



# Englobe

Soils Materials Environment

**Submitted to GM BluePlan Engineering Limited  
975 Wallace Avenue North, Listowel, Ontario N4W 1M6**

**New Sanitary Forcemain Construction Crossing  
1200 Highway 23  
Municipality of Perth North, Ontario**

## **FINAL GEOTECHNICAL INVESTIGATION AND DESIGN REPORT**

Date: October 26, 2017

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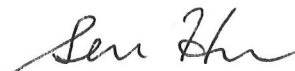
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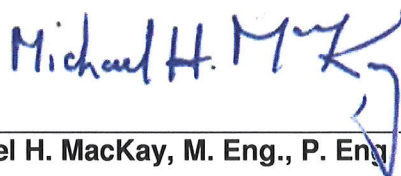
Prepared by:



**Sen Hu, P. Eng.**

Senior Geotechnical Engineer

MTO RAQS Tunnelling Specialty – Medium Complexity



Reviewed by:

**Michael H. MacKay, M. Eng., P. Eng.**

Vice President – Expertise

Pavement Technology & Geotechnical Engineering

MTO Designated Contact



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Client:

GM BluePlan Engineering Limited  
975 Wallace Avenue North  
Listowel, Ontario N4W 1M6

Attention: **Mr. Matt Ash, C.E.T.**

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# 1 INTRODUCTION

Englobe Corp. (Englobe) was retained by the Municipality of Perth North (MPN) to carry out a geotechnical investigation in 2016 for the proposed North Perth Wastewater Treatment Plant and the associated headworks upgrades within the project areas in the Municipality of Perth North, Ontario. A Geotechnical Engineering Report titled “*North Perth Wastewater Treatment Plant, Headworks Upgrades 6115 Line 84 and 1200 Highway 23, Municipality of Perth North, Ontario*” dated July 13, 2016 (Englobe Reference Number: 163-P-0010059-0-01-100-GE-R-0001-00) was prepared and submitted to MPN. As a section of the proposed new sanitary forcemain crosses Highway 23, this supplementary geotechnical engineering report has been prepared to specifically address the geotechnical aspects associated with the new forcemain installation across Highway 23.

It is understood that trenchless construction techniques are currently being considered for the proposed new sanitary forcemain construction between two proposed construction shafts approximately located along the new sanitary forcemain alignment and crossing Highway 23 (Mitchell Road South) between the properties at 1319 Mitchell Road South and 1200 Mitchell Road South, as shown on a key plan of Drawing No.1, Appendix 1. It is also understood that the new 500 mm diameter sanitary forcemain will be installed within a 900 mm diameter steel casing advanced using trenchless construction techniques (see Enclosure No. 5, Appendix 4). The annular space between the new sanitary forcemain and the steel casing will be grouted as required. As part of the initial Englobe investigation, Englobe completed one foundation borehole adjacent to each of the proposed construction shafts (total of two foundation boreholes) on April 5, 2016.

The Ministry of Transportation, West Region (MTO), completed an initial review of the Corridor Encroachment Permit application package submitted by GM BluePlan Engineering Ltd. (GM BluePlan) in early 2017 and provided review comments to the project application dated February 23, 2017. To fully address the MTO initial review comments, a supplementary site investigation was undertaken by Englobe on August 3, 2017 to advance an additional borehole on the west shoulder of Highway 23 to meet the MTO requirements as described in “*Guidelines for Foundation Engineering - Tunnelling Specialty for Corridor Encroachment Permit Application (MTO Guidelines for Corridor Encroachment Permit Application)*” dated April 3, 2008 and published by (MTO); these Guidelines have been reproduced as Enclosure No. 6, Appendix 4 of this supplementary geotechnical report.

Englobe has investigated the site subsoil and groundwater conditions for the proposed new sanitary forcemain crossing Highway 23 by the drilling boreholes, carrying out in-situ tests, and performing laboratory testing on selected samples. As required for the Corridor Encroachment Permit Application, the factual information of subsurface conditions, results of the geotechnical laboratory tests carried out on the soil samples recovered at locations of three boreholes as

well as geotechnical recommendations for the proposed construction shafts and tunnelling/trenchless construction are included in this Geotechnical Investigation and Design Report.

## 2 SITE DESCRIPTION

An existing pumping station is located south of the Middle Maitland River on the east side of Highway 23 between Line 84 and Barnett Street in the Municipality of Perth North, Ontario. The proposed forcemain will be located north of the existing pumping station, with the section crossing Highway 23 (Mitchell Road South) extending from the properties approximately located at 1319 Mitchell Road South and 1200 Mitchell Road South. The topography in the general vicinity of this site is generally flat. The site is located south of the Middle Maitland River and generally crosses the highway in a west-east direction. The ground surface in this area generally slopes down northward to the Middle Maitland River.

The existing highway embankment currently supports one traffic lane in each direction generally running in a north-south direction at this new sanitary forcemain crossing location. The existing highway at the proposed sanitary forcemain crossing location is constructed on an embankment consisting of the roadway pavement structure over approximately 3.4 to 3.8 m of mixed embankment fill overlying native soils along the proposed new forcemain alignment. The highway centreline is approximately at Elevation 377.2 within the limits of proposed forcemain crossing section. At the west side of highway, the edge of embankment is about 2.6 m above the existing drainage ditch. The proposed 900 mm diameter steel casing at this highway crossing will be some 42.5 m in length and installed at approximate depths ranging from 4.2 to 4.8 m below the grade of highway (i.e. invert at Elevation 372.4 m) along the new forcemain alignment.

### 2.1 SITE PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The site is located within the physiographic region of Southern Ontario known as the Stratford Till Plain as indicated in the publication titled "The physiography of southern Ontario" published by L. J. Chapman and D. F. Putnam in 1984. The region is mostly level, modified by occasional moderate hills and ridges. The soil materials are fairly uniform and comprise silt and clay tills. Sand and gravel is present in terraces along some of the river valleys.

The region is underlain by Middle Devonian bedrock of the Paleozoic system. The predominant rock types are limestone and dolomite of the Detroit River Group. The bedrock surface dips gently to the southwest. The soil cover over bedrock is generally about 60 m in thickness.

### 3 INVESTIGATION PROCEDURES

The three boreholes included in this investigation were carried out on April 5<sup>th</sup>, 2016 and August 3<sup>rd</sup>, 2017, respectively. Two (2) boreholes were advanced adjacent to the proposed construction shaft locations on April 5<sup>th</sup>, 2016 as part of the initial Englobe geotechnical investigation, and a single additional borehole was subsequently advanced through the highway embankment at the west shoulder of Highway 23 on August 3<sup>rd</sup>, 2017 as part of this supplementary investigation.

The field investigation was carried out respectively using track and truck mounted drilling rigs equipped with hollow stem augers, standard solid stem augers and routine geotechnical sampling equipment. Soil samples were obtained at the borehole locations at regular intervals of depth using the standard 50 mm O.D. split spoon sampler advanced in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586). The SPT method involves advancing a 50 mm O.D. split spoon sampler with the force of a 63.5 kg hammer freely dropping 760 mm. The number of blows per 300 mm penetration was recorded as the SPT “N” value. All samples taken during this investigation were stored in labeled airtight containers for transport to our Kitchener laboratory for visual examination and laboratory testing.

Groundwater conditions in the open boreholes were observed during the advancement of and immediately following completion of the individual boreholes. A 19 mm diameter standpipe piezometer was installed in the shoulder borehole (Borehole No. 01-17) prior to backfilling to allow for further monitoring of the shallow groundwater level after completion of the borehole. All open boreholes were backfilled upon completion with compacted auger cuttings in the same general order that they were removed, and where necessary, bentonite pellet backfill was added to the boreholes to bring them up to grade in accordance with requirements of Ontario Regulation 903. The standpipe piezometer was decommissioned on August 11<sup>th</sup>, 2017 per Ontario Regulation 903 requirements.

The fieldwork for this investigation was under the full time direction of a senior member of the engineering staff from the Englobe Kitchener office who was responsible for locating the boreholes, clearing the borehole locations of underground services, in-situ sampling and testing operations, logging of the boreholes, labeling and preparation of samples for transport to the Englobe Kitchener laboratory, as well as overall drill supervision. All samples received a visual confirmatory inspection in our laboratory. Laboratory testing of selected samples included routine testing for natural moisture content determination, particle size analysis and Atterberg Limits. The shear strength was measured on selected cohesive samples using the laboratory vane, vane collar, and calibrated torque meter. The results of the in-situ and laboratory testing are presented on the individual Record of Borehole Sheets (Appendix 2), with a summary of results presented on the laboratory sheets in Appendix 3 (Figures Nos. L-1 to L-4 and Table No. L-5).

The location of the supplementary borehole on the highway shoulder was determined in the field using the reference features shown on GM BluePlan Figure No. 1 Encroachment Permit (reproduced and appended as Enclosure No. 5, Appendix 4) and an offset of approximately 3 m north of the centreline of the proposed new sanitary forcemain alignment. The borehole coordinates and elevations were provided by GM BluePlan after completion of the field investigation. The MTO co-ordinates, northing and easting, were established for the borehole locations using coordinates from MTM Zone 10, NAD 83 CSRS. Elevations contained in this report are referenced to geodetic datum.

