



REPORT

Foundation Investigation and Design Trenchless Crossing Highway 417 Westbound Off-Ramp to Walkley Road 50 m South of Walkley Road Ottawa, Ontario *G.W.P. No. 4099-11-00*

Submitted to:

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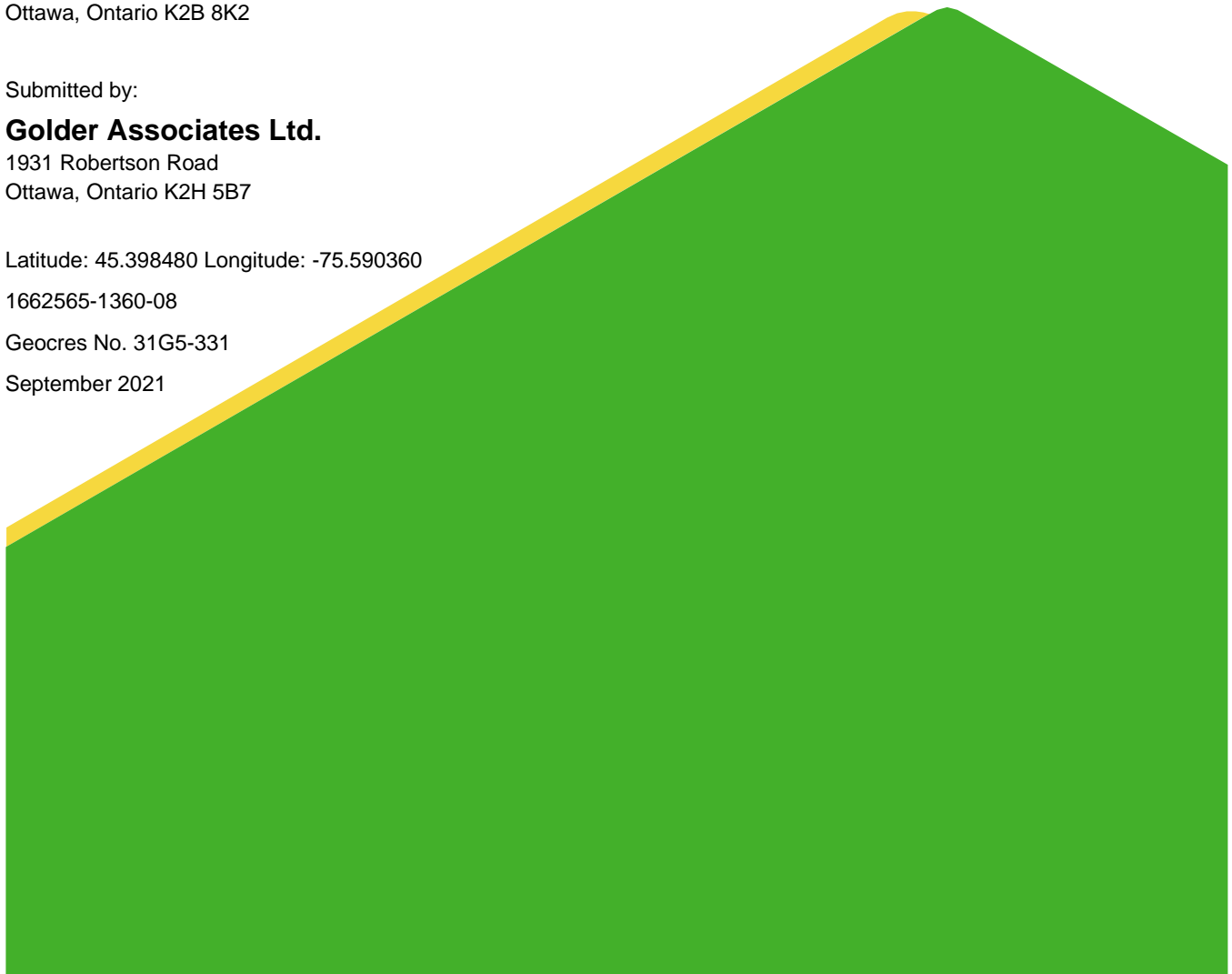
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PART A

Foundation Investigation Report
Highway 417 Westbound Off-Ramp to Walkley Road
50 m South of Walkley Road
Ottawa, Ontario
G.W.P. 4099-11-00

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 nine (9) trenchless crossings involving culvert and utility rehabilitations and/or replacements on Highway 417 between the Aviation Parkway and Ramsayville Road, as well as the widening of Highway 417 from Ottawa Road 174 to Hunt Club Road in Ottawa, Ontario (Assignment number 4016-E-0008).

This report presents the results of the foundation investigation carried out to provide foundation design recommendations of the proposed trenchless crossing of the crossing located at the Highway 417 Westbound to Walkley Road Off-Ramp in Ottawa, Ontario (G.W.P. 4099-11-00).

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 this non-structural culvert crossing 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 proposed culvert replacement is located on the Highway 417 Westbound Off-Ramp to Walkley Road, approximately 50 m south of Walkley Road in Ottawa, Ontario. At this location, the Off-Ramp from Highway 417 Westbound is a single lane of approximately 5 m width. Highway 417 at this location is a divided highway with two eastbound travel lanes, two westbound travel lanes and a speed change lane, separated by a green median area with an approximate width of 25 m.

The proposed culvert replacement consists of a 40 m long, 0.9 m diameter culvert beneath the Highway 417 Westbound Off-Ramp to Walkley Road. The proposed culvert is to have an invert ranging in elevation from 63.7 m (west end) to 63.5 m (east end). The new culvert will be located about 6 m south of the existing small diameter culvert that it will replace.

2.2 Regional Geology

As delineated in *The Physiography of Southern Ontario*¹, this section of Highway 174 lies on the boundary of the minor physiographic regions known as the Ottawa Valley Clay Plain and the Russell and Prescott Sand plain, both of which lie 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 bedrock².

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.

This region is underlain by a series of sedimentary rocks, consisting of sandstones, dolostones, limestones and shales that are, in turn, underlain at depth by igneous and metamorphic bedrock of the Precambrian Shield. Regional bedrock mapping indicates that the bedrock at this site is primarily shale bedrock of the Carlsbad Formation.

3.0 INVESTIGATION PROCEDURES

The subsurface investigation for the culvert replacement was carried out on September 12 and November 25, 2019. During that time, three boreholes (19-3622 to 19-3624, inclusive) were advanced at the ditches on the west and east sides of the Highway 417 Westbound Off-Ramp to Walkley Road at the ends of the trenchless crossing and through the Off-Ramp at the proposed trenchless alignment. The borehole locations are shown on Drawing 1.

Borehole 19-3623 was advanced using 108 mm inside diameter (200 mm outside diameter) continuous flight hollow stem augers on the truck mounted drill rig supplied and operated by Forage Downing Drilling, Ontario. Borehole 19-3623 was drilled to a depth of about 13.3 m below the existing ground surface. The remaining boreholes (19-3622 and 19-3624) were advanced using portable rotary drilling equipment, operated by CCC Geotechnical & Environmental Drilling Ltd., to depths of 7.6 and 8.1 m below the existing ground surface.

Samples of the overburden from Boreholes 19-3622, 19-3623, and 19-3624 were obtained at 0.6 m intervals of depth using 50 mm outside diameter split-spoon samplers in general accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586-11).

Upon reaching refusal to casing advancement or auger refusal, the boreholes were advanced into the bedrock surface to depths of 7.6 m to 13.3 m below existing ground surface using rotary diamond drilling techniques while retrieving NQ or NQ3 sized core. A water truck was on site to supply the drill rigs with water for advancing the casing in the overburden and for the coring 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.

One monitoring well was installed in Borehole 19-3622 to measure the groundwater level at the site. The monitoring well consisted of 19 mm outside diameter PVC tubing with a 1.5 m long screen. The groundwater level was measured in the monitoring well on January 22, 2020 and April 23, 2021. The well was subsequently decommissioned according to Ontario MOE Regulation 903 (O.Reg 903) by a licenced well technician on April 23, 2021.

The remainder of the boreholes were backfilled with bentonite mixed with soil cuttings. 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 examination and for testing. Index and classification tests consisting of water content determinations, Atterberg Limit tests, and grain size distribution analyses were carried out on selected soil samples at the Golder Ottawa laboratory. Unconfined compressive strength tests were carried out on selected rock core samples at Geomechanica Inc. The laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate.

One soil sample from Borehole 19-3623 was submitted to Eurofins Environment Testing for chemical analysis related to potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack).

The borehole locations and elevations were surveyed by Golder using a Trimble R10 GPS unit referenced to the NAD83 CSRS CBNv6-2010.0 MTM Zone 9 geodetic datum. The borehole locations, including northing and easting coordinates, ground surface elevations, and drilled depths, are summarized in Table 1.

Table 1: Summary of Boreholes

Borehole Number	Borehole Location	MTM NAD83 Zone 9 Northing (m)	MTM NAD83 Zone 9 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
19-3622	Hwy 417 WB Off-Ramp to Walkley Road (E-E/W) Proposed Trenchless Entrance/Exit	5029122.2	375996.3	64.8	7.6
19-3623	Hwy 417 WB Off-Ramp to Walkley Road (E-E/W) Proposed Trenchless Alignment	5029129.2	376012.0	67.4	13.3
19-3624	Hwy 417 WB Off-Ramp to Walkley Road (E-E/W) Proposed Trenchless Entrance/Exit	5029135.6	376028.6	64.3	8.1

4.0 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 General

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 B6 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 trenchless crossing 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.

In general, the subsurface conditions at the borehole locations consist of granular road structure over embankment fill or surficial fill extending down to depths of about 0.6 m to 3.7 m (Elevations 63.7 m to 64.2 m). The embankment/surficial fill is underlain by a deposit of silty clay extending to depths of about 1.2 m to 4.4 m (Elevations 62.7 m to 63.1 m) over glacial till extending to depths of about 5.3 m to 9.8 m (Elevations 57.6 m to 59.1 m) over shale bedrock. The groundwater level was encountered at an Elevations of about 63.7 m.

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

4.2 Road Structure and Fill

Surficial fill exists at Boreholes 19-3622 and 19-3624 and extends to a depth of about 0.6 m below existing ground surface. The fill at these locations is generally cohesive and consists of silty clay with some sand to sandy, containing some organic matter (rootlets). The results of Standard Penetration Test (SPT) “N” values measured in the cohesive fill range from 4 to 5 blows per 0.3 m of penetration, indicating a soft to firm consistency.

Borehole 19-3623 was advanced through the road structure of the Off-Ramp unpaved shoulder. The road structure consists of 300 mm of granular base at surface consisting of gravelly sand containing some organic matter. The granular base is underlain by a 3.4 m thick layer of granular embankment fill varying from sandy gravel to sand and gravel with varying amounts of silt, and shale fragments. The embankment fill extends to a depth of about 3.7 m below the existing ground surface, (Elevation 63.7 m).

The Standard Penetration Test (SPT) “N” values measured in the granular embankment fill range from 15 to 37 blows per 0.3 m of penetration, indicating a compact to dense state of compactness.

The results of grain size distribution testing carried out on one sample of the embankment fill material is shown on Figure B1 in Appendix B. The measured natural water contents of three samples of the granular fill range from about 3 to 6 per cent.

4.3 Silty Clay

A deposit of silty clay to clay was encountered underlying the fill at all borehole locations. At all borehole locations the entire deposit of silty clay has been weathered to a brown to grey-blue crust (Weathered Crust) and extends to depths varying from about 1.2 to 4.4 m below existing ground surface, or Elevations of 62.7 m to 63.1 m. At Boreholes 19-3623 and 19-3624 the deposit of silty clay is grey-blue in colour, contains silt and sand layers and various amounts of organics.

The SPT N values measured within the weathered clay deposit range from 6 to 11 blows per 0.3 m of penetration, indicating a very stiff consistency.

The result of an Atterberg limit test carried out on two samples of the weathered silty clay deposit are shown on Figure B2 in Appendix B and indicates plasticity index values of about 15 and 24 percent and liquid limit values of about 36 and 44 percent indicating a silty clay of intermediate plasticity. The results of grain size distribution testing carried out on two selected samples of the weathered crust silty clay material are shown on Figure B3 in Appendix B.

The measured water content of three samples of the weathered silty clay deposit range from about 29 to 39 percent.

4.4 Till

A deposit of till was encountered underlying the silty clay deposit at all the borehole locations. The surface of the till deposit was encountered at depths ranging from 1.2 m to 4.4 m, corresponding to Elevations 62.7 m to 63.1 m. The glacial till generally consists of silty sand to gravel and sand containing various amounts of gravel, cobbles and boulders. The till extends to depths ranging from about 5.3 m to 9.8 m below the existing ground surface (i.e., Elevations 59.1 m to 57.6 m).

The SPT N values measured within the till deposit range from 11 to 99 blows per 0.3 m of penetration, indicating a compact to very dense state of compactness. The higher blow counts may reflect the presence of cobbles and/or boulders rather than the actual state of the soil matrix.

The results of grain size distribution testing carried out on five samples of the till material are shown on Figure B4 in Appendix B. The result of an Atterberg limit test carried out on one sample of the cohesive portion of the till deposit is shown on Figure B5 in Appendix B and indicates a plasticity index value of about 7 percent and a liquid limit value of about 23 percent indicating a soil of low plasticity. The measured natural water contents of ten samples of the till range from about 8 to 14 per cent.

