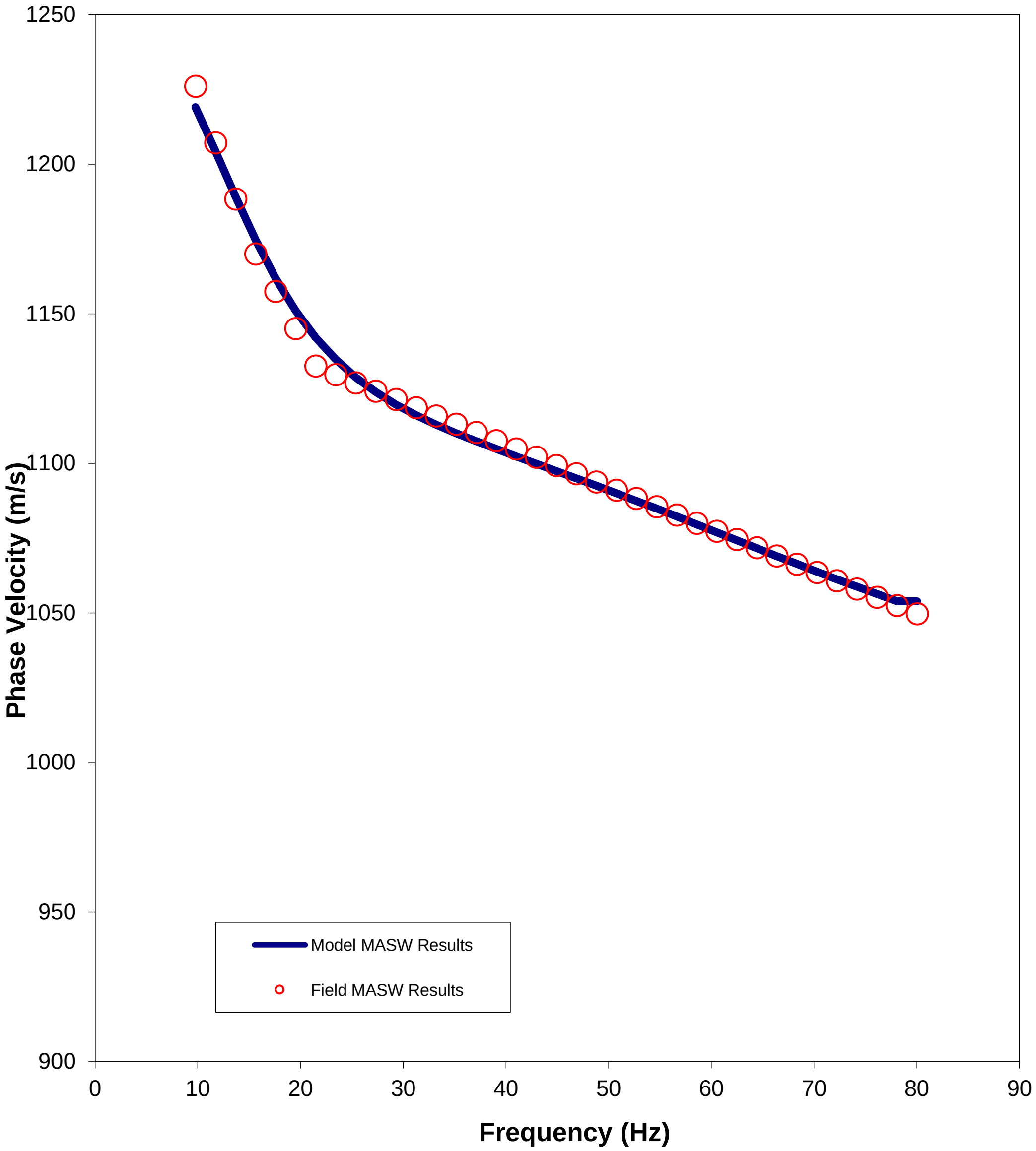


Figure 9: Comparison of Field (red dots) vs. Modelled Data (blue line) along MASW Line 2

To calculate the average shear-wave velocity as required by the CHBDC 2014, the results were modelled to 30 metres below ground surface. The average shear-wave velocity along MASW Line 1 in the north was found to be 863 m/s (Table 1). The average shear-wave velocity along MASW Line 2 in the south was found to be 969 m/s (Table 2).

