



**FOUNDATION INVESTIGATION AND DESIGN REPORT**

**Highway 66, Station 17+221, Township of Lebel  
Culvert Replacement  
Ministry of Transportation, Ontario  
GWP 5210-14-00**

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 66, STA 17+221, TOWNSHIP OF LEBEL  
CULVERT REPLACEMENT  
MINISTRY OF TRANSPORTATION, ONTARIO  
GWP 5210-14-00

## 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 66 at Station 17+221, in the Township of Lebel, approximately 1.4 km east of Bidgood Road near King Kirkland, Ontario. The Key Plan of the general location of this section of Highway 66 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 work 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 work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services 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 Drawing 1. For the purpose of this report, Highway 66 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 south to north direction.

The existing culvert consists of a 1.2 m diameter, 44 m long Corrugated Steel Pipe (CSP). The culvert invert, as taken from AECOM's centreline survey profile, at the inlet and outlet is approximately Elevations 316.4 m and 315.8 m, respectively. In general, the topography within the vicinity of the culvert consists of forested hills with exposed bedrock near the site. The culvert is located about 300 m southeast of Mud Lake. The embankment is approximately 6.8 m high relative to the culvert invert and the embankment/side slopes appear to be performing well, with no visible signs of slope instability or roadway settlement sources although the embankment slope surfaces appear to be undulating as a result of surface water runoff gullies / erosion, and there are longitudinal and transverse cracks in the roadway pavement in the culvert area. The ground surface conditions at select locations of the culvert area are shown on Photographs 1 to 4.

## 3.0 INVESTIGATION PROCEDURES

Field work for this subsurface exploration was carried out between May 6 and 8, and on May 29 and 30, 2019, during which time five boreholes (Boreholes C228-1 to C228-5) were advanced at the approximate locations shown on Drawing 1. Boreholes C228-1 to C228-3 were advanced through the roadway embankment and Borehole C228-5 was advanced near the north toe of the highway embankment adjacent to the culvert outlet using a track mounted CME-55LC drilling rig supplied and operated by George Downing Estate Drilling (Downing) of Grenville-Sur-La-Rouge, Quebec. Borehole C228-4 was advanced near the south toe of the highway embankment adjacent to the culvert inlet using a portable tripod rig supplied and operated by Landcore Drilling (Landcore) of Chelmsford, Ontario. Traffic control, where required, was performed in accordance with MTO's Ontario Traffic Control Manual Book 7 – Temporary Conditions.

Boreholes C228-1 to C228-3 and C228-5 were advanced using 76 mm I.D. Hollow Stem Augers, NW casing with wash boring techniques, and NQ coring; and Borehole C228-4 was advanced using NW casing with wash boring techniques. Due to casing refusal at a depth of 3.0 m below ground surface at Borehole C228-4 the following additional exploration drilling was carried out:

- a Dynamic Cone Penetration Test (DCPT) was advanced from the bottom of the original borehole and refusal to further penetration was also encountered at 3.0 m depth
- a Dynamic Cone Penetration Test (DCPT) was advanced 1.0 m west of the original borehole and refusal to further penetration was encountered at 13.7 m depth
- a second borehole was attempted 1.3 m west of the original borehole and refusal to further penetration was encountered at 3.5 m depth (no sampling)
- a third borehole was attempted 0.5 m west of the original borehole and Sample 5 was obtained from 3.1 m to 3.7 m depth (as shown on the borehole record)

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 or cathead hammer in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586). The groundwater level inside the augers/casing was noted / recorded during and upon completion of the drilling operations. The boreholes were backfilled upon completion in accordance with Ontario Regulation 903 (wells) as amended. The roadway surface at the boreholes drilled through Highway 66 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 distributions, 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. One soil sample was submitted to Bureau Veritas Laboratories (formally Maxxam) of Mississauga, an accredited analytical laboratory, for testing a suite of corrosivity indicator parameters.

The as-drilled borehole locations were measured relative to highway chainages/station marked on the pavement by a member of our technical staff and converted into northing/easting coordinates on the plan drawing. The ground surface elevations at the borehole locations were surveyed by Golder relative to the highway and culvert centreline, with the elevation of the centrelines 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 borehole depths at each borehole location are presented on the borehole records in Appendix A and summarized below.

| Borehole Number | MTM NAD 83 Northing<br>(m)<br>(Latitude) | MTM NAD 83 Easting<br>(m)<br>(Longitude) | Ground Surface<br>Elevation<br>(m) | Borehole Depth<br>(m)         |
|-----------------|--|--|------------------------------------|-------------------------------|
| C228-1          | 5335749.7<br>(48.155658)                 | 384044.0<br>(-79.934791)                 | 322.8                              | 20.4                          |
| C228-2          | 5335759.6<br>(48.155748)                 | 384031.4<br>(-79.934959)                 | 323.1                              | 15.9                          |
| C228-3          | 5335735.3<br>(48.155527)                 | 384052.1<br>(-79.934685)                 | 322.9                              | 15.9                          |
| C228-4          | 5335727.8<br>(48.155461)                 | 384044.6<br>(-79.934787)                 | 318.1                              | 3.7 (DCPT to<br>13.7 m Depth) |
| C228-5          | 5335772.2<br>(48.155861)                 | 384044.2<br>(-79.934785)                 | 318.2                              | 9.8                           |

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain Study (NOEGTS)<sup>1</sup> mapping, the subsoils in the vicinity of the culvert site are comprised primarily sands of outwash plain and valley train landforms.

Based on geological mapping (MNDM)<sup>2</sup>, the site is underlain by foliated tonalite suite bedrock, or tonalite to granodiorite-foliated to massive bedrock.

### 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 plotted 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 Bureau Veritas Laboratories) 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.

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

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

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 160 mm to 430 mm thick layer of asphalt pavement was encountered in the roadway boreholes C228-1 to C228-3 between surface Elevations 322.8 m and 323.1 m.

A 7.1 m to 8.3 m thick layer of embankment fill consisting of various layers of silt, sand, gravelly sand, and sand and gravel was encountered below the asphalt. Asphalt coated particles were encountered in Boreholes C228-1 and C228-2 between depths of 0.2 m to 0.4 m below the roadway surface. Cobbles and/or boulders were noted as follows in the various roadway boreholes:

- Borehole C228-1: Cobbles encountered from 1.5 m to 1.8 m depth; 2.7 m to 3.0 m depth; and 5.5 m to 5.7 m depth
- Borehole C228-2: 800 mm boulder encountered at 3.0 m depth and 400 mm boulder encountered at 3.9 m depth
- Borehole C228-3: Cobble encountered from 2.1 m to 2.3 m depth; 600 mm boulder at 2.7 m depth and 400 mm boulder at 3.3 m depth

An approximately 100 mm to 200 mm thick layer of organic silty sand or topsoil fill was encountered from ground surface in Boreholes C228-4 and C228-5 at Elevations 318.1 m and 318.2 m, respectively. A 2.1 m to 2.4 m thick layer of fill consisting of various layers of clayey silt, silt and sand, and sand and gravel was encountered below the organic fill. Cobbles and/or boulders were noted as follows in these two boreholes:

- Borehole C228-4: cobbles (and gravel) encountered within the clayey silt fill layer between depths of 0.7 m and 1.5 m
- Borehole C228-5: 300 mm boulder encountered at 2.3 m depth

The SPT “N”-values measured within the fill range from 2 blows to 70 blows per 0.3 m of penetration, indicating a loose to very dense compactness condition.

Grain size distribution testing was carried out on; three samples of sand to sand and gravel fill and the results are presented on Figure B-1 in Appendix B; and two samples of the silt to silt and sand fill and the results are presented on Figure B-2.

The natural moisture content measured on three samples of the sand and gravel to sand fill ranges from 9 per cent and 17 per cent. The natural moisture content measured on the two samples of the silt to silt and sand fill is 16 per cent and 31 per cent.

#### 4.2.2 Silt to Clayey Silt

In Borehole C228-2, a 7.6 m thick deposit of silt to clayey silt was encountered underlying the fill deposit at Elevation 315.8 m.

The SPT “N”-values measured within the cohesive deposit range from 9 blows to 20 blows per 0.3 m of penetration, indicating that the deposit has a stiff to very stiff consistency / loose to compact compactness condition.

Atterberg limits tests completed on the deposit yielded a liquid limits of 26 per cent and 29 per cent, plastic limits of 19 per cent and 20 per cent, resulting in a plasticity indices of 7 per cent and 9 per cent. The tests indicated the material is classified as a clayey silt of low plasticity. The results of the test are presented on Figure B-3 in Appendix B.

Grain size distribution analysis was carried out on two samples of the silt to clayey silt deposit and the results are presented on Figure B-4 in Appendix B. The natural moisture content measured on samples of the deposit ranges from 22 per cent to 32 per cent.

### 4.2.3 Sand

A 7.5 m, 3.0 m and 1.5 m thick deposit of sand was encountered in Boreholes C228-1, C228-3, and C228-4 at Elevations 315.5 m, 314.2 m, and 315.9 m, respectively. Cobbles were encountered within the sand deposit in Borehole C228-1 at depths of 8.7 m to 8.9 m, 10.2 m to 10.3 m, and 11.3 to 11.5 m. Borehole C228-4 was terminated within the sand deposit (potentially on a boulder) at 3.7 m depth due to split spoon refusal after penetrating 1.5 m into the deposit.

The SPT “N”-values measured within the sand deposit range from 13 blows to 34 blows per 0.3 m of penetration, indicating that the deposit has a compact to dense compactness condition.

Grain size distribution analysis was carried out on three samples of the sand deposit and the results are presented on Figure B-5 in Appendix B. The natural moisture content measured on samples of the sand deposit ranges from 18 per cent to 23 per cent.

### 4.2.4 Sand and Gravel

A 1.0 m to 7.2 m thick deposit of silty sand and gravel to sand and gravel to sandy gravel was encountered in Boreholes C228-1 to C228-3 and C228-5 between Elevations 315.6 m and 308.0 m. All four of these boreholes were terminated within the sand and gravel layer at depths between 9.8 m and 20.4 m below ground surface.

The SPT “N”-values measured within the overall sand and gravel deposit range from 10 blows and 54 blows per 0.3 m of penetration, indicating that the deposit has a compact to very dense compactness condition.

Grain size distribution analysis was carried out on three samples of the sandy gravel to sand and gravel portions of the deposit and the results are presented on Figure B-6 in Appendix B. The moisture contents measured on three samples of the sand and gravel deposit ranges from about 8 per cent to 23 per cent.

A DCPT was advanced from ground surface adjacent to Borehole C228-4 and penetrated to below the sand deposit, to a depth of 13.7 m below ground surface (Elevation 304.4 m). It is noted that the resistance to driving (increase in blows per 0.3 m of penetration) increases below a depth of about 10.9 m below ground surface (Elevation 307.2 m) suggesting the inference of the presence on sand and gravel deposit from this depth to the bottom of the DCPT at 13.7 m below ground surface.

### 4.3 Groundwater Conditions

The unstabilized groundwater levels relative to ground surface measured inside the casing or augers upon completion of drilling are summarized below. 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) |
|--------------|---|---------------------------------------|
| C228-1       | 5.2   | 317.6                                 |
| C228-2       | 5.4   | 317.7                                 |
| C228-3       | 4.5   | 318.4                                 |
| C228-4       | 0.5   | 317.6                                 |
| C228-5       | 2.3   | 315.9                                 |

### 4.4 Analytical Laboratory Testing Results

Analytical testing was carried out on a sample of sand recovered from Borehole C228-1 (Sample #7). The soil sample was submitted to Bureau Veritas Laboratories of Mississauga, Ontario for corrosivity testing. The analytical laboratory test results are summarized below, and the detailed analytical laboratory test report is included in Appendix B.

| Borehole No. | Borehole Sample No. | Depth (m) | Parameters           |                                   |  |                              |                    |      |
|--------------|---------------------|-----------|----------------------|-----------------------------------|--|------------------------------|--------------------|------|
|              |                     |           | Resistivity (ohm-cm) | Electrical Conductivity (µmho/cm) | Soluble Sulphate (SO <sub>4</sub> ) Content (µg/g) | Chloride (Cl) Content (µg/g) | Sulphide (µg/g)    | pH   |
| C228-1       | 7                   | 7.6 – 8.2 | 12,000               | 84                                | <20 <sup>1</sup>                                   | 29                           | <0.30 <sup>2</sup> | 6.56 |

Note:

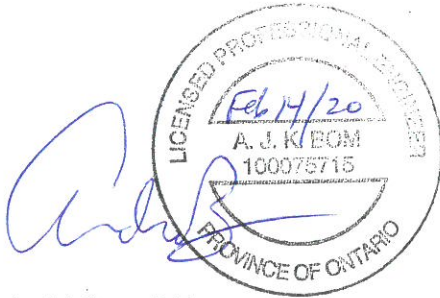
1. The sulphate concentration is below the reportable detection limit of 20 µg/g.
2. The sulphide was below the reportable detection limit of 0.30 µg/g.

### 5.0 CLOSURE

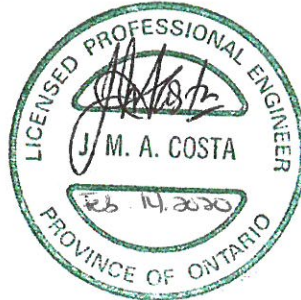
The field drilling program was carried out under the supervision of Mr. Mathew Riopelle and Yusuf Soliman, EIT, under the overall direction of Mr. André Bom, P.Eng., an Associate of Golder. This Foundation Investigation Report was prepared by Mr. Gavin Mundry, and Mr. André Bom provided a technical review 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 this report.

## Signature Page

### Golder Associates Ltd.



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



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

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**PART B**

FOUNDATION DESIGN REPORT  
HIGHWAY 66, STA 17+221, TOWNSHIP OF LEBEL  
CULVERT REPLACEMENT  
MINISTRY OF TRANSPORTATION, ONTARIO  
GWP 5210-14-00

## 6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the replacement of the culvert crossing Highway 66 at about Station 17+221, Township of Lebel, Ontario, located about 300 m southeast of Mud Lake. These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current subsurface exploration. The discussion and recommendations presented are intended to provide the designer with sufficient information to assess feasible foundation alternatives and culvert types and to design the proposed replacement culvert. The foundation investigation report, discussion and recommendations are intended for the use of the 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 to be replaced consists of a 1.2 m diameter, 44 m long Corrugated Steel Pipe (CSP). Based on the drawings provided by AECOM via email on July 2, 2019, and our site observations during the foundation exploration work, the existing culvert crosses the existing Highway 66 embankment on a skew alignment; and we understand from AECOM that the proposed replacement culvert will cross the highway on or near the same alignment and will be of similar length and diameter as the existing culvert. The existing embankment side slopes at the culvert location are inclined at about 2.5 Horizontal to 1 Vertical (2.5H:1V) on the south and north sides and the embankment is between about 6.4 m and 7.0 m high relative to the culvert invert at the inlet (south end) and outlet (north end). The invert at the inlet and outlet of the existing culvert is about Elevations 316.4 m and 315.8 m, respectively. We understand from AECOM that a temporary roadway protection system is being considered for staging of the culvert replacement in open cut, and that a permanent grade raise or widening of the roadway embankment is not required. We further understand that a full road closure and temporary detour is not being considered for traffic staging during culvert replacement operations.