4.5 Bedrock

Bedrock was encountered underlying the till deposit at all borehole locations and was proven at depths ranging from 5.3 to 9.8 m below the existing ground surface (Elevations 59.1 m to 57.6 m). The bedrock was cored between about 1.9 m to 3.5 m using NQ or NQ3 sized coring equipment, to depths ranging from about 7.6 m to 13.3 m below existing ground surface (Elevations 57.2 m to 54.1 m). The upper 1.4 m of the bedrock at borehole 19-3624 was slightly weathered from a depth of 5.3 m to 6.6 m below ground surface (i.e., competent bedrock was found at an elevation of 57.7 m).

The following table summarizes the 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)
19-3622	64.8	5.7	59.1
19-3623	67.4	9.8	57.6
19-3624	64.3	5.3	59.0

The bedrock consists of weathered to fresh, thinly bedded, black to dark grey, fine grained, non-porous shale of the Carlsbad Formation. The Rock Quality Designation (RQD) values measured on recovered bedrock core samples ranged from about 0 to 82 percent, but more generally between 0 and 31 percent indicating a very poor to poor 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 B6. Based on the measured unconfined compressive strength of 171 MPa, the shale bedrock is classified as very strong.

4.6 Groundwater Conditions

A groundwater monitoring well was installed in Borehole 19-3622 to monitor the groundwater level at the site.

Table 3 summarizes the depths and the elevations of the groundwater levels measured in the monitoring well installed at the site. The final groundwater levels were measured in the wells on dates indicated in Table 3 and were then subsequently decommissioned according to Ontario MOE Regulation 903 (O.Reg 903) by a licenced well technician.

As shown in Table 3 it is expected that the groundwater levels will be subject to fluctuations both seasonally and as a result of precipitation events.

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
19-3622	64.8	Bedrock	1.1	63.7	January 22, 2020
			1.5	63.3	April 23, 2021

4.7 Corrosion and Sulphate Attack Potential

One soil sample from Borehole 19-3623 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	Sample Depth (m)	Sample Type	Chloride Soil (%)	pH	Electrical Conductivity Soil (mS/cm)	Resistivity (ohm-cm)	Sulphate Soil (%)
19-3623	7.62 – 7.90	Soil	0.017	8.17	0.64	1,560	0.06

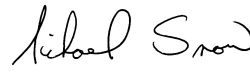
5.0 CLOSURE

This report was prepared by Ms. Kim MacDonald, P.Eng. and It was reviewed by Michael Snow, P.Eng. a Principal, Senior Geotechnical Engineer with Golder. William Cavers, P.Eng. an Associate, Senior Geotechnical Engineer with Golder and the Designated MTO Foundations Contact for this project, carried out an independent quality control review of this report.

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[https://golderassociates.sharepoint.com/sites/11263g/shared documents/01_foundations/6 - reports/1360 trenchless crossings/tc8 - 417 wb off-ramp walkley/3 - final/1662565-1360_tc8 final fdr hwy 417 wb off walkley_202109-13.docx](https://golderassociates.sharepoint.com/sites/11263g/shared%20documents/01_foundations/6_reports/1360_trenchless_crossings/tc8_417_wb_off-ramp_walkley/3_final/1662565-1360_tc8_final_fdr_hwy_417_wb_off_walkley_202109-13.docx)

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PART B

Foundation Investigation and Design Report
Highway 417 Westbound Off-Ramp to Walkley Road
50 m South of Walkley Road
Ottawa, Ontario
G.W.P. 4099-11-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides foundation design recommendations for the installation of a replacement culvert located approximately 50 m south of Walkley Road and crossing the Highway 417 Westbound Off-Ramp to Walkley Road in Ottawa, Ontario as part of G.W.P., 4099-11-00.

The input provided herein is based on interpretation of the factual data obtained from the boreholes advanced during the current investigation, and in accordance with the 2014 Canadian Highway Bridge Design Code CAN/CSA-S6-14 (CHBDC) and MTO's Pipe Installation by Trenchless Method Special Provision.

The foundation investigation 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.

A description of the proposed culvert and general guidelines for design of the crossing are provided below.

6.2 Proposed Structure

The proposed works related to the installation of the replacement culvert is based on the information provided by WSP on April 7, 2020.

The proposed culvert is to be located at approximate Station 67+222 under the Highway 417 Westbound (E-E/W) Off-Ramp to Walkley Road, approximately 50 m south of Walkley Road and 6 m south of the existing culvert. The proposed culvert is to be about 40 m long with an internal diameter of 0.9 m and with invert elevations ranging from 63.7 m (west end) to 63.5 m (east end).

It is understood that it is currently proposed to install this culvert employing trenchless techniques. However, from a foundation perspective it is considered feasible to construct this culvert using conventional open cut methods. As such, recommendations for both trenchless and open cut installation methods have been provided in the following sections.

6.3 Trenchless Technologies

The Contractor should be responsible for choosing the method and equipment for the crossing installation, 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 and tunnel digging machine (i.e., open face shield tunneling). 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 D.

The following is a general summary of the geotechnical considerations for the design and construction of the particular trenchless methodologies.

1) Pipe Jacking and Horizontal Auger Boring (also referred to as Auger Jack and Bore):

A pipe jacking operation involves pushing an oversized liner pipe (casing) horizontally into the ground by jacking through reaction against a thrust block (i.e., backstop) located within the jacking pit. 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 casing may be lubricated to reduce the frictional forces between casing and the surrounding soil. The profile needs to be approximately horizontal and there is limited ability to steer the casing during jacking.

The jack and bore method is generally suitable for penetrating cohesive soils (silt and clay) and wet but unsaturated cohesionless soils that are well-graded (i.e., broadly graded). This method is not feasible in flowing ground which can lead to excessive ground losses, settlement and development of sinkholes extending to the surface when passing through saturated (flowing) sand, silt and/or gravel.

This method is only applicable to installation in the overburden and may not be feasible in bouldery soils (e.g., glacial till) as the presence of boulders and cobbles can obstruct augering operations, damage the equipment and require manual interventions that slow progress. The removal of obstructions may also result in loss of ground at the face and ground settlement at the ground surface, depending on the soil conditions.

However, this method can be adapted for use in certain mixed-face conditions, with the addition of a Small Boring Unit (SBU) cutterhead. The SBU is equipped with mini disc cutters on the cutterhead and is welded to the lead casing to facilitate cutting through mixed ground containing cobbles and boulders and/or bedrock. With the addition of the rotating cutterhead, the SBU also allows for some additional steering capability.

Jacking and receiving pits are required. The size of the jacking pit is controlled by the equipment size, operator access requirements and the length of the casing sections which are being installed. Typically, a work area of about 10 m long by about 3 m to 5 m wide is required to accommodate the jacking/drive pit for jack and bore operations. The receiving pit is typically about 3 m square. The excavation depth for the pits will depend on the final invert elevation of the crossing alignment.

2) Pipe Ramming:

Pipe ramming is a trenchless method that uses a pneumatic tool to hammer a steel pipe or casing with a cutting shoe attached into the ground. The pipe is almost always driven open-ended to thereby direct the soil into the pipe interior instead of compacting it outside the pipe thereby reducing the potential for ground loss into the casing during driving. As each casing length is installed, the hammer is removed, the next casing is welded in place and the hammer replaced and restarted. 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.

Entry and receiving pits are also required for pipe ramming but as there is no need for a thrust block in the entry pit, a smaller pit size is required than in jack and bore installations (which is an advantage for congested urban highways). The excavation depth for the pits will depend on the final invert elevation of the crossing alignment.

Pipe ramming is best suited for overburden installations in soft to firm clays and very loose to compact sands above the water table. This method is not considered feasible in mixed face conditions. These methods are also better suited for penetrating through/displacing potential obstructions such as cobbles and boulders in comparison to jack and bore installation method, though this method can still be obstructed by cobbles and boulders depending on their size and number. Pipe ramming is non-steerable, so there is no control over the profile and alignment of the bore once the pipe ramming has started. Vibrations from the pipe ramming operations may result in settlement of loose materials in the immediate vicinity of the installation. Furthermore, a “plug” of soil may form at the head of the casing inducing surficial heave as the pipe is advanced.

Compared to the jack and bore method, the most important advantage of pipe ramming is that the soil is typically removed from the pipe only after the pipe has fully passed beneath overlying infrastructure. Depending on the length of the installation, the soils inside the pipe can be removed either during or after the installation by auguring, compressed air or water jetting.

3) Pilot Tube Micro-tunneling:

Pilot Tube Micro-tunneling (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 microtunneling.

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.

In this method, a bore hole is drilled with a steering head connected to pilot tubes whose size is smaller than the required casing size. A slanted steering head is used for pilot boring and adjustment of alignment and grade and the bore hole is subsequently enlarged by a reamer with a casing following behind the reamer, with an auger string inside the casing used to remove cuttings. The product pipes follow the casing to be installed in the ground.

A typical PTMT construction sequence is as follows.

- Excavate and prepare the driving and receiving shafts.
- Lower the thrust frame into the driving shaft and set it up. Set up the guidance system including the steering head and target in the driving shaft.
- Install the pilot tube behind the steering head. The boring process proceeds with the rotation and thrust of the pilot tube. Deviations are continuously adjusted through video monitor surveillance of the illuminated target.
- When the steering head reaches the receiving shaft, the reamer and casing with auger inside are connected to the last segment of pilot tube. The reamer and auger enlarge the pilot bore hole by rotating and thrusting the reamer and casing. The steering head and the pilot tubes are then retrieved at the receiving shaft.

4) Micro-tunneling:

Micro-tunneling 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. Availability of this equipment locally is limited.

Micro-tunneling is a very precise method of tunneling and there is relatively little settlement with this method, if the face pressure and cutting tools are appropriate for the ground and are maintained over the length of the drive.

This method can be applied to a wide range of ground conditions from saturated sands and gravels, through to soft or stiff, dry or saturated clays and mudstones, to solid rock. Specialist advice on machine selection should be sought and recommendations regarding the machine design for the given ground conditions should be supported by the manufacturer. Appropriate machine design refinements may be used to extend the application range of the machine to cover more adverse soil conditions, including mixed face conditions and handling of obstructions such as cobbles and boulders.

5) 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 is typically used for smaller diameter crossings below embankments or rivers and is not suited to gravity pipes (such as sewers). 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 mm in diameter. Sufficient cover is important to minimize the risk of hydraulic fracturing of the ground and loss of drilling fluid to the surface.

6) Tunnel Boring Machine (TBM):

TBM tunneling 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-tunneling.

7) Tunnel Digging Machine (TDM):

TDM tunneling, also called open-face shield tunneling, involves excavating the soils using a hydraulic excavator arm, working within a full-circumference tunneling shield. Alternatively, hand mining (i.e., manual excavation) within the tunneling 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 Proposed Alignment and Profile Considerations

Based on the proposed invert elevations, the proposed culvert crossing will generally be advanced through the variable fill and native silty clay deposit.

The base plan mapping provided by WSP for this project and the ground surface elevations at the borehole locations surveyed during the field investigation indicate that the top of the existing off-ramp in the vicinity of the proposed culvert alignment is about 67.4 m. As outlined above the proposed culvert is to have invert elevations ranging from Elevation 63.5 to 63.7 m and an internal diameter of 0.9 m; corresponding to an obvert elevation ranging from 64.4 and 64.6 m. However, depending on tunnelling method, a casing liner with a diameter of about 1.2 m would be installed in conjunction with installation of the smaller 0.9 m diameter culvert pipe. The minimum cover below the highway surface should be estimated based on the larger liner pipe diameter corresponding to an obvert elevation ranging from 64.9 to 64.7 m. Therefore, the minimum cover based on the larger diameter liner pipe would be between 2.5 and 2.7 m below the highway surface, providing a cover-to-diameter ratio of between 2.1 and 2.2. The minimum will be reduced at the entry/exit pit locations, depending on how close to the embankment the pits are located. As such, it is assumed the entry/exit pits will be constructed closer to the ramp embankment to provide the minimum sufficient cover for trenchless installation.

For tunnels under 400-series highways, MTO generally requires that the minimum overburden cover shall not be less than one (and preferably two) tunnel diameters, at any point along the entire length of the tunnel crossing. Based on the profiles provided by WSP and the estimates given above, the on-ramp crossing has generally greater than two tunnel diameters of cover along the alignment length.

Typically, it is recommended that the tunnel invert or obvert be a minimum of 0.5 m above or below (respectively) the interface of the fill materials, native materials and/or bedrock so that the tunnel horizon is not through mixed face conditions. As noted above, the tunnel invert will encounter the fill/native interface, which will limit the feasibility of trenchless methods due to the mixed-face conditions.

6.5 Anticipated Ground Behaviour

At the crossing location, the subsurface conditions generally consist of embankment fill, overlying silty clay and a localized deposit of silty sand, over glacial till and shale bedrock of the Carlsbad formation. The groundwater level was measured at the site at a depth of 1.1 m, corresponding to Elevation 63.7 m.

The ground conditions along the culvert alignment within the tunnel vertical limits (i.e., invert and obvert of the casing) are likely to consist of a mixed interface of compact to dense sand and gravel embankment fill over a very stiff native silty clay. Based on interpolation between boreholes, this should be expected to be the case for the majority of length of the proposed tunnel.

