



FOUNDATION INVESTIGATION AND DESIGN REPORT

**Highway 65, Station 20+638, Township of James
Culvert Replacement
Ministry of Transportation, Ontario
GWP 5204-14-00**

Submitted to:

AECOM Canada Ltd

189 Wyld Street, Suite 103
North Bay, ON P1B 1Z2

Submitted by:

Golder Associates Ltd.

33 Mackenzie Street, Suite 100
Sudbury, Ontario, P3C 4Y1, Canada
+1 705 524 6861

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PART A

FOUNDATION INVESTIGATION REPORT
HIGHWAY 65, STA 20+638, TOWNSHIP OF JAMES
CULVERT REPLACEMENT
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5204-14-00

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services related to the replacement of the culvert on Highway 65 at Station 20+638, in the Township of James, Ontario, approximately 3.3 km northwest of the intersection with Payne Road. The Key Plan of the general location of this section of Highway 65 and the location of the investigated area are shown on Drawing 1.

The purpose of this investigation is to establish the subsurface conditions at the culvert replacement site by borehole drilling with laboratory testing carried out on selected soil samples.

The Terms of Reference (TOR) and the scope of services for the foundation investigation are outlined in MTO's Request for Proposal, dated February 2018, and the subsequent clarifications/addenda, which forms part of the Consultant's Assignment Number 5017-E-0039 for this project. The services have been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering for this project dated November 2018.

2.0 SITE DESCRIPTION

It should be noted that the orientation (i.e., north, south, east, west) stated in the text of the report is typically referenced to project north and therefore may differ from magnetic north shown on the Drawing 1. For the purpose of this report, Highway 65 is oriented in a west-east direction with the culvert positioned perpendicular to the highway generally in a north-south orientation. At the culvert location, the creek flows in a north to south direction.

The existing culvert consists of a 1.8 m diameter, 33 m long Corrugated Steel Pipe (CSP). The culvert inlet (north end) and outlet (south end) inverts are approximately Elevations 281.3 m and 280.6 m, respectively. In general, the topography within the vicinity of the culvert consists of relatively flat terrain, with the Montreal River flowing easterly about 300 m to the south of Highway 65. At the culvert location, the highway grade is at approximately Elevation 287.5 m and the embankment is approximately 6.6 m high relative to the culvert invert. The ground surface conditions at select locations for the culvert area are shown on Photographs 1 to 4.

3.0 INVESTIGATION PROCEDURES

Field work for this subsurface investigation was carried out between November 7 and 14, 2018, during which time five boreholes (Boreholes C14-1 to C14-5) were advanced at approximate locations shown on Drawing 1. Three boreholes were advanced through the roadway embankment and two boreholes were advanced near the toes of the highway embankment slopes adjacent to the culvert inlet and outlet. Boreholes C14-1, C14-2 and C14-4 were advanced using a track mounted CME-55 drill rig supplied and operated by Landcore Drilling of Chelmsford, Ontario. Boreholes C14-3 and C14-5 were advanced using a track mounted CME-55LC drill rig supplied and operated by George Downing Estate Drilling of Grenville-Sur-La-Rouge, Quebec. Traffic control, where required, was performed in accordance with MTO's Ontario Traffic Control Manual Book 7 – Temporary Conditions.

Boreholes C14-1, C14-2, C14-4 and C14-5 were advanced using 108 mm I.D. Hollow Stem Augers while Borehole C14-3 was advanced with 108 mm I.D. Hollow Stem Augers and NW casing with wash boring techniques. Soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers driven by an automatic hammer in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586). The groundwater level inside the augers/casing was observed during

drilling operations. The boreholes were backfilled in accordance with Ontario Regulation 903. The roadway surface at the boreholes drilled through Highway 65 were capped at ground surface using cold patch asphalt.

Field work was supervised on a full-time basis by a member of Golder's technical staff who: located the boreholes in the field; arranged for the clearance of underground services; supervised the drilling and sampling operations; logged the boreholes; and examined the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder's geotechnical laboratory in Sudbury for further examination and laboratory testing. Index and classification testing consisting of water content determinations, grain size distribution, and Atterberg limits was carried out on selected soil samples. The geotechnical laboratory testing was completed according to ASTM and MTO LS standards, as applicable. A soil sample was submitted to an accredited analytical laboratory (Maxxam) for testing of a suite of corrosivity indicator parameters.

The as-drilled borehole locations were measured relative to highway chainages/stations marked on the pavement by a member of our technical staff to an accuracy of 0.1 m and converted into northing/easting coordinates on the plan drawing. The ground surface elevation at the borehole locations was surveyed by Golder relative to the highway and culvert centreline to an accuracy of 0.1 m, with the elevation of the centreline provided by AECOM. The MTM NAD 83-CSRS CBN v6-2010.0 (Zone 12) northing and easting coordinates, geographical coordinates, ground surface elevations referenced to Geodetic datum, and drilled depths of each borehole are presented on the borehole records in Appendix A and summarized below.

Borehole Number	MTM NAD 83 Northing (m) (Latitude)	MTM NAD 83 Easting (m) (Longitude)	Ground Surface Elevation (m)	Borehole Depth (m)
C14-1	5284082.6 (47.693581)	359201.9 (-80.275211)	287.6	15.9
C14-2	5284102.5 (47.693761)	359184.4 (-80.275441)	287.4	15.9
C14-3	5284088.8 (47.693637)	359192.6 (-80.275334)	287.4	20.4
C14-4	5284107.4 (47.693803)	359207.4 (-80.275134)	282.8	9.8
C14 -5	5284087.9 (47.693631)	359173.3 (-80.275591)	282.0	11.3

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain Study (NOEGTS)¹ mapping, the subsoils in the vicinity of the culvert site are located within a glaciolacustrine plain, consisting of clay and sand.

Based on geological mapping (MNDM)², the site is underlain by mafic and related intrusive rocks and mafic dikes.

¹ Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41PNE

² Ontario Ministry of Northern Development and Mines. Bedrock Geology of Ontario, East-Central Sheet. Map 2543

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the summary results of in situ and laboratory testing are given on the Record of Borehole sheets contained in Appendix A. The detailed results of geotechnical laboratory testing are contained in Appendix B. The results of the in-situ field tests (i.e., SPT “N”-values) as presented on the Record of Borehole sheets and discussed in Section 4.2 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profiles shown on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The results of the analytical laboratory testing (by Maxxam) are summarized in Section 4.4 and the detailed laboratory testing report is included in Appendix B.

The subsurface conditions will vary between and beyond the borehole locations, however, the factual data presented on the Record of Borehole sheets governs any interpretation of the site conditions. A summary description of the soil deposits and groundwater conditions encountered in the boreholes is provided below. It should be noted that the interpreted stratigraphy shown on Drawing 1 is a simplification of the subsurface conditions.

4.2.1 Asphalt/Fill

An approximately 90 mm to 100 mm thick layer of asphalt pavement was encountered from ground surface in the roadway Boreholes C14-1 to C14-3 between Elevations 287.6 m and 287.4 m. Below the asphalt, a 0.2 m to 0.3 m layer of sand and gravel fill was encountered underlain by a 100 mm to 200 mm thick layer of asphalt pavement. Underlying the second layer of asphalt, a 4.5 m to 6.1 m thick layer of embankment fill consisting of interlayers of silt, sandy silt to silt and sand to sand and gravel and was encountered. Boreholes C14-1 and C14-3 encountered auger grinding at depths between about 2.3 m and 4.6 m below ground surface. A 100 mm layer of asphalt pavement was encountered in Borehole C14-3 at Elevation 282.8 m. The fill in Borehole C14-1 contains trace organics between Elevations 285.6 m and 285.5 m. Borehole C14-3 encountered trace organics and trace wood between Elevations 286.0 m and 285.3 m and wood pieces between Elevations 282.7 and 280.8.

An approximately 0.3 m thick layer of sandy topsoil fill was encountered from ground surface in Borehole C14-4 at Elevation 282.8 m, underlain by an approximately 0.5 m thick layer of silt fill.

An approximately 0.8 m thick layer of silty sand fill was encountered from ground surface in Borehole C14-5 at Elevation 282.0 m, underlain by a 100 mm thick layer of asphalt pavement, underlain by a 0.5 m thick layer of silty sand fill.

The SPT “N”-values measured within the silt to silty sand to sand to sand and gravel fill range between two blows and 36 blows per 0.3 m of penetration and one SPT “N”-value of 71 blows per 0.3 m of penetration within a zone noted as auger grinding, generally indicating a very loose to dense compactness condition.

Grain size distribution analysis was carried out on three samples of the fill and the results are presented on Figure B-1 in Appendix B. The water content measured on the samples of the fill generally range from 3 per cent to 10 per cent and one water content of 24 per cent water content.

4.2.2 Peat

An approximately 0.3 m thick layer of amorphous peat was encountered in Borehole C14-1 at Elevation 282.6 m. An approximately 0.1 m thick deposit of silty peat was encountered within Borehole C14-3 at Elevation 280.8.

4.2.3 Silt to Silt and Sand

A deposit of non-cohesive, interlayered strata comprised of silt to sandy silt to silt and sand to sand was encountered underlying the fill or peat in Boreholes C14-1 to C14-5 between Elevations 282.3 m and 280.6 m. Pockets of organic soil ranging from 0.6 m to 0.8 m thick were encountered in Boreholes C14-2, C14-4 and C14-5 within the samples near the surface of the deposit as noted on the Record of Boreholes. Silty clay layer/seams ranging in thickness between 25 mm and 400 mm were encountered in Boreholes C14-3 to C14-5 within lower portions of the non-cohesive deposit as noted on the Record of Boreholes. Boreholes C14-1 to C14-5 were terminated within the silt to silt and sand deposit after exploring the deposit for thicknesses between 9.0 m and 13.7 m.