Table 1: Shear-Wave Velocity Profile along MASW Line 1

Model Layer (mbgs)		Layer Thickness (m)	Shear Wave Velocity (m/s)	Shear Wave Travel Time Through Layer (s)
Top	Bottom			
0.00	1.07	1.07	250	0.004286
1.07	2.31	1.24	250	0.004945
2.31	3.71	1.40	823	0.001703
3.71	5.27	1.57	829	0.001889
5.27	7.01	1.73	847	0.002044
7.01	8.90	1.90	885	0.002143
8.90	10.96	2.06	964	0.002138
10.96	13.19	2.23	1073	0.002074
13.19	15.58	2.39	1160	0.002060
15.58	18.13	2.55	1206	0.002118
18.13	20.85	2.72	1223	0.002224
20.85	23.74	2.88	1234	0.002338
23.74	26.79	3.05	1261	0.002417
26.79	30.00	3.21	1346	0.002387
			Vs Average to 30 mbgs (m/s)	**863**

Table 2: Shear-Wave Velocity Profile along MASW Line 2

Model Layer (mbgs)		Layer Thickness (m)	Shear Wave Velocity (m/s)	Shear Wave Travel Time Through Layer (s)
Top	Bottom			
0.00	1.07	1.07	300	0.003571
1.07	2.31	1.24	300	0.004121
2.31	3.71	1.40	1059	0.001323
3.71	5.27	1.57	1089	0.001438
5.27	7.01	1.73	1142	0.001515
7.01	8.90	1.90	1190	0.001593
8.90	10.96	2.06	1217	0.001693
10.96	13.19	2.23	1223	0.001820
13.19	15.58	2.39	1212	0.001972
15.58	18.13	2.55	1197	0.002134
18.13	20.85	2.72	1187	0.002291
20.85	23.74	2.88	1190	0.002424
23.74	26.79	3.05	1215	0.002511
26.79	30.00	3.21	1262	0.002546
			Vs Average to 30 mbgs (m/s)	**969**

The CHBDC 2014 requires special site specific evaluation if certain soil types are encountered on the site, so the site classification stated here should be reviewed, and modified if necessary, according to borehole stratigraphy, standard penetration resistance results, and undrained shear strength measurements, if available for this site.

Limitations

This technical memorandum is based on data and information collected by Golder Associates Ltd. and is based solely on the conditions of the properties at the time of the work, supplemented by historical information and data obtained by Golder Associates Ltd. as described in this memo.

Golder Associates Ltd. has relied in good faith on all information provided and does not accept responsibility for any deficiency, misstatements, or inaccuracies contained in the reports as a result of omissions, misinterpretation, or fraudulent acts of the persons contacted or errors or omissions in the reviewed documentation.

The services performed, as described in this memo, were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

Any use which a third party makes of this memo, or any reliance on, or decisions to be made based on it, are the responsibilities of such third parties. Golder Associates Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this memo.

The findings and conclusions of this memo are valid only as of the date of this memo. If new information is discovered in future work, including excavations, borings, or other studies, Golder Associates Ltd. should be requested to re-evaluate the conclusions of this memo, and to provide amendments as required.

Closure

We trust that this technical memorandum meets your needs at the present time. If you have any questions or require clarification, please contact the undersigned at your convenience.

GOLDER ASSOCIATES LTD.

Stephane Sol, Ph.D., P. Geo.
Senior Geophysicist

Christopher Phillips, M.Sc., P. Geo.
Senior Geophysicist, Principal

SS/CRP/jl

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APPENDIX E

Site Photographs

Photograph 1: Site No. 3-763C, East outlet (WBL), looking west (November 08, 2018).

Photograph 2: Site No. 3-763C, West inlet, looking east (September 20, 2019).

CLIENT
WSP CANADA GROUP LIMITED

PROJECT
UNNAMED CREEK CULVERT
SITE NO. 3-763C
HIGHWAY 417, OTTAWA, ONTARIO

CONSULTANT
GOLDER

YYYY-MM-DD	2019/12/13
PREPARED	KM
DESIGN	--
REVIEW	MSS
APPROVED	FJH

TITLE
SELECTED SITE PHOTOGRAPHS

PROJECT No.	Phase	Rev.	Figure
1662565	**1320**	**1**	**E1**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
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APPENDIX F

Special Provisions

Pipe Installation by Trenchless Methods

SP 517F01 – Dewatering System

Earth Excavation for Structure

Obstructions

Dewatering Structure Excavations

PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Special Provision November 2018

CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY TRENCHLESS METHODS

TABLE OF CONTENTS

1.0 SCOPE

This specification covers the requirements for the installation of pipe by a selected trenchless method.