Based on the soil descriptions, the soils present have been classified according to the Tunnelman's Ground Classification System by Terzaghi as reported in Heuer (1974). This system is commonly used to describe the expected behaviour of an unsupported tunnel face during excavation and uses qualitative "stand-up time" criteria to classify the ground at and above the tunnel face into the following principal categories: hard, firm, slow ravelling, fast ravelling, squeezing, swelling, cohesive-running, running, very soft squeezing, flowing, and bouldery.

The embankment fill would be classified as cohesive-running and the native silty clays would be classified as firm above the water table to slow ravelling below the water table material under the Tunnelman's Ground Classification System. The groundwater level is near the invert of the tunnel.

6.6 Feasibility of Tunneling Methods

Based on the borehole data collected at the proposed crossing, the ground conditions along the culvert replacement within the tunnel vertical limits (i.e., invert and obvert of the casing) are likely to consist of compact to dense variable fill overlying stiff to very stiff silty clay with the possibility of encountering the till interface. At the borehole locations, the interface between these two deposits is within or very near the proposed tunnel cross section. Based on interpolation between boreholes, this should be expected to be the case for the majority of length of the proposed tunnel. The groundwater was measured at Elevation 63.7 m on January 22, 2020.

Given the anticipated mixed face conditions along the bore alignment, groundwater elevation and relatively small culvert diameter, of the methods outlined in Section 6.3, Jack and Auger Bore, Pipe Ramming with a Pilot Tube or Micro-tunnelling are considered feasible installation options for this site.

As noted in Section 6.2, from a foundation perspective it is also considered feasible to construct/install this culvert using conventional open cut methods. Recommendations for this installation method are provided in Sections 6.11.1 and 7.0.

The following presents the feasibility of the various trenchless replacement methods, some disadvantages and geotechnical concerns.

6.6.1 Pipe Jacking and Horizontal Auger Boring

Jacking and boring operations can be carried out below the groundwater table in soils that have a high fines content and exhibit suitable "stand-up" time, except those in mixed face conditions with rock and overburden and those with cohesionless soils below the water table. Based on the information in Section 6 the measured groundwater level at the crossing is at the proposed pipe invert.

The contractor should consider the groundwater level when selecting the installation method. However, under such conditions the specifications should require that a plug of soil remain in the lead end of the casing at all times. This can be achieved by maintaining the cutting head at the appropriate distance behind the leading edge of the casing or retracting it into the casing during the jacking operations through such soils. The objective is to balance the potential inflow of material into the casing, with a plug of soil at the front of the casing to minimize ground loss and consequent settlement. The disadvantage is the greater difficulty with steering. In certain cases, contractors prefer to have the lead end of the auger at or ahead of the lead edge of the casing. This practice could lead to excessive ground losses and is not recommended for these crossings.

Once started, the jack and bore operation should continue without interruption until completed.

If obstructions, such as a boulder or a nest of cobbles, are encountered, it would be necessary to remove the augers and soil plug, and manually remove the obstruction. This is not anticipated to be the case at this location based on the subsurface conditions. Depending on the soil conditions at the location of the obstructions and on the amount of cover, this may result in loss of ground at the face and settlement at the ground surface. Typically, native cohesive deposits will have a greater “stand-up time” compared to cohesionless soil and fill. For cohesionless soil above the water table, the greater the fines content and the more broadly graded the soil is, the greater the stand-up time will be, and the greater the likelihood that the obstructions can be removed without significant ground settlement. In the event the obstructions are encountered below the groundwater table in cohesionless soils, then the risk of ground settlements occurring is greatly increased. The contractor should have a contingency plan for such an event that includes highway or ramp closures to protect the travelling public.

Soils that are classified as “running” (e.g., water bearing sand and silt) are not considered suitable for the jack and bore method because of the risk for uncontrolled inflows into the casing that would lead to increased settlement (and potentially sink holes) at the ground surface. This method can be utilized if the sand and silt deposits are dewatered/depressurized such that the groundwater level is lowered to below the tunnel invert along the full alignment. Based on the borehole and groundwater information provided in Sections 4.2 to 4.7, the measured groundwater level at the crossing location is at or just below the proposed pipe inverts with gravel and sand embankment fill (Borehole 19-3623). In a moist, depressurized condition, the embankment fill would behave as ravelling to cohesive running and the ability to advance should have minimal ground losses, provided the excavation is undertaken on a continuous controlled basis.

6.6.2 Pipe Ramming

Pipe ramming is not steerable, so there is no control over the profile and alignment of the bore once the pipe ramming has started. Considering the interface conditions between the fill and native silty clay anticipated along a majority of the alignment, as well as the possibility of encountering the till interface, which all have differences in compactness and consistency, along with the groundwater conditions present at an elevation of 63.7 m, some issues or difficulties steering with mixed face conditions are anticipated. However, to accommodate the potential for disturbance, a ‘pilot tube’ pipe ramming methods can be used, which is a newer technology that uses a directional initial pilot hole to guide the casing.

Vibrations from the pipe ramming operations pose risks in settlement of the upper fill and native sands and silts.

With pipe ramming the soil is typically removed from the pipe following full or partial advancement of the pipe along the alignment. A “plug” of soil may form at the head of the casing inducing surficial heave as the pipe is advanced. Depending on the length of the installation, the soils inside the pipe can be removed either during or after the installation by auguring, compressed air or water jetting.

However, cleaning out the spoil from inside the casing can result in the loss of ground at the face of the casing, if the amount of cover above the casing is low. The proposed alignment has a minimum cover-to-diameter ratio of about 2.0 and increases to 3.3 under the off-ramp, as such, the loss of ground at the face caused from cleaning out the spoil is considered a relatively low risk to subsidence at the surface of the off-ramp.

Dewatering and lowering of the groundwater to beneath the bore alignment would be required for pipe ramming. Further discussion on groundwater control is provided in Section 6.11.2.

When the pipe is not being advanced (during welding of casing extensions) the stresses around the circumference of the pipe may increase, depending on the ground conditions and duration of delay, which will further increase the friction around the pipe, making it more difficult to advance the pipe. Once started, the ramming operation should continue without interruption until completed. The casing may be lubricated to reduce the frictional forces between casing and the surrounding soil and/or the Contractor may utilize a higher energy hammer and thicker wall pipe in such conditions.

6.6.3 Micro-Tunneling

To reduce the risk of project delays resulting from encountering significantly variable soil conditions in the fill, completing the bore with micro-tunneling may be preferred. Though micro-tunneling is more expensive than pipe ramming, it offers several advantages to deal with mixed-face and challenging conditions.

The micro-tunnel boring machine (MTBM) has a rotating cutting head to excavate the ground encountered and can be equipped with a leading crushing cone to crush larger particles into smaller sizes for transport back to the jacking shaft through the slurry lines. A pressurized slurry mixing chamber is present behind the cutter head to maintain face stability. As such, the MTBM is capable of independently counter-balancing earth and hydrostatic pressures as the bore advances. Groundwater pressure can be counter balanced by using pressurized slurry.

Since this method of boring is essentially a steerable, remote-controlled pipe jacking operation controlled from the surface, the necessity for personnel to enter the bore is eliminated.

6.6.4 Open Cut Replacement

As the new culvert is to be located on an off-ramp and due to the relatively short alignment lengths, relatively small diameter, and property constraints, it may be more feasible to use select open cut techniques under a full ramp closure to install the new culvert. General excavation recommendations are provided in Section 6.11.1 and open cut construction considerations are provided in Section 7.0.

6.7 Risk Assessment and Mitigation

As a general guideline, the required cover above the crown of the tunnel/bore should be at least one tunnel/bore diameter relative to the ground surface provided the methodology would not have an unsupported face, and ideally two to three diameters should be provided to reduce the risk of settlement. As the overburden cover decreases, the risk of concentrated subsidence or heave increases.

Further discussion on the potential ground movements is provided in Section 6.9. A plan should be in-place to rapidly repair any distress to the pavement, if needed (and to re-direct traffic, if required).

Given the potential for obstructions which require removal to be encountered during the boring operations, a Non-Standard Special Provision (NSSP) should be included in the contract documents to address this issue and a sample version is included in Appendix D.

There is a significant risk that removal of spoil or equipment that is supporting the bore face for dealing with “plugs” or obstructions will result in loss of ground, sinkholes and potentially an immediate hazard to traffic on the highway. Mitigation plans outlining the required dewatering, instrumentation, monitoring and traffic control, that may include closing the ramp during such operations, and emergency response plans must be developed prior to initiating the bore.

6.8 Pipe Materials and Liner Design

Installation of the culvert by either jack and bore or pipe ramming will require that a steel casing be installed during boring or ramming. The steel casing could remain in place, with a smaller diameter culvert pipe installed within the casing. In this case, it is recommended that grout be injected in the annular space between the culvert pipe and the steel casing. As discussed in Section 6.4, this would decrease the cover-to-diameter ratio to about 2.1 to 2.2, which is still considered a feasible cover-to-diameter ratio for pipe ramming and jack and bore methods.

The casing must be designed to accommodate hoop stress and sufficient nominal wall thickness must be provided to meet this design requirement. The casing should conform to OPSS 1802 (Smooth Walled Steel Pipe) and at least the nominal wall thickness provided in Table 1 of this specification will apply.

The casing must also be designed to withstand the jacking/ramming stresses. Additional wall thickness could be required. For pipe ramming installations, bentonite slurry is commonly used as exterior lubrication for the casing to reduce frictional drag with the soil, and to thereby limit the required jacking forces.

6.9 Ground Movements

To reduce the risk of ground settlement/subsidence, trenchless installations require a minimum depth of overburden cover over the tunnel crown. As the depth of overburden cover decreases, the risk of concentrated subsidence increases, as does the risk of extreme events such as sinkholes forming at the ground surface. In Ontario, the general practice is to maintain a depth of cover equivalent to 2 to 3 tunnel diameters, at least for open-faced tunneling methods. Lesser cover can be feasible (i.e., as low as 1 diameter) for some methods (e.g., pipe ramming provided the casing is not cleaned out during driving).

At this site, the proposed culvert alignment has a minimum assumed/estimated cover of 1.8 m at the entry and exit locations (at the toes of the highway embankment) and about 2.2 m for the majority of the crossing beneath the off-ramp. The actual cover-to-diameter ratio will depend on the amount of overcutting required for the selected tunnel installation method but based on the above ranges from about 1.8 at the entry and exit locations to about 2.6 beneath the off-ramp.

The groundwater level was measured at about Elevation 63.7 m, at or about 0.2 m above the proposed invert level. Local dewatering will likely be required for construction of the entry and exit pits and to maintain the groundwater level below the tunnel along the length of the alignment. The nominal required dewatering is not expected to have a significant impact on the off-ramp.

The potential settlement also depends on the construction practices. To avoid excessive settlements:

- Auguring ahead of the carrier pipe should not be permitted.
- Pauses/delays in the ramming operation should be minimized.

Furthermore, should the casing encounter obstructions which prevent its advancement, and the casing needs to be cleaned-out so that hand-mining can be used to remove the obstruction, there is a potential for larger settlements to occur.

There is a somewhat lower potential for significant settlement with pipe ramming compared to jack and bore or other trenchless installation methods since the soil is typically not removed from within the casing until it has been fully advanced to the exit pit. With no unsupported working face, there is less risk for a corresponding reduction in stress in the ground above the tunnel, and potential for movement of the ground towards the face (such as would often be the case for conventional tunnel construction). The settlements should therefore be more limited in magnitude, provided the gap around the casing created by the overcut is limited in size.

There is a risk of heave for pipe ramming, however, it is considered relatively low based on a cover-to-diameter ratio of between 2.1 to 2.2.

For the ground conditions encountered, there remains a risk of at least some level of impact (i.e., heave or settlement) to the on-ramp surface. It is expected that settlements or heave directly over the tunnel would likely not exceed about 25 mm, provided good construction procedures are followed and obstructions are not encountered which require removal. But the risk of larger settlements or heave magnitudes is significant and contingency measures should be in place, as described below in Section 6.10.

It is expected that the bore construction will not result in measurable ground surface settlements beyond a distance on either side of the bore alignment equal to the bore depth.

6.10 Settlement Monitoring

6.10.1 General

In accordance with MTO's Pipe Installation by Trenchless Method Special Provision, provided in Appendix D, a settlement monitoring program will need to be implemented. That settlement monitoring will serve to:

- Document the effects of the culvert installation on the overlying roadways, adjacent structures or services lines/pipes.
- Obtain advanced warning of ground movements that could occur due to the construction methods.
- Allow adjustments to be made to the trenchless construction method such that the established settlement limits are not exceeded, recognizing however that there is typically some delay between the trenchless construction and the full manifestation of the ground surface settlements.

6.10.2 Instruments

A specialist surveying firm should be retained to confirm the set-up and to carry out the settlement monitoring during construction. 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.

Monitoring of settlement instruments on this project is constrained by the continuous and high traffic volume and the limited periods during which access to Highway 417 Eastbound lanes can be obtained. By necessity, a non-intrusive system is recommended for ground surface (i.e., pavement) monitoring points, such as by the use of reflectorless total station monitoring.

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.

In-ground settlement monitoring points shall be installed beyond the traffic lanes and shoulders to monitor settlement and stability of the ground surface between the surface settlement monitoring points and the entry and exit portals.

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.

6.10.3 Monitoring and Reporting Frequency

The recommended survey frequency is as follows:

Baseline readings:

- Three consecutive daily sets of readings at least one week prior to commencement of the tunnel construction.