The SPT “N”-values measured within the silt to sand and silt deposit range from 0 blows (weight of hammer) to 18 blows per 0.3 m of penetration indicating that the deposit is in a very loose to compact compactness condition.

Grain size distribution analysis was carried out on twelve samples of the deposit and the results are presented on Figure B-2 in Appendix B. Atterberg limits tests were carried out on two samples of the non-cohesive portion of the deposit and one sample of the cohesive interlayers/seams. The non-cohesive samples yielded non-plastic results while the sample from the cohesive interlayer measured a liquid limit of 48 per cent, a plastic limit of 17 per cent and a plastic index of 31 per cent. The result of the Atterberg limits test on the cohesive sample is presented on Figure B-3 in Appendix B and indicates that the cohesive layers are comprised of silty clay of intermediate plasticity. The water content measured on thirteen samples of the deposit range from 21 per cent to 25 per cent, with a water content of 36 per cent measured and sample of silty clay seam.

4.3 Groundwater Conditions

The unstabilized groundwater levels relative to ground surface measured inside the casing or hollow stem augers upon completion of drilling are summarized below. The top of frozen creek surface near the culvert outlet, as surveyed by Golder on November 14, 2018, was about Elevation 280.0 m. Groundwater and creek water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

Borehole No.	Depth to Unstabilized Groundwater Level (m)	Approximate Groundwater Elevation (m)
C14-1	5.6	282.0
C14-2	5.0	282.4
C14-3	4.3	283.1
C14-4	1.6	281.2
C14-5	2.0	280.0

4.4 Analytical Laboratory Testing Results

Analytical testing of a suite of corrosivity indicator parameters was carried out on a silty sand soil sample recovered from Borehole C14-3 by Maxxam Analytics of Sudbury, Ontario. The analytical laboratory test results are summarized below and the detailed analytical laboratory test report is included in Appendix B.

Borehole No.	Sample No.	Depth (m)	Parameters					
			Resistivity (ohm/cm)	Electrical Conductivity (µmho/cm)	Soluble Sulphate (SO ₄) Content (µg/g)	Sulphide (µg/g)	Chloride (Cl) Content (µg/g)	pH
C14-3	8	6.1 – 6.7	1,200	868	<20 ¹	7.35	430	7.23

Note:

1. The sulphate concentration is below the reportable detection limit of 20 µg/g.

5.0 CLOSURE

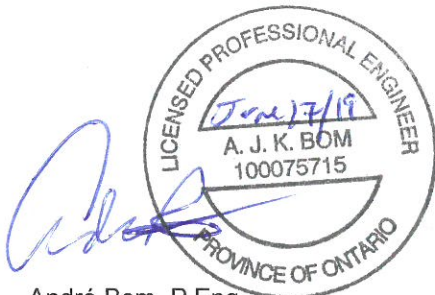
The field drilling program was carried out under the supervision of Mr. Tibor Berecz, under the overall direction of Mr. André Bom, P.Eng. This Foundation Investigation Report was prepared by Mr. Gavin Mundry, and Mr. André Bom, P.Eng., provided a technical review of the report. Mr. Jorge Costa, P.Eng., an MTO Foundations Designated Contact and Senior Consultant for Golder, conducted an independent quality control review of the report.

Signature Page

Golder Associates Ltd.



Gavin Mundry, EIT
Geotechnical Engineer-in-Training



André Bom, P.Eng.
Senior Geotechnical Engineer, Associate



Jorge M. A. Costa, P.Eng.
MTO Foundations Designated Contact, Senior Consultant

GM/AB/JMAC/sb

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PART B

FOUNDATION DESIGN REPORT
HIGHWAY 65, STA 20+638, TOWNSHIP OF JAMES
CULVERT REPLACEMENT
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5204-14-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the replacement of the culvert crossing Highway 65 at about Station 20+638, Township of James, Ontario, approximately 3.3 km northwest of the intersection with Payne Road. These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current subsurface investigation. The discussion and recommendations presented are intended to provide the designer with sufficient information to assess feasible foundation alternatives and to design the proposed replacement culvert. 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 or design-build 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, and for which special provisions may be required in the Contract Documents. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 Proposed Culvert Alignment and Installation Options

The existing culvert consists of a 1.8 m diameter, 33 m long Corrugated Steel Pipe. Based on the drawings provided by AECOM via email on March 14, 2019 and our site observations during the Foundations Investigation, the existing culvert crosses the existing Highway 65 embankment on a perpendicular alignment; and we understand from AECOM that the proposed replacement culvert will cross the highway on or near the existing culvert alignment and will be of similar circular size as the existing culvert. As noted in Section 2.0, the existing embankment is about 6.6 m high relative to the culvert invert, and the invert at the inlet (north end) and outlet (south end) of the proposed culvert are about Elevations 281.3 m and 280.6 m, respectively. Based on documentation supplied by AECOM and our site observations, the existing culvert appears to be in good condition with minor rusting. There are no indications of embankment or pavement distress in the immediate vicinity of the culvert. We understand from AECOM that temporary grade lowering of the highway is being considered to allow for culvert replacement, but a permanent grade raise or widening is not required. We further understand that a temporary detour will not be required/utilized for traffic staging during culvert replacement operations.

Depending on construction staging and as an alternative to open cut construction of the new culvert, consideration may also be given to replacing the culvert using a trenchless method. Based on the existing ground surface profile along the proposed culvert alignment, the existing soil cover over the top of the culvert is about 4.8 m, and the ratio of existing cover-to-pipe diameter is about 2.6. The proposed replacement culvert is also 1.8 m in diameter, resulting in a soil cover-to-tunnel diameter ratio of about 2.4 if a 2.0 m diameter liner is used, which is considered a suitable condition for a trenchless installation method, and the actual ratio will depend on the installation method and size of liner actually used.

6.2 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the *Canadian Highway Bridge Design Code* (CHBDC, 2014) and its *Commentary*, the section of Highway 65 crossing over the proposed culvert and its foundation system is expected to carry medium traffic volumes and its performance will have potential impacts on other transportation corridors;

hence, the structure is classified as having a “typical consequence level” associated with exceeding limits states design. In addition, given the typical project-specific foundation investigation carried out at this site (as presented in Part A of the report), in comparison to the degree of site understanding in Section 6.5 of *CHBDC* (2014), the level of confidence for design is considered to be a “typical degree of site and prediction model understanding.” Accordingly, the appropriate corresponding ultimate limit state (ULS) and serviceability limit state (SLS) consequence factor, Ψ , and geotechnical resistance factors, ϕ_{gu} and ϕ_{gs} , from Tables 6.1 and 6.2 of the *CHBDC* have been used for design.

6.3 Circular Culvert Installation by Open Cut Excavation

6.3.1 Settlement and Stability

Provided the proposed reconstructed embankment is not widened or raised following culvert replacement, immediate or long-term settlement of the foundation soils beneath the culvert is not anticipated. For the purposes of this report, we have assumed that a temporary widening is not required. If a temporary or permanent grade raise or widening is required, then a settlement analysis should be carried out, although it is expected that settlement of the subgrade would be less than 25 mm and occur during construction given the presence of primarily non-cohesive soils below ground surface.

The proposed reconstructed embankment (after culvert replacement) will be stable from a slope stability perspective if it is reconstructed of granular material and with side slopes at an inclination of 2 horizontal to 1 vertical (2H:1V).

6.3.2 Bedding and Cover

It is not necessary to found a pipe culvert below the depth for frost penetration, as pipe culverts are tolerant of small magnitudes of movement related to freeze-thaw cycles. A circular pipe concrete culvert installed by open cut method should be completed in accordance with Ontario Provincial Standard Drawing (OPSD) 802.031 (*Rigid Pipe Bedding, Cover and Backfill*), and should be designed in accordance with the MTO Gravity Pipe Design Guidelines (2014). If the replacement culvert is to consist of a CSP or plastic pipe installed by open cut method, it should be constructed in accordance with OPSD 802.014 (*Flexible Pipe Embedment in Embankment*). All unsuitable, deleterious, organic materials and fill materials are to be removed from the base/below the culvert along the entire alignment. The bedding should be compatible with the class of pipe, the surrounding subsoil and anticipated loading conditions and should consist of OPSS.PROV 1010 (Aggregates) Granular ‘A’ material. Depending on the success of the contractor’s groundwater control methods, and the quality of the bearing stratum exposed at the base of the excavation, a thicker bedding layer, may be required at some locations where wet and softened soil conditions, unsuitable fill, or organic material are present at base of the excavation. Therefore, the Contract Documents should include a provision for additional thickness of compacted Granular ‘A’ bedding, if required.

From the top of the bedding to 300 mm above the obvert of the culvert, Granular ‘A’ should be used around the culvert. All bedding and cover materials should be placed, and culvert construction carried out in accordance with OPSS.PROV 421 (*Pipe Culvert Installation in Open Cut*) and OPSS 401 (*Trenching, Backfilling and Compacting*), and the bedding/cover soil should be compacted in accordance with OPSS.PROV 501 (*Compacting*). If the bottom of the excavation is wet and dewatering is not satisfactorily maintaining the water level sufficiently below the base of the excavation to allow compaction, it is recommended that OPSS.PROV 1010 (*Aggregates*) Granular

'B' Type II material be used for bedding and as any additional sub-excavation backfill below the bedding, as required.