Depending on construction staging requirements / constraints and as an alternative to open cut construction of the new culvert, consideration may also be given to replacing the culvert using a trenchless installation method. Based on the existing ground surface profile along the proposed culvert alignment, the existing soil cover over the top of the culvert relative to the highway surface grade is about 5.6 m, and the ratio of existing soil cover-to-pipe diameter is about 4.7. The proposed replacement culvert is also 1.2 m in diameter, resulting in a soil cover-to-tunnel diameter ratio of about 4.0, assuming a 1.4 m diameter liner is used, which is considered a suitable condition for a trenchless installation method. The actual soil cover thickness to culvert diameter ratio will depend on the installation method and size of liner actually used.

A comparison between an open cut (cut and cover) method of culvert installation and the preferred trenchless installation method at this site (as discussed in Section 6.4) is presented in Table 1 following the text of this report.

## 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 culvert crosses Highway 66 at Station 17+221, and the highway and culvert and foundation system are expected to carry medium traffic volumes and their performance will have potential impacts on other transportation corridors; hence, the culvert foundation system 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,  $\Psi$ , and geotechnical resistance factors,  $\phi_{gu}$  and  $\phi_{gs}$ , from Tables 6.1 and 6.2 of the *CHBDC* have been used for design, as applicable.

## 6.3 Circular Culvert Installation by Open Cut Excavation

### 6.3.1 Settlement and Stability

Provided the existing / proposed reconstructed embankment is not widened or raised during or following culvert replacement, settlement of the foundation soils beneath the culvert is not anticipated to be a concern. If a grade raise or widening is being considered, a settlement analysis of the culvert/embankment foundation soils should be carried out.

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 no steeper than of 2 horizontal to 1 vertical (2H:1V).

### 6.3.2 Bedding / Embedment and Cover

Pipe culverts (less than 3 m diameter) should be designed in general accordance with the MTO Gravity Pipe Design Guidelines (2014). It is not necessary to found a pipe culvert below the depth of frost penetration, as pipe culverts are generally tolerant of small magnitudes of movement related to freeze-thaw cycles.

A circular, concrete pipe 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*). If the replacement culvert is to consist of a Corrugated Steel Pipe (CSP) or plastic (HDPE or PVC) pipe installed by open cut method, it should be constructed in accordance with OPSD 802.010 (*Flexible Pipe Embedment and Backfill*) for Type 3 Soil.

All unsuitable, deleterious, organic materials and fill materials are to be removed from the base/below the culvert (and bedding) footprint, along its entire alignment. The bedding should be 300 mm thick and be compatible with the type/class of pipe material, 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 if wet and softened soil conditions, unsuitable fill, or organic material are present at the base of the excavation.

From the top of the bedding to 300 mm above the top of the culvert, Granular ‘A’ should be used around the culvert. All bedding, embedment 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.PROV 401 (*Trenching, Backfilling and Compacting*), and the bedding/embedment/cover soil should be compacted in accordance with OPSS.PROV 501 (*Compacting*) as amended by Special Provision (SP) 105S22. 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 additional sub-excavation backfill below the bedding, as may be required.

### 6.3.2.1 Trench Backfill

The excavated embankment fill materials from the culvert site will vary in quality and composition, and are comprised of silt, sandy silt, sand, and sand and gravel. The existing organic and clayey fill materials should not be reused as backfill for reconstruction of the highway embankment in the immediate vicinity or over the new culvert.

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*), as amended by SP 105S22.

## 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. Generally, the soils encountered along the proposed tunnel horizon (vertical culvert alignment) include loose to compact silt and/or sand and gravel (with cobbles and boulders) embankment fill. The groundwater level measured inside the hollow stem augers or casing on completion of drilling in Boreholes C228-1, C228-4, and C228-5 nearest the existing culvert ranges between Elevations 317.6 m and 315.9 m. Therefore, the groundwater level is expected to be above or at about the proposed culvert/tunnel horizon.

Correlating the soil classification noted above with the Tunnelman's Ground Classification System (Heuer, 1974, modified from Terzaghi, 1950), existing embankment fill along the tunnel horizon (silt, sand and gravel) and the native soils (sand, sand and gravel, silt to clayey silt) 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 trenchless 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 / trenchless 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 SP titled "Pipe Installation by Trenchless Method" presented in Appendix C for inclusion into the Contract Documents.

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

- **Horizontal Directional Drilling (HDD):** HDD involves drilling of a relatively small diameter pilot hole (on the order of 100 to 150 mm) using a remotely controlled and 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 is typically reamed in one or more passes to a larger diameter, and then the final pipe is 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 drilling is very challenging in bouldery ground. Deep entrance and exit pits are generally not required; however, larger laydown areas are required to install the final pipe, and the crossing typically needs to be longer to accommodate the shallow entry and exit angles for the drilling equipment (on the order of 10 to 30 degrees from horizontal). 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.
- **Horizontal Auger Boring – "Jack and Bore":** In Ontario, a traditional "jack and bore" operation involves pushing a steel pipe (casing) horizontally into the ground by jacking while simultaneously cutting the ground with an auger head operating near the leading end of the steel pipe. 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. Jacking and receiving pits are required. Typically, there is limited ability to steer the casing during jacking. This method is only applicable to construction in soils and may not be feasible in bouldery soils (e.g., glacial till). In some cases, contractors will run the auger cutting head in front of the lead end of the casing to advance the pipe in difficult ground; however, this approach can lead to high risks for ground losses (settlement, sinkholes). This method is also not feasible in running or flowing ground (dry or saturated sand and silt).

In some cases, traditional "jack and bore" equipment is supplemented with a specialized rotating cutting head, sometimes referred to as a "small boring unit". These cutting heads are welded to the lead end of steel casings, can sometimes include limited alignment adjustment capabilities, and can be fitted with rock disc cutters. In the right ground conditions (e.g., hard glacial till, weathered rock), the small boring heads can be advantageous. However, these systems are not well suited to and should not be used in saturated and potentially flowing ground conditions. Further, these systems should not be confused with microtunnelling systems that operate using very different principles of ground support.

- **Pipe Ramming:** Pipe ramming 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, number, and their positions relative to the pipe leading edge. 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.” Partial or full removal of materials from within the pipe, to facilitate driving, should not be carried out if the ground through which the pipe is being driven consists of saturated granular soils (silt, sand, gravel). As with traditional jack and bore methods, flowing ground conditions and/or operating the cleanout augers beyond, at or near the leading edge of the casing can result in significant ground losses, excessive surface settlement and, in some cases, sinkholes that propagate to the surface.

- **Micro-tunnelling Boring Machine (MTBM):** MTBM is a method of installing pipes in bores ranging from 0.6 to 3 metres in 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. Some MTBMs are promoted as being able to “crush” cobbles with internal cone crushing systems. Others have been promoted as capable of passing boulders of as much as 1/3 of the bore diameter. However, both approaches to managing larger stones can be highly problematic and incapable of completing construction in boulder ground. Large numbers of cobbles can also “choke” these machines and result in failure of the bore. In bouldery ground, where the boulders can be firmly held in place by the surrounding soil matrix, equipping MTBMs with rock-disc cutters can be successful. In all cases, detailed review of the conditions and equipment configuration are needed prior to construction to achieve a reasonable probability of success.

- **Pilot Tube Micro-tunnelling (PTMT):** PTMT employs augers for excavation and soil removal and a jacking system for advancing the drill pipes, casings and final 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. Configurations of “reamer” tools varies widely within the industry, with some including rotating cutting tools, while others are a simplified cage-like head that allows soils to be forced into the openings as the larger diameter pipe is pulled and pushed into the ground. These reamer systems can have a significant influence on both the feasibility and risks of using this method and should be evaluated with caution.

- **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. Specialized earth pressure balance or slurry shield TBMs are available, which pressurize the face of the excavation and improve face stability. 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.
- **Tunnel Digging Machine (TDM):** “Tunnel digging machine (TDM) tunnelling,” also called open-face shield tunnelling, involves excavating the soils using a hydraulic excavator arm, working within a full-circumference tunnelling shield. Typically, the temporary tunnel liner (i.e., steel casing, steel ribs and lagging, steel liner plates, etc.) will be constructed from within the shield 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. However, similar to jack and bore, groundwater lowering is necessary to control cohesionless soils below the groundwater level. Machine-assisted excavation generally requires a tunnel diameter of about 1.8 m or more. In some instances, vacuum well points installed from within the tunnel at an angle through the face (sometimes called “lances”) can be used to control groundwater levels as the tunnel progresses.
- **Manual Tunnelling:** Manual excavation within an open-face shield involves excavating the soils using pneumatic or hand tools working within a full-circumference tunnelling shield or at the lead end of the pipe. Typically, the temporary tunnel liner (i.e., steel casing, steel ribs and lagging, steel liner plates, etc.) will be constructed from within a shield, or final pipe would be jacked in sections from the launching shaft. This method includes personnel within the tunnel to allow control over the operations and removal of obstructions. Groundwater lowering is necessary to control cohesionless soils below the groundwater level. Manual excavation generally requires a tunnel diameter of about 1.2 m or more, though in some circumstances, smaller diameters and small square tunnels can be constructed depending on groundwater conditions. As for the TDM methods, drainage lances can be used in some cases to proactively dewater the ground from within the tunnel as the tunnel face advances.

### 6.4.3 Assessment for Feasible Installation Methods

Based on the ground conditions at the culvert site and the anticipated relatively short tunnel length of about 44.0 m, HDD, TBM, and PTMT methods are likely not suitable and are not cost-effective. The diameter of the culvert will preclude the use of HDD, TDM, or TBM systems. The presence of cobbles and boulders (i.e., as encountered in Boreholes C228-1, C228-2, C228-3, and C228-4) that may be encountered along the tunnel horizon would likely preclude the use of HDD, traditional “jack and bore,” and MTBM. The use of pipe ramming is likely to be the most feasible and suitable method for the culvert installation in the anticipated ground conditions. Based on the larger casing size, relative to the culvert size at this site, manual tunneling with a hooded shield and dewatering may be an alternative for this site. It should be noted that interventions to remove obstructions may be

necessary, and the contractor should be prepared to implement such interventions at this site. The following geotechnical issues/risks associated with the trenchless construction that should be considered and evaluated at this site are:

- Ground or Road Heave – culverts installed at shallow depth and with diameters that are relatively large as compared to the depth of burial are particularly susceptible to heaving the roadway if the pipe is rammed into place – i.e., having a cover to diameter (C/D) ratio of less than about 2, which is not the case at this site given the 1.4 m diameter liner required to accommodate the 1.2 m diameter culvert and 5.5 to 5.6 m thickness of soil cover.
- Obstructions – Cobbles and/or boulders were encountered in Boreholes C228-1, C228-2, C228-3, and C228-4 at this site. 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 above the culvert invert at the time of construction, there is the potential for flow of saturated granular soils (silt, sand, sand and gravel) 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 excavation. For any method that requires groundwater control for managing risks of ground losses, gravity flow to sumps and pumps or into permeable linings should not be relied upon except as a supplement to a fully designed vacuum well point or eductor system.

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 (if separate casing and pipes will be used) or oversize final pipes should be installed to permit final adjustments of the invert channel elevations for final flow control given the challenges associated with maintaining alignment. Selection of casing size should consider the potential for mis-alignment over the tunnel length due to ground conditions (i.e., cobbles/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 is not typical for centreline culverts in MTO's Northeast Region. However, a 2-pass lining may be advantageous to facilitate some methods of tunnelling and for achieving final alignment control, depending on the final hydraulic opening and lining design requirements. 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 6.6.8) 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 as per the SP for Pipe Installation by Trenchless Method.

## 6.5 Analytical Testing of Existing Soil

The results of analytical tests on one sample of sand fill, recovered in Borehole C228-1 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. The culvert should be designed with consideration given to Table 7.1 of the MTO Gravity Pipe Design Guidelines (2014).

### 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, when the designer is selecting the exposure class for the culvert/structure, the effects of sulphates from within the near surface/culvert invert native soil(s) may not need to be considered. However, as the culvert will extend 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.

### 6.5.2 Potential for Corrosion

The soil has a pH of 6.6 and according to the MTO Gravity Pipe Design Guidelines (2014), the pH is not considered detrimental to culvert durability. The resistivity is 12,000 ohm-cm, which indicates that the soil corrosiveness is Very Low (below 10,000 > R > 6,000 ohm-cm), as per Table 3.2 of the MTO Gravity Pipe Design Guidelines (2014). It is also noted that sulphide is considered very corrosive to cast iron/steel materials (Cashman and Preene, 2001), however, the sulphide concentration is below the reportable detection limit of 0.30 µg/g in the analyzed soil sample.

## 6.6 Construction Considerations

### 6.6.1 Open Cut Excavation

The proposed open cut excavation through the embankment and into the subgrade to the base of the culvert bedding level associated with the removal of the existing culvert and construction of the new culvert by open cut and re-construction of the embankment, will advance through the granular embankment fill and potentially into the sand, sand and gravel, silt to clayey silt deposits, and the excavation is anticipated to extend below the groundwater level. Excavations of entry / exit pits for trenchless pipe installation will also extend through the native sand, silt to clayey silt deposit and potentially into the sandy gravel to sand and gravel deposit. Where space permits for an open cut excavation into these materials, the excavation must 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 materials are classified as Type 3 soil, 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 materials and underlying native 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 / Surface Water Control

The groundwater level is expected to be at or above the proposed culvert horizon along most of its alignment; the excavation for the culvert replacement should be expected to extend below the groundwater level. The groundwater should be lowered to at least 1 m below the base of the excavation to maintain basal stability and allow for construction in dry conditions. Groundwater may be controlled by providing an active dewatering system consisting of an adequate number of sumps and pumps installed and operated in advance/during the excavation, or in combination with temporary support systems such as a sheet piling wall and/or cofferdams (as required).

The contractor is responsible for the assessment of dewatering requirements, which depends on their chosen method of open cut excavation for replacement, as well as on the method and procedure for construction/operation/maintenance and decommissioning. The contractor is also responsible for confirming that the radius of groundwater drawdown does not impact the existing embankment and any surrounding features. The design of dewatering, unwatering, and temporary flow passage system is the responsibility of the contractor.

Surface water should be directed away from open excavation areas to prevent ponding of water that could result in disturbance and weakening of the subgrade and/or affect construction or lining operations, as applicable. Depending on the water flow through the watercourse at the time of construction and staging/diversion requirements/limitations, temporary cofferdams may also be required to carry out the design of the system.

Groundwater and surface water control will be required for excavation and construction of the culvert replacement and for any trenchless lining option being considered. Dewatering operations must be in accordance with OPSS.PROV 517 (*Dewatering*) as amended by SP 517F01 (*Dewatering System/Temporary Flow Passage System*), recommending that a design engineer be required to carry out the design of the system. The return period flow estimates in Table A of SP 517F01 (included in Appendix C) shall be filled-in by the hydraulic design engineer. Given the potential for loosening of the gravelly silty sand subgrade at this site, the Designer Engineer fill-in for Note 1 in Table A shall indicate "yes". Given the apparent lack of infrastructure present in the vicinity of the culvert, a preconstruction survey is not considered to be required at this site and the fill-in for Note 2 should be N/A.