Construction readings:

- Once per shift or once daily during tunnelling operations period whichever results in the more frequent reading intervals.
- Two sets of readings per day or shift, if 'review' or 'alert' levels are reached (see below).
- Continuous readings during high risk operations (such as removing face support to deal with obstructions), reviewed on site by the contractor's geotechnical engineer during such operations.

Post-construction readings:

- One set of readings per week for a period of one month.

6.10.4 Criteria for Assessment of Roadway Subsidence/Heave

A protocol for assessing the seriousness of any indicated movement is necessary to ensure a timely and appropriate response by the personnel on site. Any significant measured movement could indicate that a response and corrective measure is needed.

The following protocol is therefore recommended.

1) 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 to mitigate further ground displacement. If this Review Level is exceeded, the Contractor shall immediately notify the Contract Administrator (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.

2) Alert Level

If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations (if safe to do so), inform the CA and execute pre-planned measures to secure the site, to mitigate further movements. 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) The corrective/preventive measures deemed necessary are implemented, and,
- iv) The CA deems it is safe to proceed.

A settlement monitoring plan consistent with the MTO guidelines should be established as part of the contract.

6.11 Tunnelling Construction Considerations

6.11.1 Open Cut Excavations

Shallow excavations up to about 4 m deep are anticipated for the entrance and exit pits made through the existing highway fill and native overburden.

No unusual problems are anticipated with excavating the overburden soils using conventional excavating equipment.

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 soil at this site is generally classified as Type 2 soil (compact to dense and stiff to very stiff above groundwater level) in accordance with the OHSA, if above the natural or lowered groundwater table). Below the groundwater table, the soil would be classified as Type 4 soil, in which unsupported side slopes may be sloped at no steeper than 3H:1V.

However, due to the proximity of the existing highway, sloped excavations in the overburden may not be feasible and may need to be carried out in fully braced, steel trench boxes for worker safety. The excavation support may also need to be designed to act as a backstop for the jacking forces and boring operations.

6.11.2 Groundwater and Surface Water Control

The Contractor must be prepared to control the groundwater and surface water flow at the site to permit the excavation of the existing embankment, the preparation of the entry/exit pits and the installation of the proposed culvert in dry and stable excavations. It is recommended that the culvert construction be conducted during a drier season such as after the spring freshet or prior to the fall.

The selection and design of temporary unwatering/dewatering system is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility and to design the required systems in accordance with MTO SPFOUN0003 (Dewatering Structure Excavations) which amends OPSS 902 and OPSS.PROV 517 (Dewatering) with amendments as per SP 517F01 (Dewatering System).

Given the groundwater and soil conditions at this site, it is not required that the design Engineer and design-checking Engineer of the dewatering system have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work as per Table A of SP 517F01.

6.11.3 Erosion Protection and Site Restoration

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes during installation and after reconstructing the embankment slopes. The contractor should provide silt fences and erosion control blankets, as required, throughout the duration of the construction to prevent silt/sediments from running off the site as per OPSS.PROV 805 (Temporary Erosion and Sediment Control Measures).

To reduce erosion of the embankment side slopes due to surface water runoff, placement of topsoil and seeding or pegged sod is recommended as soon as practicable after construction of the embankments. The erosion protection should be in accordance with OPSS.PROV 804 (Seed and Cover).

Site restoration shall be in accordance with OPSS.PROV 492. Excavated material or new imported material conforming to OPSS.PROV 1010 Select Subgrade Material (SSM) may be used as backfill material. Compaction of backfill materials should be carried out in accordance with OPSS.PROV 501.

7.0 OPEN CUT CONSTRUCTION CONSIDERATIONS

7.1 Open Cut with a Full Road Closure

Installation of a new culvert using open cut techniques during a full ramp closure with a detour route is a feasible alternative from a foundation perspective. This option would allow for an expedient construction schedule and reduced costs. However, it is understood that a detailed review including the availability of detour routes has yet to be undertaken and this may not be feasible from a traffic operations perspective.

7.2 Steel CSP

A steel CSP pipe type culvert installed with invert elevations ranging from 63.5 m to 63.7 m and a 300 mm bedding layer consisting of Granular A is considered feasible at this site. The base of excavation is expected to be at an approximate elevation between 63.2 and 63.4 m at this elevation the anticipated founding material would be the silty clay and glacial till for the majority of the culvert alignment.

Design and installation of a CSP culvert should be carried out in accordance with the height of fill tables in the OPSD 800 drawing series.

7.3 Site Preparation and Construction

7.3.1 General

Excavation and backfilling for installation of the new culvert should be carried out in accordance OPSS 902 (*Construction Specification for Excavating and Backfilling – Structures*) and MTO Special Provision (SP) No. 109S12, Amendment to OPSS 902, August 2018.

Construction for the installation of new pipe culverts should be carried out in accordance with OPSS.PROV 421 (*Construction Specification for Pipe Culvert Installation in Open Cut*).

7.3.2 Subgrade Preparation and Backfilling

Based on the proposed invert elevations of 63.5 and 63.7 m, it is anticipated that the culvert would be founded on native silty clay to clay and till and/or engineered fill overlying the till.

Subgrade preparations for the culvert should include excavation of the existing pavement structure and embankment fill and portions of the silty clay.

Excavation recommendations outlined in Section 6.11.1 Open Cut Excavations would apply for open cut installations.

The recommendations outlined in Section 6.11.2 Groundwater and Surface Water Control would also apply for open cut installation.

Backfill for the culvert should consist of compacted free-draining granular material. It is recommended that the backfill detailing of OPSD 803.010 (*Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m*) be utilized with a frost penetration line above the top of the culvert. The frost treatment depth, k , should be set at 1.8 m. The depth of roadbed granulars, d , should be set at a minimum of 0.6 m as indicated in OPSD 803.010.

7.3.3 Embankment Design and Reinstatement

The existing embankments have slopes that are at approximately 5H:1V. Embankment reinstatement, after culvert replacement, should be carried out in accordance with OPSS.PROV 206 (*Construction Specification for Grading*) and should match the adjacent slope geometry. The new embankment material should consist of imported Granular B Type II material. Excavated granular fill may also be reused as embankment fill provided there is no organic material in the excavated fill and there is sufficient space to stockpile on site and control the moisture content within acceptable limits for compaction. Excavated granular fill must not be used as culvert bedding, backfill or highway base or subbase materials.

Granular fill should be placed and compacted in accordance with OPSS.PROV 501 (*Construction Specification for Compacting*). Where new embankment fill is placed against existing embankment slopes the existing earth or fill slope must be benched in accordance with OPSD 208.010 (*Benching of Earth Slopes*).

Provided the subgrade is prepared as outlined and embankment fill is placed as recommended herein, an embankment slope inclined at 2H:1V or flatter, will remain stable.

7.3.4 Temporary Protection Systems

If the ramp is fully closed the use of temporary protection systems will likely not be required, however, the following foundation recommendations have been provided should temporary protection be necessary for staging.

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 to facilitate excavation to the foundation level for the replacement of the culvert and removal of the existing culvert.

The design of the shoring will be entirely the responsibility of the contractor. Where required, temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*), and the lateral movement should meet Performance Level 2 provided that any existing adjacent utilities can tolerate this magnitude of deformation. Traffic loading should be included as a surcharge. Traffic loading does not account for construction equipment loadings which may be higher; the contractor's shoring designer should confirm those load requirements.

Increased difficulty with the installation of temporary protection systems should be anticipated due to the presence of the relatively shallow depth to the bedrock surface. For preliminary assessment purposes, the use of sheet piles is not considered feasible. One option is to use H-piles and timber lagging with the H-piles installed in pre-drilled holes into the bedrock.

8.0 CORROSION AND CEMENT TYPE

One soil sample from Borehole 19-3623 was submitted to Eurofins Environment Testing for chemical analysis related to potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements. The test results are provided in Appendix C.

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. The sulphate results generally indicate a low degree of sulphate attack potential on concrete structures at this site. As such, GU cement may be used for concrete in below grade applications.


The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. Generally, the test results indicate a higher potential for corrosion of exposed ferrous metal at the site which should be considered in the design.


9.0 CLOSURE


This report was prepared by Ms. Kim MacDonald, P.Eng., and was reviewed by Mr. Michael Snow, P.Eng. provided technical input and Mr. William Cavers, P.Eng., Designated MTO Foundations Contact, conducted an independent quality control review of this report.

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KM/KCP/MSS/WC/hdw

[https://golderassociates.sharepoint.com/sites/11263g/shared documents/01_foundations/6 - reports/1360 trenchless crossings/tc8 - 417 wb off-ramp walkley/3 - final/1662565-1360_tc8 final fidr hwy 417 wb off walkley_202109-13.docx](https://golderassociates.sharepoint.com/sites/11263g/shared%20documents/01_foundations/6%20reports/1360%20trenchless%20crossings/tc8%20-%20417%20wb%20off-ramp%20walkley/3%20-final/1662565-1360_tc8%20final%20fidr%20hwy%20417%20wb%20off%20walkley_202109-13.docx)

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Table 5: Feasibility of Pipe Jacking and Horizontal Boring, Pipe Ramming and Micro-tunneling

Approximate Station	Relevant Boreholes ¹	Existing Ground Surface Elevation (m)	Proposed Invert Elevation (m)	Proposed Pipe Diameter (m)	Soil Conditions ² (below surface cover to invert)	Behaviour	Feasibility of Method		
							Pipe Jacking and Horizontal Auger Boring	Micro-Tunneling	Pipe-Ramming with 'Pilot Tube'
67+223	19-3622	64.8	63.7 to 63.5	0.9 m	Firm sandy silty clay (FILL) Very stiff to stiff silty clay to clay	Firm to slow ravelling	Feasible with dewatering along the alignment	Feasible	Feasible with addition of pilot tube dewatering along the alignment
	19-3623	67.4			Very dense to compact sandy gravel (FILL) Compact sand and gravel (FILL) Very stiff to stiff silty clay to clay	Cohesive-running to firm to slow ravelling			
	19-3624	64.3			Soft to Firm silty clay (FILL) Very stiff silty clay to clay	Firm to slow ravelling			

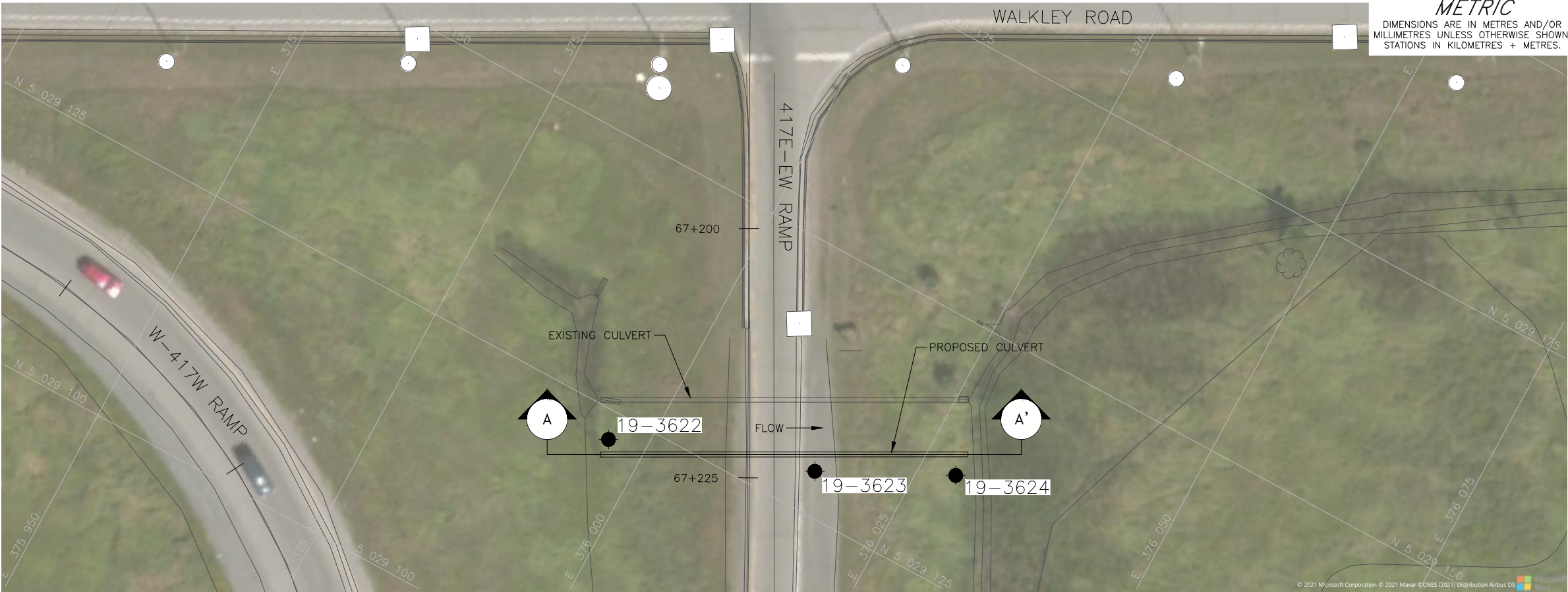
¹ Boreholes are listed from inlet to outlet of the pipe (down gradient)

² Soil conditions from ground surface to invert, where soils in bold indicate the anticipated conditions at the tunnel horizon