6.3.2.1 Trench Backfill

The excavated fill materials from the culvert site will vary in quality and composition of sand and gravel to sand to silty sand to silt. The majority of the excavated fill materials, where encountered above the water table, should be generally near their estimated optimum water contents for compaction provided they are protected from precipitation once they are exposed. Soils encountered below the water table would likely require significant drying in order to reach optimum water content for compaction. The excavated granular fill where encountered above the groundwater level and maintained at suitable water content, may be reused as trench backfill over the culvert cover material, provided these materials are free of organics, or other deleterious material (wood, construction rubble) and are placed and compacted accordance with OPSS.PROV 501 (*Compacting*). The silt to silty sand fill, or the native sand to silt if excavated, should not be reused as backfill.

Alternatively, granular material which meets the requirements of OPSS.PROV 1010 (*Aggregates*) Select Subgrade Material (SSM) or Granular 'B' Type I may be used as trench backfill. These materials should also be placed and compacted in accordance with OPSS.PROV 501 (*Compacting*).

6.4 Assessment of Trenchless Installation Methods

6.4.1 Subsurface Conditions and Tunnelman's Ground Classification

We understand that consideration may be given to replacement of the culvert by a trenchless method. The soil conditions encountered along the proposed culvert alignment are relatively consistent, and generally the soils encountered along the proposed tunnel horizon include very loose to compact silty sand embankment fill and very loose to compact deposits of silt to sandy silt to silty sand. The groundwater level measured inside the hollow stem augers casing on completion of drilling in Boreholes C14-3 to C14-5 nearest the existing culvert range between Elevation 283.1 m and 280.0 m, compared to the frozen creek surface which was measured at the outlet at Elevation 280.0 m on November 14, 2018. Therefore, the groundwater level is expected to be at about the proposed culvert/tunnel horizon.

Correlating the soil classification with the Tunnelman's Ground Classification System (Heuer, 1974, modified from Terzaghi, 1950), existing embankment fill along the tunnel horizon (silty sand) and the primarily fine, relatively uniform, native granular soils (silt to sandy silt to silt and sand) can be considered "cohesive running" to "running" above the groundwater level and "flowing" below the groundwater level. It is expected that these soils, when exposed fully above groundwater or after dewatering, may be able to stand unsupported for a limited length of time prior to "running" or exhibiting "cohesive running" behaviour (in the order of a few minutes to hours). Below groundwater levels, the existing embankment fill and native soils will be unable to stand unsupported for any length of time and will exhibit "flowing" behaviour and destabilize any overlying materials.

6.4.2 General Description of 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 by the contractor, however this report provides guidance on the influence of ground behaviour on some

possible pipe culvert/tunnel installation methods. It should not be construed that the contractor is restricted to the particular methods considered herein, and in the event of alternative methods, the contractor must make his own interpretation of the anticipated ground behaviour, based on the factual information from the investigation. Trenchless work should be carried out in accordance with MTO's Special Provision (SP) titled "Pipe Installation by Trenchless Method" included in Appendix C.

For the proposed culvert installation for this project, a number of trenchless construction methods were considered for completeness, though the practicality of some of these techniques for this project may be doubtful if not entirely unsuitable. The trenchless techniques considered from a general perspective include horizontal directional drilling (HDD), pipe jacking and horizontal auger boring, pipe ramming, micro-tunneling by MTBM, pilot tube micro-tunneling, tunnel boring machine (TBM) and tunnel digging machine (TDM - i.e., open face shield tunnelling). In brief, these construction methods involve the following:

- **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 carrier would be pulled through the bore (using the drill rods to pull the pipe into place). HDD equipment is available for drilling in both bedrock and overburden but is very challenging in bouldery ground. Deep entrance and exit pits are generally not required, however, larger laydown areas are required to install the carrier 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 m in diameter. Control of line and grade to the degree needed for gravity flow at shallow storm or sanitary sewer slopes may be problematic.
- **Pipe Jacking and Horizontal Auger Boring "Jack and Bore":** A pipe jacking operation involves pushing an oversized liner pipe (casing) horizontally into the ground by jacking. The spoil is generally removed from within the casing using an auger boring machine. The cutting head is driven by, and is positioned at, the leading end of an auger string that is established within the casing pipe. The profile needs to be approximately horizontal. Jacking and receiving pits are required. There can be limited ability to steer the casing during jacking. This method is only applicable to construction in the overburden and may not be feasible in bouldery soils (e.g., glacial till). This method is also not feasible in "running" or "flowing" ground (dry or saturated silt, silt and sand, sand silt).
- **Pipe Ramming:** Pipe ramming is a trenchless method that uses a pneumatic tool to hammer a steel pipe or casing into the ground. The pipe is almost always driven 'open' to thereby direct the soil into the pipe interior instead of compacting it outside the pipe. The leading edge of the pipe typically has a small overcut to reduce friction between the carrier pipe and soil and to improve the load conditions on the pipe. Soil/pipe friction reduction can also be achieved with lubrication, and different types of bentonite and/or polymers can be used for this purpose. Depending on the length of the installation, the soils inside the pipe can be removed either during or after the installation by augering, compressed air or water jetting. Pipe ramming 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 has also been used to accomplish culvert replacement in which a larger diameter pipe is rammed through the ground immediately around an existing pipe and both the existing pipe and ground are removed from within the rammed pipe by manual methods. This technique is sometimes called "pipe eating" or "pipe swallowing."
- **Micro-tunnelling Boring Machine (MTBM):** MTBM is a method of installing pipes in bores ranging from 0.6 m to 3 m diameter behind a steerable remote-controlled shield that is pressurized with a bentonitic slurry at

the cutting face to minimize ground losses. The process is essentially remote-controlled pipe jacking where all operations are controlled from the surface, cuttings are removed by the circulating slurry, and the necessity for personnel to enter the bore is eliminated. Micro-tunnelling equipment is generally more suited to tunnelling through overburden. Availability of this equipment in the project area is limited. Non-slurry MTBM installation methods are not suitable for these cohesionless ground conditions at this site.

- **Pilot Tube Micro-tunnelling (PTMT):** PTMT employs augers for excavation and soil removal and a jacking system for advancing the drill pipes, casings and carrier pipes. The guidance system comprises a target with LEDs mounted in the steering head of the equipment that is monitored through a TV monitor. The PTMT operation includes pilot boring and reaming and, since this technique is used for smaller size pipes, the equipment and space required for this operation is smaller than what is normally required for pipe jacking or microtunnelling. PTMT can obtain an accuracy of 10 mm per 100 m of pipe length; however, the accuracy depends on the ground conditions, the accuracy of the guidance system and the operator's skill. The "pilot tube" is advanced in a similar fashion to horizontal directional drilling with a guidance system used to control alignment and grade.

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 steering head is used for pilot boring and adjustment of alignment and grade and the bore hole is subsequently enlarged by a reamer with an auger string inside the casing used to remove cuttings. Temporary casings, if applicable, or the final pipe follows the reamer into the ground.

- **Tunnel Boring Machine (TBM):** TBM tunnelling operations involve the advance of a steerable machine with a rotating cutter head that is jacked horizontally into the ground at the lead end of the pipe or temporary lining system. Successive sections of temporary liner pipe or the final product pipe advance behind the TBM by pipe jacking. Alternatively, steel liner plates, steel ribs and wood lagging or segmental precast concrete liner systems can be installed as the TBM advances. The spoil is removed from the tunnel as the TBM is advanced, using a combination of screw augers (in some instances), conveyor belts or mucking cars. The cutting head is driven and steered by an operator inside the TBM and the TBM head and face may be partially open or provided with doors to allow for access to the face. Jacking and receiving pits are required. Locally, this method is generally used for construction in overburden, and open-faced machines have been used in cohesive and bouldery soils that exhibit significant "stand up time" (e.g., glacial till). Excavations through sandy soils below groundwater levels 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 microtunnelling.
- **Tunnel Digging Machine (TDM):** TDM tunnelling, also called open-face shield tunnelling, involves excavating the soils using a hydraulic excavator arm, working within a full-circumference tunnelling shield. Alternatively, hand mining (i.e., manual excavation) within the tunnelling shield could be carried out whereby the soil would be excavated using manual equipment with workers at the face. Typically, the temporary tunnel liner (i.e., steel casing, steel ribs and lagging, steel liner plates, etc.) will be constructed from within the machine or final pipe would be jacked in sections from the launching shaft. Unlike traditional "jack and bore" methods, 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.

6.4.3 Assessment for Feasible Installation Methods

The ground conditions along the culvert alignment within the tunnel vertical limits are likely to generally consist of silty sand fill and native silt to silt and sand to sand at or below the groundwater levels along the invert and silty sand fill along the obvert. Based on the ground conditions and the anticipated relatively short tunnel distance of about 35 m, HDD, TBM, TDM and PTMT methods are likely not suitable and are not cost-effective. The diameter of the culvert will preclude the use of HDD. MTBM would likely be effective in the anticipated ground conditions but is uneconomical over short distances but could be economical for multiple sites in the same area.