## **4 SUBSURFACE CONDITIONS**

Details of the subsurface conditions revealed by the investigation program are presented on the enclosed Records of Borehole Logs (Appendix 2) and on Drawing No. 2 (Appendix 3). Please note that stratigraphic delineation presented on the borehole logs and soil strata plot are the results of non-continuous sampling, response to drilling progress, the results of SPT, and field observations. Typically such boundaries represent transitions from one zone to another and are not an exact demarcation of specific geological unit. Additional consideration should be given to the fact that subsurface conditions may vary markedly between boreholes and beyond any specific boring location, and the stratigraphic delineations shown on the drawings have been provided for illustration purposes only.

### **4.1 SANITARY FORCEMAIN CROSSING GENERAL CONDITIONS**

A plan and profile illustrating the borehole locations and stratigraphic sequences is shown on Drawing No. 2, Appendix 3. During the course of the exploration program, three (3) sampled boreholes were put down at this site, with Borehole No. 01-17 advanced through the embankment in the west shoulder area on Highway 23, Borehole Nos. 06-16 advanced at the proposed west construction shaft, and Borehole No. 07-16 advanced at to the proposed east construction shaft. At the time of the subsurface investigation, the ground surface elevations at Borehole Nos. 06-16, 07-16 and 01-17 were recorded as Elevations 376.2, 376.3 and 377.2 m, respectively.

#### **4.1.1 Embankment Fills**

##### **4.1.1.1 Sandy Silt Fill**

Underlying the grade at Borehole Nos. 06-16 and 07-16, a layer of fill consisting of dark brown to brown sandy silt, some gravel, was penetrated. Occasional cobbles were encountered in the fill stratum. The natural moisture content measured on a retrieved sample of this fill was in the order of 12%. This sandy silt fill was encountered to depths of 0.2 and 0.8 m below grade at Borehole Nos. 06-16 and 07-16, respectively (Elevations 376.0 and 375.5 m, respectively).

#### 4.1.1.2 **Sand and Gravel to Sand Fill**

Underlying the sandy silt fill at Borehole No. 07-16 and underlying the grade at Borehole No. 01-17, a layer of fill consisting of dark brown silty sand and gravel to brown sand, gravelly, some silt, was penetrated. Occasional cobbles were encountered in this fill stratum. The natural moisture contents measured on retrieved samples of this fill material were generally in the order of 4 to 18%. A gradation (sieve) analysis was carried out on one (1) sample of this fill material, and the results indicated 51% gravel size particles, 38% sand size particles, and 11% silt and clay size particles (Figure No. L-1, Appendix 3). Based on SPT 'N' values of 12 to 91 blows per 300 mm penetration, the compactness/relative density of the sand and gravel to sand fill was described compact to very dense, but generally dense on average. This fill was encountered to depths of 1.5 and 3.4 m below grade at Borehole Nos. 07-16 and 01-17, respectively (Elevations 374.8 and 373.8 m, respectively).

#### 4.1.1.3 **Silt Fill**

Underlying the sandy silt fill at Borehole No. 06-16, underlying the silty sand gravel fill at Borehole No. 07-16, a layer of fill consisting of brown silt, some gravel some sand was penetrated. The natural moisture contents measured on retrieved samples of this material were generally in the order of 12 to 22% except one sample at 41% encountered in Borehole No. 07-16. Based on SPT 'N' values of 6 to 18 blows per 300 mm penetration, the compactness/relative density of the silt fill was described loose to compact, but generally compact on average. This fill material was encountered to depths of 3.1 and 3.8 m below grade at Borehole Nos. 06-16 and 07-16, respectively (Elevations 373.2 and 372.5 m, respectively).

#### 4.1.1.4 **Clayey Silt Fill**

Underlying the silt fill at Borehole No. 06-16, a layer of fill consisting of dark brown clayey silt, some gravel was penetrated. The natural moisture content measured on a retrieved sample of this layer was in the order of 34%. Based on a SPT 'N' value of 7 blows per 300 mm penetration, the consistency of this fill layer was described firm. This layer was encountered to a depth of 3.8 m below grade at Borehole No. 06-16 (Elevation 372.4 m).

#### 4.1.2 **Silt**

Underlying the embankment fill material at Borehole No. 01-17, a layer of dark brown to grey silt, trace gravel, some sand, trace clay was penetrated. The natural moisture contents measured on retrieved samples of this deposit were generally in the order of 28 to 65%. A gradation (hydrometer) analysis was carried out on one (1) sample of this deposit, and the results indicated 2% gravel size particles, 20% sand size particles, 68% silt size particles, and 10% clay size particles (Figure No. L-2, Appendix 3). Based on SPT 'N' values of 2 to 18 blows per 300 mm penetration, the compactness/relative density of the deposit was described very loose to compact. This deposit was encountered to a depth of 5.3 m below grade at Borehole No. 01-17 (Elevation 371.9 m).

#### 4.1.3 Silty Clay Till

Underlying the embankment fill at Borehole Nos. 06-16 07-16, and underlying the silt at Borehole No. 01-17, the glacial till consisting of silty clay, trace to some gravel, trace to with sand was penetrated. The natural moisture contents measured on retrieved samples of this deposit were generally in the order of 11 to 17%. The gradation (hydrometer) analyses were carried out on three (3) samples of this till, and the results indicated 4 to 6% gravel size particles, 20 to 25% sand size particles, 37 to 50% silt size particles, and 25 to 34% clay size particles (Figure No. L-3, Appendix 3). Atterberg Limits testing was carried out on one (1) sample of this silty clay till, and the results indicated a Plastic Limit of 14% and a Liquid Limit of 23% to result in a Plasticity Index equal to 9% (Figure No. L-4, Appendix 3). Results of Atterberg Limits testing indicate the soil to be classified as “Silty Clay” with a low degree of plasticity per MTO’s Soil Classification criteria. Based on a SPT ‘N’ values ranging from 15 to 43 blows per 300 mm penetration and laboratory shear strengths greater than 100 kPa, the consistency of this till was described as very stiff to hard, generally very stiff on average. Sampling was terminated in this till at depths of 6.6, 6.6 and 8.1 m below grade at Borehole Nos. 06-16, 07-16 and 01-17, respectively (Elevations 369.7, 369.8 and 369.1 m, respectively).

#### 4.2 GROUNDWATER DATA

Measurements of the groundwater table and cave-in levels were undertaken, where possible, in the open boreholes during the advance of the individual borings and upon completion. A standpipe was installed in Borehole No. 01-17 to enable measurement of the ‘stabilized’ water level post-borehole completion. These levels are recorded on the individual Record of Borehole Log Sheets (Appendix 2).

The water levels were measured at Elevations 374.7 and 374.0 m at Borehole Nos. 06-16 and 07-16, respectively, immediately after completion of drilling in the field and prior to backfilling. Consequently, these water levels might not have fully stabilized. The ‘stabilized’ water level was measured at Elevation 371.7 m in the standpipe installed in Borehole No. 01-17 approximately a week after completion of drilling in the field.

The groundwater should be expected to fluctuate somewhat in response to seasonal conditions.

## 5 DISCUSSION AND RECOMMENDATIONS

### 5.1 GENERAL

The previous Englobe geotechnical engineering report titled “*North Perth Wastewater Treatment Plant, Headworks Upgrades 6115 Line 84 and 1200 Highway 23, Municipality of Perth North, Ontario*” dated July 13, 2016 (Englobe Reference Number: 163-P-0010059-0-01-100-GE-R-0001-00) was prepared for the entire Wastewater Treatment Plant and the proposed headworks upgrades project in 2016. As part of this investigation, two boreholes (i.e. Borehole Nos. 06-16 and 07-16) were put down at the proposed construction shaft locations on the either side of the Highway 23 crossing location for the new sanitary forcemain.

After submission of the previous geotechnical report described above, Englobe prepared this supplementary geotechnical investigation report to specifically address the Highway 23 crossing, with an additional borehole (Borehole No. 01-17) advanced on the west shoulder of Highway 23, and associated geotechnical laboratory tests carried out for evaluation of the trenchless technology options for forcemain installation in accordance with the MTO Corridor Encroachment Permit Application guidelines for geotechnical investigations.

### 5.2 FROST PENETRATION

At this site, the frost penetration depth below cleared highway pavement surfaces is approximately 1.6 m. The proposed new sanitary forcemain at this crossing location will be installed at depths more than 3 m below grade and as such, the sanitary forcemain will not require frost treatments.

### 5.3 FOUNDATION CONSIDERATIONS

The compact silt and very stiff to hard native silty clay till strata present below the existing highway embankment at the proposed sanitary forcemain founding level are considered to be adequate for the support of the proposed steel casing and forcemain and the existing highway embankment as described previously. Geotechnical bearing resistance should not be a concern provided the natural bearing surface of the subgrade is not disturbed during construction and groundwater is controlled throughout construction as discussed in Section 5.4.

Based on the characteristics of the native silt to silty clay till subgrade present below the proposed steel casing and the condition of the existing embankment, a factored bearing resistance at ULS of 175 kPa can be used for the associated construction work at the proposed construction shafts. In consideration of the dimensions of the construction shafts, depth of overburden, and condition of the adjacent embankment, a geotechnical reaction at SLS of 140 kPa, established at an approximate depth of 4 m below grade and founded on the very stiff native silty clay till (not greater than Elevation 372.4 m), can be used for the temporary work design of shoring protection and placement of the trenchless equipment at the construction shafts.