2.0 REFERENCES

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

Ontario Provincial Standard Specifications, General

OPSS 180	Management of Disposal of Excess Material

Ontario Provincial Standard Specifications, Construction

OPSS 401	Trenching, Backfilling, and Compacting
OPSS 402	Excavating, Backfilling, and Compacting for Maintenance Holes, Catch Basins, Ditch Inlets and Valve Chambers
OPSS 403	Rock Excavation for Pipelines, Utilities, and Associated Structures in Open Cut
OPSS 404	Support Systems
OPSS 409	Closed-Circuit Television (CCTV) Inspection of Pipelines

OPSS 491	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 517	Dewatering
OPSS 539	Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

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

CSA Standards

B182.6	Profile polyethylene (PE) sewer pipe and fittings for leak-proof sewer applications
A3000	Cementitious Materials Compendium
W59	Welded Steel Construction (Metal Arc Welding)

American Society for Testing and Materials (ASTM) International Standards

A 252	Standard Specification for Welded and Seamless Steel Pipe Piles
D 2657	Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings
D 3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
D6910	Standard Specification for Marsh Funnel Viscosity of Clay Construction Slurries
F 894	Standard Specification for Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

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

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

3.0 DEFINITIONS

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

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

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

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

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

Design Checking Engineer means the Engineer retained by the Contractor who checks the original design and working drawings. The design checking engineer shall be licensed to practice in the Province of Ontario, shall not be an employee of the Contractor and shall be independent from the Design Engineer.

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

Horizontal Directional Drilling (HDD) means horizontal directional boring or guided boring.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Reaming means a process for enlarging the bore path

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

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

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

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

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

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

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

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

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

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

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

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.01 Design

4.01.01 General

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

The installation method selected for each pipe crossing shall be designed for the subsurface conditions as reported in the Contract Documents.

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

Pipe ramming, HDD, TDM, and PTMT methods are likely not suitable for the installation of pipes by trenchless methods.

4.02 Submission Requirements

4.02.01 Qualifications

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

4.02.01.01 Project Superintendent

The Project Superintendent shall have a minimum of five years' experience on projects with similar scope and complexity.

During construction, the project superintendent shall not change without written permission from the Contract Administrator. A proposal for a change in the project superintendent shall be submitted at least one week prior to the actual change in project superintendent.

4.02.01.02 Trenchless Contractor

The Trenchless Contractor shall have a minimum of five years' experience on projects with similar scope and complexity

4.02.01.03 Design Engineer

The Design Engineer shall have a minimum of five years' experience on projects with similar scope and complexity

4.02.01.04 Design Checking Engineer

The Design Checking Engineer shall have a minimum of five years' experience on projects with similar scope and complexity

4.02.02 Working Drawings

Three sets of Working Drawings for the trenchless installation method selected shall be submitted to the Contract Administrator (CA) for purposes of documentation and quality assurance at least two week prior to the commencement of the work. All Working Drawings shall bear the seal and signature of the Design Engineer and Design Checking Engineer.

The working drawings shall be submitted to the Contract Administrator under cover with a Request to Proceed.

The Contractor shall not proceed with the work until a Notice to Proceed has been received from the Contract Administrator

A copy of the Working Drawings shall be kept at the site during construction.

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

a) Plans and Details:

   i. Plans and profiles defining all horizontal and vertical alignment positions and positions of all utilities and other infrastructure within the zone of influence of the work;
   ii. A work plan outlining the materials, procedures, methods and schedule to be used to execute the work.
   iii. A list of personnel, including backup personnel, and their qualifications and experience.
   iv. A safety plan including the company safety manual and emergency procedures.
   v. The work area layout.
   vi. An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail.
   vii. A contingency plan with specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner.