Considering the ground conditions, groundwater levels, tunnel distances and local capabilities, the use of Pipe Ramming is likely to be the most feasible and suitable trenchless installation method of the culvert at this site. It should be noted that interventions to remove obstructions may still be necessary. The following geotechnical issues/risks associated with the trenchless construction that should be considered and evaluated at this site are:

- Ground or Road Heave – a shallow culvert with diameter that is relatively large as compared to the depth of burial is particularly susceptible to heaving the roadway if the pipe is rammed into place.
- Obstructions – Although cobbles or boulders were not encountered in any of the boreholes advanced at this site, it should be noted that an asphalt layers/fragments and auger grinding were encountered/noted within the fill, and cobbles, boulders, wood, etc. can obstruct or foul trenchless construction equipment if they are encountered while boring. As the culvert would be installed close to or along the interface between the original ground surface and the overlying roadway embankment there is a risk of encountering such objects, depending on how the ground was cleared, stripped, and grubbed prior to embankment placement. In some instances, low and wet areas have historically been filled with larger rock materials in attempts to stabilize the ground. In culvert sites that had such cases, pipe ramming is the least susceptible to equipment fouling and damage if wood debris is encountered.
- Ground or Road Settlement – Given that the water level at this site would likely be at or below the culvert obvert at the time of construction, there is the potential for flow of saturated granular soils (silt/sandy silt, silt and sand) and groundwater back through the spoils within the casing and towards the entrance pit. Such flow could cause significant loss of ground at and above the face of the excavation. These conditions are particularly problematic for traditional “jack and bore”, “small boring unit” and pilot tube micro-tunnelling systems that do not utilize pressurized viscous fluids to support the excavation face. Consideration should be given to specifically identifying the methods that are not suitable since they can commonly be less costly and can be attractive for achieving low bids except the risk of ground losses and roadway settlement would likely be unacceptable. The trenchless methods that are to be considered not suitable at this site have been noted in the SP for Pipe Installation by Trenchless Methods, included in Appendix C.

As a general guideline, the depth of cover above the crown of the new pipe installation should be greater than or equal to the cut diameter of whatever trenchless system is used to excavate the ground or the largest pipe diameter that will be installed, whichever is greater. Similarly, the separation between newly installed pipes should be at least one, and preferably two, tunnel diameters in both the vertical and horizontal directions. Oversize casings should be installed for subsequent installation of the culvert or to permit fine adjustments of the invert channel elevations for final flow control. Selection of casing size should consider the potential for mis-alignment over the tunnel length due to ground conditions (i.e., boulders), access to the tunnel face (if potentially necessary), proposed tunneling methodology and the length of the tunnel drive. We understand from AECOM that a 2 pass-system of tunneling is not typical for centreline culverts in Northeast Ontario. In general, a settlement monitoring program should be implemented that is consistent with OPSS.PROV 539 (Temporary Protection Systems) for shoring systems at the pits if these are near the roadway, as discussed further in Section 6.6.3.

Settlement monitoring of the trenchless crossing (refer to Section 6.6.7) should also be carried out over the entire centreline length of the new culvert alignment at the edge of all pavements, in landscape areas leading to the pavement from the entry pit and at perpendicular off-sets of about 2 m from the centre line at all pavement shoulder edges for a distance equal to the depth from road surface to invert. Given the elevated risk of settlement or heave for this project, contingency plans for traffic management and road repair should be in-place to rapidly mitigate or limit any distress to the overlying highway embankment, if needed.

6.5 Analytical Testing for Construction Materials

The results of analytical tests on one sample of silty sand fill recovered in Borehole C14-3 is summarized in Section 4.4. The potential for sulphate attack and corrosion are discussed in the following paragraphs; however, it is ultimately up to the designer to determine the appropriate construction materials, including the exposure class and ensuring that all aspects of CSA A23.1-14 (2014) Section 4.1.1 "Durability Requirements" are followed when designing concrete elements.

6.5.1 Potential for Sulphate Attack

The analytical test results were compared to CSA A23.1-14 Table 3 ("Additional requirements for concrete subjected to sulphate attack") for the potential sulphate attack on concrete. The water soluble-sulphate concentration measured in the soil sample is less than the reportable detection limit of 0.002 per cent, which is below the exposure class of S-3 (Moderate) and is considered Negligible according to Table 7.2 in the MTO Gravity Pipe Design Guidelines (2014). Therefore, based on the test result for the sample of fill, when the designer is selecting the exposure class for the structure, the effects of sulphates from within the fill may not need to be considered.

6.5.2 Potential for Corrosion

The soil has a pH of 7.3 and according to the MTO Gravity Pipe Design Guidelines (2014), the pH is not considered detrimental to culvert durability. The resistivity is 1,200 ohm-cm, which indicates that the soil corrosiveness is Severe ($2,000 > R$ ohm-cm), as per Table 3.2 of the MTO Gravity Pipe Design Guidelines (2014). It is also noted that sulphide at a concentration of about 7.4 µg/g was detected in the analyzed test sample; and sulphide is considered very corrosive to cast iron/steel materials (Cashman and Preene, 2001). As the culvert will be located under the roadway shoulders and be exposed to de-icing salt, concrete should be designed for a "C" type exposure class as defined by CSA A23.1-14 Table 1. The culvert should be designed with consideration given to Table 7.1 of the MTO Gravity Pipe Design Guidelines (2014).

6.6 Construction Considerations

6.6.1 Open Cut Excavation

The proposed open cut excavations, either for the access shafts for a trenchless pipe installation or for the open cut trench associated with excavating through the embankment and into the subgrade to the base of the culvert bedding level will generally advance through sand and gravel fill and silt to silt and sand to sand fill and into the silt to silt and sand native soils. The excavations are anticipated to extend to or to below the groundwater level. Where space permits, open cut excavations into these materials should be carried out in accordance with the

guidelines outlined in the Occupation Health and Safety Act (OHSA) for Construction Activities. Above the water table, the existing fill material and underlying native granular soils are classified as Type 3 soil (assuming that the native granular soils are dewatered), according to OHSA and temporary excavations (i.e. those which are open for a relatively short time period) should be made with side slopes no steeper than 1 horizontal to 1 vertical (1H:1V). Below the water table, the existing fill material and underlying native fine grained granular soils are classified as Type 4 soil, according to OHSA and temporary excavations (i.e., those which are open for a relatively short time period) into this soil type should be made with side slopes no steeper than 3 horizontal to 1 vertical (3H:1V).

Depending upon the construction procedures adopted by the contractor, groundwater seepage conditions and weather conditions at the time of construction, some local flattening of the slopes of open cut excavations may be required, especially in looser/softer zones or where localized seepage is encountered. Further, layering of soils and the effectiveness of the contractor's dewatering systems could affect the OHSA classification and, therefore, the classification of soils for OHSA purposes must be made at the time the excavation is open and can be directly observed during construction.

6.6.2 Groundwater Control

The groundwater level is expected to be at or slightly below the proposed liner culvert obvert and excavations, whether for open cut installation or entry and exit shafts for trenchless installation, should be expected to extend below the groundwater level. Groundwater control will be required to allow for stable open cut excavations and excavations for entry and exit shafts for trenchless installation, if adopted. The groundwater should be lowered to at least 1 m below the base of excavation to maintain basal stability. Groundwater may be controlled by providing an active dewatering system installed and operated in advance of the excavation, or in combination with a sheet piling wall.

The contractor is responsible for the assessment of dewatering requirements, which depends on their chosen method of open cut excavation and / or trenchless installation, as well as construction / operation / maintenance and decommissioning. The contractor is also responsible for confirming that the radius of the drawdown does not impact the existing embankment. Groundwater and/or surface water control will be required for excavation and construction of the culvert. Dewatering should be carried out in accordance with OPSS.PROV 517 (*Dewatering*) and in accordance with OPSS.PROV 421 (*Pipe Culvert Installation in Open Cut*).

Surface water into excavations should be directed away from open excavation areas to prevent ponding of water that could result in disturbance and weakening of the subgrade.

6.6.3 Temporary Protection Systems

The temporary excavation protection and support systems should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*). The lateral movement of the protection systems should meet Performance Level 2 as specified in OPSS.PROV 539, provided that any utilities, if present, can tolerate this magnitude of deformation.

It is anticipated that a driven interlocking sheet pile system would be suitable and constructible for entry and exit shafts for the trenchless culvert installation, as the Standard Penetration Test (SPT) "N"-values are generally less than about 20 blows per 0.3 m of penetration. The contractor may elect to use a soldier pile and lagging system;

however, the site would need to be adequately dewatered prior to installation of the lagging boards as the silt deposit will not have adequate stand-up time to permit installation of the lagging boards.

The sheet piles or soldier piles will need to extend and be socketed to a sufficient depth to provide the necessary passive resistance for the retained soil height, plus any surcharge loads behind the protection system. Lateral support to the sheet pile wall or soldier pile wall could be provided in the form of rakers or temporary anchors, if and as required.

Vibratory equipment for the installation of temporary protection systems may be used at this site provided that it does not impact the embankment or nearby buried infrastructure. The installation of temporary protection systems by vibratory equipment should be monitored to ensure the vibration levels produced by such construction activity are within tolerable limits and in consultation with the infrastructure / utility and property owners within the zone of influence of the site.

While the selection and design of the temporary protection system will be the responsibility of the contractor, the following information is provided to MTO and its designers to aid in the assessment of the approximate construction costs during detail design.

Stratigraphic Unit	Bulk Unit Weight, γ (kN/m ³)	Internal Angle of Friction, ϕ (degrees)	Undrained Shear Strength, s_u (kPa)	Lateral Earth Pressure Coefficients ^{1/2}		
				Passive, K_p^3	Active, K_a	At-rest, K_o
Embankment Fill – Very loose to dense sand and gravel/silt to silt and sand to sand	20	32	-	3.25	0.31	0.47
Loose to compact silt to sandy silt to silt and sand	19	29	-	2.85	0.35	0.52

Notes:

1. The design groundwater level may be assumed to be Elevation 283 m, based on the water levels in the boreholes.
2. The lateral earth pressure coefficients presented above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are expected, the coefficients should be corrected accordingly.
3. The total passive resistance below the base of the excavation (i.e. adjacent to the temporary protection system) may be calculated based on the values of K_p indicated above but reduced by an appropriate factor that considers the allowable wall movement in accordance with Figure C6.16 of the CHBDC (2014) to account for the fact that a large strain would be required for mobilization of the full passive resistance.