If construction dewatering is required and the quantity of water taken is between 50,000 litres/day and 400,000 litres/day under normal operations, an Environmental Activity and Sector Registry (EASR) is required in accordance with Part II.2 of the *Environmental Protection Act* (EPA or Act), *Ontario Regulation (O. Reg.) 245/11* (Registrations Under II.2 of the Act – General) and *O. Reg. 63/16* (Registrations under II.2 of the Act – Water Taking). The need for an EASR should be evaluated by the contractor, given this construction methods/operations and groundwater control system, in advance of construction operations to minimize any potential impacts on the construction schedule. Given the granular nature of the subsurface soils and embankment fill materials at this site, it is considered prudent to register under the EASR for construction dewatering/unwatering operations at this site.

### 6.6.3 Temporary Protection Systems

In order to replace the existing culvert and allow at least one lane of live traffic to pass during construction, temporary protection systems will likely be required. The temporary excavation protection and support systems shall be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*) as amended by SP 105S09. The lateral movement of the protection systems shall 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 steel sheet pile system might not be suitable at this site due to the presence of cobbles and boulders within the embankment fill and native soil deposits. The contractor may use a soldier pile and lagging system with socketing through the cobbles/boulders; however, the site would need to be adequately dewatered prior to installation of the lagging boards as the cohesionless fills and saturated 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 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 struts, 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 or structures, if present. 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 feasible alternatives.

| Stratigraphic Unit                                      | Bulk Unit Weight, $\gamma$ (kN/m <sup>3</sup> ) | Angle of Internal Friction, $\phi$ (degrees) | Undrained Shear Strength, $s_u$ (kPa) | Lateral Earth Pressure Coefficients <sup>1/2</sup> |               |                |
|---|---|--|---------------------------------------|--|---------------|----------------|
|   |   |  |                                       | Passive, $K_p^3$                                   | Active, $K_a$ | At-rest, $K_o$ |
| Embankment Fill – Loose to very dense sand and gravel   | 20  | 32   | -                                     | 3.25   | 0.31          | 0.47           |
| Embankment Fill – Very loose to loose sandy clayey silt | 18  | 28   | -                                     | 2.77   | 0.36          | 0.53           |
| Compact to very dense sand to sand and gravel           | 20  | 34   | -                                     | 3.54   | 0.28          | 0.44           |
| Loose to compact - silt to clayey silt                  | 18  | 28   | 50                                    | 2.77   | 0.36          | 0.53           |

## Notes:

1. The design groundwater level may be assumed to be Elevation 317.6 m near the inlet and outlet, based on the ground surface and 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 66 surface 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). Vibration and noise controls during extraction of any temporary systems should meet the same tolerable limits used for installation.

#### 6.6.4 Obstructions

Cobbles and/or boulders were encountered within the embankment fill in Boreholes C228-1 to C228-3 and C228-5 and in the native soil in Borehole C228-1, which would affect the installation of the temporary protection systems. A Notice to Contractor to identify to the contractor the possible presence of cobbles, boulders and deleterious material within the fill and native soils and wood/trees 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

Engineered 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), as amended by Special Provision (SP) 105S22, and OPSS.PROV 206 (Grading). Embankment side slopes should be constructed no steeper than 2H:1V in granular fill.

### 6.6.7 Surficial Embankment Stability and Erosion Protection

If the culvert is replaced by the open cut method, depending on the selected embankment reconstruction fill material type, slope geometry, surface treatment and weather conditions (i.e., precipitation, cycles of wetting-drying, and/or freezing-thawing), surficial instability of the embankment side slopes may occur, which could include localized sloughing and erosion. As such, in order to maintain the integrity of the new embankments, erosion protection measures may be required depending on the fill type selected for construction.

Based on the specified material types and hence the gradation envelope, granular fill such as OPSS.PROV 1010 (Aggregates) Granular 'A', or Granular 'B' Type I or Type II, have a low potential for erosion. For embankments constructed of granular fill, erosion control may be limited to seeding following the construction specifications of OPSS 802 (Topsoil) and OPSS.PROV 804 (Seed and Cover). On-going maintenance for embankments constructed of this material is not expected to be required once the vegetation has been established.

The specification for OPSS.PROV 1010 (Aggregates) SSM allows for much more variation in the gradation of the material compared to Granular 'A', or Granular 'B' Type I or Type II, and therefore has the potential to be low - erodible to moderate - erodible. Erosion protection for slopes constructed of SSM should consist of erosion control blankets and seeding. Slopes constructed of SSM and properly protected from erosion should require limited on-going maintenance.

### 6.6.8 Instrumentation and Monitoring Program

It is understood from AECOM that the preferred culvert replacement method is by open cut and a trenchless installation operation (method) will not be pursued, hence a program for settlement monitoring during and after culvert construction is not considered required.

An instrumentation and settlement monitoring program should however be considered at the culvert location if a trenchless installation method is 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 SP 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 trenchless 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 (CA) 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 trenchless 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 66 paved surface and embankment along the culvert alignment in the event of settlement during the installation process. It is understood from AECOM that granular 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."

### 6.6.9 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. Tibor Berecz, a geotechnical EIT 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.**

*Tibor Berecz*

Tibor Berecz, EIT  
Geotechnical EIT



*André Bom*

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



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

GM/TB/AB/JMAC/ca

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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 802.010 | Flexible Pipe Embedment and Backfill, Earth Excavation                  |
| 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 517  | Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation |
| OPSS.PROV 539  | Construction Specification for Temporary Protection Systems   |
| OPSS 802       | Construction Specification for Topsoil  |
| OPSS.PROV 804  | Construction Specification for Seed and Cover   |
| OPSS.PROV 1010 | Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material        |
- Special Provisions
- |           |                       |
|-----------|-----------------------|
| SP 105S22 | Amendment to OPSS 501 |
| SP 105S09 | Amendment to OPSS 539 |

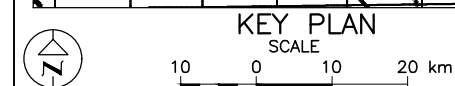
**Table 1: Culvert Replacement Alternatives – Highway 66 Station 17+221 Township of Lebel**

| Replacement Alternatives | Advantages  | Disadvantages  | Risks   |
|--------------------------|---|--|---|
| Pipe Ramming             | <ul style="list-style-type: none"> <li>Installed without significant removal of soils prior to full casing penetration through embankment.</li> <li>Relatively low cost.</li> <li>Relatively small site operations footprint.</li> <li>Within size range typical in Ontario.</li> <li>Better than other low-cost technologies for penetrating ground that potentially includes cobbles and small boulders.</li> </ul>   | <ul style="list-style-type: none"> <li>Combination of ground density, final pipe diameter and length of installation may be near the upper limit of feasibility for a single pipe installation – telescoping casing sizes or use of dual smaller diameter pipes may assist with feasibility.</li> <li>Density of ground in some areas may encourage or require premature removal of soils from within the casing.</li> <li>Concentrations of cobbles and boulders or large boulders as encountered in Boreholes C228-1 to C228-3), or large pieces of wood (structural timbers, stumps, logs) could obstruct operations.</li> <li>Obstructions may require shaft excavation from the surface.</li> <li>Vibrations from pipe driving can lead to densification and settlement of loose granular materials surrounding and overlying pipe and result in settlement of roadway surface.</li> <li>Alignment control can be difficult when penetrating soils of differing densities or when encountering cobbles and boulders.</li> </ul> | <ul style="list-style-type: none"> <li>Telescoping casing would likely require partial removal of soils from within the pipe to reduce potential for jamming and obstruction and, therefore, flowing ground risks may require additional mitigation (localized dewatering).</li> <li>Need for removal of soil from within casings because of driving resistance (binding of casings, weight of spoil, obstructions) could lead to excess ground losses and surface settlement.</li> </ul> |
| Cut and Cover            | <ul style="list-style-type: none"> <li>Risks of ground losses affecting traffic are better controlled than for trenchless methods.</li> <li>Depth of excavation is within typical limits for conventional excavation support, slopes and dewatering systems.</li> <li>With appropriate planning, excavation methods can be easily adapted to address removal of boulders as encountered in Boreholes C228-1 to C228-4, or other obstructions, and loose soils.</li> </ul> | <ul style="list-style-type: none"> <li>Traffic disruption (staging of crossing construction).</li> <li>Roadway protection required for staged excavation.</li> <li>Proactive dewatering required (e.g., vacuum well points).</li> </ul>  | <ul style="list-style-type: none"> <li>Difficulties may be experienced during installing temporary roadway protection if cobbles/boulders are present in embankment fill and native soils.</li> <li>Traffic staging problems (e.g., temporary concrete barriers, seasonal construction).</li> <li>Dewatering planning as part of bid may not be adequate and result in real or strategic claims.</li> </ul>   |

| Replacement Alternatives                            | Advantages   | Disadvantages   | Risks  |
|---|--|---|--|
| Manual Tunnelling with Hooded Shield and Dewatering | <ul style="list-style-type: none"> <li>■ Relatively low cost.</li> <li>■ Relatively small site operations footprint.</li> <li>■ Within size range typical in Ontario.</li> <li>■ Best for penetrating ground that includes cobbles and boulders of all sizes, as encountered in Boreholes C228-1 to C228-3 at this site</li> <li>■ Driving plates or bars ahead of excavation into the crown of the tunnel (spiling, forepoling) can be used to help control loose or ravelling ground.</li> </ul> | <ul style="list-style-type: none"> <li>■ An oversize tunnel diameter (liner) (compared to desired pipe size) may be necessary to better facilitate tunnelling.</li> <li>■ Full alignment length must be dewatered in advance of excavation using proactive methods from surface and/or within tunnel.</li> <li>■ Inadequate groundwater control can lead to excess ground losses and surface settlement.</li> <li>■ Spiling or forepoling may be required to control ravelling ground, increasing cost and schedule.</li> <li>■ "Two pass" lining system may be required (e.g., steel liner plates followed by pre-cast concrete panels).</li> <li>■ Slow rate of tunnel advancement</li> </ul> | <ul style="list-style-type: none"> <li>■ Dewatering planning as part of bid may not be adequate and result in real or strategic claims.</li> <li>■ Inadequate dewatering could lead to ground losses and excess surface settlement.</li> </ul> |

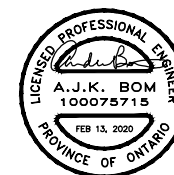


**GOLDER**



|   |  |
|---|--|
|  | Borehole – Current Investigation                                   |
|  | Dynamic Cone Penetration Test – Current Investigation              |
| N   | Standard Penetration Test Value                                    |
| 16  | Blows/0.3m unless otherwise stated<br>(Std. Pen. Test, 475 j/blow) |
| R   | Refusal  |
|  | WL upon completion of drilling                                     |

| BOREHOLE CO-ORDINATES (NAD 83 MTM ZONE 12) |           |           |          |
|--|-----------|-----------|----------|
| No.  | ELEVATION | NORTHING  | EASTING  |
| C228-1                                     | 322.8     | 5335749.7 | 384044.0 |
| C228-2                                     | 323.1     | 5335759.6 | 384031.4 |
| C228-3                                     | 322.9     | 5335735.3 | 384052.1 |
| C228-4                                     | 318.1     | 5335727.8 | 384044.6 |
| C228-5                                     | 318.2     | 5335772.2 | 384044.2 |

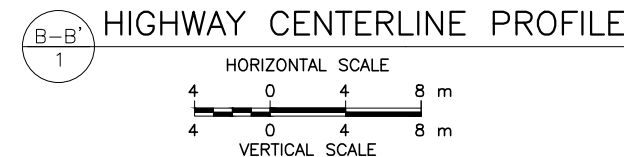
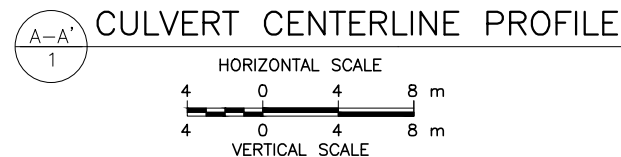


This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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 CALLON DIETZ LTD. drawing file no. qwp52101400a.dwg, received AUG 14, 2019.

|                    |  |                     |  |                |  |          |  |
|--------------------|--|---------------------|--|----------------|--|----------|--|
| NO.                |  | DATE                |  | BY             |  | REVISION |  |
| Geocres No. 32D-25 |  |                     |  |                |  |          |  |
| HWY. 66            |  | PROJECT NO. 1896349 |  |                |  | DIST. .  |  |
| SUBM'D. .          |  | CHKD. TB            |  | DATE: 2/7/2020 |  | SITE: .  |  |
| DRAWN: TR          |  | CHKD. AB            |  | APPD. JMAM     |  | DWG. 1   |  |





**Photograph 1: Drilling Rig Positioned at Borehole C228-2, Facing West (May 2019)**



**Photograph 2: Embankment North Slope Near Culvert Outlet, Facing South East (May 2019)**



**Photograph 3: Culvert Outlet, North Side of Embankment (May 2019)**



**Photograph 4: Culvert Inlet, South Side of Embankment (May 2019)**

**APPENDIX A**

**Record of Boreholes**

# ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

## MINISTRY OF TRANSPORTATION, ONTARIO

### PARTICLE SIZES OF CONSTITUENTS

| Soil Constituent | Particle Size Description | Millimetres                                     | Inches (US Std. Sieve Size)                  |
|------------------|---------------------------|---|--|
| BOULDERS         | Not Applicable            | >300  | >12  |
| COBBLES          | Not Applicable            | 75 to 300                                       | 3 to 12                                      |
| GRAVEL           | Coarse<br>Fine            | 19 to 75<br>4.75 to 19                          | 0.75 to 3<br>(4) to 0.75                     |
| SAND             | Coarse<br>Medium<br>Fine  | 2.00 to 4.75<br>0.425 to 2.00<br>0.075 to 0.425 | (10) to (4)<br>(40) to (10)<br>(200) to (40) |
| FINES            | Classified by plasticity  | <0.075  | < (200)                                      |

### MODIFIERS FOR SECONDARY COMPONENTS<sup>1,2</sup>

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

1. Only applicable to components not described by Primary Group Name.

2. Classification of Primary Group Name based on Unified Soil Classification System (ASTM D2487) for coarse-grained soils; fine-grained soils described per current MTO Soil Classification System.

### PENETRATION RESISTANCE

#### Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

#### Cone Penetration Test (CPT)

An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm<sup>2</sup> pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q<sub>t</sub>), porewater pressure (u) and sleeve friction (f<sub>s</sub>) are recorded electronically at 25 mm penetration intervals.