Table 6: Evaluation of Culvert Installation Methods

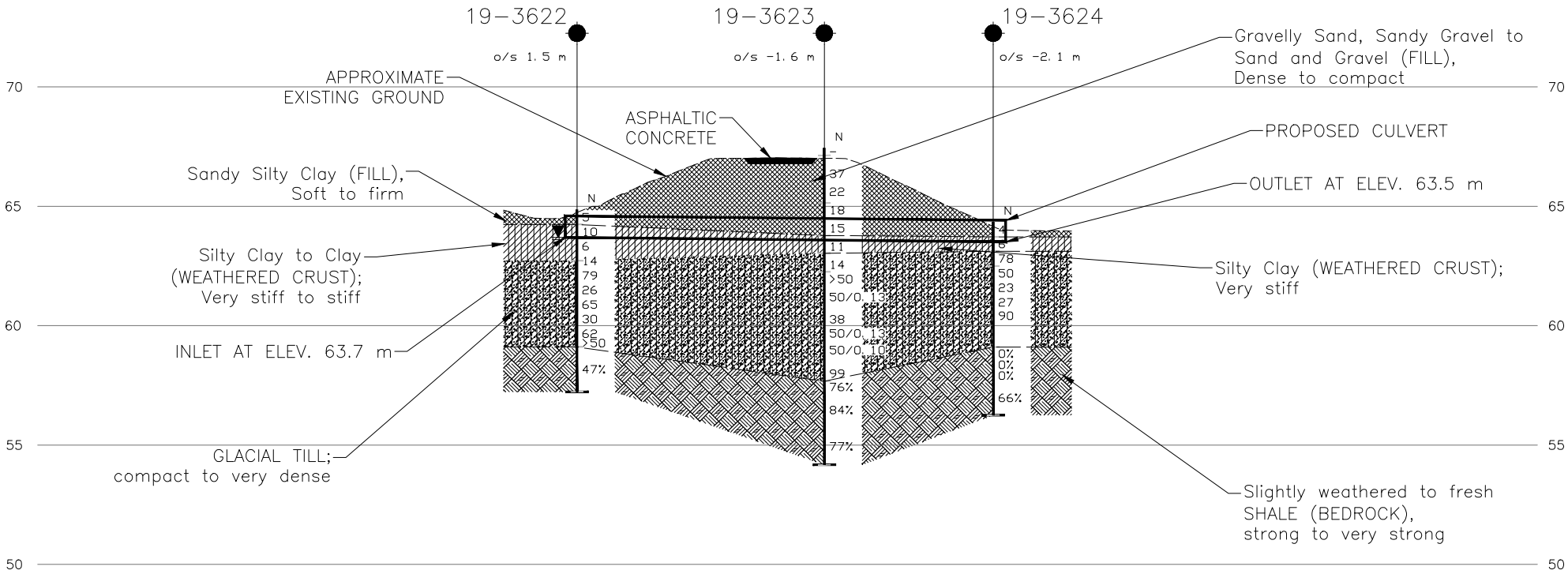
Method	Rank	Feasibility	Advantages	Disadvantages	Relative Cost	Risk/Consequences
Open Cut with ramp closure	1	<ul style="list-style-type: none">■ Feasible■ Preferred option from a foundation perspective	<ul style="list-style-type: none">■ Quicker installation than with trenchless methods■ Does not require traffic staging with ramp closure■ Better control over culvert grade and alignment■ Simple construction method.■ Equipment and skilled construction workforce available.	<ul style="list-style-type: none">■ Traffic impacts, ramp closure and detour routes would be required■ Groundwater lowering is required along the pipe alignment.	<ul style="list-style-type: none">■ Low	<ul style="list-style-type: none">■ Delays in construction could increase length of time highway ramp is closed.■ Detour maintenance could increase costs further
Pipe-ramming with 'pilot tube'	3	<ul style="list-style-type: none">■ Feasible, with dewatering along alignment	<ul style="list-style-type: none">■ Simple construction method.■ Equipment and skilled construction workforce available.	<ul style="list-style-type: none">■ Obstructions (e.g., cobbles and boulders) may deflect and/or halt bore. Higher risk of ground subsidence of highway, particularly if obstructions that slow installation procedures or if granular soils (particularly below the water table) encountered.■ Limited ability to steer to correct for line and grade during installation, higher risk in alignment and face stability issues are anticipated.■ Groundwater lowering is required at both the entry/exit pits and along the pipe alignment.	<ul style="list-style-type: none">■ Lowest cost relative to Pipe Jack and Bore	<ul style="list-style-type: none">■ Large cobbles and/or boulders can impede the ramming operations where removal of obstructions is not possible.■ Obstructions can result in deflection of the casing resulting in misalignment of gravity culvert.
Pipe Jack and Auger Bore	4	<ul style="list-style-type: none">■ Feasible, with dewatering along alignment	<ul style="list-style-type: none">■ Simple construction method.■ Equipment and skilled construction workforce available.	<ul style="list-style-type: none">■ Slower process compared to other trenchless methods.■ Significant backstop and jacking/receiving pits are required.■ Obstructions (e.g., cobbles and boulders) may deflect and/or halt bore. Higher risk of ground subsidence of highway, particularly if obstructions must be manually removed.■ Groundwater lowering is required at both the entry/exit pits and along the pipe alignment.■ Limited ability to steer to correct for line and grade during installation.	<ul style="list-style-type: none">■ Moderate	<ul style="list-style-type: none">■ Large cobbles and/or boulders can impede the auger boring operations where removal of obstructions is not possible.■ Obstructions can result in deflection of the casing resulting in misalignment of gravity culvert.■ Potential for loss of ground into casing, particularly if flowing conditions are encountered.■ Risk of ground surface subsidence increases with decreasing cover.
Micro-Tunneling	2	<ul style="list-style-type: none">■ Feasible	<ul style="list-style-type: none">■ Unsupported face condition not created■ Ability to steer allowing greater certainty about final profile and alignment.■ Better suited for tunneling in mixed face conditions■ Better suited for penetrating through potential obstructions such as cobbles, boulders and bedrock than jack and bore methods.■ Does not require groundwater lowering along the pipe alignment.	<ul style="list-style-type: none">■ Limited of availability of machines though availability has increased in recent years■ Relatively expensive compared to other methods.■ Requires skilled construction workforce	<ul style="list-style-type: none">■ Higher than auger bore and pipe-ramming methods	<ul style="list-style-type: none">■ Hydraulic fracture (frac-out) could occur at sites where relatively shallow overburden cover exists.■ Time delay in sourcing a machine.

Method	Rank	Feasibility	Advantages	Disadvantages	Relative Cost	Risk/Consequences
			<div>■ Relatively small working area required compared to other methods.</div>			
Horizontal Directional Drilling	N/A	<div>■ Not feasible</div>	<div>■ N/A</div>	<div>■ N/A</div>	<div>■ N/A</div>	<div>■ N/A</div>
Tunnel Boring Machine		<div>■ Not feasible</div>	<div>■ N/A</div>	<div>■ N/A</div>	<div>■ N/A</div>	<div>■ N/A</div>
Tunnel Digging Machine		<div>■ Not feasible</div>	<div>■ N/A</div>	<div>■ N/A</div>	<div>■ N/A</div>	<div>■ N/A</div>



PLAN

SCALE



PROFILE A-A'

SCALE



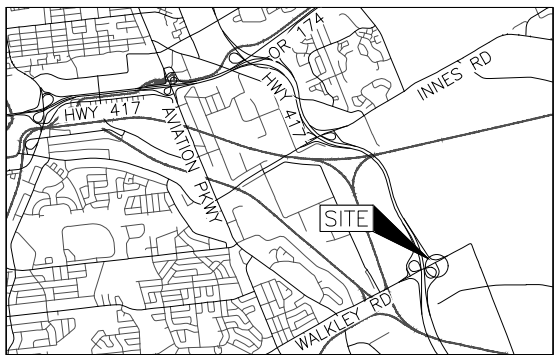
METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No. _____
GWP No. 4099-11-00



HWY 417 WB TO WALKLEY RD OFF-RAMP
CULVERT REPLACEMENT
HIGHWAY 417
BOREHOLE LOCATIONS AND SOIL STRATA
LAT. 45.398480, LONG. -75.590360

SHEET



KEY PLAN

SCALE



LEGEND

- Borehole - Current Investigation
- Borehole - Previous 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 January 22, 2019
- ≡ WL upon completion of drilling

BOREHOLE CO-ORDINATES NAD83 (CSRS) MTM ZONE 9

No.	ELEVATION	NORTHING	EASTING
19-3622	64.8	5029122.2	375996.3
19-3623	67.4	5029129.2	376016.0
19-3624	64.3	5029135.6	376028.6

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 plan provided in digital format by WSP, drawing file no. culvert borehole locations overall.dwg, received JULY 31, 2019.

NO.	DATE	BY	REVISION
1	10/6/2021	JM	1
Geocres No. 31G5-331			
HWY. 417	PROJECT NO. 1662565-8	DIST. EASTERN	
SUBM'D. KM	CHKD. KM	DATE: 10/6/2021	SITE:
DRAWN: JM	CHKD. KM	APPD. MSS	DWG. 1

APPENDIX A

Borehole and Drillhole Records, Current Investigation
List of Abbreviations and Symbols,
Lithological and Geotechnical Rock Description Terminology,
Bedrock Core Photographs, Figures A1 to A3

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

MINISTRY OF TRANSPORTATION, ONTARIO

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>200	>8
COBBLES	Not Applicable	75 to 200	3 to 8
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
FINES	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY COMPONENTS^{1,2}

Percentage by Mass	Modifier
> 35	Use 'and' to combine primary and secondary component (<i>i.e.</i> , SAND and gravel)
> 20 to 35	Primary soil name prefixed with "gravelly, sandy" as applicable
> 10 to 20	some (<i>i.e.</i> , some sand)
≤ 10	trace (<i>i.e.</i> , trace fines)

- Only applicable to components not described by Primary Group Name.
- Classification of Primary Group Name based on Unified Soil Classification System (ASTM D2487) for coarse-grained soils; fine-grained soils described per current MTO Soil Classification System.

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.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

Cone Penetration Test (CPT)

An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (*q_t*), porewater pressure (*u*) and sleeve friction (*f_s*) are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); 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, 60° 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

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC / SC	Rock core / Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample
OD / ID	Outer Diameter / Inner Diameter
HSA / SSA	Hollow-Stem Augers / Solid-Stem Augers

SOIL TESTS

w	water content
PL, w _p	plastic limit
LL, 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
GS	specific gravity
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 (FV)	field vane (LV-laboratory vane test)
Y	unit weight

- Tests anisotropically consolidated prior to shear are shown as CAD, CAU.

COARSE-GRAINED SOILS

Compactness¹

Term	SPT 'N' (blows/0.3m) ²
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	> 50

- Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grain size. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.
- SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.

FINE-GRAINED SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N' ^{1,2} (blows/0.3m)
Very Soft	< 12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	> 200	> 30

- SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.
- SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

LIST OF SYMBOLS

MINISTRY OF TRANSPORTATION, ONTARIO

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
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, 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 $= (w_l - w_p)$
NP	non-plastic
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_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 $= \sigma'_p / \sigma'_{vo}$

(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
2

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

$$\text{shear strength} = (\text{compressive strength})/2$$

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERING CLASSIFICATION

Fresh (W1): no visible sign of rock material weathering.

Slightly Weathered (W2): discoloration indicates weathering of rock mass material on discontinuity surfaces. **Less than 5%** of rock mass is altered or weathered.

Moderately Weathered (W3): less than 50% of the rock mass is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.

Highly Weathered (W4): more than 50% of the rock mass is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.

Completely Weathered (W5): 100% of the rock mass is decomposed and/or disintegrated to a soil. The original mass structure is still largely intact.

Residual Soil (W6): all rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.

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, recovered at full diameter, 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

AXJ Axial Joint	KV Karstic Void
BD Bedding	K Slickensided
BC Broken Core	LC Lost Core
CC Continuous Core	MB Mechanical Break
CL Closed	PL Planar
CO Contact	PO Polished
CU Curved	RO Rough
CT Coated	SA Slightly Altered
FLT Fault	SH Shear
FOL Foliation	SM Smooth
FR Fracture	SR Slightly Rough
GO Gouge	SY Stylolite
IN Infilled	UN Undulating
IR Irregular	VN Vein
JN Joint	VR Very Rough

ISRM Intact Rock Material Strength Classification

Grade	Description	Approx. Range of Uniaxial Compressive Strength (MPa)
R0	Extremely weak rock	0.25 – 1.0
R1	Very weak rock	1.0 – 5.0
R2	Weak rock	5.0 – 25
R3	Medium strong rock	25 – 50
R4	Strong rock	50 -100
R5	Very strong rock	100 -250
R6	Extremely strong rock	>250

ROCK WEATHERING CLASSIFICATION

Term	Symbol	Description	Discoloration Extent	Fracture Condition	Surface Characteristics
Residual soil	W6	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.	Throughout	N/A	Resembles soil
Completely weathered	W5	100% of rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.	Throughout	Filled with alteration minerals	Resembles soil
Highly weathered	W4	More than 50% of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.	Throughout	Filled with alteration minerals	Friable and possibly pitted
Moderately weathered	W3	Less than 50% of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones. Visible texture of the host rock still preserved. Surface planes are weathered (oxidized or carbonate filling) even when breaking the "intact rock".	>20% of fracture spacing on both sides of fracture	Discoloured, may contain thick filling	Partial to complete discoloration, not friable except poorly cemented rocks
Slightly weathered	W2	Discoloration indicates weathering of rock material on discontinuity surfaces (usually oxidized). Less than 5% of rock mass altered.	<20% of fracture spacing on both sides of fracture	Discoloured, may contain thin filling	Partial discoloration
Fresh	W1	No visible sign of rock material weathering.	None	Closed or discoloured	Unchanged

Reference:

Brown, 1981. "Suggested Methods for Rock Characterization Testing and Monitoring", International Society for Rock Mechanics.