## 5.4 SANITARY FORCEMAIN CONSTRUCTION CONSIDERATIONS

The existing highway embankment currently supports two traffic lanes of highway. The existing highway embankment, with the current grades approximately ranging from Elevations 374.5 at the bottom of the west side ditch to 377.2 m at the centreline of existing highway along the centreline of the new sanitary forcemain, consisted of some 3.4 to 3.8 m thick embankment fills overlying the silt then the silty clay till deposits within the limits of proposed highway crossing. The proposed 900 mm diameter steel casing (invert Elevation 372.4 m) will be some 48 m in length and installed at depths approximately ranging from 2.1 to 4.8 m below existing grade along the new forcemain alignment crossing the highway.

### 5.4.1 Tunnelling/Trenchless Construction Techniques

The boreholes through the embankment indicate that the embankment fills primarily consisted of sandy silt fill to sand and gravel to sand fills overlying silt fill overlying clayey silt fill. A tunnelling/trenchless construction approach for the installation of the proposed 900 mm diameter steel casing will eliminate the need for open cuts and/or roadway protection systems founded in the low plastic silty clay to silt deposits, and associated traffic delays during construction. Several trenchless technologies are feasible for the project as outlined in the table below.

The following table summarizes the general advantages and disadvantages of the different trenchless construction techniques for potential consideration at this site. A Horizontal Directional Drilling (HDD) operation would be carried out in accordance with Ontario Provincial Standard Specification (OPSS) 450. The trenchless construction should be carried out in accordance with OPSS 415.

METHOD	ADVANTAGES	DISADVANTAGES
Horizontal Directional Drilling	<ul style="list-style-type: none"> <li>Can be used in most ground conditions</li> <li>Generally does not require staging pits; therefore minimal ground water control required</li> <li>Alignment can be adjusted to avoid obstructions</li> <li>New steel casing size within the practical construction limits between 140 and 1200 mm</li> </ul>	<ul style="list-style-type: none"> <li>Site grades may require longer bore or staging construction shafts</li> <li>Larger drilling equipment may be required</li> <li>Requires drilling fluid to maintain the bore, which could result in heave</li> <li>Presence of cobbles or boulders can potentially affect the productivity and effectiveness of construction</li> </ul>

METHOD	ADVANTAGES	DISADVANTAGES
Jack and Bore	<ul style="list-style-type: none"> <li>• Good contractor availability</li> <li>• Good for shorter tunnel lengths (less than 120 m)</li> <li>• Good gradient control</li> <li>• New steel casing size within the practical construction limits between 200 and 1500 mm</li> </ul>	<ul style="list-style-type: none"> <li>• Requires construction shafts</li> <li>• Groundwater control may be required for the bore and construction shafts</li> <li>• Elevated potential for ground subsidence</li> <li>• Larger boring diameter required to allow removal occasional cobbles/boulders</li> <li>• Presence of cobbles or boulders can potentially affect the productivity and effectiveness of construction</li> <li>• Not well suited for use in rock fills or if there is a high concentration of large obstructions</li> </ul>
Pipe Jacking/Micro-Tunneling	<ul style="list-style-type: none"> <li>• Shield face can accommodate high groundwater conditions</li> <li>• Can accommodate cobble/boulders with appropriate shield</li> <li>• Alignment can be altered during bore</li> </ul>	<ul style="list-style-type: none"> <li>• Groundwater control may be required at construction shafts</li> <li>• Requires thrust block of sufficient mass to jack pipe</li> <li>• Presence of cobbles or boulders can potentially affect the productivity and effectiveness of construction</li> </ul>
Pipe Ramming	<ul style="list-style-type: none"> <li>• Minimal groundwater control required along the installation route</li> <li>• Can penetrate soils containing cobbles/boulders if obstruction less than casing diameter</li> <li>• New steel casing size within the practical construction limit of 2 m</li> </ul>	<ul style="list-style-type: none"> <li>• Installation problems can occur in very stiff to stiff clay deposits and very dense soils with cobble/boulders</li> <li>• Requires staging construction shafts</li> <li>• Groundwater control may be required at construction shafts</li> <li>• Possible ground displacement/heaving in the soils above the crown</li> <li>• Presence of cobbles or boulders can potentially affect the productivity and effectiveness of construction</li> </ul>

From a geotechnical viewpoint, the subsurface conditions encountered at locations of Borehole Nos. 06-16, 07-16 and 01-17 indicate that the jack and bore, pipe jacking/micro-tunneling, and horizontal directional drilling methods are all considered to be generally feasible in the very stiff to hard silty clay till to compact silt deposits encountered at this site. Pipe ramming is not recommended for this site due to the very stiff to hard consistency of the till deposit and the possibly mixing conditions of varying soil conditions, as the resistance of pipe advancement will quickly build up to cause the potential ground heave and vibration under the Highway 23, especially at the area of the west side ditch with the overburden less than 2 m in thickness.

Considering the above methods, a jack and bore method is considered by Englobe to be the most favourable method from a cost point of view, provided that adequate dewatering and groundwater control is implemented during the excavation at construction shafts and during the

advancement of steel casing. Jack and Bore installation should be carried out in accordance with OPSS 416.

As noted, obstructions due to the presence of cobble/boulder sized rock fragments may be randomly encountered within the till deposits. These obstructions could limit the feasibility of some of trenchless installation methods at this site, and the potential to encounter such obstructions should be anticipated in the contract documents.

The contingency plans for the tunnelling/trenchless construction for the highway crossing should be prepared by the Contractor to address the possibility of temporarily closing the highway and local roads with very short notice (in 10 minutes) and rerouting the traffic to local roads while the emergent repairs to the roadways are carried out if required.

Additional consideration may be also addressed in the tender contract to have the tunnelling/trenchless crossing advancement be undertaken during the off-peak periods (e.g. overnight, weekends and/or statutory holidays), especially in the area adjacent to the west side ditch of highway. If the tunnelling/trenchless construction operations have to stop, the Contractor should immediately provide support at the cutting face (such as using the suitable pre-cut boards). Filling the gaps/voids between the steel casing and the ground should be carried out as soon as the casing is installed using bentonite grout/lubricant for the jacked pipes, and with the backfill grout at the completion of construction.

#### 5.4.2 Construction Shafts

As indicated on Figure No.1 (Enclosure No.5, Appendix 4), the proposed entry shaft will be on an approximate size of 10 m x 5 m (L x W) and located at an approximate distance of 2.5 m beyond the west side of highway right of way. The proposed exit shaft will be on an approximate size of 4 m x 4 m (L x W) and located at an approximate distance of 3 m beyond the east side of highway right of way. Assuming that the construction shafts will be excavated to the native subgrade at least 0.3 m below the invert of the steel casing at the base of each shaft, excavations will be located about 3.9 to 5.2 m below existing grade at the west entry shaft (i.e. Elevation 372.1 m) and 4.3 m below existing grade at the east exit shaft (i.e. Elevation 372.1 m).

The stabilized groundwater level encountered at Borehole No. 01-17 was measured at Elevation 371.7 m during the geotechnical investigation. This level is about 0.4 m lower than the base of proposed excavation (Elevation 372.1 m) at construction shafts and 0.7 m lower than the invert of the steel casing (approximately Elevation 372.4 m) for tunnelling/trenchless construction crossing highway. As such, the groundwater table will not be anticipated to be encountered during construction although some seepage of perched groundwater may be encountered, depending on the time of year and conditions when construction is undertaken. Any surface water or groundwater seepage through the overburden should be controllable by

directing to properly filtered sumps with pumps. It should be noted that the groundwater levels should be expected to fluctuate seasonally.

All temporary excavations greater than 1.2 m in depth must, at a minimum, be sloped or shored in accordance with the Occupational Health and Safety Act Regulations for Construction Projects. The embankment materials, above the water table, are considered as Type 3 soil as defined in the Occupational Health and Safety Act and Regulations for Construction Projects. Temporary open excavations above the groundwater table, could be cut back at an inclination angle of 1H:1V, provided they are monitored continuously; however, below the groundwater table, the side slopes in fill an/or native materials may slough to angles as flat as 3H:1V or possibly shallower, dependent upon the Contractors' chosen method of controlling the groundwater.

#### 5.4.3 Temporary Protection Systems

Based on the locations of two construction shafts currently proposed, the distance between the closest edges of two construction shafts and the highway rights of way at this highway crossing location, as described above, will not be adequate to carry out open unsupported excavations at the two proposed construction shafts; therefore consideration must be given to providing temporary vertical shoring for excavation support and use as a protection system. The vertical shoring provided to support the excavation sidewalls for the proposed construction shafts can be considered as a temporary protection system.

The installation of a temporary protection system for the construction shafts will require penetration through some 3.8 m of embankment fills consisting of sandy silt fill to sand and gravel to sand fills overlying silt fill overlying clayey silt fill and the very stiff native silty clay till at the remaining depths above the bottom of excavation. Considering the existing subsurface conditions, constructing a protection system in the embankment is recommended using H piles (soldier piles) extending into the underlying subsoils and installing timber lagging or driving sheet pile walls into the underlying subsoils. The temporary shoring piles and/or sheeting should extend a sufficient embedment depth below the base of proposed excavation to achieve adequate factors of safety against basal stability and heave due to excavations. The H piles would be installed at an interval of 2.5 to 3 m apart and the lagging would be installed as the excavation progresses. Depending on the structural design, a waler and raker system or tie back anchor system may be needed as the excavation advances. The contractor must prepare for adequate dewatering control as the excavation progresses without compromising the adjacent active lanes of traffic on the highway.