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

b) Designs

- i. Primary liner design (e.g., steel liner plates, steel ribs and wood lagging, steel casing pipe, etc.),
- ii. Design assumption and material data when materials other than those specified are proposed for use.
- iii. Drill path design, details of alignment and alignment control, maximum curvature and reaming stages.

c) Materials:

- i. Certification from the manufacturer that the product furnished on the contract meets the specifications cited in the manufacturer's product specification and that the materials supplied are suitable for the application.
- ii. Manufacturer data sheets for all drilling fluids and additives for use in Earth Pressure Balance, Slurry Pressure Balance
- iii. Manufacturer data sheets for drilling systems.
- iv. Mix designs, target rheology criteria (e.g., viscosity, density, shear strength, gel time, pressure-filtration – fluid losses under pressure, etc.) and additive dosage rates for all slurries and EPB TBM and MTBM operations.
- v. The proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces.
- vi. Compressive strength of concrete pipe products.
- vii. Pipe class for all steel pipe products.
- viii. Steel for Permanent Casings
    - One copy of a mill test certificate certifying that the steel meets the requirements for the appropriate standards for permanent casings shall be submitted to the Contract Administrator at the time of delivery.
    - Where mill test certificates originate from a mill outside Canada or the United States of America, the information on the mill certificates shall be verified by testing by a Canadian laboratory. The laboratory shall be certified by an organization accredited by the Standards Council of Canada to comply with the requirements of ISO/IEC 17025 for the specific tests or type of tests required by the material standard specified on the mill test certificate.
    - The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date (i.e., yyyy-mm-dd), and the signature of an authorized officer of the Canadian testing laboratory

- ix. The Contractor shall submit the followings to the Contract Administrator two weeks prior to construction:

- type, source, and physical and chemical properties of bentonite, polymer or other additives;
- source of water;
- method of mixing;
- the water to solids ratio and the mass and volumes of the constituent parts, including any chemical admixtures or physical treatment employed to achieve required physical properties;
- details of procedure to be used for monitoring physical properties of slurry, drilling fluids and tunnelling fluids or EPB spoil; and method of disposal of the slurry, drilling fluids and associated spoil

d) Upstream/Downstream Portal Installation Procedure:

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

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

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

f) Excavation and Dewatering:

i. Equipment and methods for control, handling, treatment, and disposal of groundwater and water or fluids introduced by the Contractor;
ii. Equipment and methods for maintaining control of ground inflow at the excavation face during excavation;
iii. Equipment and methods for removal of cobbles and boulders;
iv. Manufacturer data sheets for each TBM, shield, tunnelling system or drilling system noting all intermediate and final cut dimensions, and methods and equipment for controlling and measuring drilling fluid, SPB and EPB pressures;
v. Methods for measuring excavated volumes or weights of earth and rock materials cut from ground on a per meter or per pipe basis up to a maximum of 3 m long intervals per measurement;
vi. Target operating pressures (minimum and maximum) and range of expected pressure variation for slurry or EPB spoil at excavated face or drilling fluids at lead end of drilling equipment and in annular gap between maximum excavated dimensions and outside dimensions of tunnelling equipment, drilling equipment and primary liner systems;
vii. Basis for setting target operating conditions (pressures, flow rates, advance rates) and the relationship of target operating conditions to ground conditions;
viii. Basis for selection of excavation tools (e.g., bits, TBM face tools, MTBM face tools, excavator fittings, etc.) as related to expected ground conditions;
ix. Jacking forces for installation of pipe, for driving of trenchless equipment forward and, in the case of Auger Jack & Bore, for advancing the lead end of the casing ahead of the lead end of the auger cutting tools.

g) Monitoring Method:

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

i. Maintaining the alignment of the installation;
ii. EPB, SPB and drilling fluid pressures at the leading edge of excavation (face), flow rates and volume or weights of spoil;
iii. Jacking forces on pipes, linings and cutting tools;
iv. Torque, total revolutions and revolution rates on rotating equipment such as TBM or MTBM heads, auger flights, drill bits, etc.
v. Grout injection pressures and volumes;
vi. Longitudinal position of all casings and excavation cutting tools (auger flight heads, TBM face, drill bit position, etc.);
vii. Ground displacements (heave and settlement); and noise and ground vibrations induced by trenchless construction

4.02.03 Quality Control Certificate

The Contractor shall submit a Quality Control Certificate to the Contract Administrator for documentation and quality assurance purposes, prepared and stamped by the Design and Design Checking Engineers, a minimum of two weeks 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 Quality Control Certificate sealed and signed by the Design and Design Checking Engineer upon completion of each of the following operations and prior to commencement of each subsequent operation for each pipe installation:

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

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

The Contractor shall submit a Request to Proceed to the Contract Administrator upon completion of each of the milestones.