PROJECT 1662565-1360		RECORD OF BOREHOLE No 19-3622		SHEET 1 OF 1		METRIC											
G.W.P. 4099-11-00		LOCATION N 5029122.2; E 375996.3 MTM NAD 83 ZONE 9 (LAT. 45.398420; LONG. -75.590620)		ORIGINATED BY HRL													
DIST Eastern HWY 417		BOREHOLE TYPE Portable Drill, BW Casing/Rotary Drill, NQ Core		COMPILED BY ZS													
DATUM Geodetic		DATE November 25, 2019		CHECKED BY KM													
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	20 40 60 80 100	W _p	W	W _L	γ	GR	SA	SI	CL
64.8	GROUND SURFACE																
0.0	(CI) Sandy silty clay contains organic matter (rootlets) (FILL) Very stiff to stiff Grey-brown Moist		1	SS	5												
64.2	(CI/CH) SILTY CLAY to CLAY (WEATHERED CRUST) Very stiff Brown Moist		2	SS	10		64										
0.6			3	SS	6												
62.7	(ML/SM/SP) Sandy SILT to SILTY SAND, some gravel to gravelly, contains cobbles and boulders (TILL) Compact to very dense Grey-brown Moist to wet		4	SS	14		63										
2.1			5	SS	79		62										
			6	SS	26												
			7	SS	65		61										
			8	SS	30		60										
			9	SS	62												
			10	SS	>50												
59.1	Shale (BEDROCK)						59										
5.7	Bedrock cored from depths 5.7 m to 7.6 m For bedrock coring details refer to Record of Drillhole 19-3622		1	RC	REC 81%		58										
			2	RC	REC 100%												
57.2	END OF BOREHOLE																
7.6	NOTES: 1. Water level in well screen at a depth of 1.1 m below ground surface (Elev. 63.7 m), measured on Jan. 22, 2020. 1. Water level in well screen at a depth of 1.46 m below ground surface (Elev. 63.3 m), measured on April 23, 2021.																

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMTOHWY417\REHAB&WIDENING\02_DATA\GINT\1662565.GPJ GAL-GTA.GDT 21-9-5 ZS

PROJECT: 1662565-1360

RECORD OF DRILLHOLE: 19-3622

SHEET 1 OF 1

LOCATION: N 5029122.2 ;E 375996.3

DRILLING DATE: November 25, 2019

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: Portable Drill

DRILLING CONTRACTOR: CCC Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY														FEATURES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
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DEPTH SCALE

1 : 50




LOGGED: HRL

CHECKED: KM

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GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMTO\HWY417REHAB&WIDENING\02_DATA\GINT\1662565.GPJ GAL-GTA.GDT 21-9-5 ZS

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

PROJECT 1662565-1360		RECORD OF BOREHOLE No 19-3623				SHEET 2 OF 3		METRIC								
G.W.P. 4099-11-00		LOCATION N 5029129.2; E 376016.0 MTM NAD 83 ZONE 9 (LAT. 45.398480; LONG. -75.590360)				ORIGINATED BY JS										
DIST Eastern HWY 417		BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stone)				COMPILED BY ZS										
DATUM Geodetic		DATE September 12, 2019				CHECKED BY KM										
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
	--- CONTINUED FROM PREVIOUS PAGE ---						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					25 50 75				GR SA SI CL
54.1	Shale (BEDROCK)		1	RC												RQD = 76%
13.3	Bedrock cored from depths 9.8 m to 13.3 m		2	RC	REC 100%											RQD = 82%
	For bedrock coring details refer to Record of Drillhole 19-3623		3	RC	REC 100%											RQD = 75%
54.1 13.3	END OF BOREHOLE															

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMTOHWY417REHAB&WIDENING\02_DATA\GINT\1662565.GPJ GAL-GTA.GDT 21-9-5 ZS

PROJECT: 1662565-1360

RECORD OF DRILLHOLE: 19-3623

SHEET 3 OF 3

LOCATION: N 5029129.2 ;E 376016.0

DRILLING DATE: September 12, 2019

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME 55

DRILLING CONTRACTOR: Downing Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY																FEATURES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
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UCS = 170.9 MPa

DEPTH SCALE

1 : 50



LOGGED: JS

CHECKED: KM

GTA-RCK 031 N:\ACTIVE\SPATIAL _IMMTOHW\417REHAB&WIDENING\02_DATA\GINTV\1662565.GPJ GAL-MISS.GDT 21-9-5 ZS

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

PROJECT: 1662565-1360

RECORD OF DRILLHOLE: 19-3624

SHEET 2 OF 2

LOCATION: N 5029135.6 ;E 376028.6

DRILLING DATE: November 25, 2019

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: Portable Drill

DRILLING CONTRACTOR: CCC Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY														FEATURES
							RECOVERY		R.Q.D. %	FRACT. INDEX PER	DIP W/L CORE AXIS	DISCONTINUITY DATA		HYDRAULIC CONDUCTIVITY K, cm/sec	WEATH- ERING INDEX						
							TOTAL CORE %	SOLID CORE %				Jr	Ja		W1	W2	W3	W4	W5	W6	

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DEPTH SCALE

1 : 50



LOGGED: HRL

CHECKED: KM

GTA-RCK 031 N:\ACTIVE\SPATIAL _IMMTOHWY417REHAB&WIDENING02_DATA\GINTV1662565.GPJ GAL-MISS.GDT 21-9-5 ZS

BH 19-3622 (Dry)
Cored From Elev. 59.11 m to 57.23 m
Core Box 1 of 1

Top of Bedrock
Elevation 59.11 m



Elevation 57.23 m
End of Borehole



GOLDER

Foundation Investigation

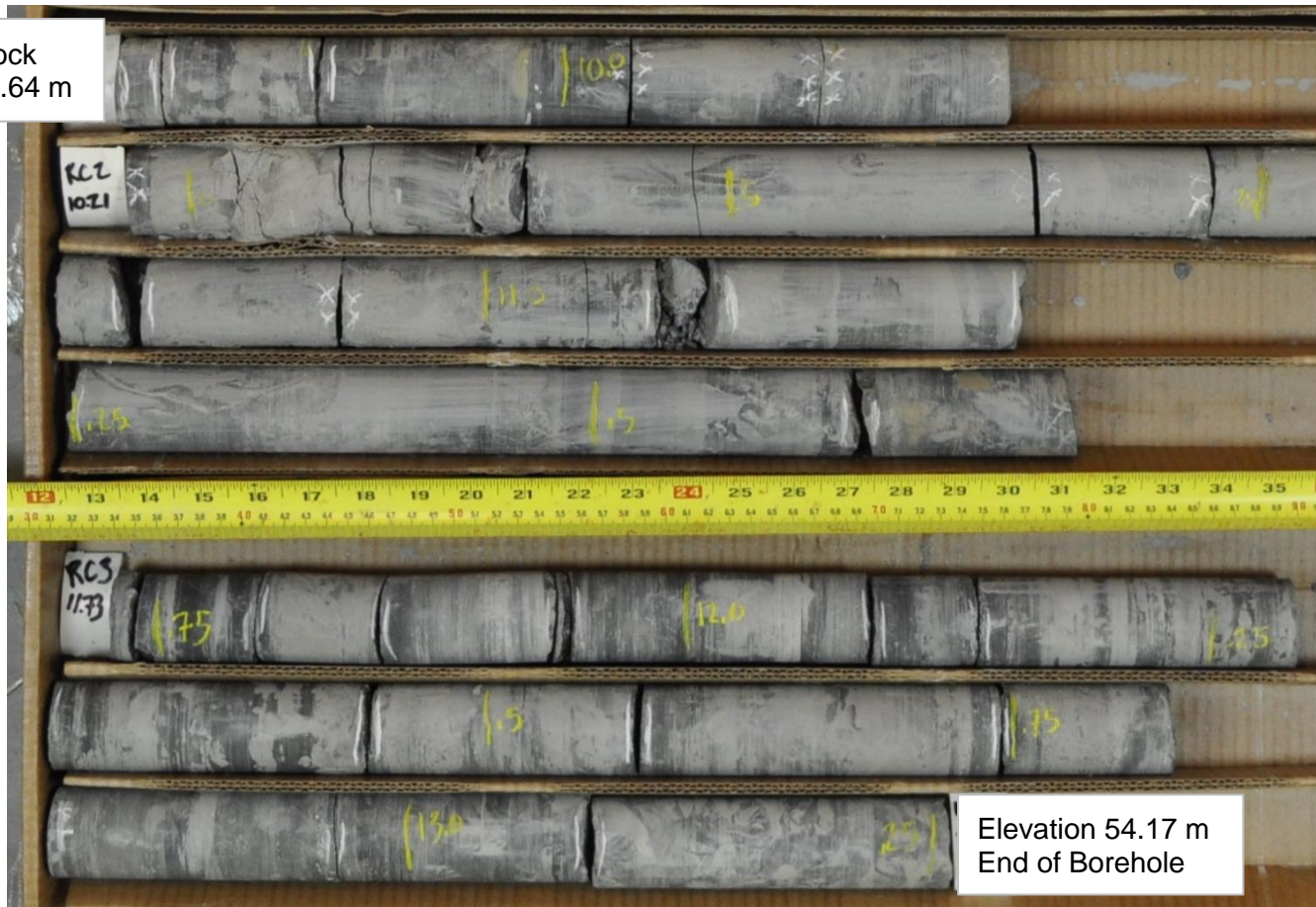
Trenchless Crossing
Highway 417 Westbound Offramp to Walkley Road
Ottawa, Ontario
G.W.P. 4099-11-00

Project No.	1662565 -1360
Drawn:	KM
Date:	2019-12-20
Checked:	GM
Review:	KCP

Figure A1

BH 19-3623 (Dry)
Cored From Elev. 57.64 m to 54.17 m
Core Box 1 and 2 of 2

Top of Bedrock
Elevation 57.64 m



Elevation 54.17 m
End of Borehole



Foundation Investigation
Trenchless Crossing
Highway 417 Westbound Offramp to Walkley Road
Ottawa, Ontario
G.W.P. 4099-11-00

Project No.	1662565 -1360
Drawn:	KM
Date:	2019-12-20
Checked:	GM
Review:	KCP

Figure A2

BH 19-3624 (Dry)
Cored From Elev. 59.05 m to 56.25 m
Core Box 1 and 2 of 2

Top of Bedrock
Elevation 59.05 m



Elevation 56.25 m
End of Borehole



GOLDER

Foundation Investigation
Trenchless Crossing
Highway 417 Westbound Offramp to Walkley Road
Ottawa, Ontario
G.W.P. 4099-11-00

Project No.	1662565 -1360
Drawn:	KM
Date:	2019-12-20
Checked:	GM
Review:	KCP

Figure A3

APPENDIX B

Laboratory Test Results, Current Investigation,

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

Figure B2 - Plasticity Chart - Silty Clay to Clay (WEATHERED CRUST),

Figure B3 - Grain Size Distribution Results - Silty Clay (WEATHERED CRUST)

Figure B4 - Grain Size Distribution Results – TILL

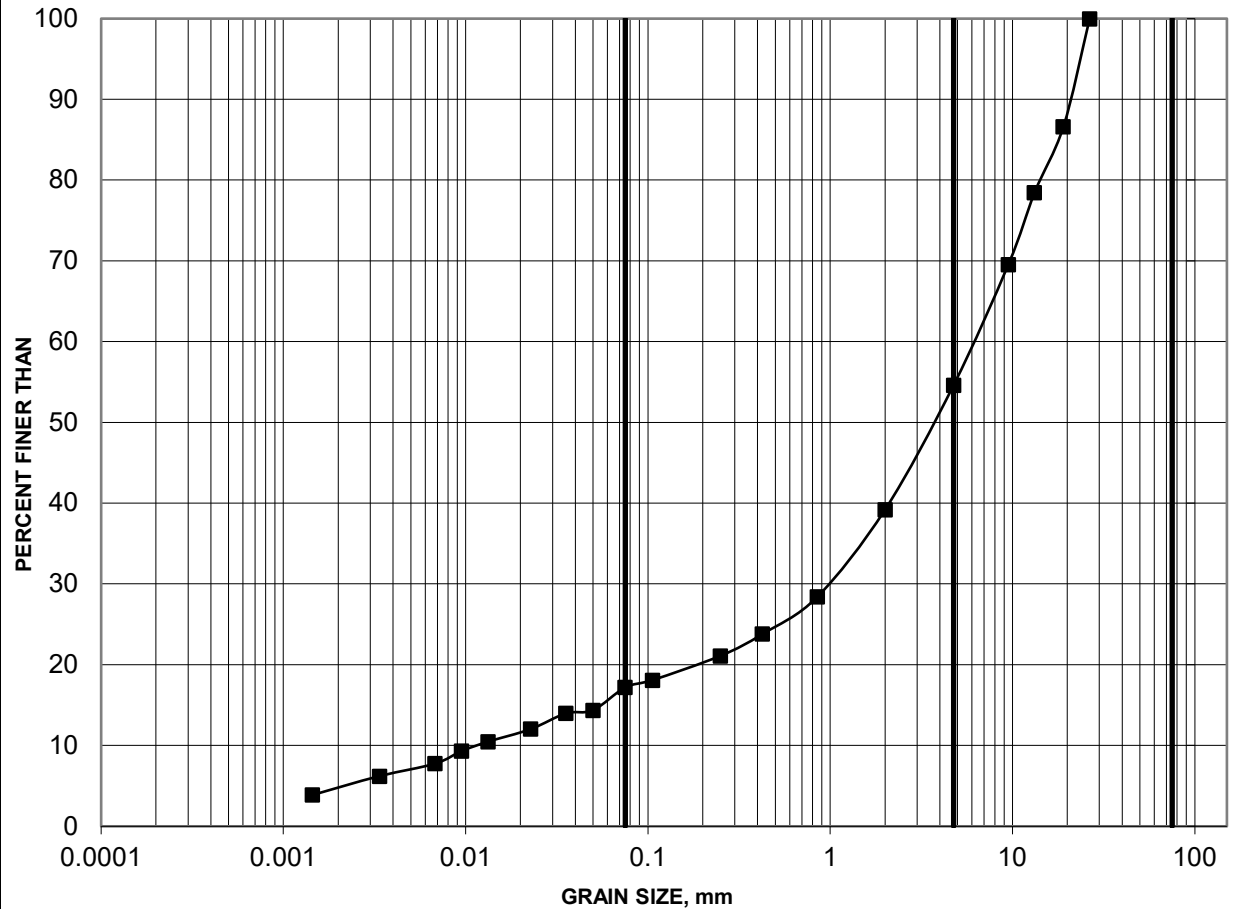
Figure B5 – Plasticity Chart – Silty Sand (TILL)