The sandy silt to sand and gravel to sand fills and native silts encountered in the highway embankment are considered to be cohesionless, and as such, a rectangular apparent pressure distribution over the height of the cut would be appropriate for design of the temporary shoring in cohesionless fills. The width of the apparent rectangular pressure distribution, over the height of excavation, can be considered equal to  $0.65 \cdot K_a \cdot \gamma \cdot H$ , where:

$K_a$  = active earth pressure coefficient, as described in Section 5.5,

$\gamma$  = unit weight, as described in Section 5.5, and

$H$  = height of wall above the base of excavation.

The existing silty clay till deposit, underlying the embankment fills, and the clayey silt fill encountered at Borehole Nos. 06-16 and 07-16, are composed of cohesive materials (clayey to silty clay). This material will be replaced with granular fill during the backfilling inside the construction shafts. However, the presence of the cohesive deposits behind the temporary protection system may require that the loads acting on the protection system be checked using the “layered strata” method, as outlined in the Canadian Foundation Engineering Manual, 4<sup>th</sup> Edition, Section 26.10.7.

All backfill in the construction shafts should be placed in maximum 300 mm loose lifts and uniformly compacted to at least 95 percent of Standard Proctor Maximum Dry Density (SPMDD) in accordance with OPSS 501.

Surcharge loads from the active lane of traffic must also be considered during design of the temporary shoring system. The contractor’s shoring/protection system design must be carried out by a qualified geotechnical engineer with appropriate experience. The design package of the temporary work should be submitted to the Engineer/MTO for review at least two weeks prior to construction.

The temporary protection system should be designed and constructed to comply with OPSS.PROV 539. In consideration of the location of the protection system distant to the traffic lanes of highway, a Performance Level 2 is considered appropriate.

#### 5.4.4 Dewatering

Dewatering should be carried out with reference to OPSS 517. As noted, groundwater control may be required to maintain a stable and undisturbed subgrade during excavating, construction, and filling operations. A ‘dry’ subgrade condition must be maintained at all times during the in-ground operations until backfilling has reached a sufficient height above the prevailing groundwater table (i.e. at a minimum 1 m) at the construction shafts. The groundwater table should be temporarily drawn down to a sufficient depth below the base of excavation to maintain subgrade stability and to allow for tunnelling construction, placement of the engineered fill, and/or construction of temporary structures.

Ultimately, the method of dewatering will be the choice of the contractor. Failure by the contractor to adequately control the groundwater can result in disturbance to the founding/supporting subgrades, which can result in having to carry out corrective measures (i.e. additional excavation, time delays, etc.) to improve the subgrade. Corrective measures required to improve subgrades where groundwater is not adequately controlled will be at the Contractors cost.

In order to be effective, any dewatering operation must be started well in advance of the excavating operations and be continuously maintained throughout the subsurface construction operations.

#### 5.4.5 Subgrade Preparation

Assuming 0.3 m excavation below the invert of the steel casing, the bottom of the proposed construction shafts will be located at Elevation 372.1 m; therefore the very stiff silty clay till is anticipated to be at the subgrade inside the construction shafts. Every effort must be made by the Contractor to prevent disturbing the founding subgrade during excavating and construction operations. All deleterious materials (i.e. disturbed soils, etc.) should be removed from the subgrade and replaced with the engineered fills consisting of either OPSS Granular B Types 1 or 2 materials per OPSS.PROV 1010.

As noted previously, the native soils along the proposed alignment profile consist predominantly of low plasticity silty clay till to compact silt. When wet, silts are very sensitive to disturbance due to vibrations (i.e. resulting from excavating, movement of equipment/personnel across the exposed subgrade, etc.) and the silty clay material can be disturbed to result in reduced bearing capacity and stability. The Contractor must take every precaution to minimize disturbing the subgrade during the temporary work construction and placement of the trenchless equipment at the construction shafts. Adequately controlling the groundwater in silty clay subgrades greatly reduces the potential for disturbance.

### 5.5 LATERAL EARTH PRESSURES

Lateral earth pressures should be computed in accordance with the Canadian Highway Bridge Design Code (CHBDC). The parameters for backfill materials are based on compaction levels of 100% Standard Proctor Maximum Dry Density (SPMDD). The design parameters for the backfill materials are as follows:

PARAMETER	GRANULAR A	GRANULAR B TYPE I	EMBANKMENT FILL			SILT	SILTY CLAY TILL
			SAND AND GRAVEL FILL	SAND FILL	SANDY SILT TO SILT FILL		
Unit Weight (kN/m <sup>3</sup> )	22.8	21.2	19.0	18.5	18.5	18.5	18.0
Angle of Internal Friction	35°	33°	34°	30°	28°	29°	28°
Coefficient of Active Earth Pressure ( $K_a$ )	0.27	0.30	0.28	0.33	0.36	0.35	0.36
Coefficient of Passive Earth Pressure ( $K_p$ )	3.70	3.33	3.57	3.00	2.78	2.86	2.78

It should be noted that these earth pressure coefficients assume that the back of the temporary protection wall is vertical and the ground surface behind the wall is flat. Different values of the earth pressure coefficients should be estimated separately if these assumptions vary.

For flexible structures, such as shoring wall, deflection can occur; as such, the “active” condition ( $K_a$ ) applies.

## 5.6 INSTRUMENTATION MONITORING DURING AND AFTER CONSTRUCTION

Based on the MTO *Guidelines for Corridor Encroachment Permit Application* (Appendix 4), surface settlement monitoring points are required at the minimum quantities described below.

- Surface settlement points with optical targets at the top, or equivalent instruments, are to be installed to an approximate depth of 1.8 m below grade at approximate 3 m intervals in the unpaved areas along the forcemain alignment across Highway 23; and
- Paired of three 2 ½” x ¼” mag nails with a ½” diameter with optical targets (i.e. one at the centerline and two nails at a distance of 1 m to the centerline each side separately), or equivalent instruments, are to be installed at approximately 2 m intervals in the paved areas along the proposed forcemain alignment across Highway 23.

A detailed pavement condition survey of the existing pavement within the anticipated influence zones along the crossing of Highway 23 shall be completed by the Contractor during the installation of the monitors and after the tunnel has been completed. The condition survey should be completed in accordance with MTO SP-024 (Manual for Condition Rating of Flexible Pavements) and should include detailed photographs of any observed distresses indicating the length and relative severity during both surveys.

The surface settlement monitoring points installed in the unpaved areas will consist of a 12 mm diameter rebar to be pre-inserted into a 25 mm PVC pipe and seated on top of a 100 mm thick concrete base placed into the bottom of each drilled borehole. The void between the rebar and PVC pipe will be filled with environmentally acceptable grease. The boreholes will be backfilled with the auger cuttings after installation of rebar with PVC pipe. Locations of the surface settlement points may be adjusted based on the site conditions after approval by MTO.

A complete set of ground movement readings will consist of elevations and the coordinates of each of installed instrument. Monitoring of settlement instruments is constrained by the limited periods to access the highway due to its continuous traffic volumes; therefore it is recommended the monitoring work be read remotely using robotic systems and reflectorless surveying techniques or some other MTO-approved form of monitoring with adequate traffic controls carried out by a specialist surveying company on site. The baseline readings and regular monitoring of instruments will be based on the monitoring frequencies outlined in the MTO *Guidelines for Corridor Encroachment Permit Application* for trenchless construction.

The overall uncertainty (including all sources of uncertainty, for example equipment and human errors, system accuracy, etc.) of the elevation readings should be within 2 mm accuracy at 95% confidence level. Three sets of consecutive baseline readings shall be taken, based on established temporary bench mark out of the influence zone of construction on site, to set up the initial reading for each instrument one week prior to commencing the trenchless construction.

After the start of the trenchless work, a complete set of monitoring readings will be taken minimum twice a day, regardless if the trench is being advanced or work has been halted. This frequency may have to be increased if readings are found to be outside of the anticipated limits. Upon completion of the trenchless construction advancement, the monitoring of instruments will be taken twice for one week following completion of construction, and continue weekly for at least another one week provided that any further settlement of instruments has stopped. Additional last monitoring readings should be taken before decommissioning the settlement points after completion of construction of the backfill grouting into the voids between at the steel casing and the sanitary forcemain pipe.

Daily monitoring data will be submitted to the Engineer by the Contractor and used to provide early warning of excessive ground movement. A Review Level of ten (10) mm relative to the baseline readings and an Alert Level of fifteen (15) mm relative to the baseline readings are recommended for the project. If the Review Level is reached, then the work will need to be reviewed and/or modified to assess the potential impact and mitigate further ground movement. If the Alert level is reached, then the construction work should be immediately ceased and the emergency action plan activated in order to mitigate further movements and ensure safety of the travelling public on the highway.

A final monitoring report shall be prepared by the Contractor and submitted to the Engineer and MTO to include all installation records, baseline readings, instrument location plan, diary of the construction activities, survey data collected in tabular as well as graphical formats as plots of time versus cumulative movement.