The Contractor shall not proceed to the subsequent operation until a Notice to Proceed has been received from the Contract Administrator

In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a final Quality Control Certificate sealed and signed by the Design and Design Checking 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 Pipe

5.01.01 General

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

All joints shall be suitable for jacking operations as specified in the working drawings.

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

All fittings shall be designed to be watertight.

5.01.02 Steel Pipe

Steel pipe shall be according to ASTM A252.

All steel casing pipe shall be square cut.

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

5.01.03 HDPE Pipe

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

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

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

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

5.01.04 Concrete Pipe

Concrete pipe shall be according to OPSS 1820.

5.02 Concrete

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

5.03 Steel Reinforcement

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

5.04 Wood

Wood shall be according to OPSS 1601.

5.05 Drilling Fluids

Drilling fluid shall be mixed according to the working drawings.

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

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

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

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

5.06 Grout

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

6.0 EQUIPMENT

6.01 Auger Jack & Bore

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

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

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

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

6.02 Pipe Ramming

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

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

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

6.03.01 General

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

6.03.02 Drilling Rig

The horizontal directional drilling rig shall:

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

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

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

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

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

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

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

6.03.03 Drill Head

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

6.03.04 Guidance System

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

6.03.05 Drilling Fluid Mixing System

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

6.03.06 Drilling Fluid Delivery System

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

6.04 Tunnelling

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

a) rock or boulder breaking and removal;

b) equipment used within shields for spilling, fore-poling, face drainage, breasting boards/plates and for otherwise maintaining support of the tunnel crown and face under all anticipated conditions;

c) jacking systems;

d) alignment control systems;

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

6.05 Microtunnelling Equipment

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

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

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

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

  i. Allows for operation of the system without the need for personnel to enter the microtunnel. Has a display available to the operator, at a remote operation console, showing the position of the shield in relation to a design reference together with other information such as face pressure, roll, pitch, steering attitude, valve positions, thrust force cutter head torque, rate of advance and installed length.

- ii. Integrates the system of excavation and removal of spoil and its simultaneous replacement by Product Pipe. As each pipe section is jacked forward, the control system shall synchronize all of the operational functions of the system.
- iii. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.
- iv. The system shall monitor and continuously balance the soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.
- v. The pressure at the excavation face shall be managed by controlling the volume of spoil removal with respect to the advance rate.
- vi. The system shall include a separation process designed to provide adequate separation of the spoil from the slurry so that slurry with a sediment content within the limits required for successful microtunnelling, can be returned to the cutting face for reuse. Appropriately contain spoil at the site prior to disposal.
- vii. 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.
- viii. The system shall allow the composition of the slurry to be monitored to maintain the slurry weight and viscosity limits required.

b) Active Direction Control - Provide an MTBM that includes an active direction control system with the following features:

- i. Controls line and grade by a guidance system that relates the actual position of the MTBM to a design reference Provides active steering information that shall be monitored and transmitted to the operating console and recorded.
- ii. Provides positioning and operation information to the operator on the control console.

6.05.01 Pipe Jacking Equipment

Provide a pipe jacking system with the following features:

a) Has the main jacks mounted in a jacking frame located in the launch shaft.
b) Has a jacking frame that successively pushes towards a receiving shaft, a string of Product Pipe that follows the microtunnelling excavation equipment.
c) Has sufficient jacking capacity to push the microtunnelling excavation equipment and the string of pipe through the ground.
d) The main jack station may be complemented with the use of intermediate jacking stations as required.
e) Has a capacity at least 20 percent greater than the calculated maximum jacking load.
f) Develops a uniform distribution of jacking forces on the end of the casing pipe.
g) Provides and maintains a pipe lubrication system at all times to lower the friction developed on the surface of the pipe during jacking.
h) Jack Thrust Blocking shall adequately support the jacking pressure developed by the main jacking system.
i) Special care shall be taken when setting the pipe guide rails in the jacking shaft to ensure correctness of the alignment, grade, and stability.

6.05.02 Spoil Separation System

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

6.05.03 Electrical Equipment, Fixtures and Systems

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

7. CONSTRUCTION

7.01 General

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

The Project Superintendent shall supervise the work at all times.