It is recommended that the ground surface extending back/upwards from the top of the protection system to the existing Highway 65 be graded to an inclination no steeper than 2 horizontal to 1 vertical (2H:1V). This should be shown on the Contract staging drawings.

The loading from construction equipment as well as any material stockpiles within a distance defined by a 1 horizontal to 1 vertical line drawn from the bottom of the excavation to the existing ground surface should be included as a surcharge in the design of the temporary protection system.

Consideration could be given to either partial or full removal of the temporary protection system upon completion of construction or each stage of construction (as required). At this site, full removal of the protection system should be considered to mitigate potential impediments to future rehabilitation/reconstruction work. If partial removal is required rather than full removal, an NSSP amending OPSS PROV 539 should be included in the Contract; an example NSSP is included in Appendix C. Vibration and noise controls during extraction of any temporary systems should meet the same tolerable limits used for installation.

6.6.4 Obstructions

Evidence of boulders and cobbles were not directly encountered during the drilling investigation, but they may be inferred to be present from observations during drilling progress in the fill (augers grinding), and buried asphalt layers/fragments were encountered within the fill. Based on experience on similar projects, cobbles and boulders can be present within highway embankment fill which could affect the installation of temporary protection systems or trenchless installations. There is also the potential for the presence of organic material (as encountered in all Boreholes), roots and tree stumps, at the interface of fill and native soils under the existing embankment, due to possible poor stripping practices during the embankment construction. A Notice to Contractor to identify to the contractor the possible presence of cobbles, boulders and deleterious material such as asphalt fragments within the fill soils and organics at the fill and native soil interface, should be included in the Contract Documents; a copy of which is included in Appendix C.

6.6.5 Subgrade Protection

For open cut culvert installation, the subgrade soils will be susceptible to disturbance from construction traffic and/or ponded water. To limit this degradation, it is recommended that the granular bedding layer be placed immediately after preparation and approval of the subgrade.

6.6.6 Embankment Reconstruction/Erosion Protection/Topsoil-Seeding

Fill for reconstruction of the embankment after open cut culvert replacement should consist of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type I or Type II material. The embankment fill should be placed and compacted in accordance with OPSS.PROV 501 (Compacting) and OPSS.PROV 206 (Grading). Embankment side slopes should be constructed no steeper than 2 Horizontal to 1 Vertical (2H:1V) in granular fill.

Erosion protection should be addressed by the designers at the culvert ends if the potential for hydraulic scour is possible depending on the creek water flow conditions.

To reduce surface water erosion on the granular embankment side slopes below the pavement structure, topsoil and seeding as per OPSS 802 (Topsoil) and OPSS.PROV 804 (Seed and Cover) should be carried out as soon as possible after construction of the embankments. If this slope protection is not in place before winter, then alternate protection measures, such as covering the slope with straw, or gravel sheeting as per OPSS.PROV 511 (Rip Rap, Rock Protection and Granular Sheeting) and OPSS.PROV 1004 (Aggregates – Miscellaneous) will be required to reduce the potential for erosion and to reduce the potential for the requirement of remedial works on the side slopes in the spring prior to topsoil dressing and seeding.

6.6.7 Instrumentation and Monitoring Program

Depending on the final size of culvert chosen, the thickness of cover up to the final Highway 65 grade, for a similar size pipe as the existing culvert, is about 4.8 m at the highway centreline (and range from this thickness to minimal cover at the inlet and outlet ends). An instrumentation and monitoring program is recommended at the culvert location if a trenchless installation method is to be used for culvert construction to:

- Document the effects of the culvert installation on the overlying highway and adjacent underground utilities/services, if applicable.

- Potentially identify adverse ground movement trends that could occur due to the construction methods and equipment or unforeseen ground conditions.
- Evaluate the contractor's compliance with the settlement limits specified in the Contract Documents.
- Allow adjustments to be made to the culvert installation methods such that the settlement limits established are not exceeded.

The Special Provision for "Pipe Installation by Trenchless Method" (Appendix C) contains the details of the settlement monitoring program to be implemented to measure ground settlement at the existing roadway prior to, during and following the proposed installation. If a trenchless installation method is adopted, a site-specific Supply/Installation of Instrumentation Plan and a Monitoring Plan for embankment construction/staging options and settlement monitoring should be prepared for the contractor and Contract Administrator assignment for inclusion in the Contract Documents/Provided to the CA.

It is also recommended that, to the extent practicable and possible, the weight or volume of ground removed from beneath the highway be measured and compared to the theoretical cut hole volume on a frequency of at least once per 3 m section of tunnel / pipe installed. On-site observations of construction operations and measurements of grout and/or lubricant volumes should assist in identifying atypical conditions that could be indicative of unacceptable ground losses.

Provision should be included in the Contract Documents for rehabilitation of the Highway 65 embankment along the culvert alignment in the event of settlement during the installation process. It is understood from AECOM that driving restrictions will govern timing of paving such that if settlement occurs, repairs would be performed during the Contract.

Further, the location (depth/alignment), type and tolerances to movement and vibrations of any existing buried utilities (functioning or decommissioned) would have to be clearly established prior to any trenchless installation operation, and the Review Level and Alert Level tolerances for settlement confirmed in the SP for "Pipe Installation by Trenchless Method."

6.6.8 Grouting

Post installation grouting to fill the annular space between the carrier pipe (culvert) and the casing may need to be carried out after the permanent culvert pipe is installed within the casing as noted in the SP for "Pipe Installation by Trenchless Method" included in Appendix C. For any installations at which the settlement monitoring or excavation volume monitoring indicates that pavement settlement or ground loss might have occurred, or where signs of ground loss have been noted, provision should also be made for a program of compensation grouting above the casing pipe and/or repair of the pavements.

7.0 CLOSURE

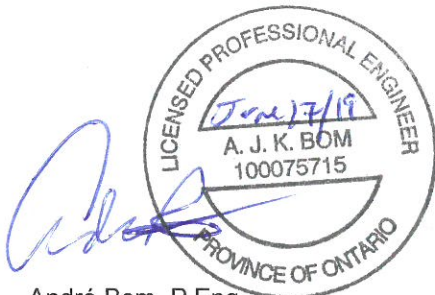
This foundation design report was prepared by Mr. Gavin Mundry, a member of the geotechnical group with Golder, and the technical aspects were reviewed by Mr. André Bom, P.Eng., a senior geotechnical engineer and Associate of Golder. Mr. Jorge Costa, P.Eng., an MTO Foundations Designated Contact and Senior Consultant with Golder conducted an independent and quality control review of the report.

Signature Page

Golder Associates Ltd.



Gavin Mundry, EIT
Geotechnical Engineer-in-Training



André Bom, P.Eng.
Senior Geotechnical Engineer, Associate



Jorge M. A. Costa, P.Eng.
MTO Foundations Designated Contact, Senior Consultant

GM/AB/JMAC/sb

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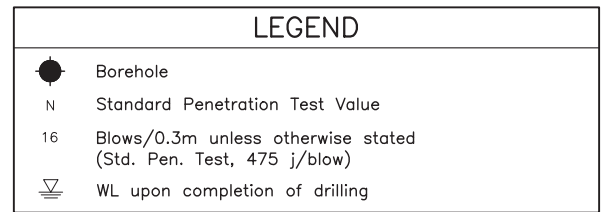
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- ASTM International:
- ASTM D1586 Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils
- Ontario Provincial Standard Drawings (OPSD)
- | | |
|--------------|---|
| OPSD 802.014 | Flexible Pipe Embedment in Embankment Original Ground: Earth or Rock |
| OPSD 802.031 | Rigid Pipe Bedding, Cover, And Backfill, Type 3 Soil - Earth Excavation |
- Ontario Provincial Standard Specifications (OPSS) – Provincial Oriented
- | | |
|----------------|---|
| OPSS.PROV 206 | Construction Specification for Grading |
| OPSS.PROV 401 | Construction Specification for Trenching, Backfilling and Compacting |
| OPSS.PROV 421 | Construction Specification for Pipe Culvert Installation in Open Cut |
| OPSS.PROV 501 | Construction Specification for Compacting |
| OPSS.PROV 511 | Construction Specification for Rip-Rap, Rock Protection, and Granular Sheetting |
| OPSS.PROV 517 | Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation |
| OPSS.PROV 539 | Construction Specification for Temporary Protection Systems |
| OPSS. PROV 802 | Construction Specification for Topsoil |
| OPSS.PROV 804 | Construction Specification for Seed and Cover |
| OPSS.PROV 1004 | Material Specification for Aggregates - Miscellaneous |
| OPSS.PROV 1010 | Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material |



SHEET



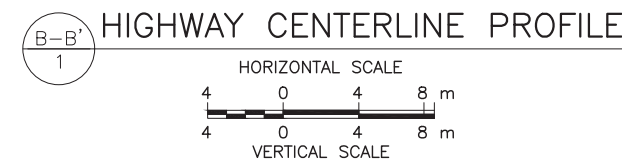
NOTES

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.

Base plans provided in digital format by AECOM, drawing file nos. B065jam.DWG, received MAR 15, 2019.