## **5.7 CONSTRUCTION CONCERNS**

Considering the nature of the embankment fills, native silt and silty clay till, no major construction concerns are anticipated if construction is carried out in general conformance with the above recommendations. However, it is recommended that the potential to encounter the cobble and boulder sized rock pieces of requiring removal in the till deposit be considered in the Contract documents. The Contractor must be prepared to excavate and advance if the oversized obstacle is encountered during the excavation and/or trenchless construction. The Contractor must also be prepared to deal with seasonal and yearly fluctuations of groundwater.

The Contractor should submit a detailed method statement to Engineer and MTO for review, no later than two weeks prior to commencement of the construction, including the proposed tunnelling/trenchless methodology, equipment, design and the layout of temporary protection system, dewatering plan, construction schedule, the proposed monitoring program, calculations with the stamped engineering drawings and the contingency plans. The dewatering plan should include all aspects from methodology (i.e. sump holes and pumps, drainage ditches, etc.) to construction of system (sump hole details, placement, etc.) and operation of system, etc.

## 6 STATEMENT OF LIMITATIONS

The design recommendations given in this geotechnical report are applicable only to the project described in the text and only if constructed substantially in accordance with details of alignment and elevations stated in the report. Since all details of the design may not be known, in our analysis certain assumptions had to be made. The actual conditions may however, vary from those assumed, in which case changes and modifications may be required to our geotechnical recommendations. We recommend, therefore, that we be retained and provided the opportunity during the design stage to review the design drawings, site survey information, proposed elevations, etc. to verify that they are consistent with our recommendations or the assumptions made in our analysis. It is further recommended that we be retained to review the final design drawings and specifications relative to the geotechnical recommendations.

If, during construction, conditions in the field vary from those assumed at the design stage, an engineer from this office must be notified immediately.

Proper subgrade preparation, groundwater control, compaction, etc. are all critical aspects of the bearing capacity of native soils. It must be noted that different aspects of the geotechnical design are based on the assumption that Englobe will be retained during site preparation and construction of the proposed works to ensure that both the geotechnical site characteristics and the construction operations/techniques are consistent with our recommendations. Should Englobe not be involved during the full construction phase, our liability is strictly limited to the factual information contained herein only.

The comments in this report are intended solely for the guidance of the design engineer and address the geotechnical conditions only. The number of boreholes required to determine the localized conditions between boreholes directly affecting construction costs, equipment, scheduling, etc. would in fact be greater than what has been carried out for design purposes. Therefore, contractors bidding on this project or undertaking this work should make their own interpretations of the factual borehole results and carry out further work as they deem necessary to assess the scope of the project.

Section 5 of this reported is intended for the use of the client and the design team only and is not intended to be included in the tender documents. Inclusion of the factual information (Sections 1 to 5 inclusive) in the tender documents is furnished merely for the general information of bidders and is not in any way warranted or guaranteed by or on behalf of the owner or the owner's consultants and its subconsultants or the consultants' or subconsultants' employees, and neither the owner nor its consultants or its employees shall be liable for any representations negligent or otherwise contained in the documents.

## Appendix 1   Key Plan

Drawing No. 1

Key Plan

# MACRO KEY PLAN

Drawing No.1

NOT TO SCALE



## GEOTECHNICAL INVESTIGATION AND DESIGN REPORT

New Sanitary Forcemain Tunnel Construction  
Crossing Highway 23

North Perth, Ontario

Reference No: P-0013501-0-00

October 2017



## Appendix 2    Subsurface Data

Enclosure No. 1	List of Abbreviations and Symbols
Enclosure Nos. 2 to 4	Records of Borehole Sheet

## LIST OF ABBREVIATIONS & DESCRIPTION OF TERMS

The abbreviations and terms, used to describe retrieved samples and commonly employed on the borehole logs, on the figures and in the report are as follows:

### 1. ABBREVIATIONS

AS	Auger Sample
CS	Chunk Sample
DS	Denison type sample
FS	Foil Sample
NFP	No Further Progress
PH	Sampler advanced by hydraulic pressure
PM	Sampler advanced by manual pressure
RC	Rock core with size & percentage of recovery
SS	Split Spoon
ST	Slotted Tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash Sample
WH	Sampler advanced by static weight of hammer and/or rods
Rec	% recovery from individual run of rock core
RQD	Rock quality designation (%)

### 2. PENETRATION RESISTANCE/"N"

#### Dynamic Cone Penetration Test (DCPT):

A continuous profile showing the number of blows for each 300 mm of penetration of a 50 mm diameter 60° cone attached to AW rod driven by a 63 kg hammer falling 760 mm.

Plotted as —●—●—●—●—

#### Standard Penetration Test (SPT) or "N" Values

The number of blows of a 63 kg hammer falling 760 mm required to advance a 50 mm O.D. drive open sampler 300 mm.

### 3. SOIL DESCRIPTION

#### a) Cohesionless Soils:

"N" (blows/0.3 m)	Relative Density
0 to 4	very loose
4 to 10	loose
10 to 30	compact
30 to 50	dense
over 50	very dense

#### b) Cohesive Soils:

Undrained Shear Strength (kPa)	Consistency
Less than 12	very soft
12 to 25	soft
25 to 50	firm
50 to 100	stiff
100 to 200	very stiff
over 200	hard

### 3. SOIL DESCRIPTION (Cont'd)

#### c) Bedrock:

RQD (%)	Classification
Less than 25	Very poor quality
25 to 50	Poor quality
50 to 75	Fair quality
75 to 90	Good quality
90 to 100	Excellent quality

#### d) Method of Determination of Undrained Shear Strength of Cohesive Soils:

- + 3.2 - Field Vane test in borehole.  
The number denotes the sensitivity to remoulding.
- D - Laboratory Vane Test
- " - Compression test in laboratory

For a saturated cohesive soil the undrained shear strength is taken as one-half of the undrained compressive strength.

#### e) Soil Moisture:

Moisture	Described as
Dry	Below optimum moisture content
Moist	Near optimum moisture content
Wet	Above optimum moisture content

### 4. TERMINOLOGY

Terminology used for describing soil strata is based on the proportion of individual particle sizes present in the samples (please note that, with the exception of those samples subject to a grain-size analysis, all samples were classified visually and the accuracy of visual examination is not sufficient to determine exact grain sizing):

Trace, or occasional	Less than 10%
Some	10 to 20%
With	20 to 30%
Adjective (i.e. silty or sandy)	30 to 40%
And (i.e. sand and gravel)	40 to 60%

Terminology for cobbles and boulders is based on auger response and field observations:

Occasional	Obstructions encountered in borehole, however advance is not impeded
Numerous	Obstructions are essentially continuous over drilled length

**SAMPLE DESCRIPTION NOTES:**

1. **FILL:** The term fill is used to designate all man-made deposits of natural soil and/or waste materials. The reader is cautioned that fill materials can be very heterogeneous in nature and variable in depth, density and degree of compaction. Fill materials can be expected to contain organics, waste materials, construction materials, shot rock, rip-rap, and/or larger obstructions such as boulders, concrete foundations, slabs, abandoned tanks, etc.; none of which may have been encountered in the borehole. The description of the material penetrated in the borehole therefore may not be applicable as a general description of the fill material on the site as boreholes cannot accurately define the nature of fill material. During the boring and sampling process, retrieved samples may have certain characteristics that identify them as 'fill'. Fill materials (or possible fill materials) will be designated on the Borehole Logs. If fill material is identified on the site, it is highly recommended that testpits be put down to delineate the nature of the fill material. However, even through the use of testpits defining the true nature and composition of the fill material cannot be guaranteed. Fill deposits often contain pockets or seams of organics, organically contaminated soils or other deleterious material that can cause settlement or result in the production of methane gas. It should be noted that the origins and history of fill material is frequently very vague or non-existent. Often fill material may be contaminated beyond environmental guidelines and the material will have to be disposed of at a designated site (i.e. registered landfill). Unless requested or stated otherwise in this report, fill material on this site has not been tested for contaminants however, environmental testing of the fill material can be carried out at your request. Detection of underground storage tanks cannot be determined with conventional geotechnical procedures.
2. **TILL:** The term till indicates a material that is an unstratified, glacial deposit, heterogeneous in nature and, as such, may consist of mixtures and pockets of clay, silt, sand, gravel, cobbles and/or boulders. These heterogeneous deposits originate from a geological process associated with glaciation. It must be noted that due to the highly heterogeneous nature of till deposits, the description of the deposit on the borehole log may only be applicable to a very limited area and therefore, caution must be exercised when dealing with a till deposit. When excavating in till, contractors may encounter cobbles/boulders or possibly bedrock even if they are not indicated on the borehole logs. It must be appreciated that conventional geotechnical sampling equipment does not identify the nature or size of any obstruction.
3. **BEDROCK:** Auger refusal may be due to the presence of bedrock, but possibly could also be due to the presence of very dense underlying deposits, boulders or other large obstructions. Auger refusal is defined as the point at which an auger can no longer be practically advanced. It must be appreciated that conventional geotechnical sampling equipment does not differentiate between nature and size of obstructions that prevent further penetration of the boring below grade. Bedrock indicated on the borehole logs will be labeled 'possibly' or 'probable' etc. based on the response of the boring and sampling equipment, surrounding topography, etc. Bedrock can be proven at individual borehole locations, at your request, by diamond core drilling operations or, possibly, by testpits. It must also be appreciated that bedrock surfaces can be, and most times are, very erratic in nature (i.e. sheer drops, isolated rock knobs, etc.) and caution must be used when interpreting subsurface conditions between boreholes. A bedrock profile can be more accurately estimated, at the clients' request, through a series of closely positioned unsampled auger probes combined with core drilling.
4. **GROUNDWATER:** Although the groundwater table may have been encountered during this investigation and the elevation noted in the report and/or on the record of boreholes, it must be appreciated that the elevation of the groundwater table will fluctuate based upon seasonal conditions, localized changes, erratic changes in the underlying soil profile between boreholes, underlying soil layers with highly variable permeabilities, etc. These conditions may affect the design and type and nature of dewatering procedures. Cave-in levels recorded in borings give a general indication of the groundwater level in cohesionless soils however, it must be noted that cave-in levels may also be due to the relative density of the deposit, drilling operations etc.