7.01.01 Layout, Alignment and Depth Control

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

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

The Contractor shall calibrate tracking and locating equipment at the beginning of each work day, and shall monitor and record the alignment and depth readings provided by the tracking system every 2 m.

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

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

7.01.02 Construction Shafts

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

Shafts shall be maintained in a drained condition.

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

7.01.03 Protection Systems

The construction of all protection systems shall be according to OPSS539. 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 disturbance to the ground surface (settlement or heave) as a result of the pipe installation shall be immediately corrected by the Contractor, at no additional cost to the Ministry.

7.01.05 Stability of Excavation

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

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

7.01.06 Preservation and Protection of Existing Facilities

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

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

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

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer’s handling and storage recommendations shall be followed.

7.01.08 Trenching, Backfilling and Compacting

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

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

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

7.01.10 Dewatering

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

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

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

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

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

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Cobbles and Boulders

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

7.01.14 Management of Excess Material

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

7.01.15 Site Restoration

Site restoration shall be according to OPSS 492.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

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

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

7.02.02 Pipe Installation

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

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

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

7.03 Pipe Ramming Installation

For pipe ramming installation the following requirements apply:

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

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

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

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

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

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

7.04 Horizontal Directional Drilling Installation

7.04.01 General

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

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

7.04.02 Site Preparation

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

7.04.03 Pilot Bore

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

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

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

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

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

7.04.04 Drilling Fluid Losses to Surface (“Frac-Out”)

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

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

7.04.05 Reaming

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

7.04.06 Product Installation

7.04.06.0 General

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

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

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

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

7.04.06.02 Pullback and Grouting

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

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

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

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

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

7. 05 Tunnelling Installation

7.05.01 General

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

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

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

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

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

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

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

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

7.05.01 Tunnelling Method

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

7.05.02 Primary Liner (Support System)

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

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

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

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

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

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

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

7.05.03 Secondary Liner

7.05.03.01 Placing of Grout

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

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

7.06 Microtunnelling

7.06.01 General

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

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

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

The Contractor shall maintain clean working conditions at all times.

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

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

7.06.02 Method of Installation

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

7.06.03 Casing Installation

Casing must withstand the jacking forces determined by the Contractor.

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

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

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

7.07 Instrumentation and Monitoring

7.07.01 Surface Monitoring Points

Surface settlement points for monitoring ground stability shall be installed at the pavement/ground surface level on the shoulder, side slope and pavement at intervals of 5 m or less along the tunnel alignment centreline and as arrays of three points in each shoulder of the highway crossing and centred on the tunnel alignment. The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within a repeatability (combined accuracy and precision of equipment and methods) ± 2 mm of the actual elevation.

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

7.07.02 In-Ground Monitoring Points

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

7.07.03 Installation, Replacement and Abandonment

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

7.07.03 Monitoring and Reporting Frequency

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

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

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

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

7.07.03 Benchmarks

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

7.08 Criteria for Assessment of Roadway Subsidence/Heave

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

a) Review Level: If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate or sequence of construction or ground stabilization measures to mitigate further ground displacement. If this Review Level is exceeded, the Contractor shall immediately notify the CA and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.

b) Alert Level: If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic. No construction shall take place until all of the following conditions are satisfied:

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

9. MEASUREMENT FOR PAYMENT

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

10. BASIS OF PAYMENT

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

Payment for the pipe installed inside the pipe liner shall be paid separately under the appropriate tender items.

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

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

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

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

Payment for removal of boulders exceeding Boulder Volume Rations (BVR) and Boulder Number Ration (BNR) shall be by Time and Material.

<u>DEWATERING SYSTEM</u> - Item No.
<u>TEMPORARY FLOW PASSAGE SYSTEM</u> - Item No.

Special Provision No. 517F01 July 2017

Amendment to OPSS 517, November 2016

Design Storm Return Period and Preconstruction Survey Distance

517.01 SCOPE

Section 517.01 of OPSS 517 is deleted in its entirety and replaced with the following:

This specification covers the requirements for the design, operation, and removal of a dewatering or temporary flow passage system or both to control water during construction, and the control of the water prior to discharge to the natural environment and sewer systems.