#### Dynamic Cone Penetration Resistance (DCPT); N<sub>d</sub>:

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

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

**WH:** Sampler advanced by static weight of hammer

**WR:** Sampler advanced by weight of sampler and rod

### SAMPLES

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

### SOIL TESTS

|                    |   |
|--------------------|---|
| w                  | water content   |
| PL, w <sub>p</sub> | plastic limit   |
| LL, w <sub>L</sub> | liquid limit  |
| C                  | consolidation (oedometer) test  |
| CHEM               | chemical analysis (refer to text)   |
| CID                | consolidated isotropically drained triaxial test <sup>1</sup>                                       |
| CIU                | consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup> |
| D <sub>R</sub>     | relative density (specific gravity, G <sub>s</sub> )  |
| DS                 | direct shear test   |
| GS                 | specific gravity  |
| M                  | sieve analysis for particle size  |
| MH                 | combined sieve and hydrometer (H) analysis  |
| MPC                | Modified Proctor compaction test  |
| SPC                | Standard Proctor compaction test  |
| OC                 | organic content test  |
| SO <sub>4</sub>    | concentration of water-soluble sulphates  |
| UC                 | unconfined compression test   |
| UU                 | unconsolidated undrained triaxial test  |
| V (FV)             | field vane (LV-laboratory vane test)  |
| Y                  | unit weight   |

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

### COARSE-GRAINED SOILS

#### Compactness<sup>1</sup>

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

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

4. SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.

### FINE-GRAINED SOILS

#### Consistency

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

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.

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

### Field Moisture Condition

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

# LIST OF SYMBOLS

## MINISTRY OF TRANSPORTATION, ONTARIO

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

### I. GENERAL

|             |                                       |
|-------------|---------------------------------------|
| $\pi$       | 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

|                                |   |
|--------------------------------|---|
| $\gamma$                       | shear strain                                  |
| $\Delta$                       | change in, e.g. in stress: $\Delta\sigma$     |
| $\varepsilon$                  | linear strain                                 |
| $\varepsilon_v$                | volumetric strain                             |
| $\eta$                         | coefficient of viscosity                      |
| $\nu$                          | Poisson's ratio                               |
| $\sigma$                       | total stress                                  |
| $\sigma'$                      | effective stress ( $\sigma' = \sigma - u$ )   |
| $\sigma'_{vo}$                 | initial effective overburden stress           |
| $\sigma_1, \sigma_2, \sigma_3$ | principal stress (major, intermediate, minor) |

|                |  |
|----------------|--|
| $\sigma_{oct}$ | mean stress or octahedral stress<br>$= (\sigma_1 + \sigma_2 + \sigma_3)/3$ |
| $\tau$         | 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   |
| $\gamma'$          | unit weight of submerged soil<br>( $\gamma' = \gamma - \gamma_w$ )                                   |
| $D_R$              | relative density (specific gravity) of solid particles ( $D_R = \rho_s / \rho_w$ ) (formerly $G_s$ ) |
| E                  | void ratio   |
| N                  | porosity   |
| S                  | degree of saturation   |

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

#### (a) Index Properties (continued)

|             |  |
|-------------|--|
| w           | water content  |
| $w_l$ or LL | liquid limit   |
| $w_p$ or PL | plastic limit  |
| $I_p$ or PI | plasticity index = $(w_l - w_p)$   |
| NP          | non-plastic  |
| $w_s$       | shrinkage limit  |
| $I_L$       | liquidity index = $(w - w_p) / I_p$  |
| $I_C$       | consistency index = $(w_l - w) / I_p$  |
| $e_{max}$   | void ratio in loosest state  |
| $e_{min}$   | void ratio in densest state  |
| $I_D$       | density index = $(e_{max} - e) / (e_{max} - e_{min})$<br>(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<br>(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  |
| $C_\alpha$  | 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                               |
| $\sigma'_p$ | pre-consolidation stress                              |
| OCR         | over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$ |

#### (d) Shear Strength

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

Notes: 1  
2

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


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

SUD-MTO 001 S:\CLIENTS\MTO\HWY65&66\02 DATA\GIN\1896349.GPJ GAL-MISS.GDT 11-7-19 TR

| PROJECT 1896349   |   | <b>RECORD OF BOREHOLE No C228-1</b>   |        |      |                            | 2 OF 2 <b>METRIC</b> |  |                    |  |  |  |  |                   |  |   |  |  |  |
|-------------------|---|---|--------|------|----------------------------|----------------------|--|--------------------|--|--|--|--|-------------------|--|---|--|--|--|
| G.W.P. 5210-14-00 |   | LOCATION N 5335749.7; E 384044.0 NAD83 MTM ZONE 12 (LAT. 48.155658; LONG. -79.934791) |        |      |                            | ORIGINATED BY MR     |  |                    |  |  |  |  |                   |  |   |  |  |  |
| DIST _____ HWY 66 |   | BOREHOLE TYPE 76 mm I.D. Hollow Stem Augers, NW Casing, NQ Coring                     |        |      |                            | COMPILED BY GM       |  |                    |  |  |  |  |                   |  |   |  |  |  |
| DATUM GEODETIC    |   | DATE May 8, 2019  |        |      |                            | CHECKED BY AB        |  |                    |  |  |  |  |                   |  |   |  |  |  |
| SOIL PROFILE      |   | SAMPLES   |        |      | GROUND WATER<br>CONDITIONS | ELEVATION SCALE      | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT  |                    |  |  |  | PLASTIC NATURAL LIQUID<br>LIMIT MOISTURE LIMIT<br>CONTENT  |                   |  | UNIT<br>WEIGHT<br>$\gamma$<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%)<br>GR SA SI CL |  |  |
| ELEV<br>DEPTH     | DESCRIPTION   | STRAT PLOT  | NUMBER | TYPE |                            |                      | "N" VALUES   | SHEAR STRENGTH kPa |  |  |  |  | WATER CONTENT (%) |  |   |  |  |  |
|                   | --- CONTINUED FROM PREVIOUS PAGE ---  |   |        |      |                            |                      | <div style="display: flex; justify-content: space-between;"> <span>20 40 60 80 100</span> <span>20 40 60 80 100</span> </div> <div style="display: flex; justify-content: space-between;"> <span>○ UNCONFINED + FIELD VANE</span> <span>● QUICK TRIAXIAL × REMOULDED</span> </div> |                    |  |  |  | <div style="display: flex; justify-content: space-between;"> <span>W<sub>p</sub></span> <span>W</span> <span>W<sub>L</sub></span> </div> |                   |  |   |  |  |  |
| 308.0             | SAND, trace gravel, trace silt<br>Compact to dense<br>Brown<br>Wet  |   | 10     | SS   | 13                         |                      |  |                    |  |  |  |  |                   |  |   |  |  |  |
|                   |   |   |        |      |                            |                      |  |                    |  |  |  |  |                   |  |   |  |  |  |
|                   |   |   | 11     | SS   | 16                         |                      |  |                    |  |  |  |  |                   |  |   |  |  |  |
|                   |   |   |        |      |                            |                      |  |                    |  |  |  |  |                   |  |   |  |  |  |
| 14.8              | SAND and GRAVEL<br>Compact to very dense<br>Brown<br>Wet  |   | 12     | SS   | 17                         |                      |  |                    |  |  |  |  |                   |  |   |  |  |  |
|                   |   |   |        |      |                            |                      |  |                    |  |  |  |  |                   |  |   |  |  |  |
|                   |   |   | 13     | SS   | 28                         |                      |  |                    |  |  |  |  |                   |  |   |  |  |  |
|                   |   |   |        |      |                            |                      |  |                    |  |  |  |  |                   |  |   |  |  |  |
|                   |   |   | 14     | SS   | 54                         |                      |  |                    |  |  |  |  |                   |  |   |  |  |  |
|                   |   |   |        |      |                            |                      |  |                    |  |  |  |  |                   |  |   |  |  |  |
|                   |   |   | 15     | SS   | 40                         |                      |  |                    |  |  |  |  |                   |  |   |  |  |  |
| 302.4             | END OF BOREHOLE   |   |        |      |                            |                      |  |                    |  |  |  |  |                   |  |   |  |  |  |
| 20.4              | NOTE:<br><br>1. Water level at a depth of 5.2 m<br>below ground surface (Elev. 317.6 m)<br>upon completion of drilling. |   |        |      |                            |                      |  |                    |  |  |  |  |                   |  |   |  |  |  |

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

| PROJECT <u>1896349</u>               |   | <b>RECORD OF BOREHOLE No C228-2</b>  |         |      |            | 2 OF 2 <b>METRIC</b>                     |                 |   |                                 |  |                                       |          |
|--------------------------------------|---|--|---------|------|------------|--|-----------------|---|---------------------------------|--|---------------------------------------|----------|
| G.W.P. <u>5210-14-00</u>             |   | LOCATION <u>N 5335759.6; E 384031.4 NAD83 MTM ZONE 12 (LAT. 48.155748; LONG. -79.934959)</u> |         |      |            | ORIGINATED BY <u>MR</u>                  |                 |   |                                 |  |                                       |          |
| DIST <u>          </u> HWY <u>66</u> |   | BOREHOLE TYPE <u>76 mm I.D. Hollow Stem Augers, NW Casing, NQ Coring</u>                     |         |      |            | COMPILED BY <u>GM</u>                    |                 |   |                                 |  |                                       |          |
| DATUM <u>GEODETIC</u>                |   | DATE <u>May 6, 2019</u>  |         |      |            | CHECKED BY <u>AB</u>                     |                 |   |                                 |  |                                       |          |
| SOIL PROFILE                         |   |  | SAMPLES |      |            | DYNAMIC CONE PENETRATION RESISTANCE PLOT |                 | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT |                                 | UNIT WEIGHT<br>$\gamma$<br>kN/m <sup>3</sup> | REMARKS & GRAIN SIZE DISTRIBUTION (%) |          |
| ELEV<br>DEPTH                        | DESCRIPTION   | STRAT PLOT   | NUMBER  | TYPE | "N" VALUES | GROUND WATER CONDITIONS                  | ELEVATION SCALE | 20 40 60 80 100                                     | W <sub>p</sub> W W <sub>L</sub> |  |                                       | 20 40 60 |
|                                      | --- CONTINUED FROM PREVIOUS PAGE ---  |  |         |      |            |  |                 |   |                                 |  |                                       |          |
| 308.2                                | SILT to CLAYEY SILT<br>Loose to compact / stiff to very stiff<br>Grey<br>Wet                                      |             | 10      | SS   | 9          |  | 311             |   |                                 |  |                                       |          |
|                                      |   |  |         |      |            |  | 310             |   |                                 |  |                                       |          |
|                                      |   |  | 11      | SS   | 19         |  | 309             |   |                                 |  |                                       |          |
|                                      |   |  |         |      |            |  | 308             |   |                                 |  |                                       |          |
| 14.9                                 | Silty SAND and GRAVEL<br>Very dense<br>Grey<br>Wet  |  | 12      | SS   | 51         |  |                 |   |                                 |  |                                       |          |
| 307.2                                | END OF BOREHOLE   |  |         |      |            |  |                 |   |                                 |  |                                       |          |
| 15.9                                 | NOTE:<br><br>1. Water level at a depth of 5.4 m below ground surface (Elev. 317.7 m) upon completion of drilling. |  |         |      |            |  |                 |   |                                 |  |                                       |          |

|                                    |  |  |  |                         |  |
|------------------------------------|--|--|--|-------------------------|--|
| PROJECT <u>1896349</u>             |  | <b>RECORD OF BOREHOLE No C228-3</b>  |  | 1 OF 2 <b>METRIC</b>    |  |
| G.W.P. <u>5210-14-00</u>           |  | LOCATION <u>N 5335735.3; E 384052.1 NAD83 MTM ZONE 12 (LAT. 48.155527; LONG. -79.934685)</u> |  | ORIGINATED BY <u>MR</u> |  |
| DIST <u>        </u> HWY <u>66</u> |  | BOREHOLE TYPE <u>76 mm I.D. Hollow Stem Augers, NW Casing, NQ Coring</u>                     |  | COMPILED BY <u>GM</u>   |  |
| DATUM <u>GEODETIC</u>              |  | DATE <u>May 7, 2019</u>  |  | CHECKED BY <u>AB</u>    |  |

| SOIL PROFILE  |  |            | SAMPLES |      |            | GROUND WATER<br>CONDITIONS | ELEVATION<br>SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |    |    |    |     | PLASTIC NATURAL LIQUID<br>LIMIT MOISTURE CONTENT |    |    | UNIT<br>WEIGHT<br>$\gamma$<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%) |    |    |    |
|---------------|--|------------|---------|------|------------|----------------------------|--------------------|---|----|----|----|-----|--|----|----|---|---|----|----|----|
| ELEV<br>DEPTH | DESCRIPTION  | STRAT PLOT | NUMBER  | TYPE | "N" VALUES |                            |                    | SHEAR STRENGTH kPa                          |    |    |    |     | WATER CONTENT (%)                                |    |    |   |   |    |    |    |
|               |  |            |         |      |            |                            |                    | 20  | 40 | 60 | 80 | 100 | 20   | 40 | 60 |   | GR  | SA | SI | CL |
| 322.9         | GROUND SURFACE   |            |         |      |            |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
| 0.0           | ASPHALT (430 mm)   |            |         |      |            |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
| 322.5         |  |            |         |      |            |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
| 0.4           | Gravelly sand to sand and gravel,<br>some silt (FILL)<br>Compact to dense<br>Brown to grey<br>Moist to wet |            | 1       | SS   | 50         |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
|               |  |            |         |      |            |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
|               | - Cobble encountered from<br>2.1 m to 2.3 m depth  |            | 2       | SS   | 39         |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
|               |  |            | -       | RC   | -          |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
|               |  |            | 3       | SS   | 48         |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
|               | - Approximate 600 mm diameter<br>boulder encountered from 2.7 m to<br>3.3 m depth                          |            | -       | RC   | -          |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
|               |  |            |         |      |            |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
|               | - Approximate 400 mm diameter<br>boulder encountered from 3.3 m to<br>3.7 m depth                          |            | 4       | SS   | 43         |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
|               |  |            |         |      |            |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
|               |  |            | 5       | SS   | 20         |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
|               |  |            |         |      |            |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
|               | - Poor recovery in Split-Spoon in<br>Samples 5 and 6. Trace gravel<br>recovered.                           |            |         |      |            |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
|               |  |            | 6       | SS   | 38         |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
|               |  |            |         |      |            |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
|               |  |            |         |      |            |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
|               |  |            | 7       | SS   | 70         |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
|               |  |            |         |      |            |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
| 314.2         |  |            |         |      |            |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
| 8.7           | SAND, some gravel, trace silt<br>Compact<br>Brown<br>Wet   |            | 8       | SS   | 19         |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
|               |  |            |         |      |            |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
|               |  |            |         |      |            |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
|               |  |            | 9       | SS   | 13         |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
|               |  |            |         |      |            |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
| 311.2         |  |            |         |      |            |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |
| 11.7          |  |            |         |      |            |                            |                    |   |    |    |    |     |  |    |    |   |   |    |    |    |