## METRIC

## RECORD OF BH-06-16



REFERENCE P-0013501-0-00 DATUM Geodetic LOCATION N 4844038.7 E 186119.9 - 1200 Hwy. 23, Municipality of North Perth, ON ORIGINATED BY SW

PROJECT North Perth Wastewater Treatment Plant Upgrades BOREHOLE TYPE Solid Stem Auger COMPILED BY DM

CLIENT GM Blue Plan DATE (Started) 05 April 2016 TIME (Completed) 05 April 2016 CHECKED BY SH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION (see Enclosure No. 1)	STRATA PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
376.2	Ground Surface													
376.0	EMBANKMENT FILL - sandy silt, dark brown		1	AS										
0.2	EMBANKMENT FILL - silt, some gravel, some sand brown		2	SS	13									
	(compact/loose)													
	wet		3	SS	6									
	dark brown		4	SS	13									
373.2	FILL - clayey silt, some gravel dark brown		5	SS	7									
372.4	SILTY CLAY TILL - some to trace gravel, with sand grey/brown (very stiff/hard)		6	SS	22									
			7	SS	29									
	trace gravel		8	SS	43									
369.7	End of Sampling End of Borehole													
6.6														

COMMENTS	+ 3, X 3 : Numbers on right refer to Sensitivity Numbers on left refer to values greater than 100 kPa ○ 3% STRAIN AT FAILURE	WATER LEVEL RECORDS		
		Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
The stratification lines represent approximate boundaries. The transition may be gradual.		1) 05-04-17	1.52	-
		2)	-	-
		3)	-	-

MEL-GEO P-0013501 - BOREHOLE LOGS.GPJ MEL-GEO.GDT 18-10-17

## METRIC

## RECORD OF BH-07-16



REFERENCE P-0013501-0-00 DATUM Geodetic LOCATION N 4844020.3 E 186161.6 - 1200 Hwy. 23, Municipality of North Perth, ON ORIGINATED BY SW

PROJECT North Perth Wastewater Treatment Plant Upgrades BOREHOLE TYPE Solid Stem Auger COMPILED BY DM

CLIENT GM Blue Plan DATE (Started) 05 April 2016 TIME (Completed) 05 April 2016 CHECKED BY SH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION (see Enclosure No. 1)	STRATA PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
376.3	Ground Surface													
0.0	EMBANKMENT FILL - sandy silt, some gravel, occasional cobbles dark brown/brown moist to very moist		1	AS										
375.5														
0.8	EMBANKMENT FILL - silty sand and gravel, trace clay dark brown (dense) wet		2	SS	33									
374.8														
1.5	EMBANKMENT FILL - silt, some gravel, some sand, trace clay brown (compact) very moist		3	SS	10									
			4	SS	11									
			5	SS	18									
372.5														
3.8	SILTY CLAY TILL - trace gravel, with sand brown (very stiff/hard)		6	SS	12									
			7	SS	21									
			8	SS	30									
369.8	End of Sampling End of Borehole													
6.6														
COMMENTS								+ 3, X 3 : Numbers on right refer to Sensitivity Numbers on left refer to values greater than 100 kPa ○ 3% STRAIN AT FAILURE						
The stratification lines represent approximate boundaries. The transition may be gradual.								WATER LEVEL RECORDS						
								Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)				
								1) 05-04-17			2.29	▽	-	
								2)			-	▽	-	
								3)			-	▽	-	

MEL-GEO P-0013501 - BOREHOLE LOGS.GPJ MEL-GEO.GDT 18-10-17

Englobe Corp.

120 Progress Court, North Bay, On P1A 0C2 Phone: (705)476-2550 Fax: (705)476-8882 Email: northbay@englobecorp.com

## METRIC

## RECORD OF BH-01-17



REFERENCE P-0013501-0-00 DATUM Geodetic LOCATION N 4844034.6 E 186140.1 - 1200 Hwy. 23, Municipality of North Perth, ON ORIGINATED BY KRS

PROJECT North Perth Wastewater Treatment Plant Upgrades BOREHOLE TYPE Hollow Stem Auger COMPILED BY DM

CLIENT GM Blue Plan DATE (Started) 03 August 2017 TIME (Completed) 03 August 2017 CHECKED BY SH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION (see Enclosure No. 1)	STRATA PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
							20 40 60 80 100	20 40 60 80 100	20 40 60					
377.2	Ground Surface													
0.0	EMBANKMENT FILL - sand, gravelly, some silt, occasional cobbles dark brown (very dense/compact)		1	SS	44									
	trace asphalt		2	SS	91									
	wet		3	SS	20									
373.8			4	SS	12									
3.4	SILT - trace gravel, some sand, trace clay, trace organics and wood pieces dark brown/grey (very loose/compact)		5	SS	2									
	trace gravel, occasional cobbles compact		6	SS	18									
371.9			7	SS	15									
5.3	SILTY CLAY TILL - trace gravel, some to trace sand grey/brown (very stiff/hard)		8	SS	15									
			9	SS	20									
			10	SS	24									
369.1	End of Sampling End of Borehole													
8.1														
COMMENTS							+ 3, × 3 : Numbers on right refer to Sensitivity Numbers on left refer to values greater than 100 kPa ○ 3% STRAIN AT FAILURE		WATER LEVEL RECORDS Date (dd/mm/yy)/Time    Water Depth (m)    Cave In (m) 1) 11-08-17    5.5    - 2)    -    - 3)    -    -					
The stratification lines represent approximate boundaries. The transition may be gradual.														

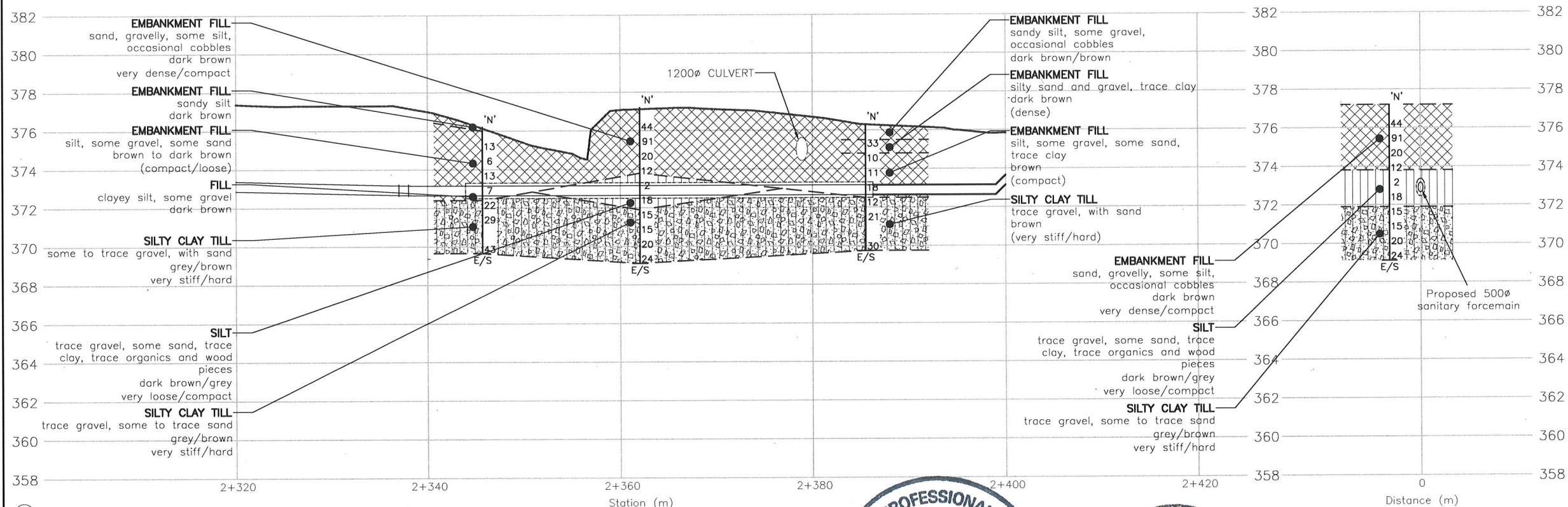
MEL-GEO P-0013501 - BOREHOLE LOGS.GPJ MEL-GEO.GDT 18-10-17

Englobe Corp.