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NO.	DATE	BY	REVISION		
Geocres No. 41P-80					
HWY. 65		PROJECT NO. 1896349		DIST. ,	
SUBM'D. GM		CHKD. TB		DATE: 5/21/2019	
DRAWN: TR		CHKD. AB		APPD. JMAC	
				DWG. 1	





Photograph 1: Culvert Inlet (North End), Facing North from Road Surface (November 2018)



Photograph 2: Culvert Outlet (South End) Facing South from Road Surface (November 2018)



Photograph 3: Culvert Inlet (North End), Borehole C14-4 location, Facing Southeast (November 2018)



Photograph 4: Culvert Outlet (South End), Facing Southeast from Road Surface (November 2018)

APPENDIX A

Record of Boreholes

LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

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

Notes: 1
2

$\tau = c' + \sigma' \tan \phi'$
shear strength = (compressive strength)/2

LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Cone Penetration Resistance; N_d :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 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

Piezo-Cone Penetration Test (CPT)

A 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 (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

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

(b) Cohesive Soils Consistency

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

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

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

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand


PROJECT 1896349		RECORD OF BOREHOLE No C14-1				1 OF 2 METRIC								
G.W.P. 5204-14-00		LOCATION N 5284082.6; E 359201.9 NAD83 MTM ZONE 12 (LAT. 47.693581; LONG. -80.275211)				ORIGINATED BY SA								
DIST _____ HWY 65		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers				COMPILED BY GM								
DATUM GEODETIC		DATE November 8, 2018				CHECKED BY AB								
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	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
287.6	GROUND SURFACE													
0.0	ASPHALT (100 mm)													
287.2	Sand and gravel (FILL)													
0.5	ASPHALT (100 mm)													
	Sand to sand and gravel, some gravel, some silt (FILL)													
	Compact to dense Brown Moist		1	SS	36									
	Trace laminate organics from 2.0 m to 2.1 m depth		A	SS	32									
			2	SS										
	Auger grinded on inferred cobbles at 2.3 m and 2.9 m depth		3	SS	16									
			4	SS	26									
283.8	Silty sand (FILL)													
3.8	Very loose Brown Moist to wet		5	SS	3									
			6	SS	2									
282.6	Amorphous PEAT													
282.3	Dark brown Wet													
5.3	Sandy SILT to SILT and SAND, trace clay Loose Grey Wet		7	SS	5									
			8	SS	7									
			9	SS	6									
			10	SS	7									
275.9														
11.7														

Continued Next Page

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

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PROJECT <u>1896349</u>		RECORD OF BOREHOLE No C14-1				2 OF 2 METRIC	
G.W.P. <u>5204-14-00</u>		LOCATION <u>N 5284082.6; E 359201.9 NAD83 MTM ZONE 12 (LAT. 47.693581; LONG. -80.275211)</u>				ORIGINATED BY <u>SA</u>	
DIST <u> </u> HWY <u>65</u>		BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Augers</u>				COMPILED BY <u>GM</u>	
DATUM <u>GEODETIC</u>		DATE <u>November 8, 2018</u>				CHECKED BY <u>AB</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)					
								20	40	60	80	100	W _p	W	W _L			
271.7 15.9	SILT, trace to some sand, trace clay Loose Grey Wet --- CONTINUED FROM PREVIOUS PAGE --- END OF BOREHOLE Note: 1. Water level at a depth of 5.6 m below ground surface (Elev. 282.0 m) upon completion of drilling.		11	SS	6	275									o 	0 11 85 4		
							274											
			12	SS	7													
							273											
			13	SS	9	272												

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

PROJECT <u>1896349</u>		RECORD OF BOREHOLE No C14-2				2 OF 2 METRIC												
G.W.P. <u>5204-14-00</u>		LOCATION <u>N 5284102.5; E 359184.4 NAD83 MTM ZONE 12 (LAT. 47.693761; LONG. -80.275441)</u>				ORIGINATED BY <u>SA</u>												
DIST <u> </u> HWY <u>65</u>		BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Augers</u>				COMPILED BY <u>GM</u>												
DATUM <u>GEODETIC</u>		DATE <u>November 7, 2018</u>				CHECKED BY <u>AB</u>												
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					W _p	W			W _L	
--- CONTINUED FROM PREVIOUS PAGE ---							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					20 40 60 WATER CONTENT (%)						
271.5 15.9	Sandy SILT to SILT and SAND, trace clay, organic pockets in upper 0.8 m Loose Dark brown to black Wet	STRAT PLOT	11	SS	5	275									○			0 18 79 3
						274												
						273												
						272												
			13	SS	6													
END OF BOREHOLE Note: 1. Water level at a depth of 5.0 m below ground surface (Elev. 282.4 m) upon completion of drilling.																		

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

PROJECT 1896349		RECORD OF BOREHOLE No C14-3				2 OF 2 METRIC											
G.W.P. 5204-14-00		LOCATION N 5284088.8; E 359192.6 NAD83 MTM ZONE 12 (LAT. 47.693637; LONG. -80.275334)				ORIGINATED BY MR/GM											
DIST _____ HWY 65		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers, NW Casing and Wash Boring				COMPILED BY GM											
DATUM GEODETIC		DATE November 13, 2018				CHECKED BY AB											
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	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					
275.1 12.3	SILT to sandy SILT, some gravel, some clay, silty clay layers/seams Compact Grey Wet Sandy SILT / SILTY CLAY interlayers Compact / stiff to very stiff Grey Wet		12	SS	13		275										0 0 94 6
							274										
			13	SS	17		273										
							272										
	SILTY CLAY layer at 15.4 m depth		14	SS	13		271										
							270										
			15	SS	12		269										
							268										
			16	SS	15		267										
							266										
267.0 20.4	END OF BOREHOLE Note: 1. Water level at a depth of 4.3 m below ground surface (Elev. 283.1 m) upon completion of drilling.		17	SS	16		265										

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PROJECT 1896349		RECORD OF BOREHOLE No C14-4				1 OF 1 METRIC											
G.W.P. 5204-14-00		LOCATION N 5284107.4; E 359207.4 NAD83 MTM ZONE 12 (LAT. 47.693803; LONG. -80.275134)				ORIGINATED BY SA											
DIST _____ HWY 65		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers				COMPILED BY GM											
DATUM GEODETIC		DATE November 8, 2018				CHECKED BY AB											
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	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
282.8	GROUND SURFACE																
0.0	Sandy topsoil (FILL)																
282.5			1	SS	7												
0.3	Silt, some sand, trace organics (FILL) Grey Moist																
282.0																	
0.8	SILT, trace sand, trace clay Loose to compact Grey Wet Organic pockets from 0.8 m to 1.4 m		2	SS	4												
			3	SS	12												
			4	SS	5												
			5	SS	5												
			6	SS	5												
			7	SS	6												
			8	SS	6												
			9	SS	10												
			10	SS	8												
273.0	END OF BOREHOLE																
9.8	Note: 1. Water level at a depth of 1.6 m below ground surface (Elev. 281.2 m) upon completion of drilling.																

PROJECT		1896349		RECORD OF BOREHOLE No C14-5				1 OF 2 METRIC										
G.W.P.		5204-14-00		LOCATION		N 5284087.9; E 359173.3 NAD83 MTM ZONE 12 (LAT. 47.693631; LONG. -80.275591)		ORIGINATED BY MR/GM										
DIST		HWY 65		BOREHOLE TYPE		108 mm I.D. Hollow Stem Augers		COMPILED BY GM										
DATUM		GEODETIC		DATE		November 14, 2018		CHECKED BY AB										
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	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)	
								20	40	60	80						100	20
282.0	GROUND SURFACE																	
0.0	Silty sand, trace organics (FILL) Loose Brown Wet		1	SS	4													
281.2	ASPHALT (100 mm)																	
0.9	Silty sand, trace gravel, with silt seams (FILL)		2	SS	9													
280.6	Loose																	
1.4	Grey Wet																	
	SILT, trace to some sand, trace clay Very loose to loose		3	SS	2													
	Grey Wet																	
	Brown / black organic pockets from 1.4 m to 2.1 m		4	SS	7											0 10 81 9		
279.0																		
3.0	SILT and SAND, trace gravel, trace clay Very loose to compact		5	SS	19													
	Grey Wet																	
			6	SS	5													
			7	SS	WH											1 44 50 5		
276.4																		
5.6	SILT, trace to some sand, trace clay Compact																	
	Grey Wet		8	SS	13													
			9	SS	11											0 10 86 4		
			10	SS	11													
	25 mm to 50 mm thick SILTY CLAY seams/layers at 9.3 and 9.5 m depth																	
			11	SS	16													
	75 mm thick SILTY CLAY seam at 11.3 m depth																	
270.7																		
11.3	END OF BOREHOLE																	