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

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|                                      |  |  |  |  |  |                         |  |
|--------------------------------------|--|--|--|--|--|-------------------------|--|
| PROJECT <u>1896349</u>               |  | <b>RECORD OF BOREHOLE No C228-3</b>  |  |  |  | 2 OF 2 <b>METRIC</b>    |  |
| G.W.P. <u>5210-14-00</u>             |  | LOCATION <u>N 5335735.3; E 384052.1 NAD83 MTM ZONE 12 (LAT. 48.155527; LONG. -79.934685)</u> |  |  |  | ORIGINATED BY <u>MR</u> |  |
| DIST <u>          </u> HWY <u>66</u> |  | BOREHOLE TYPE <u>76 mm I.D. Hollow Stem Augers, NW Casing, NQ Coring</u>                     |  |  |  | COMPILED BY <u>GM</u>   |  |
| DATUM <u>GEODETIC</u>                |  | DATE <u>May 7, 2019</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 $\gamma$<br>kN/m <sup>3</sup> | REMARKS & GRAIN SIZE DISTRIBUTION (%)<br>GR SA SI CL |  |
|---------------|--|------------|--------|------|-------------------------|-----------------|--|--------------------|----|----|-----|---|-------------------|----------------|---|--|--|
| ELEV<br>DEPTH | DESCRIPTION  | STRAT PLOT | NUMBER | TYPE |                         |                 | "N" VALUES                               | SHEAR STRENGTH kPa |    |    |     |   | WATER CONTENT (%) |                |   |  |  |
|               |  |            |        |      |                         |                 | 20                                       | 40                 | 60 | 80 | 100 | W <sub>p</sub>                                      | W                 | W <sub>L</sub> |   |  |  |
|               | --- CONTINUED FROM PREVIOUS PAGE ---   |            |        |      |                         |                 |  |                    |    |    |     |   |                   |                |   |  |  |
|               | SAND and GRAVEL, trace silt<br>Compact<br>Brown<br>Wet   | *          | 10     | SS   | 23                      |                 |  |                    |    |    |     |   |                   |                |   |  |  |
|               |  | *          |        |      |                         |                 |  |                    |    |    |     |   |                   |                |   |  |  |
|               |  | *          |        |      |                         |                 |  |                    |    |    |     |   |                   |                |   |  |  |
|               |  | *          | 11     | SS   | 22                      |                 |  |                    |    |    |     |   |                   |                |   |  |  |
|               |  | *          |        |      |                         |                 |  |                    |    |    |     |   |                   |                |   |  |  |
|               |  | *          |        |      |                         |                 |  |                    |    |    |     |   |                   |                |   |  |  |
|               |  | *          | 12     | SS   | 21                      |                 |  |                    |    |    |     |   |                   |                |   |  |  |
| 307.0         |  | *          |        |      |                         |                 |  |                    |    |    |     |   |                   |                |   |  |  |
| 15.9          | END OF BOREHOLE<br><br>NOTE:<br><br>1. Water level at a depth of 4.5 m below ground surface (Elev. 318.4 m) upon completion of drilling. |            |        |      |                         |                 |  |                    |    |    |     |   |                   |                |   |  |  |

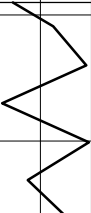
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| PROJECT 1896349   |   | RECORD OF BOREHOLE No C228-4  |         | 1 OF 2 METRIC    |                         |                 |  |                    |                                 |                               |                                |                  |                                       |
|-------------------|---|---|---------|------------------|-------------------------|-----------------|--|--------------------|---------------------------------|-------------------------------|--------------------------------|------------------|---------------------------------------|
| G.W.P. 5210-14-00 |   | LOCATION N 5335727.8; E 384044.6 NAD83 MTM ZONE 12 (LAT. 48.155461; LONG. -79.934787) |         | ORIGINATED BY YS |                         |                 |  |                    |                                 |                               |                                |                  |                                       |
| DIST _____ HWY 66 |   | BOREHOLE TYPE Portable Equipment, NW Casing, Wash Boring                              |         | COMPILED BY GM   |                         |                 |  |                    |                                 |                               |                                |                  |                                       |
| DATUM GEODETIC    |   | DATE May 29 and 30, 2019  |         | CHECKED BY AB    |                         |                 |  |                    |                                 |                               |                                |                  |                                       |
| SOIL PROFILE      |   |   | SAMPLES |                  | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT |                    | PLASTIC LIMIT<br>W <sub>p</sub> | NATURAL MOISTURE CONTENT<br>W | LIQUID LIMIT<br>W <sub>L</sub> | UNIT WEIGHT<br>γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
| ELEV<br>DEPTH     | DESCRIPTION   | STRAT PLOT  | NUMBER  | TYPE             |                         |                 | "N" VALUES                               | SHEAR STRENGTH kPa |                                 |                               |                                |                  |                                       |
| 318.1             | GROUND SURFACE  |   |         |                  |                         |                 |  |                    |                                 |                               |                                |                  |                                       |
| 0.0               | Topsoil (FILL)  |   | 1       | SS               | 10                      | ▽               | 318                                      |                    |                                 |                               |                                |                  | 2 37 59 2                             |
| 317.4             | Silt and sand, trace gravel, trace clay, trace organics, trace rootlets (FILL)<br>Loose Brown Moist |   | 2       | SS               | 44                      |                 | 317                                      |                    |                                 |                               |                                |                  |                                       |
| 316.6             | Clayey silt, with cobbles and gravel (FILL)<br>Hard Brown Moist                                     |   | 3       | SS               | 20                      |                 | 316                                      |                    |                                 |                               |                                |                  |                                       |
| 315.9             | Sand and gravel (FILL)<br>Compact Brown Wet   |   | 4       | SS               | 22                      |                 | 315                                      |                    |                                 |                               |                                |                  | 2 94 (4)                              |
|                   |   |   | 5       | SS               | 31                      |                 | 314                                      |                    |                                 |                               |                                |                  |                                       |
| 314.4             | SAND, trace gravel, trace silt<br>Compact Brown Wet   |   |         |                  |                         |                 | 313                                      |                    |                                 |                               |                                |                  |                                       |
| 3.7               | END OF BOREHOLE<br>SPLIT-SPOON REFUSAL  |   |         |                  |                         |                 | 312                                      |                    |                                 |                               |                                |                  |                                       |
|                   |   |   |         |                  |                         |                 | 311                                      |                    |                                 |                               |                                |                  |                                       |
|                   |   |   |         |                  |                         |                 | 310                                      |                    |                                 |                               |                                |                  |                                       |
|                   |   |   |         |                  |                         |                 | 309                                      |                    |                                 |                               |                                |                  |                                       |
|                   |   |   |         |                  |                         |                 | 308                                      |                    |                                 |                               |                                |                  |                                       |
|                   |   |   |         |                  |                         |                 | 307                                      |                    |                                 |                               |                                |                  |                                       |

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

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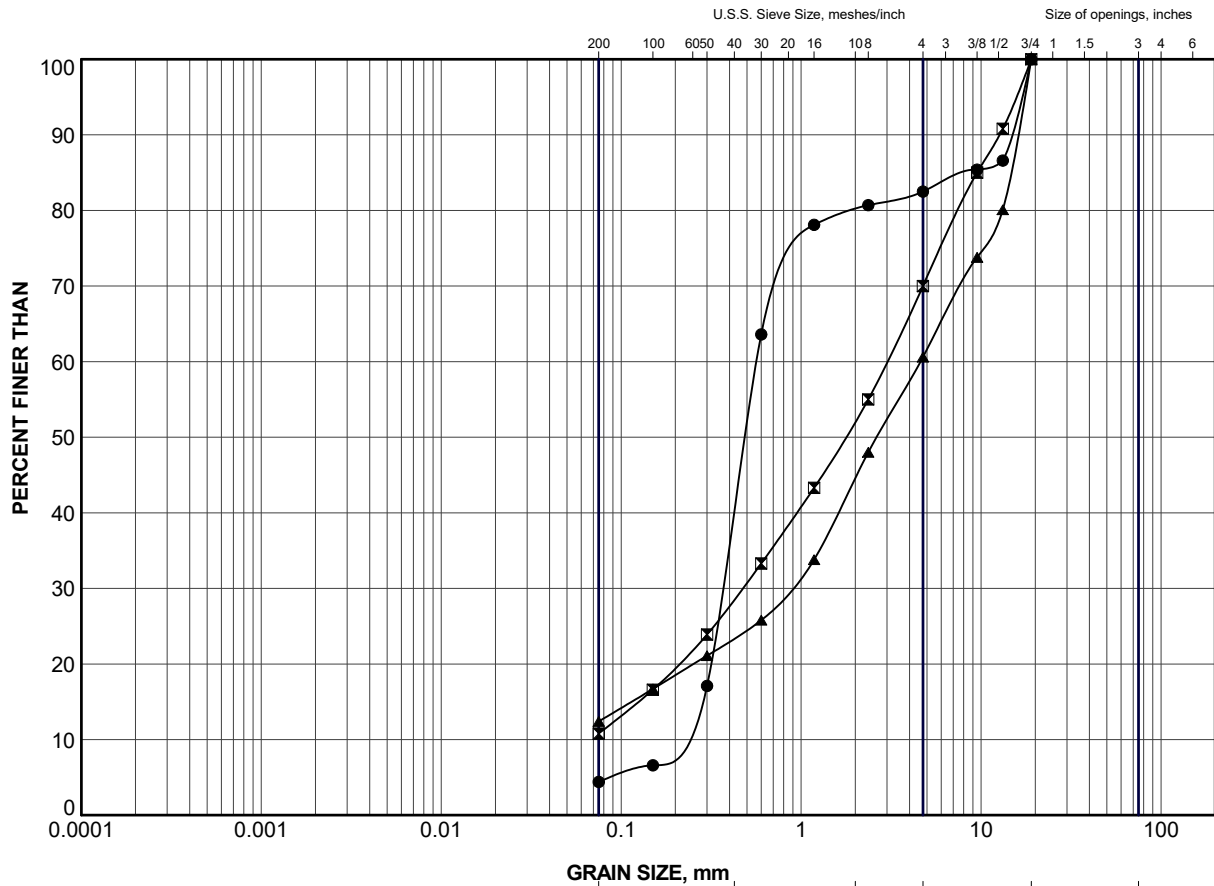
| PROJECT <u>1896349</u>               |  | <b>RECORD OF BOREHOLE No C228-4</b>  |        |      |                            | 2 OF 2 <b>METRIC</b>    |   |                    |  |  |  |   |                   |  |   |  |
|--------------------------------------|--|--|--------|------|----------------------------|-------------------------|---|--------------------|--|--|--|---|-------------------|--|---|--|
| G.W.P. <u>5210-14-00</u>             |  | LOCATION <u>N 5335727.8; E 384044.6 NAD83 MTM ZONE 12 (LAT. 48.155461; LONG. -79.934787)</u> |        |      |                            | ORIGINATED BY <u>YS</u> |   |                    |  |  |  |   |                   |  |   |  |
| DIST <u>          </u> HWY <u>66</u> |  | BOREHOLE TYPE <u>Portable Equipment, NW Casing, Wash Boring</u>                              |        |      |                            | COMPILED BY <u>GM</u>   |   |                    |  |  |  |   |                   |  |   |  |
| DATUM <u>GEODETIC</u>                |  | DATE <u>May 29 and 30, 2019</u>  |        |      |                            | CHECKED BY <u>AB</u>    |   |                    |  |  |  |   |                   |  |   |  |
| SOIL PROFILE                         |  | SAMPLES  |        |      | GROUND WATER<br>CONDITIONS | ELEVATION SCALE         | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT   |                    |  |  |  | PLASTIC NATURAL LIQUID<br>LIMIT MOISTURE LIMIT<br>CONTENT |                   |  | UNIT<br>WEIGHT<br>$\gamma$<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%)<br>GR SA SI CL |
| ELEV<br>DEPTH                        | DESCRIPTION  | STRAT PLOT   | NUMBER | TYPE |                            |                         | "N" VALUES  | SHEAR STRENGTH kPa |  |  |  |   | WATER CONTENT (%) |  |   |  |
|                                      | --- CONTINUED FROM PREVIOUS PAGE ---   |  |        |      |                            |                         | 20 40 60 80 100<br>○ UNCONFINED + FIELD VANE<br>● QUICK TRIAXIAL × REMOULDED<br>20 40 60 80 100 |                    |  |  |  | W <sub>p</sub> — W — W <sub>L</sub><br>20 40 60           |                   |  |   |  |
| 304.4                                |  |  |        |      |                            | 306                     |               |                    |  |  |  |   |                   |  |   |  |
| 13.7                                 | END OF DCPT<br><br>NOTE:<br>1. Samples 1 to 4 obtained at original borehole and refusal to further casing advancement at 3.0 m depth. Attempted DCPT from bottom of original borehole and refusal also at 3.0 m.<br>2. Advanced DCPT 1.0 m west of original borehole to 13.7 m depth.<br>3. A second borehole attempted 1.3 m west of original borehole and refusal at 3.5 m (no sampling).<br>4. Sample 5 obtained in third borehole attempted 0.5 m west of original borehole with refusal at 3.7 m depth.<br>5. Water level at a depth of 0.5 m below ground surface (Elev. 317.6 m) upon completion of drilling of third borehole. |  |        |      |                            |                         |   |                    |  |  |  |   |                   |  |   |  |

SUD-MTO 001 S:\CLIENTS\MTOT\HWY65&amp;66\02\_DATAGINT\1896349.GPJ GAL-MISS.GDT 11-7-19 TR

| PROJECT 1896349   |   | <b>RECORD OF BOREHOLE No C228-5</b>   |         |      |            | 1 OF 1 <b>METRIC</b>       |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
|-------------------|---|---|---------|------|------------|----------------------------|--------------------|---|-----------------|-----------------|-----------------|-----------------|---|-----------------|--|---|--|
| G.W.P. 5210-14-00 |   | LOCATION N 5335772.2; E 384044.2 NAD83 MTM ZONE 12 (LAT. 48.155861; LONG. -79.934785) |         |      |            | ORIGINATED BY MR           |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
| DIST _____ HWY 66 |   | BOREHOLE TYPE 76 mm I.D. Hollow Stem Augers, NW Casing, NQ Coring                     |         |      |            | COMPILED BY GM             |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
| DATUM GEODETIC    |   | DATE May 7, 2019  |         |      |            | CHECKED BY AB              |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
| SOIL PROFILE      |   |   | SAMPLES |      |            | GROUND WATER<br>CONDITIONS | ELEVATION<br>SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |                 |                 |                 |                 | PLASTIC NATURAL LIQUID<br>LIMIT MOISTURE LIMIT<br>CONTENT |                 |  | UNIT<br>WEIGHT<br>$\gamma$<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%)<br>GR SA SI CL |
| ELEV<br>DEPTH     | DESCRIPTION   | STRAT PLOT  | NUMBER  | TYPE | "N" VALUES |                            |                    | SHEAR STRENGTH kPa                          |                 |                 |                 |                 | WATER CONTENT (%)   |                 |  |   |  |
|                   |   |   |         |      |            |                            |                    | 20 40 60 80 100                             | 20 40 60 80 100 | 20 40 60 80 100 | 20 40 60 80 100 | 20 40 60 80 100 | 20 40 60 80 100   | 20 40 60 80 100 |  |   |  |
| 318.2             | GROUND SURFACE  |   |         |      |            |                            |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
| 0.0               | Organic silty sand (FILL)<br>Mottled brown and black<br>Wet   |   |         |      |            |                            |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
| 0.2               | Sand and gravel, some silt (FILL)<br>Loose to dense<br>Brown<br>Wet   |   | 1       | SS   | 5          |                            |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
|                   |   |   | 2       | SS   | 41         |                            |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
|                   |   |   |         |      |            |                            |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
|                   | - Approximate 300 mm diameter<br>boulder encountered from 2.3 m to<br>2.6 m depth                                       |   | -       | RC   | -          |                            |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
| 315.6             |   |   |         |      |            |                            |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
| 2.6               | Sandy GRAVEL to SAND and<br>GRAVEL<br>Compact<br>Brown<br>Wet   |   | 3       | SS   | 29         |                            |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
|                   |   |   | 4       | SS   | 25         |                            |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
|                   |   |   | 5       | SS   | 24         |                            |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
|                   |   |   | 6       | SS   | 20         |                            |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
|                   |   |   |         |      |            |                            |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
|                   |   |   | 7       | SS   | 10         |                            |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
|                   |   |   | 8       | SS   | 10         |                            |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
|                   |   |   |         |      |            |                            |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
|                   |   |   | 9       | SS   | 15         |                            |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
| 308.4             |   |   |         |      |            |                            |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
| 9.8               | END OF BOREHOLE   |   |         |      |            |                            |                    |   |                 |                 |                 |                 |   |                 |  |   |  |
|                   | NOTE:<br><br>1. Water level at a depth of 2.3 m<br>below ground surface (Elev. 315.9 m)<br>upon completion of drilling. |   |         |      |            |                            |                    |   |                 |                 |                 |                 |   |                 |  |   |  |