Figure B6 – Summary of Laboratory Compressive Strength Testing – Unconfined
Compression Tests

GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND AND GRAVEL (FILL)



SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

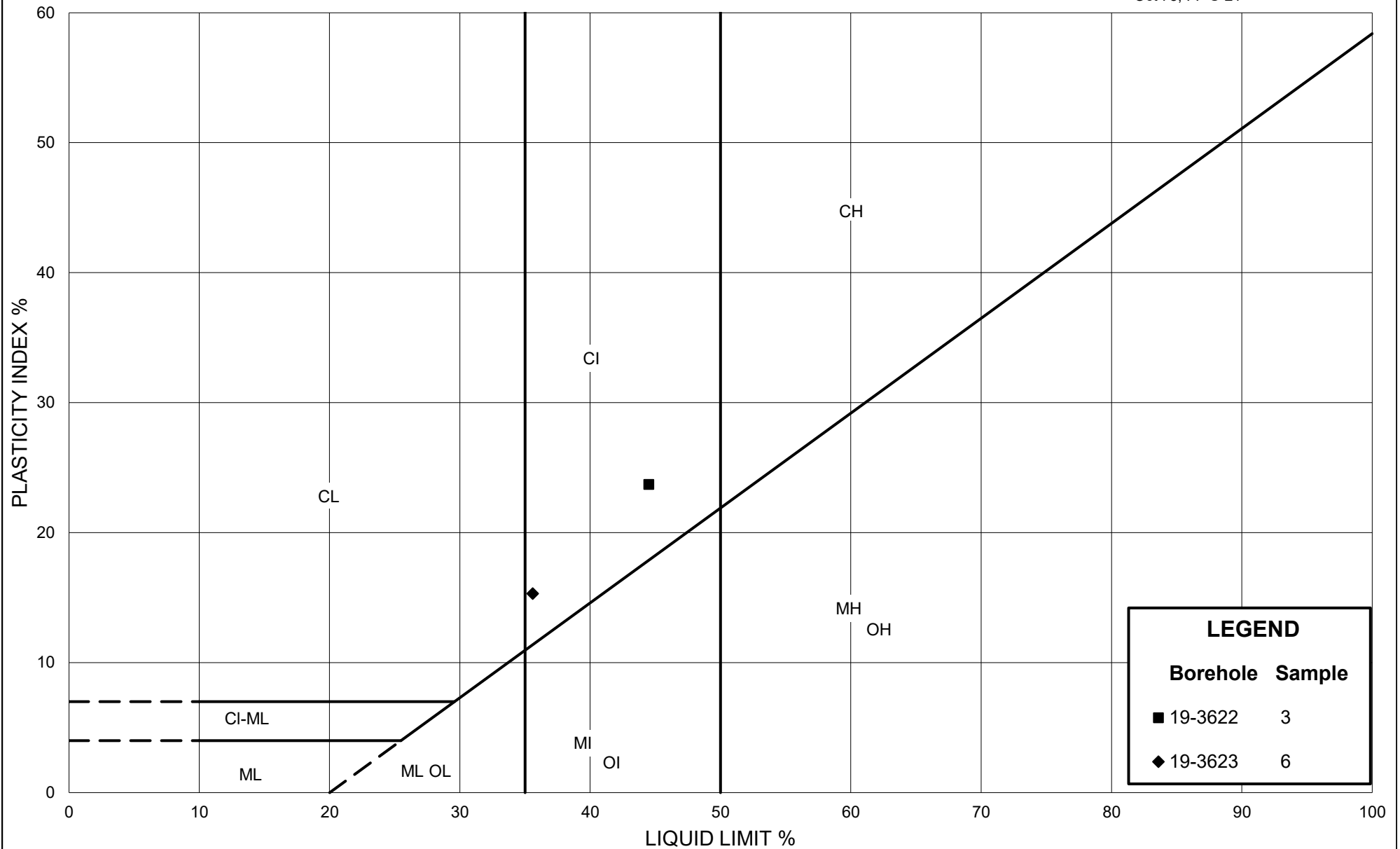
Borehole	Sample	Depth (m)
■ 19-3623	4	2.29-2.90

Project: 1662565/1360



Created by: MI
Checked by: CW

<https://golderassociates.sharepoint.com/sites/35409g/Shared Documents/Active/2016/1662565/Ph 1360/Figures/Figures for BH 3622, 3623, 3624/>



Ontario

Ministry of Transportation

PLASTICITY CHART

SILTY CLAY TO CLAY (WEATHERED CRUST)

Figure: B2

Project: 1662565/1360

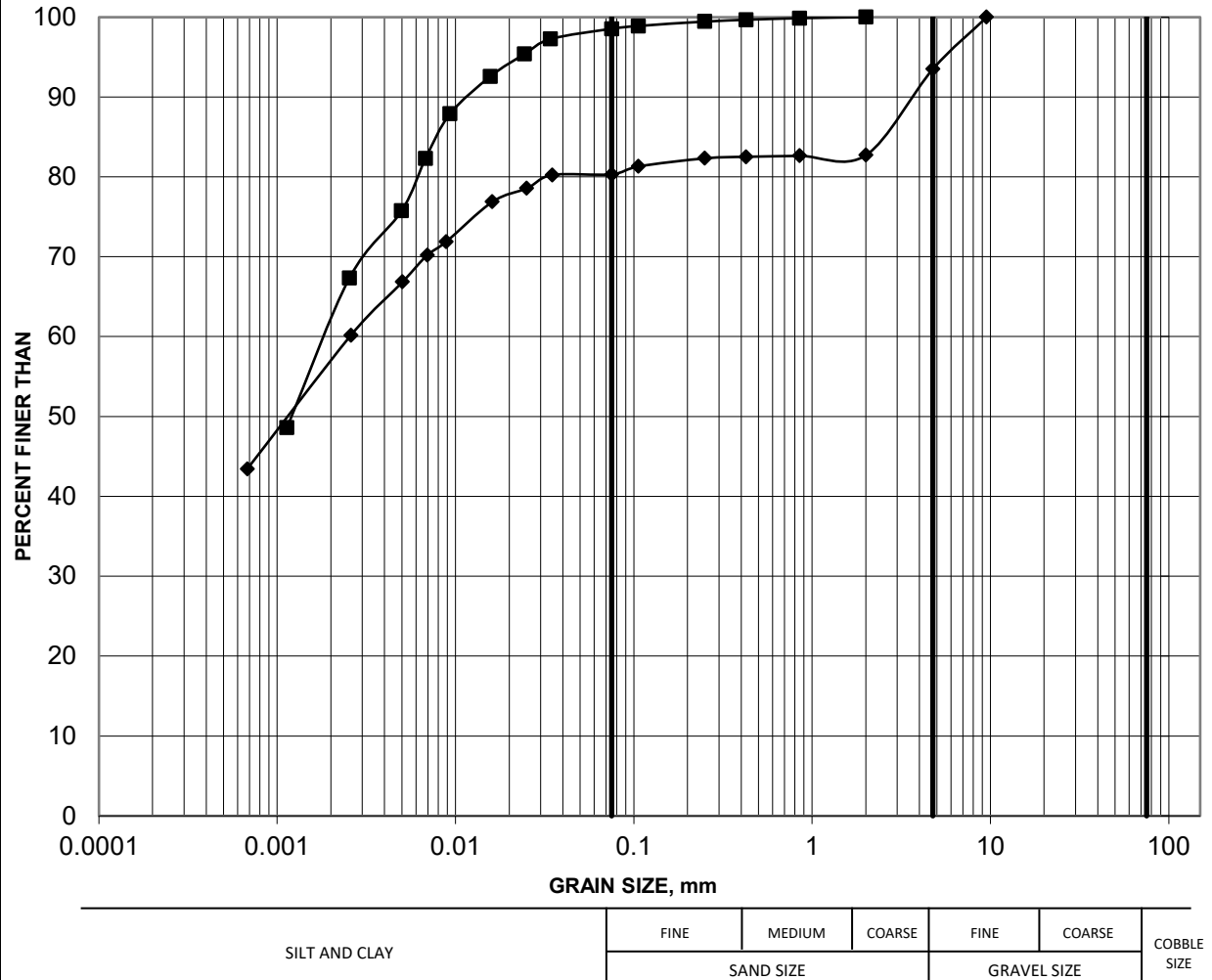
Created By: CW

Checked By: MI

GRAIN SIZE DISTRIBUTION

FIGURE B3

SILTY CLAY (WEATHERED CRUST)



	Borehole	Sample	Depth (m)
■	19-3623	6	3.81-4.42
◆	19-3624	2	0.61-1.22



Project: 1662565/1360

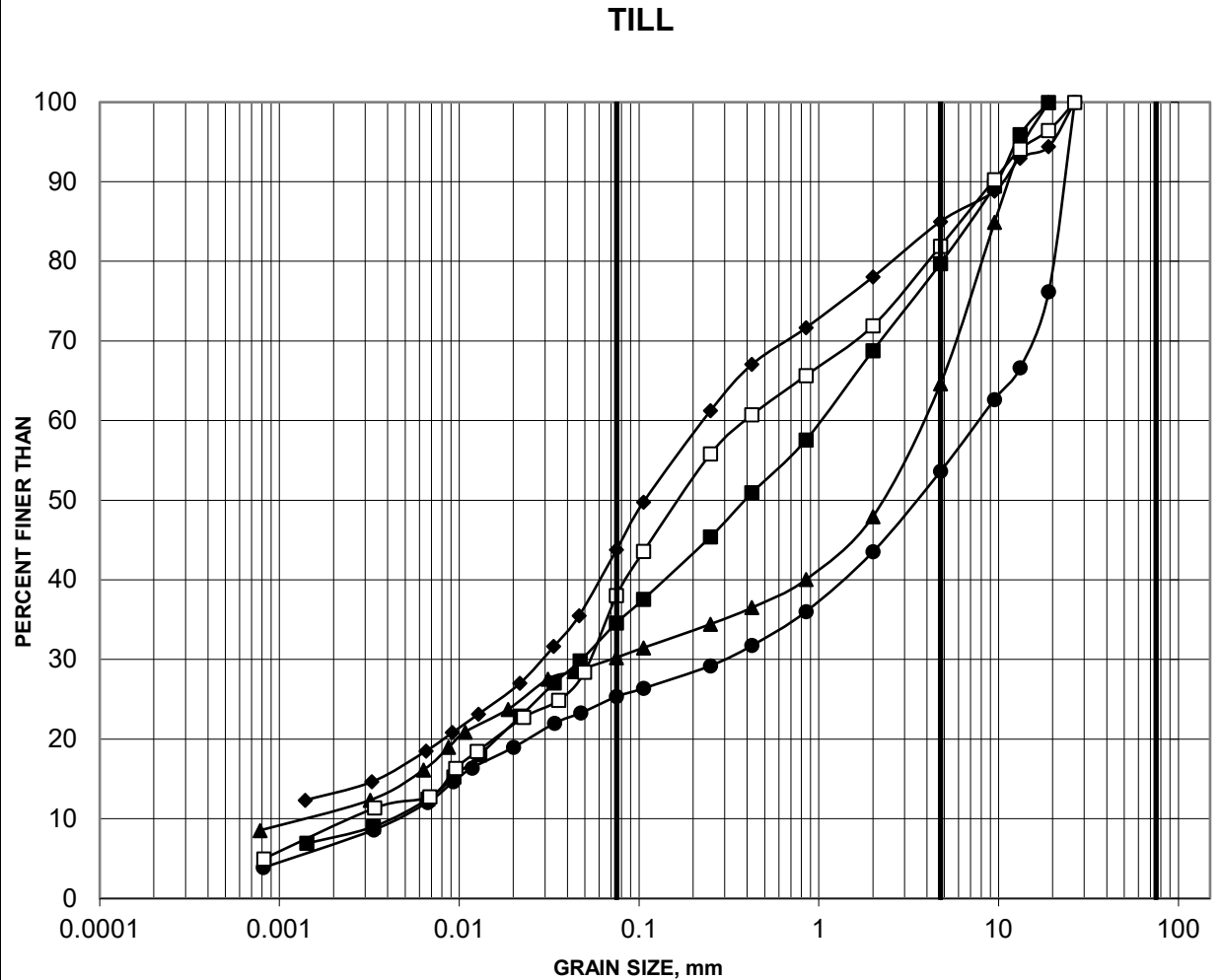
Created by: CW

Checked by: MI

<https://golderassociates.sharepoint.com/sites/35409g/Shared Documents/Active/2016/1662565/Ph 1360/Figures/Figures for BH 3622, 3623, 3624/>