120 Progress Court, North Bay, On P1A 0C2 Phone: (705)476-2550 Fax: (705)476-8882 Email: northbay@englobecorp.com

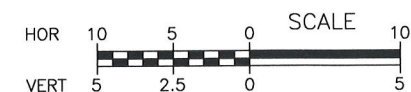
## **Appendix 3    Borehole Plan and Lab Data**

Drawing No. 2:            Borehole Location and Soil Strata  
Figure Nos. L-1 to L-3:    Grain Size Distribution Curves  
Figure No. L-4:                      Atterberg Limits  
Table No. L-5:            Laboratory Test Summary Sheet



HOR 10 5 0 10 20m

VERT 5 2.5 0 5 10m



0 2+400

LICENSED PROFESSIONAL ENGINEER

*S. Hu*

S. HU  
90524232

Oct 26, 2017

PROVINCE OF ONTARIO

DISTRICT CONT. No. GWP No.	
NEW SANITARY FORCEMAIN CONSTRUCTION CROSSING HWY 23	SHEET  2
BOREHOLE LOCATION AND SOIL STRATIGRAPHY	

**KEY PLAN**  
N.T.S.

LEGEND				
 N	Borehole			
 E/S	Blows/0.3 m (Std Pen Test, 475 J/blow)			
 E/S	Water Level at Time of Investigation			
 E/S	End of Sampling			
 E/S	Piezometer			

BOREHOLE No.	ELEVATION	O/S.	NORTHING	EASTING
01-17	377.2	3.2 m Lt	4844034.6	186140.1
06-16	376.2	-----	4844038.7	186119.9
07-16	376.3	-----	4844020.3	186161.6

**NOTES:**

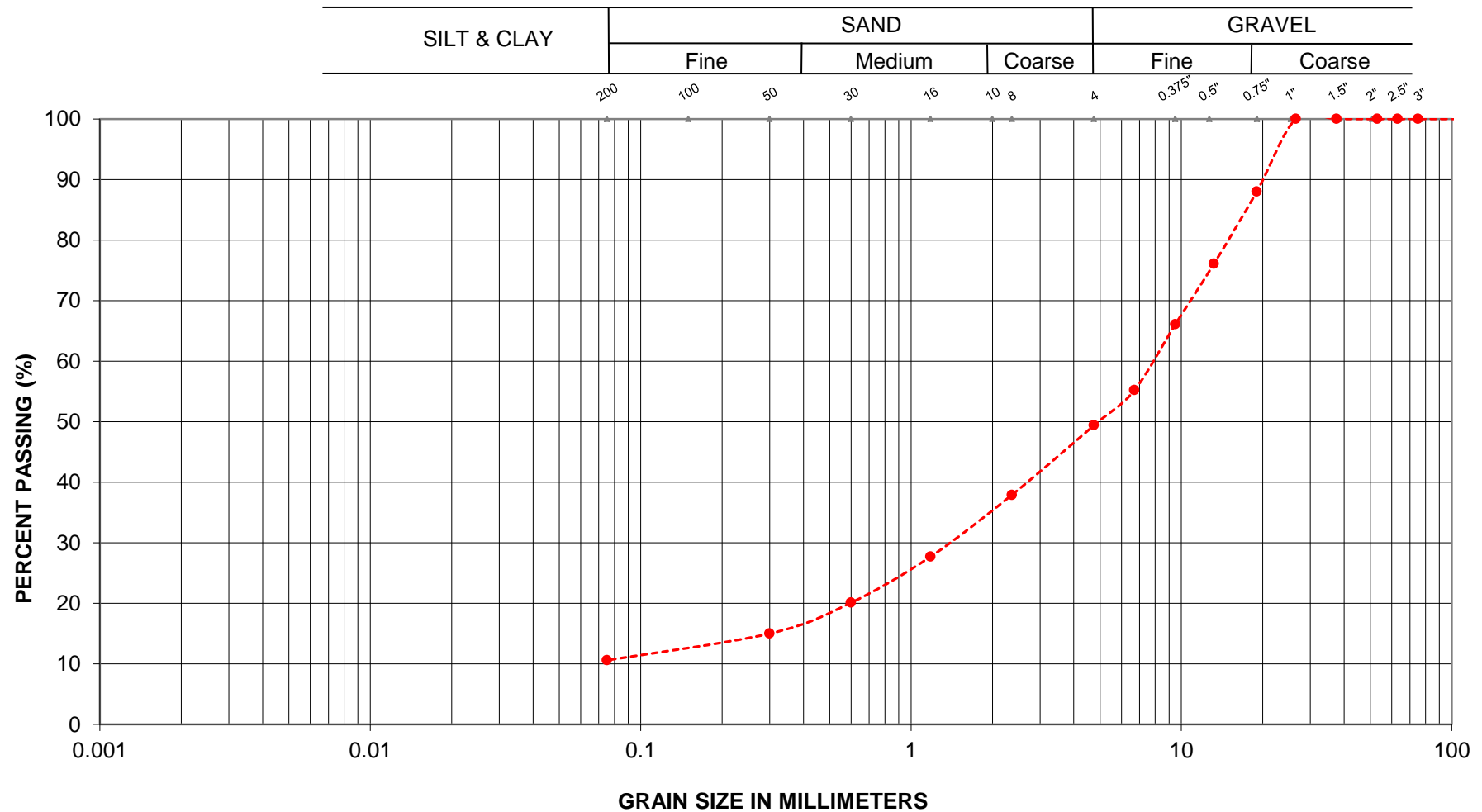
The boundaries between soil strata have been established at the borehole locations only. The boundaries illustrated and stratigraphy between boreholes on this drawing are assumed based on borehole data and may vary. They are intended for design only.

Base plan and alignment provided in digital format by GM BluePlan Engineering Limited on August 30, 2017

Coordinates based on MTM Zone 10 NAD83 CSRS

**GEOCRES No.**

REVIEWS	SEP/17	DM	DRAFT					
	OCT/17	DM	FINAL					
DESCRIPTION								
DESIGN	CHK		CODE		LOAD		DATE OCT/17	
DRAWN	DM	CHK SH	SITE		STRUCT		SCHEME	DWG 2

**GRAIN SIZE ANALYSIS**

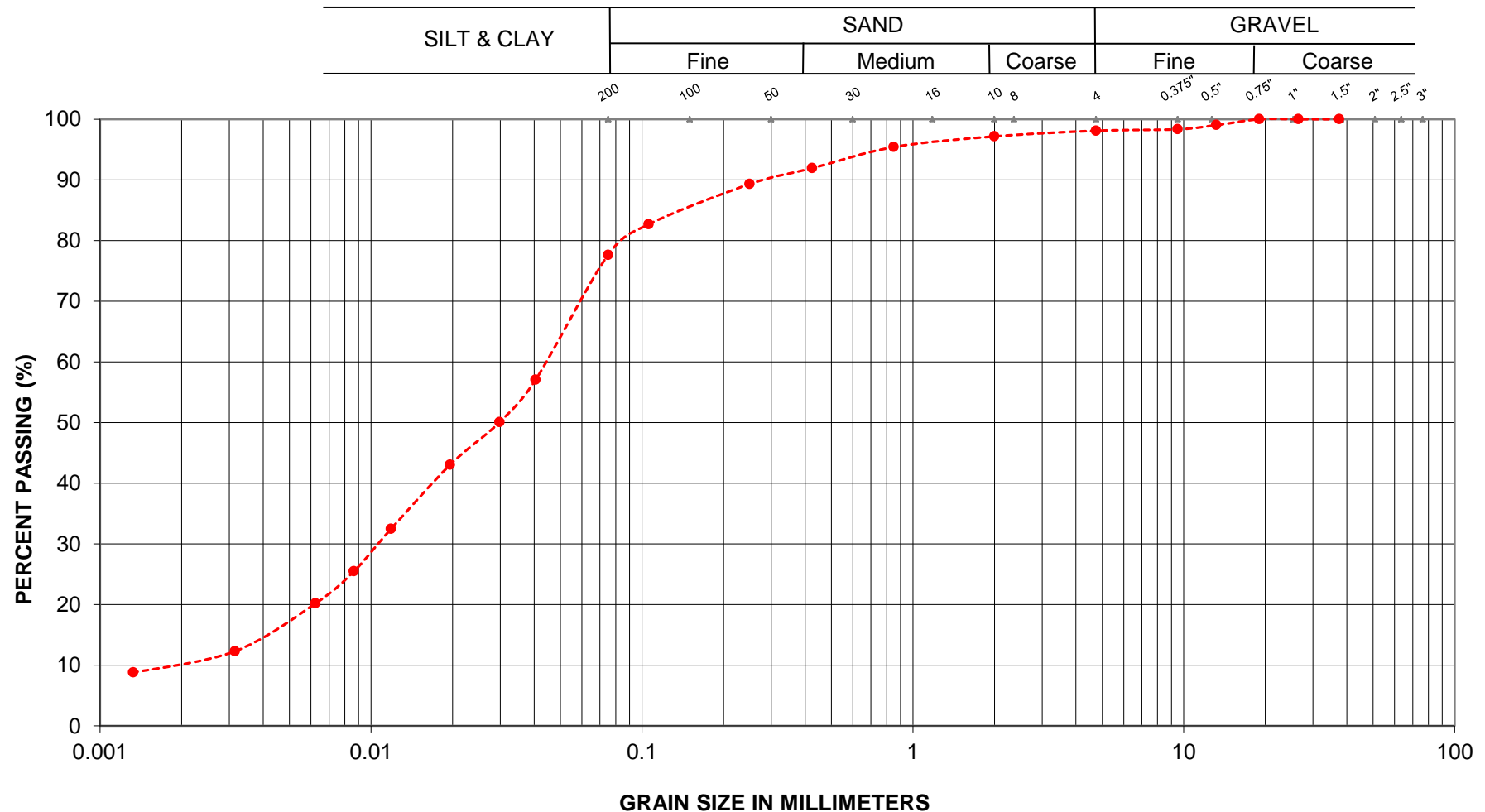
---●--- BH No.: 01-17 Sa No.: 3 Depth: 2.3 - 2.7 m

LOCATION: New Sanitary Forcemain Construction  
 Crossing Hwy 23  
 Municipality of North Perth

Embankment FILL  
 Englobe Corp.