**APPENDIX B**

# Laboratory Test Results

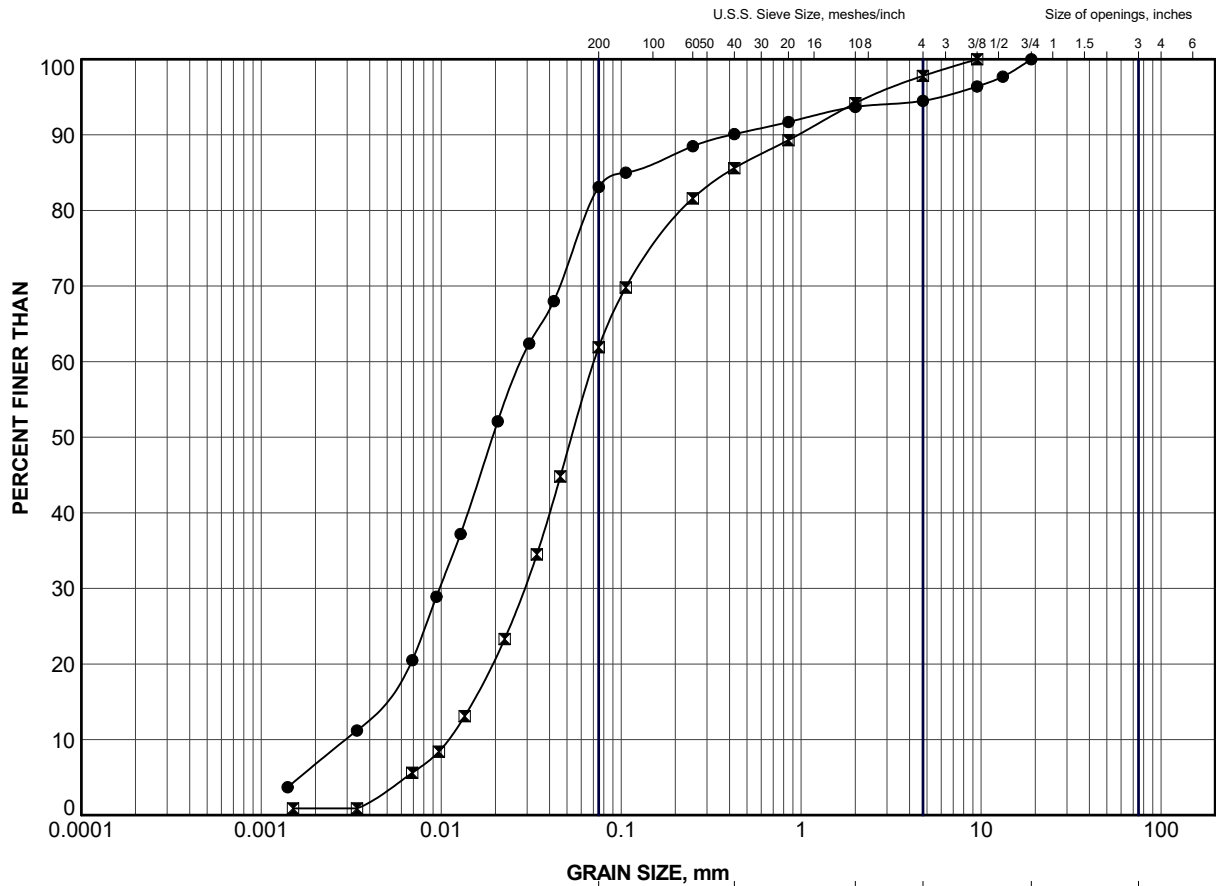


| CLAY AND SILT | GRAVEL SIZE, mm |        |        |             |        | Cobble Size |
|---------------|-----------------|--------|--------|-------------|--------|-------------|
|               | fine            | medium | coarse | fine        | coarse |             |
|               | SAND SIZE       |        |        | GRAVEL SIZE |        |             |

### LEGEND

| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|--------|----------|--------|----------|
| ●      | C228-1   | 6      | 316.4    |
| ■      | C228-3   | 5      | 318.0    |
| ▲      | C228-5   | 2      | 316.4    |


|                  |      |          |            |     |      |   |  |  |             |  |  |
|------------------|------|----------|------------|-----|------|---|--|--|-------------|--|--|
| PROJECT          |      |          |            |     |      | HIGHWAY 66<br>STATION 17+221<br>TOWNSHIP OF LEBEL CULVERT |  |  |             |  |  |
| TITLE            |      |          |            |     |      | GRAIN SIZE DISTRIBUTION<br>Sand to Sand and Gravel (FILL) |  |  |             |  |  |
| PROJECT No.      |      |          | 1896349    |     |      | FILE No.  |  |  | 1896349.GPJ |  |  |
| DRAWN            | TR   | Nov 2019 | SCALE      | N/A | REV. |   |  |  |             |  |  |
| CHECK            | AB   | Nov 2019 |            |     |      |   |  |  |             |  |  |
| APPR             | JMAC | Nov 2019 |            |     |      |   |  |  |             |  |  |
| GOLDER           |      |          | FIGURE B-1 |     |      |   |  |  |             |  |  |
| SUDBURY, ONTARIO |      |          |            |     |      |   |  |  |             |  |  |

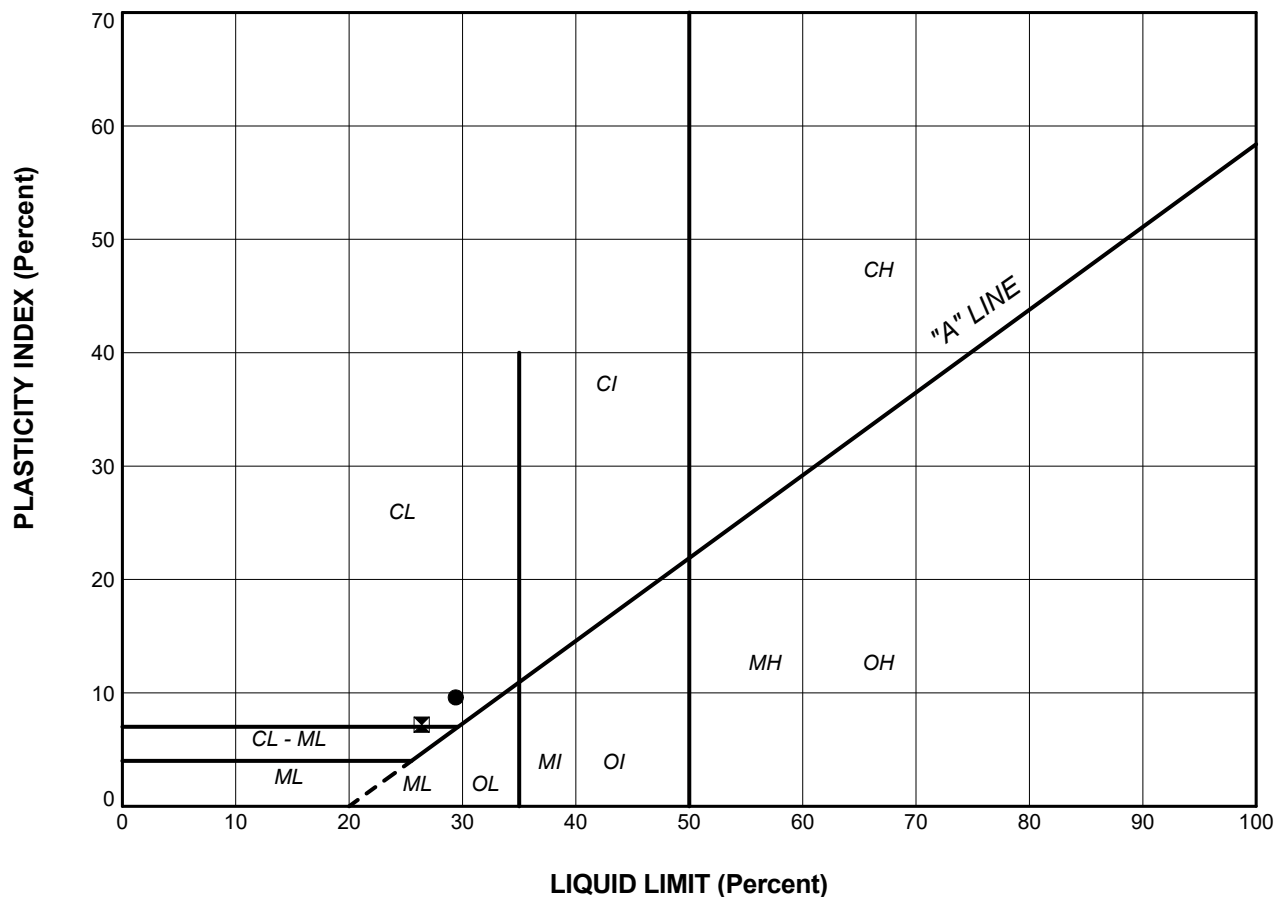


| CLAY AND SILT | GRAVEL SIZE, mm |        |        |             |        | Cobble<br>Size |
|---------------|-----------------|--------|--------|-------------|--------|----------------|
|               | fine            | medium | coarse | fine        | coarse |                |
|               | SAND SIZE       |        |        | GRAVEL SIZE |        |                |

### LEGEND


| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|--------|----------|--------|----------|
| ●      | C228-2   | 6      | 316.7    |
| ×      | C228-4   | 1      | 317.8    |

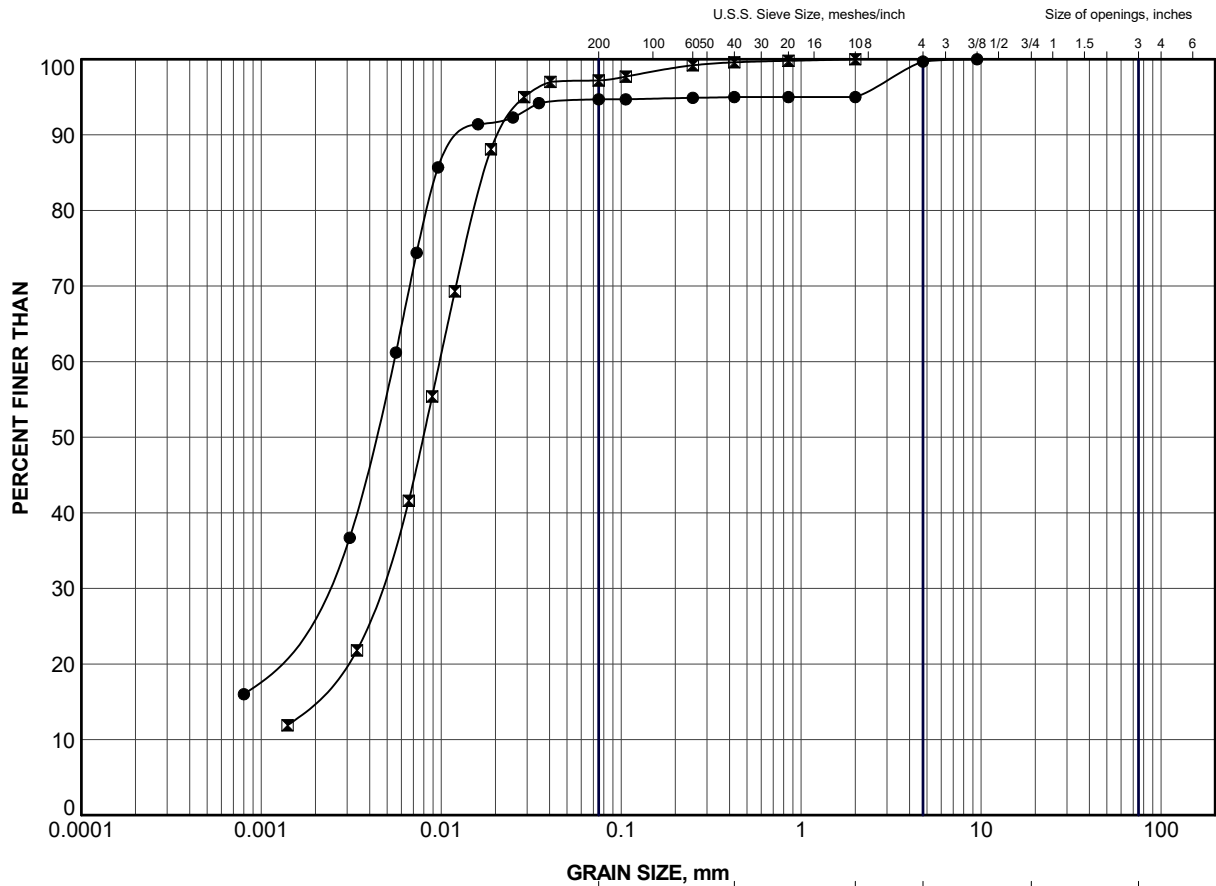
|   |  |      |  |          |  |  |  |     |  |             |  |
|---|--|------|--|----------|--|--|--|-----|--|-------------|--|
| PROJECT   |  |      |  |          |  | HIGHWAY 66<br>STATION 17+221<br>TOWNSHIP OF LEBEL CULVERT      |  |     |  |             |  |
| TITLE   |  |      |  |          |  | <b>GRAIN SIZE DISTRIBUTION</b><br>Silt to Silt and Sand (FILL) |  |     |  |             |  |
| PROJECT No.   |  |      |  | 1896349  |  | FILE No.   |  |     |  | 1896349.GPJ |  |
| DRAWN   |  | TR   |  | Nov 2019 |  | SCALE  |  | N/A |  | REV.        |  |
| CHECK   |  | AB   |  | Nov 2019 |  |  |  |     |  |             |  |
| APPR  |  | JMAC |  | Nov 2019 |  |  |  |     |  |             |  |
|  <b>GOLDER</b><br>SUDBURY, ONTARIO |  |      |  |          |  | <b>FIGURE B-2</b>  |  |     |  |             |  |
|   |  |      |  |          |  |  |  |     |  |             |  |