517.04 DESIGN AND SUBMISSION REQUIREMENTS

517.04.01 Design Requirements

Subsection 517.04.01 of OPSS 517 is amended by deleting the first paragraph in its entirety and replacing it with the following:

A dewatering or temporary flow passage system or both shall be designed to control water at the locations specified in the Contract Documents and at any other location where a system is necessary to complete the work. The design of the system shall be sufficient to permit the work at each location to be carried out as specified in the Contract Documents.

Subsection 517.04.01 of OPSS 517 is further amended by deleting the second last paragraph in its entirety and replacing it with the following:

Temporary flow passage systems shall be designed, as a minimum, for a 2 year design storm return period and groundwater discharge, except for the work specified in Table A. For the work specified in Table A, the temporary flow passage system shall be designed, as a minimum, for the design storm return period specified in Table A and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

Intensity-Duration Factor (IDF) curve location, site specific minimum return period, return period flow estimates, and other information is provided in Table A. The IDF information can be accessed through the MTO IDF Curve Look up Tool on the Drainage and Hydrology page of MTO's website. The return period flow estimates do not include flow volumes from groundwater discharge. The Owner specifically excludes these flow estimates from the warranty in the Reliance on Contract Documents subsection of OPSS 100, MTO General Conditions of Contract.

Table A

<table>
<tr><td colspan="1">IDF Curve Location</td><td colspan="3">Latitude: *</td><td colspan="3">Longitude: *</td></tr>
<tr><td colspan="7">Temporary Flow Passage Systems</td></tr>
<tr><td rowspan="2">Site Name /
Station Reference</td><td rowspan="2">Minimum Return Period (Years)</td><td colspan="4">Return Period Flow Estimates (m^3/s)</td><td rowspan="2">Design Engineer Requirements (Note 1)</td></tr>
<tr><td>2 Year</td><td>5 Year</td><td>10 Year</td><td>25 Year</td></tr>
<tr><td>**</td><td>***</td><td>****</td><td>****</td><td>****</td><td>****</td><td>*****</td></tr>
<tr><td colspan="7">Dewatering Systems</td></tr>
<tr><td>Site Name /
Station Reference</td><td colspan="5">Preconstruction Survey Distance (Note 2) (m)</td><td>Design Engineer Requirements (Note 1)</td></tr>
<tr><td>**</td><td colspan="5">******</td><td>*****</td></tr>
<tr><td colspan="7">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.</td></tr>
</table>

EARTH EXCAVATION FOR STRUCTURE – Item No.

Special Provision

Amendment to OPSS 902, November 2010

Excavating Through Obstructions – Structures

902.07 CONSTRUCTION

Section 902.07 of OPSS 902 shall be amended by the addition of the following:

The Contactor is alerted to the potential presence of shale fragments, cobbles and boulders within the fill and native glacial till. Consideration of the presence of these obstructions shall be made in the selection of appropriate equipment and procedures for excavations and temporary protection systems.

Basis of Payment

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.

END OF SECTION

OBSTRUCTIONS – Item No.

Special Provision

The fill and glacial till soils at this site are comprised of gravelly sand or silty sand and are known to contain shale fragments. Appropriate equipment and construction procedures will be required to penetrate or remove obstructions, such as cobbles and boulders, to permit installation of trenchless and of temporary protection systems.

Basis of Payment

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.

END OF SECTION

DEWATERING STRUCTURE EXCAVATIONS - Item No.

Special Provision

Amendment to OPSS 902, November 2010

902.02 REFERENCES

Section 902.02 of OPSS 902 is amended by the addition of the following:

Ontario Provincial Standard Specifications, Construction

OPSS 517	Dewatering
OPSS 805	Temporary Erosion and Sediment Control Measures

902.03 DEFINITIONS

Section 903.03 of OPSS 902 is amended by the addition of the following:

Automatic Transfer Switch means as defined in OPSS 517.

Cofferdam means as defined in OPSS 539.

Cut-Off Wall means as defined in OPSS 517.

Design Storm Return Period means as defined in OPSS 517.

Dewatering System means as defined in OPSS 517.

Groundwater Control System means as defined in OPSS 517.

Plug means as defined in OPSS 517.

Sediment means as defined in OPSS 517.

Sediment Control Measure means as defined in OPSS 517.

Temporary Flow Passage System means as defined in OPSS 517.

Unwatering means as defined in OPSS 517.

Vegetated Discharge Area means as defined in OPSS 517.

Waterbody means as defined in OPSS 517.