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

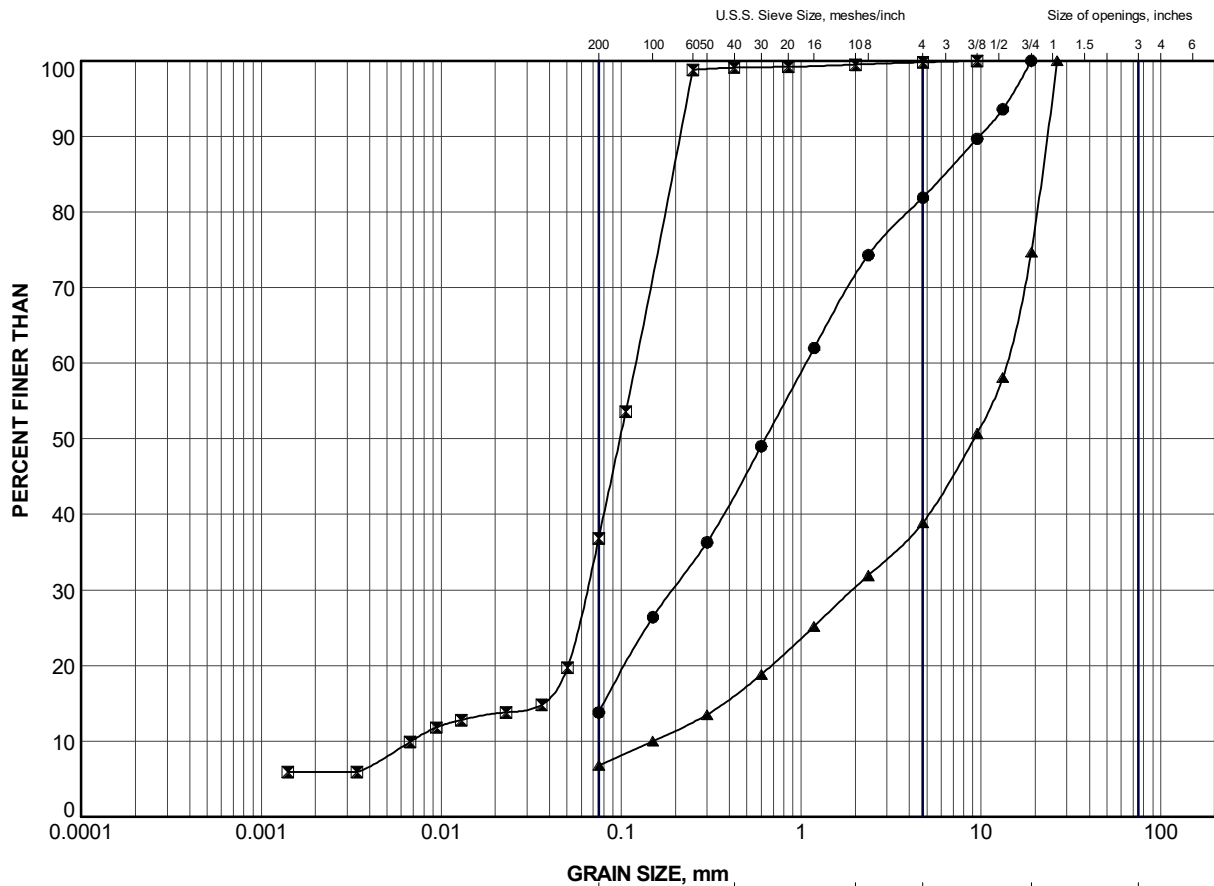


+3, ×3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

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APPENDIX B

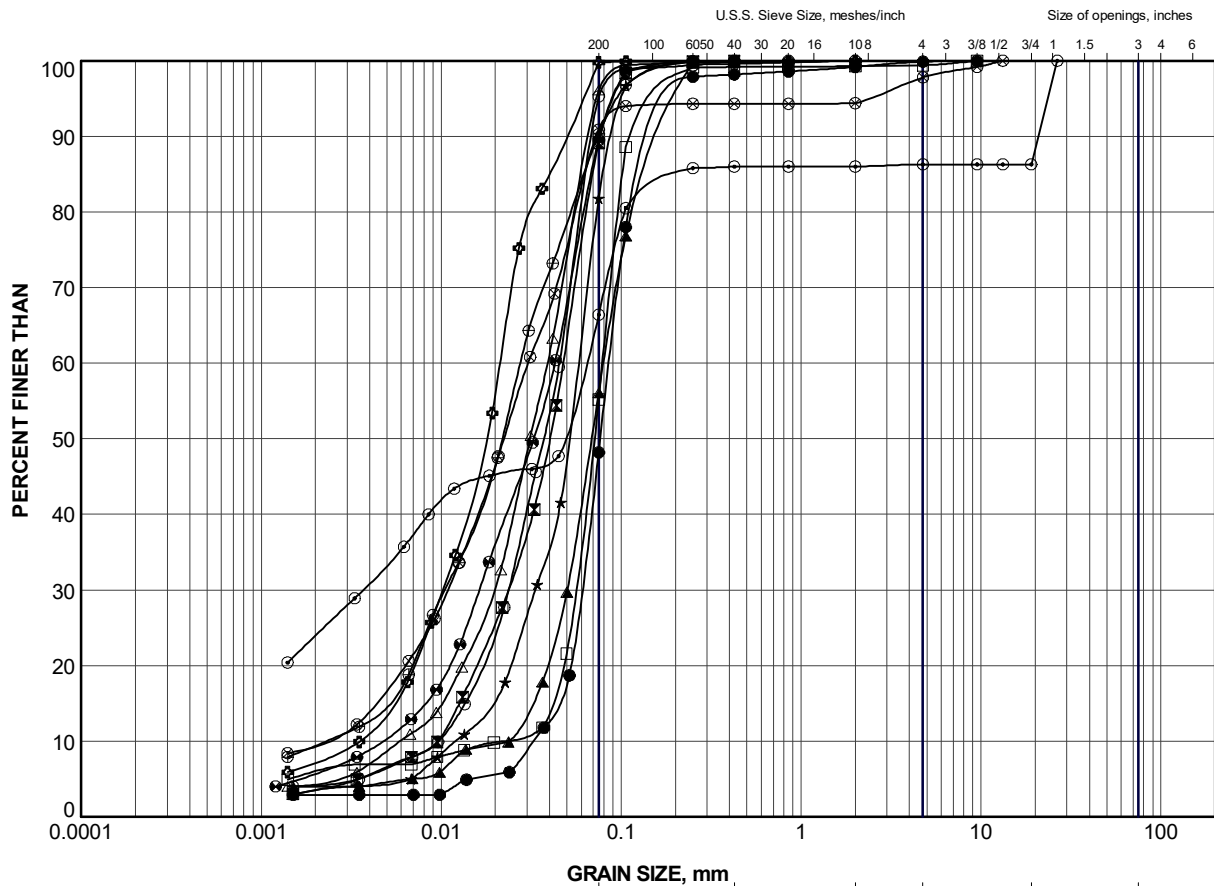
Laboratory Test Results



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C14-1	2A	285.9
⊠	C14-2	4	284.1
▲	C14-3	6	283.3

PROJECT		HIGHWAY 65 STATION 20+638 TOWNSHIP OF JAMES CULVERT			
TITLE		GRAIN SIZE DISTRIBUTION Silt and Sand to Sand and Gravel (FILL)			
PROJECT No.		1896349		FILE No. 1896349.GPJ	
DRAWN	TR	Apr 2019	SCALE	N/A	REV.
CHECK	AB	Apr 2019			
APPR	JMAC	Apr 2019			
 GOLDER SUDBURY, ONTARIO			FIGURE B-1		

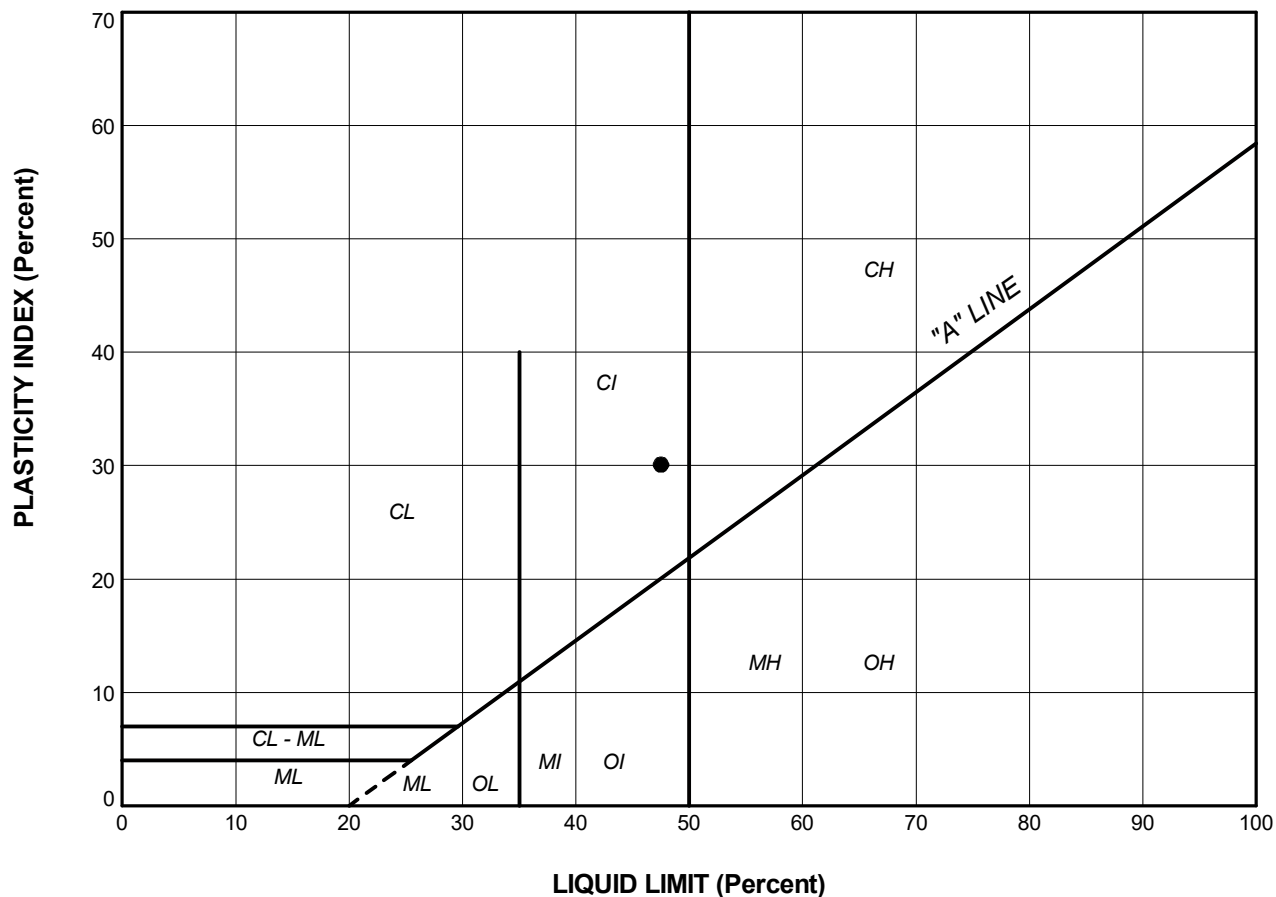


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND


SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C14-1	8	279.7
⊠	C14-1	11	275.1
▲	C14-2	9	278.0
★	C14-2	11	274.9
⊙	C14-3	9	279.5
⊗	C14-3	12	274.9
○	C14-4	4	280.2
△	C14-4	7	277.9
⊗	C14-4	9	274.9
⊕	C14-5	4	279.4
□	C14-5	7	277.1
⊗	C14-5	9	274.1