GRAIN SIZE DISTRIBUTION

FIGURE B4



SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

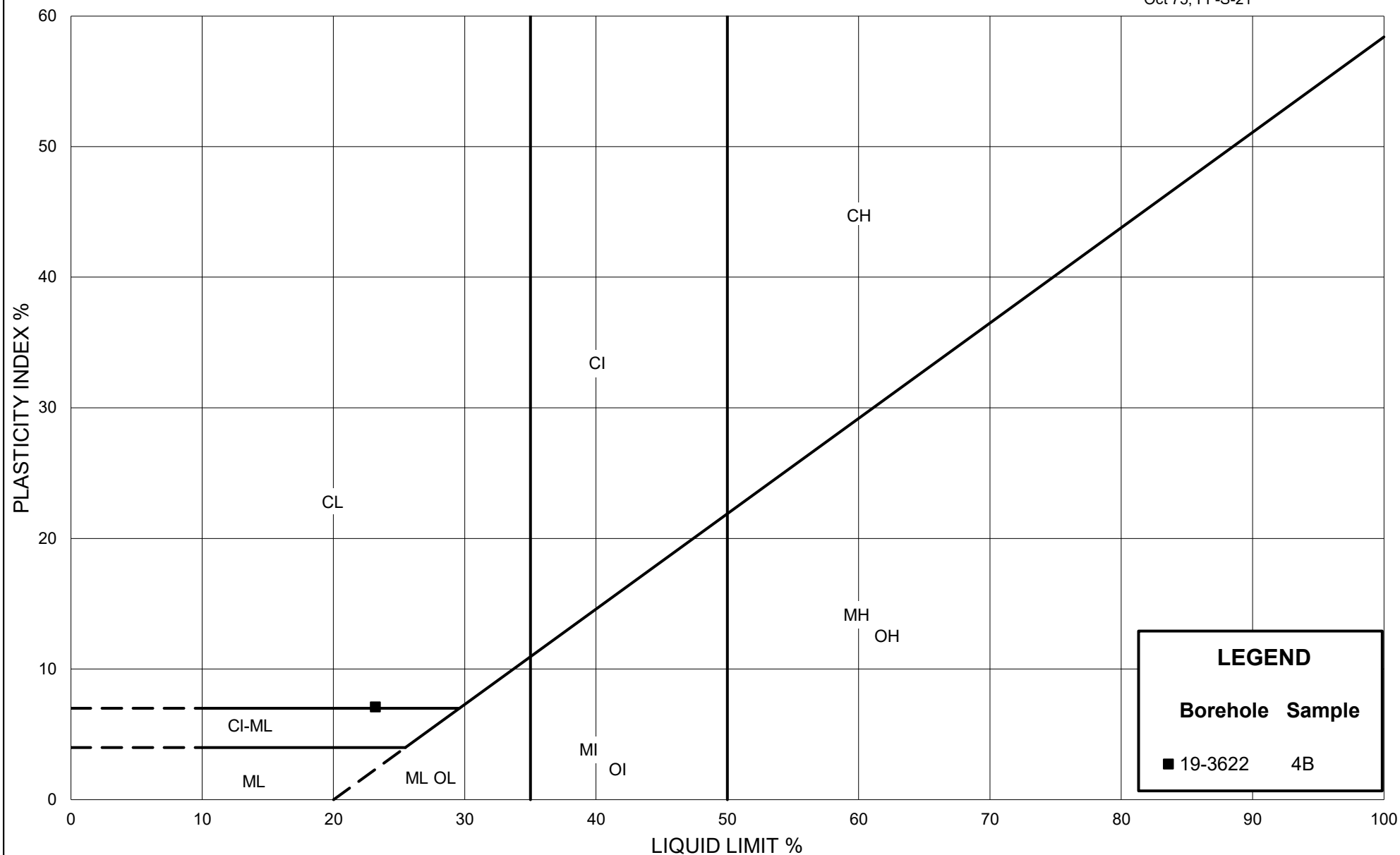
	Borehole	Sample	Depth (m)
■	19-3622	9	4.88-5.49
◆	19-3623	7	4.57-5.18
▲	19-3623	10	6.86-7.47
●	19-3623	13	9.15-9.76
□	19-3624	5	2.44-3.05

Project: 1662565/1360



Created by: MI
Checked by: CW

<https://golderassociates.sharepoint.com/sites/35409g/Shared Documents/Active/2016/1662565/Ph 1360/Figures/Figures for BH 3622, 3623, 3624/>



Ministry of Transportation

PLASTICITY CHART

SILTY SAND (TILL)

Figure: B5

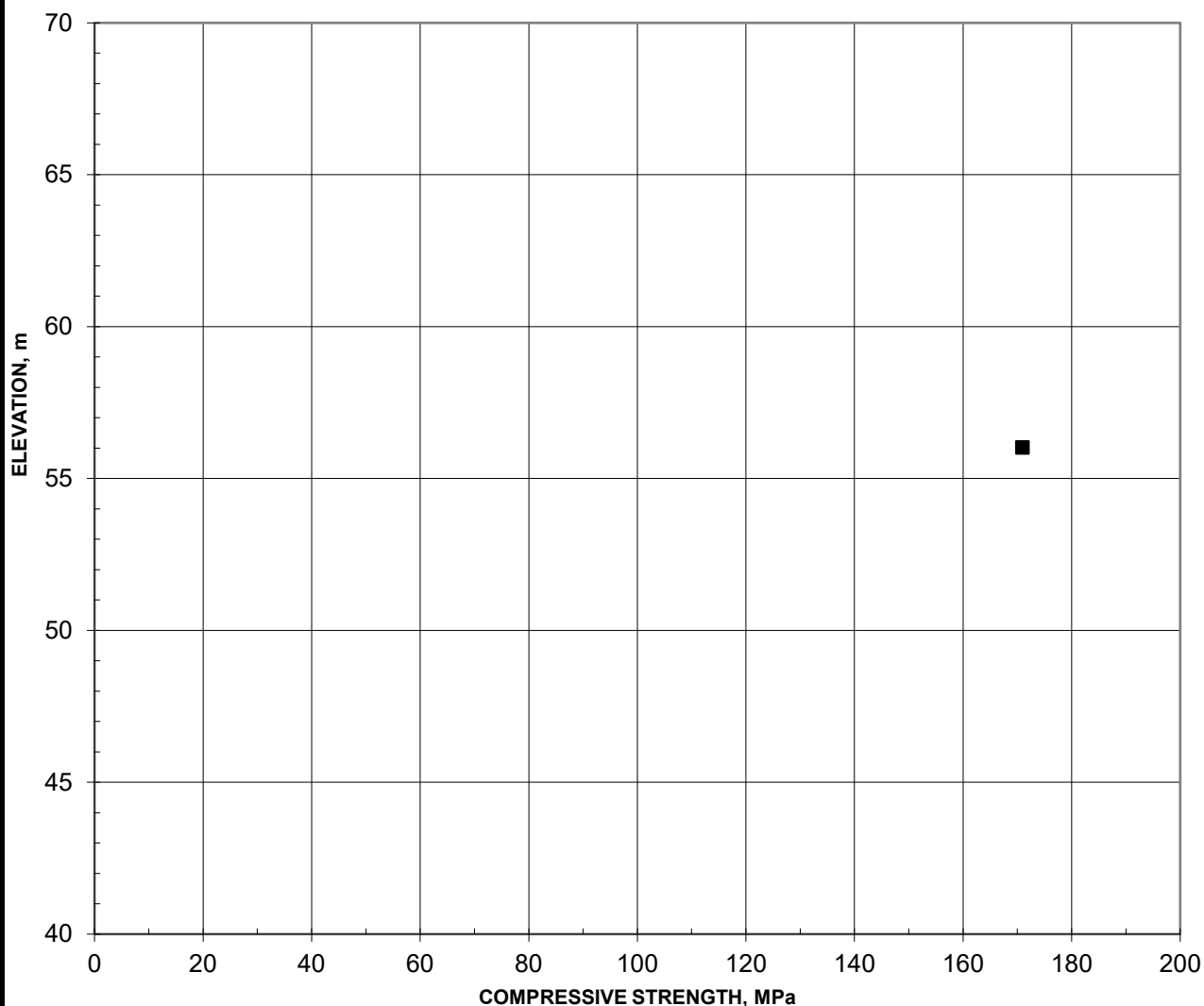
Project: 1662565/1360

Created By: MI

Checked By: CW

SUMMARY OF LABORATORY COMPRESSIVE STRENGTH UNCONFINED COMPRESSION TESTS

FIGURE B6



	Borehole	Compressive Strength (MPa)
■	BH 19-3623	171

Project: 1662565 - 1360



Created by: RK
Checked by: MJK

https://golderassociates.sharepoint.com/sites/11263g/Shared Documents/01_Foundations/6 - Reports/1360 Trenchless Crossings/

APPENDIX C

**Basic Chemical Analysis – Eurofins
Report Number 1818602**

Certificate of Analysis

Client: Golder Associates Ltd. (Ottawa)
1931 Robertson Road
Ottawa, ON
K2H 5B7
Attention: Ms. Kim MacDonald
PO#:
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1924549
Date Submitted: 2020-01-24
Date Reported: 2020-01-31
Project: 1662565 / 1360
COC #: 853765

Group	Analyte	MRL	Units	Guideline	Lab I.D. Sample Matrix Sample Type Sampling Date Sample I.D.	1476878 Soil 2019-11-17 19-3603 sa5 / 9-10'	1476879 Soil 2019-09-15 19-3605 sa4 / 7.5-8.25'	1476880 Soil 2019-09-26 19-3608 sa3A / 5-6.5'	1476881 Soil 2019-10-07 19-3612 sa8 / 14-16'
General Chemistry	Anions	Cl	0.002	%		0.012	0.025	0.041	0.027
		SO4	0.01	%		0.15	0.21	0.07	0.04
		Electrical Conductivity	0.05	mS/cm		1.02	1.69	1.38	0.80
		pH	2.00			7.55	8.00	8.61	7.91
		Resistivity	1	ohm-cm		982	590	727	1270

Group	Analyte	MRL	Units	Guideline	Lab I.D. Sample Matrix Sample Type Sampling Date Sample I.D.	1476882 Soil 2019-10-02 19-3616 sa8 / 17.5-20'	1476883 Soil 2019-10-06 19-3619 sa7 / 15-17'	1476884 Soil 2019-09-18 19-3623 sa11 / 25-25'11"	1476885 Soil 2019-12-03 19-3627 sa7/ 15-17'
General Chemistry	Anions	Cl	0.002	%		0.005	0.032	0.017	0.010
		SO4	0.01	%		0.08	0.07	0.06	0.03
		Electrical Conductivity	0.05	mS/cm		0.52	0.69	0.64	0.45
		pH	2.00			7.91	7.93	8.17	8.53
		Resistivity	1	ohm-cm		1940	1450	1560	2220

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

**Non-Standard Special Provisions,
NSSP Obstructions,
Special Provision - Pipe Installation by Trenchless Method**

OBSTRUCTIONS – Item No.

Special Provision

The native soils at this site are comprised of glacial till and are known to contain cobbles and boulders. Shale fragments were also encountered within the embankment fill material. Appropriate equipment and construction procedures will be required to penetrate or remove obstructions, such as cobbles and boulders, to permit installation of deep foundations 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

PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Special Provision

January 2019

CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY TRENCHLESS METHODS

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10.0	BASIS OF PAYMENT
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
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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 m³ 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.

4.02 Submission Requirements

4.02.01 Qualifications

At least two weeks prior to construction, the names and the demonstrated project experience 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' demonstrated 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' demonstrated experience on projects with similar scope and complexity

4.02.01.03 Design Engineer

The Design Engineer shall have a minimum of five years' demonstrated 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' demonstrated 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.

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.

7.0 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 boulders are expected within the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. Removal of cobbles shall be expected to be routine and will not be considered cause for delay or additional compensation and the Contractor's trenchless equipment shall be appropriately equipped and operated for these conditions. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

7.01.12 Removal of Obstructions

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

7.01.13 Management of Excess Material

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

7.01.14 Site Restoration

Site restoration shall be according to OPSS 492.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

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

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

7.02.02 Pipe Installation

Concrete pipe joints shall be 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 OSHA 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

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

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, settlement instrumentation and monitoring, site restoration, and all other work necessary to complete the installation as specified.

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.



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