### LEGEND

| SYMBOL | BOREHOLE | SAMPLE | LL(%) | PL(%) | PI  |
|--------|----------|--------|-------|-------|-----|
| ●      | C228-2   | 8      | 29.4  | 19.8  | 9.6 |
| ⊠      | C228-2   | 10     | 26.4  | 19.2  | 7.2 |

|   |  |      |         |          |  |   |  |     |             |      |  |
|---|--|------|---------|----------|--|---|--|-----|-------------|------|--|
| PROJECT   |  |      |         |          |  | HIGHWAY 66<br>STATION 17+221<br>TOWNSHIP OF LEBEL CULVERT |  |     |             |      |  |
| TITLE   |  |      |         |          |  | PLASTICITY CHART<br>CLAYEY SILT                           |  |     |             |      |  |
| PROJECT No.   |  |      | 1896349 |          |  | FILE No.  |  |     | 1896349.GPJ |      |  |
| DRAWN   |  | TR   |         | Nov 2019 |  | SCALE   |  | N/A |             | REV. |  |
| CHECK   |  | AB   |         | Nov 2019 |  |   |  |     |             |      |  |
| APPR  |  | JMAC |         | Nov 2019 |  |   |  |     |             |      |  |
|  <b>GOLDER</b><br>SUDBURY, ONTARIO |  |      |         |          |  | <b>FIGURE B-3</b>   |  |     |             |      |  |
|   |  |      |         |          |  |   |  |     |             |      |  |

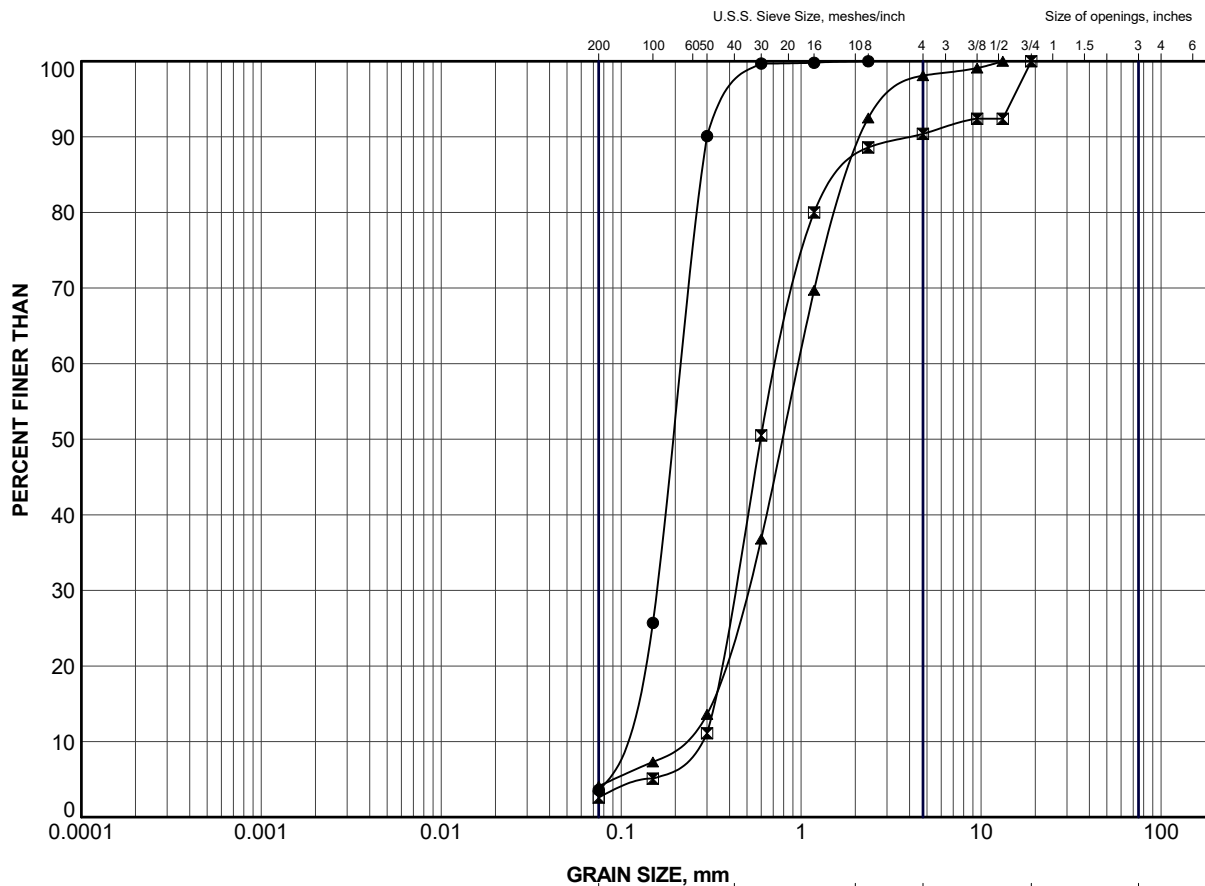


|               |           |        |        |             |        |             |
|---------------|-----------|--------|--------|-------------|--------|-------------|
| CLAY AND SILT | SAND SIZE |        |        | GRAVEL SIZE |        | Cobble Size |
|               | fine      | medium | coarse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

### LEGEND

| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|--------|----------|--------|----------|
| ●      | C228-2   | 8      | 313.7    |
| ⊠      | C228-2   | 10     | 310.6    |


|                  |      |   |  |                      |     |
|------------------|------|---|--|----------------------|-----|
| PROJECT          |      | HIGHWAY 66<br>STATION 17+221<br>TOWNSHIP OF LEBEL CULVERT |  |                      |     |
| TITLE            |      | <b>GRAIN SIZE DISTRIBUTION</b><br>SILT to CLAYEY SILT     |  |                      |     |
| PROJECT No.      |      | 1896349   |  | FILE No. 1896349.GPJ |     |
| DRAWN            | TR   | Nov 2019  |  | SCALE                | N/A |
| CHECK            | AB   | Nov 2019  |  | REV.                 |     |
| APPR             | JMAC | Nov 2019  |  |                      |     |
| GOLDER           |      | <b>FIGURE B-4</b>   |  |                      |     |
| SUDBURY, ONTARIO |      |   |  |                      |     |

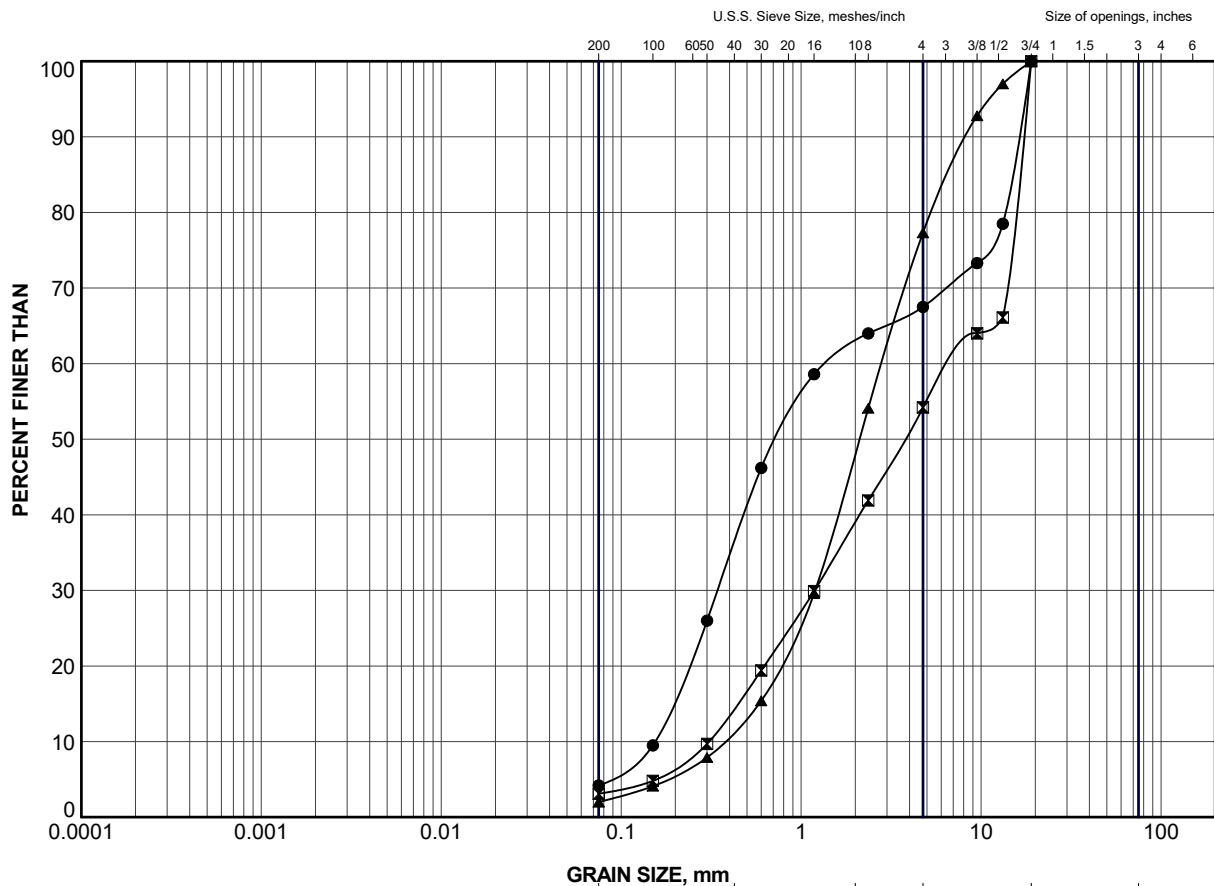


| CLAY AND SILT |  | SAND SIZE, mm |        |        |             |        | Cobble Size |
|---------------|--|---------------|--------|--------|-------------|--------|-------------|
|               |  | fine          | medium | coarse | fine        | coarse |             |
|               |  | SAND SIZE     |        |        | GRAVEL SIZE |        |             |

### LEGEND

| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|--------|----------|--------|----------|
| ●      | C228-1   | 9      | 311.8    |
| ■      | C228-3   | 8      | 313.5    |
| ▲      | C228-4   | 4      | 315.6    |


|   |  |      |  |          |  |   |  |     |  |             |  |
|---|--|------|--|----------|--|---|--|-----|--|-------------|--|
| PROJECT   |  |      |  |          |  | HIGHWAY 66<br>STATION 17+221<br>TOWNSHIP OF LEBEL CULVERT |  |     |  |             |  |
| TITLE   |  |      |  |          |  | GRAIN SIZE DISTRIBUTION<br>SAND                           |  |     |  |             |  |
| PROJECT No.   |  |      |  | 1896349  |  | FILE No.  |  |     |  | 1896349.GPJ |  |
| DRAWN   |  | TR   |  | Nov 2019 |  | SCALE   |  | N/A |  | REV.        |  |
| CHECK   |  | AB   |  | Nov 2019 |  |   |  |     |  |             |  |
| APPR  |  | JMAC |  | Nov 2019 |  |   |  |     |  |             |  |
|  <b>GOLDER</b><br>SUDBURY, ONTARIO |  |      |  |          |  | <b>FIGURE B-5</b>   |  |     |  |             |  |
|   |  |      |  |          |  |   |  |     |  |             |  |



| CLAY AND SILT | GRAVEL SIZE, mm |        |        |             |        | Cobble Size |
|---------------|-----------------|--------|--------|-------------|--------|-------------|
|               | fine            | medium | coarse | fine        | coarse |             |
|               | SAND SIZE       |        |        | GRAVEL SIZE |        |             |

### LEGEND

| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|--------|----------|--------|----------|
| ●      | C228-1   | 12     | 307.3    |
| ■      | C228-3   | 11     | 308.9    |
| ▲      | C228-5   | 7      | 311.8    |

|   |      |          |  |                   |     |   |  |  |  |             |  |
|---|------|----------|--|-------------------|-----|---|--|--|--|-------------|--|
| PROJECT   |      |          |  |                   |     | HIGHWAY 66<br>STATION 17+221<br>TOWNSHIP OF LEBEL CULVERT         |  |  |  |             |  |
| TITLE   |      |          |  |                   |     | <b>GRAIN SIZE DISTRIBUTION</b><br>Sandy GRAVEL to SAND and GRAVEL |  |  |  |             |  |
| PROJECT No.   |      |          |  | 1896349           |     | FILE No.  |  |  |  | 1896349.GPJ |  |
| DRAWN   | TR   | Nov 2019 |  | SCALE             | N/A | REV.  |  |  |  |             |  |
| CHECK   | AB   | Nov 2019 |  |                   |     |   |  |  |  |             |  |
| APPR  | JMAC | Nov 2019 |  |                   |     |   |  |  |  |             |  |
|  <b>GOLDER</b><br>SUDBURY, ONTARIO |      |          |  | <b>FIGURE B-6</b> |     |   |  |  |  |             |  |



BUREAU  
VERITAS

BV Labs Job #: B9D3975  
Report Date: 2019/06/03

Golder Associates Ltd  
Client Project #: 1896349(2100)  
Site Location: HWY 66  
Sampler Initials: MR

### RESULTS OF ANALYSES OF SOIL

| BV Labs ID    |       | JTI432              |     |          | JTI433              | JTI434              | JTI435              | JTI436              |     |          |
|---------------|-------|---------------------|-----|----------|---------------------|---------------------|---------------------|---------------------|-----|----------|
| Sampling Date |       | 2019/05/03<br>10:45 |     |          | 2019/05/04<br>14:47 | 2019/05/08<br>12:39 | 2019/05/11<br>16:36 | 2019/05/14<br>08:49 |     |          |
| COC Number    |       | 127611              |     |          | 127611              | 127611              | 127611              | 127611              |     |          |
|               | UNITS | C236-1<br>Lab-Dup   | RDL | QC Batch | C267-1              | C228-1              | C227-1              | C256-1              | RDL | QC Batch |

| CONVENTIONALS  |         |    |      |         |       |       |       |       |      |         |
|--|---------|----|------|---------|-------|-------|-------|-------|------|---------|
| Sulphide   | ug/g    |    |      |         | <0.30 | <0.30 | <0.30 | <0.30 | 0.30 | 6150574 |
| Calculated Parameters  |         |    |      |         |       |       |       |       |      |         |
| Resistivity  | ohm-cm  |    |      |         | 23000 | 12000 | 2500  | 22000 |      | 6129977 |
| Inorganics   |         |    |      |         |       |       |       |       |      |         |
| Soluble (20:1) Chloride (Cl <sup>-</sup> )   | ug/g    |    |      |         | <20   | 29    | 250   | <20   | 20   | 6133046 |
| Conductivity   | umho/cm |    |      |         | 43    | 84    | 405   | 46    | 2    | 6135430 |
| Available (CaCl <sub>2</sub> ) pH  | pH      |    |      |         | 7.74  | 6.56  | 7.00  | 6.30  |      | 6133358 |
| Soluble (20:1) Sulphate (SO <sub>4</sub> )   | ug/g    |    |      |         | <20   | <20   | <20   | <20   | 20   | 6133048 |
| Physical Testing   |         |    |      |         |       |       |       |       |      |         |
| Moisture-Subcontracted   | %       | 15 | 0.30 | 6150575 | 21    | 20    | 20    | 20    | 0.30 | 6150575 |
| RDL = Reportable Detection Limit<br>QC Batch = Quality Control Batch<br>Lab-Dup = Laboratory Initiated Duplicate |         |    |      |         |       |       |       |       |      |         |

**APPENDIX C**

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

## **PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.**

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Special Provision

January 2019

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### **CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY TRENCHLESS METHODS**

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

#### **2.0 REFERENCES**

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

##### **Ontario Provincial Standard Specifications, General**

OPSS 180 Management of Disposal of Excess Material

##### **Ontario Provincial Standard Specifications, Construction**

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

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

### **Ontario Provincial Standard Specifications, Material**

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

### **CSA Standards**

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

### **American Society for Testing and Materials (ASTM) International Standards**

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

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

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

## **3.0 DEFINITIONS**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**Reaming** means a process for enlarging the bore path

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

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

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

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

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

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

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

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

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

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

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

## **4.0 DESIGN AND SUBMISSION REQUIREMENTS**

### **4.01 Design**

#### **4.01.01 General**

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

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

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

Based on the ground conditions at the culvert site crossing Highway 66, Station 17+221, Township of Lebel and the anticipated relatively short tunnel distance of about 44 m, HDD, TBM, Tunnel Digging Machine (TDM) Pilot Tube Micro-tunnelling (PTMT), MTBM and Auger Jack and Bore methods are likely not suitable or cost-effective methods for culvert installation.