PROJECT		HIGHWAY 65 STATION 20+638 TOWNSHIP OF JAMES CULVERT			
TITLE		GRAIN SIZE DISTRIBUTION SILT to SILT and SAND			
PROJECT No.		1896349		FILE No. 1896349.GPJ	
DRAWN	TR	Apr 2019	SCALE	N/A	REV.
CHECK	AB	Apr 2019	FIGURE B-2		
APPR	JMAC	Apr 2019			
GOLDER		SUDBURY, ONTARIO			



LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	C14-3	14	47.5	17.4	30.1

PROJECT						HIGHWAY 65 STATION 20+638 TOWNSHIP OF JAMES CULVERT					
TITLE						PLASTICITY CHART SILTY CLAY					
PROJECT No.			1896349			FILE No.			1896349.GPJ		
DRAWN	TR	Apr 2019	SCALE	N/A	REV.	FIGURE B-3					
CHECK	AB	Apr 2019									
APPR	JMAC	Apr 2019									
 GOLDER SUDBURY, ONTARIO											

RESULTS OF ANALYSES OF SOIL

Maxxam ID		IKA226			IKA226			IKA227	IKA228		
Sampling Date		2018/11/13 10:41			2018/11/13 10:41			2018/11/17 11:30	2018/11/18 12:13		
COC Number		62170			62170			62170	62170		
	UNITS	C14-3 SA 1	RDL	QC Batch	C14-3 SA 1 Lab-Dup	RDL	QC Batch	C27-1 SA 1	C77-1 SA 1	RDL	QC Batch
CONVENTIONALS											
Sulphide	ug/g	7.35	0.50	5872398				<0.55	0.64	0.55	5872398
Calculated Parameters											
Resistivity	ohm-cm	1200		5859836				2000	3800		5859836
CONVENTIONALS											
Redox Potential	mV	140	N/A	5865933				140	130	N/A	5865933
Inorganics											
Soluble (20:1) Chloride (Cl-)	ug/g	430	20	5862969				250	90	20	5862969
Conductivity	umho/cm	868	2	5863312	909	2	5863312	508	266	2	5863312
Available (CaCl2) pH	pH	7.23		5864763				7.54	7.60		5864763
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	5862489				<20	<20	20	5862489
Physical Testing											
Moisture-Subcontracted	%	24	0.30	5872397				17	25	0.30	5872397
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate N/A = Not Applicable											

APPENDIX C

**Non-Standard Special Provisions
and Notice to Contractor**

PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Special Provision

November 2018

CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY TRENCHLESS METHODS

TABLE OF CONTENTS

1.0	SCOPE
2.0	REFERENCES
3.0	DEFINITIONS
4.0	DESIGN AND SUBMISSION REQUIREMENTS
5.0	MATERIALS
6.0	EQUIPMENT
7.0	CONSTRUCTION
8.0	QUALITY ASSURANCE- Not Used
9.0	MEASUREMENT FOR PAYMENT
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 micro-tunnel 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.

Based on the ground conditions at the Highway 65, Station 20+638, Township of James culvert and the anticipated relatively short tunnel distance of about 35 m, HDD, TBM, Tunnel Digging Machine (TDM) Pilot Tube Micro-tunnelling and (PTMT) methods are likely not suitable or cost-effective methods for culvert installation. The diameter of the culvert will also preclude the use of HDD.

4.02 Submission Requirements

4.02.01 Qualifications

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

4.02.01.01 Project Superintendent

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

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

4.02.01.02 Trenchless Contractor

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

4.02.01.03 Design Engineer

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

4.02.01.04 Design Checking Engineer

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

4.02.02 Working Drawings

Three sets of Working Drawings for the trenchless installation method selected shall be submitted to the Contract Administrator (CA) for purposes of documentation and quality assurance at least two weeks 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

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6.03.06 Drilling Fluid Delivery System

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

6.04 Tunnelling

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

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

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

6.05 Microtunnelling Equipment

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

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

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

- a) Remote Control System – The Contractor shall provide a MTBM that includes a remote control system with the following features:
 - i. Allows for operation of the system without the need for personnel to enter the microtunnel. Has a display available to the operator, at a remote operation console, showing the position of the shield in relation to a design reference together with other information such as face pressure, roll, pitch, steering attitude, valve positions, thrust force cutter head torque, rate of advance and installed length.
 - ii. Integrates the system of excavation and removal of spoil and its simultaneous replacement by Product Pipe. As each pipe section is jacked forward, the control system shall synchronize all of the operational functions of the system.
 - iii. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.

- iv. The system shall monitor and continuously balance the soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.
- v. The pressure at the excavation face shall be managed by controlling the volume of spoil removal with respect to the advance rate.
- vi. The system shall include a separation process designed to provide adequate separation of the spoil from the slurry so that slurry with a sediment content within the limits required for successful microtunnelling, can be returned to the cutting face for reuse. Appropriately contain spoil at the site prior to disposal.
- vii. The type of separation process shall be suited to the size of microtunnel being constructed, the soil type being excavated, and the work space available at each work area.
- viii. The system shall allow the composition of the slurry to be monitored to maintain the slurry weight and viscosity limits required.

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

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

6.05.01 Pipe Jacking Equipment

Provide a pipe jacking system with the following features:

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

6.05.02 Spoil Separation System

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

6.05.03 Electrical Equipment, Fixtures and Systems

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

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

7. CONSTRUCTION

7.01 General

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

The Project Superintendent shall supervise the work at all times.

7.01.01 Layout, Alignment and Depth Control

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

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

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

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

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

7.01.02 Construction Shafts

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

Shafts shall be maintained in a drained condition.

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

7.01.03 Protection Systems

The construction of all protection systems shall be according to OPSS539. Where the stability, safety, or function of an existing roadway, watercourse, other works, proposed works or ESA's may be impaired due to the method of operation, protection shall be provided. Protection may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works.

7.01.04 Settlement or Heave

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

7.01.05 Stability of Excavation

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

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

7.01.06 Preservation and Protection of Existing Facilities

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

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

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

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer's handling and storage recommendations shall be followed.

7.01.08 Trenching, Backfilling and Compacting

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

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

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

7.01.10 Dewatering

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

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

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

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

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

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Cobbles and Boulders

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

7.01.14 Management of Excess Material

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

7.01.15 Site Restoration

Site restoration shall be according to OPSS 492.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

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

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

7.02.02 Pipe Installation

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

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

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

7.03 Pipe Ramming Installation

For pipe ramming installation the following requirements apply:

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

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

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

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

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

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

7.04 Horizontal Directional Drilling Installation

7.04.01 General

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

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

7.04.02 Site Preparation

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

7.04.03 Pilot Bore

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

In the event the pilot bore deviates from the submitted path, the Contract Administrator shall be notified. The

Contract Administrator may require the Contractor to pullback, fill and abandon the hole and re-drill from the location along the bore path before the deviation.

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

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

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

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

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

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

7.04.05 Reaming

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

7.04.06 Product Installation

7.04.06.0 General

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

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

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

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

7.04.06.02 Pullback and Grouting

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

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

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

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

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

7.05 Tunnelling Installation

7.05.01 General

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

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

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

The Contractor shall provide ventilation and lighting in accordance with 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, supply and installation of pipe liners, settlement instrumentation and monitoring, site restoration, and all other work necessary to complete the installation as specified.

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

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

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

- (a) Where such drains and service connections are shown on the contract drawings the cost of connections shall be included in the contract price for pipe installation.
- (b) Where such drains and service connections are not shown on the contract drawings, the cost of connections will be considered an allowable extra to the contract.

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

Notes to Designer

A Foundation Engineering Specialist shall be retained by the Contract Administrator to assist the CA

in ensuring that the Design and Submission Requirements are met and to ensure quality management of the work. Terms of Reference for the Foundation Engineering Specialist shall be provided by the Foundations Office and finalized in collaboration with the Regional Operations.

WARRANT: Always with this specification

OBSTRUCTIONS – Item No.

Notice to Contractor

The contractor shall be alerted to the potential presence of cobbles, boulders, and asphalt fragments within the fill deposits along the alignment of the Highway 65, Station 20+638, Township of James culvert. Consideration of the presence of these obstructions must be made in the selection of appropriate equipment and procedures for open cut excavations, installation of temporary protection systems.

TEMPORARY PROTECTION SYSTEM – Item No.

Non-Standard Special Provision

Amendment to OPSS 539, November 2014

593.07.02 Removal of Protection Systems

Subsection 539.07.02 of OPSS 539 is deleted in its entirety and replaced with the following:

Protection systems shall be removed from the right-of-way unless it is specified in the Contract Documents that the protection system may be left in place.

Where piles are left in place, the top shall be removed to at least 1.2 m below the finishing grade or ground surface.

The method and sequence of removal shall be such that there shall be no damage to the new work, existing work or facility being protected.

All disturbed areas shall be restored to an equivalent to better condition than existing prior to the commencement of construction.



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