Watercourse means as defined in OPSS 517.

902.04 DESIGN AND SUBMISSION REQUIREMENTS

902.04.01 Design Requirements

902.04.01.01 Dewatering

Clause 902.04.01.01 of OPSS 902 is deleted in its entirety and replaced with the following:

A dewatering system shall be designed to control water and the flow of water into the excavation, prevent disturbance of the foundation, permit the placing of concrete in the dry, and complete the excavating and backfilling for structures work.

When the system includes temporary flow passage system, the system shall be designed, as a minimum, for a [* Designer Fill-In, See Notes to Designer] year design storm return period, and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

The dewatering system shall be according to the design requirements specified in OPSS 517.

902.04.02 Submission Requirements

Subsection 902.04.02 of OPSS 902 is deleted in its entirety and replaced with the following:

902.04.02.01 Working Drawings

Working Drawings for the dewatering system shall be according to OPSS 517.

902.04.02.02 Preconstruction Survey

When a groundwater control system by wells or a well point system will be used, a condition survey of property and structures that may be affected by the work shall be carried out. The condition survey shall include the location and condition of adjacent properties, buildings, underground structures, water wells, Utilities, and structures, within a distance of [** Designer Fill-In, See Notes to Designer] metres from the groundwater control system. In addition, all water wells used as a supply of drinking water and located within this distance shall be tested for compliance with Ontario Drinking Water Quality Standards.

Water wells within the preconstruction survey distance can be located using the website https://www.ontario.ca/environment-and-energy/map-well-records or its successor site.

Copies of the condition survey and water quality test results shall be submitted to the Contract Administrator prior to the operation of the groundwater control system.

902.04.02.03 Milestone Inspections

The Quality Verification Engineer shall witness the following Interim Inspections of the work:

a) Dewatering of excavation for structure.

b) Completion of excavation for foundation.

c) Excavation for backfill and frost tapers.

d) Backfilling.

A copy of the written permission to proceed shall be submitted to the Contract Administrator prior to commencement of the successive operation.

902.07 CONSTRUCTION

Subsection 902.07.04 of OPSS 902 is deleted in its entirety and replaced with the following:

902.07.04 Dewatering Structure Excavation

902.07.04.01 General

The dewatering systems shall be constructed and operated according to the Working Drawings.

Activation and deactivation of a temporary flow passage system, if applicable, shall be according to OPSS 517.

The dewatering system shall be continuously operational to control buoyancy forces until such forces can be resisted by backfill and structure self-weight, to keep excavations stable, to avoid erosion impacts from the release of accumulated water, and to keep the work area in the condition required to complete the associated work as specified in the Contract Documents.

When a temporary flow passage system is to remain operational through a seasonal shutdown period, the Contractor shall be responsible for any maintenance or repair costs due to the system during the seasonal shutdown period.

Temporary erosion and sediment control measures, including controlling the discharge of water, shall be according to OPSS 805. Measures not specified in OPSS 805 shall be according to the Working Drawings. Temporary erosion and sediment control measures and cover material to protect exposed soils, as required by the Working Drawings, shall be installed as soon as is practical.

Stranded fish shall be managed as specified in the Contract Documents.

Unwatering shall be carried out as necessary.

Water suspected of being contaminated as indicated by visual or olfactory observations shall be reported to the Contract Administrator.

Dewatering and temporary flow passage systems shall be discontinued in a manner that does not disturb any structure, pipeline, or flow channel. Operation of the dewatering system shall be shut down according to the procedures specified in the Working Drawings, where applicable.

902.07.04.02 Discharge of Water

The discharge of water shall be according to OPSS 517.

902.07.04.03 Monitoring

Monitoring shall be according to OPSS 517.

902.07.04.04 System Amendments

Amendments to stop any displacement, damage, soil loss or erosion due to the operation of the dewatering system shall be according to OPSS 517.

902.07.04.05 Removal

Removal of dewatering system and temporary flow passage system components shall be according to OPSS 517.

NOTES TO DESIGNER:

Designer Fill-Ins

* Fill in the design storm return period according to MTO Drainage Design Standard TW-1.

** Fill in the preconstruction survey distance as recommended by the foundation engineer.

WARRANT: Include with this standard tender item **only** on the recommendation of a foundation engineer.

CUSTODIAN: Tony Sangiuliano, MERO - Foundation Group.

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