### **4.02 Submission Requirements**

#### **4.02.01 Qualifications**

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

##### **4.02.01.01 Project Superintendent**

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

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

##### **4.02.01.02 Trenchless Contractor**

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

#### **4.02.01.03                      Design Engineer**

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

#### **4.02.01.04                      Design Checking Engineer**

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

#### **4.02.02                              Working Drawings**

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

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

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

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

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

##### **a) Plans and Details:**

- i. Plans and profiles defining all horizontal and vertical alignment positions and positions of all utilities and other infrastructure within the zone of influence of the work;
- ii. A work plan outlining the materials, procedures, methods and schedule to be used to execute the work.
- iii. A list of personnel, including backup personnel, and their qualifications and experience.
- iv. A safety plan including the company safety manual and emergency procedures.
- v. The work area layout.
- vi. An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail.
- vii. A contingency plan with specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner.
- viii. A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan detailing emergency procedures in the event that the fluid management plan fails.
- ix. Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations.
- x. Excavated materials disposal plan.
- xi. Locations of protection systems.

b) Designs

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

c) Materials:

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

d) Upstream/Downstream Portal Installation Procedure:

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

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

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

f) Excavation and Dewatering:

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

g) Monitoring Method:

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

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

#### **4.02.03                      Quality Control Certificate**

The Contractor shall submit a Quality Control Certificate to the Contract Administrator for documentation and quality assurance purposes, prepared and stamped by the Design and Design Checking Engineers, a minimum of two weeks prior to commencement of work under this item. The Certificate shall state that the construction procedures are in conformance with the requirements and specifications of the contract documents.

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

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

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

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

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

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

### **5.0                                      MATERIALS**

#### **5.01                                      Pipe**

##### **5.01.01                                  General**

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

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

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

All fittings shall be designed to be watertight.

##### **5.01.02                                  Steel Pipe**

Steel pipe shall be according to ASTM A252.

All steel casing pipe shall be square cut.

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

#### **5.01.03 HDPE Pipe**

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

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

Joining 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.

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

#### **5.01.04 Concrete Pipe**

Concrete pipe shall be according to OPSS 1820.

#### **5.02 Concrete**

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

#### **5.03 Steel Reinforcement**

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

#### **5.04 Wood**

Wood shall be according to OPSS 1601.

#### **5.05 Drilling Fluids**

Drilling fluid shall be mixed according to the working drawings.

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

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

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

- a) development of appropriate filter cake at excavation face to provide slurry support pressures exceeding

- ground and groundwater pressures at excavation face;
- b) lubricate installation of primary liners as required;
- c) transport spoil through pipe systems;

## **5.06 Grout**

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

## **6.0 EQUIPMENT**

### **6.01 Auger Jack & Bore**

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

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

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

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

### **6.02 Pipe Ramming**

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

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

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

### **6.03 Horizontal Directional Drilling**

#### **6.03.01 General**

The Horizontal Directional Drilling equipment shall consist of a directional drilling rig and a drilling fluid

mixing and delivery system to successfully complete the product installation without exceeding the maximum tensile strength of the product being installed.

#### **6.03.02                      Drilling Rig**

The horizontal directional drilling rig shall:

- a) Consist of a leak free hydraulically powered boring system to rotate, push, and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head.
- b) Have drill rod that is suitable for both the drill and the product pipe installation.
- c) Contain a drill head that is steerable, equipped with the necessary cutting surfaces and fluid jets, and be suitable for the anticipated ground conditions.
- d) Have adequate reamers and down-bore tooling equipped with the necessary cutting surfaces and fluid jets to facilitate the product installation and be suitable for the anticipated ground conditions.
- e) Contain a guidance system to accurately guide boring operations.
- f) Be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation.
- g) Be grounded during all operations unless otherwise specified by the drilling rig manufacturer.

#### **6.03.03                      Drill Head**

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

#### **6.03.04                      Guidance System**

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

#### **6.03.05                      Drilling Fluid Mixing System**

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

#### **6.03.06                      Drilling Fluid Delivery System**

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

### **6.04                              Tunnelling**

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

provided for:

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

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

## **6.05 Microtunnelling Equipment**

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

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

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

- a) Remote Control System – The Contractor shall provide a MTBM that includes a remote control system with the following features:
  - i. Allows for operation of the system without the need for personnel to enter the microtunnel. Has a display available to the operator, at a remote operation console, showing the position of the shield in relation to a design reference together with other information such as face pressure, roll, pitch, steering attitude, valve positions, thrust force cutter head torque, rate of advance and installed length.
  - ii. Integrates the system of excavation and removal of spoil and its simultaneous replacement by Product Pipe. As each pipe section is jacked forward, the control system shall synchronize all of the operational functions of the system.
  - iii. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.
  - iv. The system shall monitor and continuously balance the soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.
  - v. The pressure at the excavation face shall be managed by controlling the volume of spoil removal with respect to the advance rate.
  - vi. The system shall include a separation process designed to provide adequate separation of the spoil from the slurry so that slurry with a sediment content within the limits required for successful microtunnelling, can be returned to the cutting face for reuse. Appropriately contain spoil at the site prior to disposal.
  - vii. The type of separation process shall be suited to the size of microtunnel being constructed, the soil type being excavated, and the work space available at each work area.

- viii. The system shall allow the composition of the slurry to be monitored to maintain the slurry weight and viscosity limits required.
- b) Active Direction Control - Provide an MTBM that includes an active direction control system with the following features:
  - i. Controls line and grade by a guidance system that relates the actual position of the MTBM to a design reference Provides active steering information that shall be monitored and transmitted to the operating console and recorded.
  - ii. Provides positioning and operation information to the operator on the control console.

#### **6.05.01 Pipe Jacking Equipment**

Provide a pipe jacking system with the following features:

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

#### **6.05.02 Spoil Separation System**

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

#### **6.05.03 Electrical Equipment, Fixtures and Systems**

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

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

### **7.0 CONSTRUCTION**

#### **7.01 General**

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

The Project Superintendent shall supervise the work at all times.

#### **7.01.01 Layout, Alignment and Depth Control**

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

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

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

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

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

#### **7.01.02 Construction Shafts**

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

Shafts shall be maintained in a drained condition.

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

#### **7.01.03 Protection Systems**

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

#### **7.01.04 Settlement or Heave**

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

#### **7.01.05 Stability of Excavation**

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

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

#### **7.01.06 Preservation and Protection of Existing Facilities**

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

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

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

#### **7.01.07      Transporting, Unloading, Storing and Handling Materials**

Manufacturer's handling and storage recommendations shall be followed.

#### **7.01.08      Trenching, Backfilling and Compacting**

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

#### **7.01.09      Support Systems**

Support systems shall be according to OPSS 404.

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

#### **7.01.10      Dewatering**

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

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

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

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

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

Dewatering shall be according to OPSS 517.

#### **7.01.11      Removal of Cobbles and Boulders**

The Contractor is alerted that cobbles and boulders are expected within the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. Removal of cobbles shall be expected to be routine and will not be considered cause for delay

or additional compensation and the Contractor's trenchless equipment shall be appropriately equipped and operated for these conditions. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

#### **7.01.12 Removal of Obstructions**

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

#### **7.01.13 Management of Excess Material**

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

#### **7.01.14 Site Restoration**

Site restoration shall be according to OPSS 492.

### **7.02 Auger Jack & Bore Installation**

#### **7.02.01 Method of Installation Procedure**

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

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

#### **7.02.02 Pipe Installation**

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

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

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

### **7.03 Pipe Ramming Installation**

For pipe ramming installation the following requirements apply:

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

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

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

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

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

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

### **7.04 Horizontal Directional Drilling Installation**

#### **7.04.01 General**

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

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

#### **7.04.02 Site Preparation**

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

#### **7.04.03 Pilot Bore**

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

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

location along the bore path before the deviation.

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

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

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

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

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

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

#### **7.04.05 Reaming**

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

#### **7.04.06 Product Installation**

##### **7.04.06.0 General**

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

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

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

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

##### **7.04.06.02 Pullback and Grouting**

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

A swivel shall be used between the reamer and the product being installed to prevent rotational forces from

being transferred to the product. A weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

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

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

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

## **7.05 Tunnelling Installation**

### **7.05.01 General**

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

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

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

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

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

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

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

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

### **7.05.01 Tunnelling Method**

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

## **7.05.02 Primary Liner (Support System)**

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

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

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

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

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

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

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

## **7.05.03 Secondary Liner**

### **7.05.03.01 Placing of Grout**

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

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

## **7.06 Microtunnelling**

### **7.06.01 General**

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

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

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

The Contractor shall maintain clean working conditions at all times.

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

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

#### **7.06.02 Method of Installation**

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

- The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
- Selection of the excavation method and jacking equipment shall take into consideration the subsurface conditions within the tunnel alignment.
- Perform microtunnelling operations in a manner that will minimize the movement of the ground in front of and surrounding the tunnel in conformance with the limits listed in the Contract Documents.
- Prevent damage to structures and utilities above and in the vicinity of the microtunnelling operations.
- Excavated diameter should be the minimum size required to permit pipe installation by jacking.
- Whenever there is a condition encountered which could endanger the microtunnel excavation or adjacent structures if tunnelling operations cease, continue to operate without intermission including 24-hour working days, weekends and holidays, until the condition no longer exists.
- Maintain an envelope of lubricant around the exterior of the pipe during the jacking and excavation operation to reduce the exterior soil/pipe friction and possibility of the pipe seizing in place.
- In the event a section of pipe is damaged during the jacking operation or a joint failure occurs, as evidenced by inspection, visible ground water inflow or other observations, the Contractor shall submit for approval his methods for repair or replacement of the pipe.

#### **7.06.03 Casing Installation**

Casing must withstand the jacking forces determined by the Contractor.

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

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

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

#### **7.07 Instrumentation and Monitoring**

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

### **7.07.01 Surface Monitoring Points**

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

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

### **7.07.02 In-Ground Monitoring Points**

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

### **7.07.03 Installation, Replacement and Abandonment**

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

### **7.07.03 Monitoring and Reporting Frequency**

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

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

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

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

### **7.07.03            Benchmarks**

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

### **7.08                    Criteria for Assessment of Roadway Subsidence/Heave**

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

- a) Review Level: If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate or sequence of construction or ground stabilization measures to mitigate further ground displacement. If this Review Level is exceeded, the Contractor shall immediately notify the CA and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.
- b) Alert Level: If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic. No construction shall take place until all of the following conditions are satisfied:
  - i.                    The cause of the settlement has been identified.
  - ii.                   The Contractor submits a corrective/preventive plan.
  - iii.                   Any corrective and/or preventive measure deemed necessary by the Contractor is implemented.
  - iv.                   The CA deems it is safe to proceed.

## **9.                    MEASUREMENT FOR PAYMENT**

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

## **10.                   BASIS OF PAYMENT**

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

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

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

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

**DEWATERING SYSTEM - Item No.**  
**TEMPORARY FLOW PASSAGE SYSTEM - Item No.**

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Special Provision No. 517F01

July 2017

**Amendment to OPSS 517, November 2016**

**Design Storm Return Period and Preconstruction Survey Distance**

**517.01 SCOPE**

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

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

**517.04 DESIGN AND SUBMISSION REQUIREMENTS**

**517.04.01 Design Requirements**

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

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

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

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

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

**Table A**

| <b>IDF Curve Location</b>  | Latitude: 48.155597                             |  | Longitude: -79.934711 |            |            |   |
|--|---|--|-----------------------|------------|------------|---|
| <b>Temporary Flow Passage Systems</b>  |   |  |                       |            |            |   |
| Site Name /<br>Station Reference   | Minimum<br>Return Period<br>(Years)             | Return Period Flow Estimates (m <sup>3</sup> /s) |                       |            |            | Design Engineer<br>Requirements<br>(Note 1) |
|  |   | 2<br>Year  | 5<br>Year             | 10<br>Year | 25<br>Year |   |
| Highway 66, Station 17+221,<br>Township of Lebel Culvert<br>Replacement  | ***   | ****   | ****                  | ****       | ****       | Yes   |
| <b>Dewatering Systems</b>  |   |  |                       |            |            |   |
| Site Name /<br>Station Reference   | Preconstruction Survey Distance (Note 2)<br>(m) |  |                       |            |            | Design Engineer<br>Requirements<br>(Note 1) |
| Highway 66, Station 17+221,<br>Township of Lebel Culvert<br>Replacement  | N/A   |  |                       |            |            | Yes   |
| <p>Note:</p> <p>1. “Yes” means the design Engineer and design-checking Engineer shall have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work. “No” means a minimum experience level is not required for the design Engineer and design-checking Engineer.</p> <p>2. “N/A” indicates a preconstruction survey is not required.</p> |   |  |                       |            |            |   |

**NOTES TO DESIGNER:****Designer Fill-in for Table A:**

- \* Enter the latitude and longitude co-ordinates of the IDF Curve as obtained using the MTO IDF Curve Look up Tool. Create additional tables, as necessary, if more than one (1) IDF curve was used on the contract (i.e. on a very long contract there may be two IDF curves used to better represent rainfall events for two (2) different sections of the contract).
- \*\* Fill-in site name, work, and station reference as appropriate for the dewatering system and/or temporary flow passage system item locations.
- \*\*\* For temporary flow passage system item locations, fill-in the minimum design storm return period for the site based on MTO Drainage Design Standard TW-1.
- \*\*\*\* For temporary flow passage system item locations, fill-in the design flow rate estimates for the various return periods.
- \*\*\*\*\* Insert “Yes” when recommended by the Foundation Engineer. Insert “No” otherwise.
- \*\*\*\*\* Fill-in the required distance for preconstruction survey if recommended by the Foundation Engineer. Fill-in “N/A” if not recommended.

**WARRANT:** Always with these tender items.

**OBSTRUCTIONS – Item No.**

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Notice to Contractor

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The contractor shall be alerted to the presence of cobbles and/or boulders within the embankment fill and native soil along the alignment of the culvert crossing Highway 66, Station 17+221, Township of Lebel. 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 and installation of the culvert by trenchless methods.



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