FIGURE L-1

## GRAIN SIZE ANALYSIS

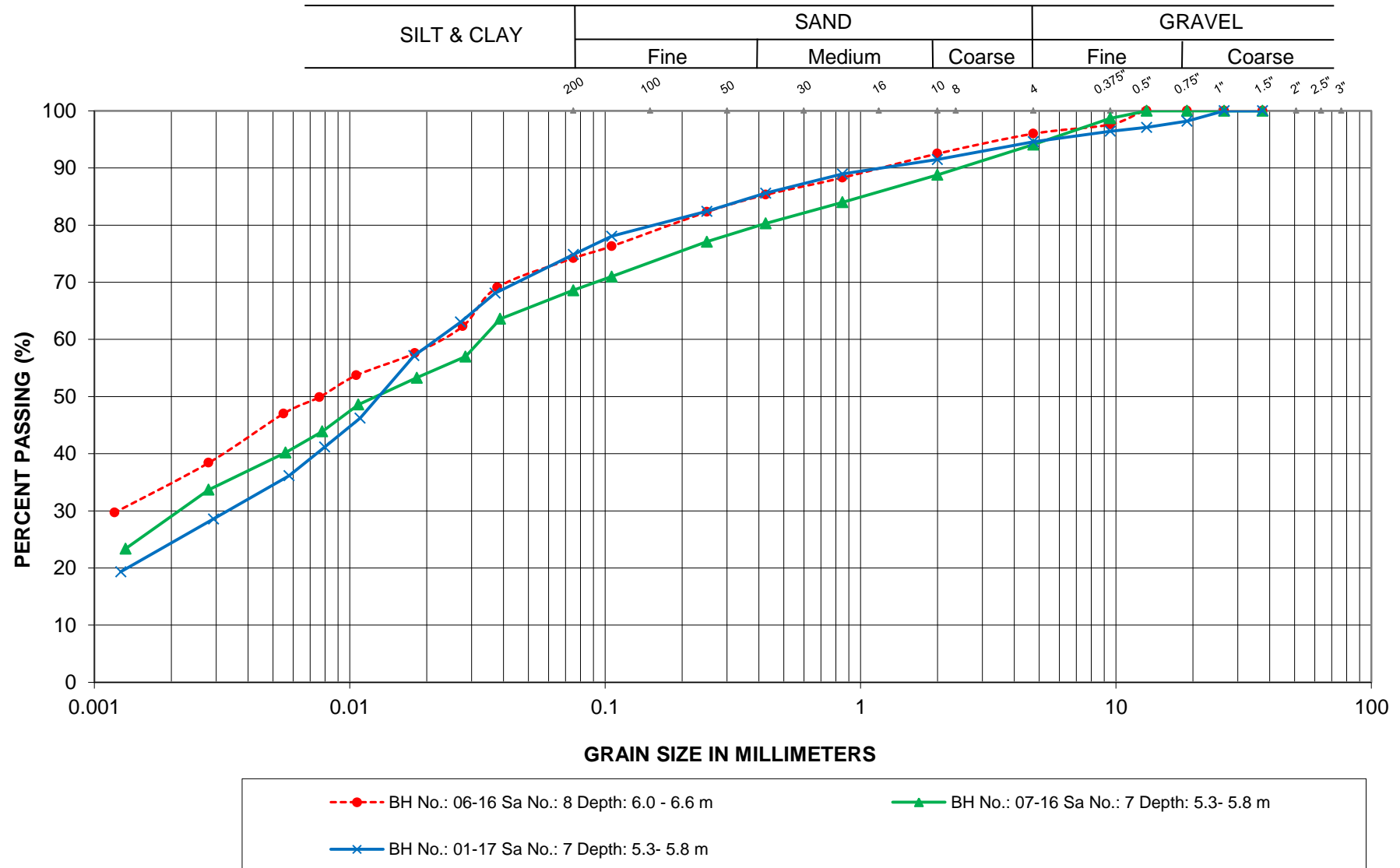


LOCATION: New Sanitary Forcemain Construction  
Crossing Hwy 23  
Municipality of North Perth

SILT  
Englobe Corp.

FIGURE L- 2

## GRAIN SIZE ANALYSIS



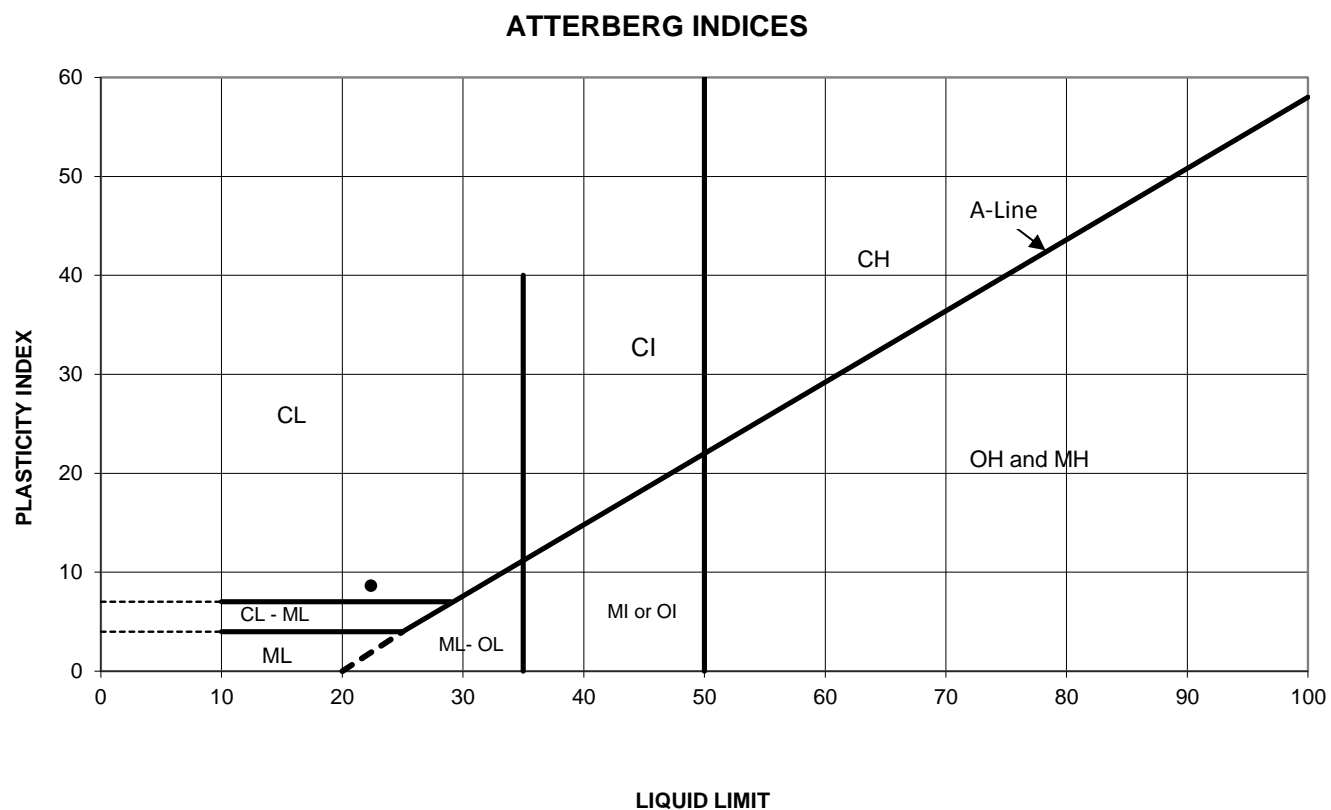
LOCATION: New Sanitary Forcemain Construction  
Crossing Hwy 23  
Municipality of North Perth

silty CLAY TILL  
  
Englobe Corp.

FIGURE L- 3

## ATTERBERG LIMITS TEST RESULTS


**FIGURE L-4**

[illegible]

Date: Sep-17  
Project: Sanitary Forcemain Construction Crossing Hwy 23  
Location: Municipality of North Perth

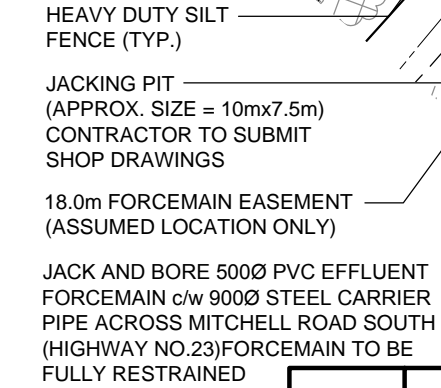
Prep'd: DM  
Chkd: SH  
Ref. No.: P-0013501-0-00-101

**Englobe Corp.**

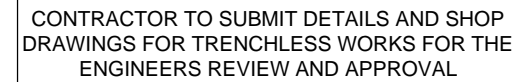
Laboratory Tests - Summary Sheet														
Borehole No.	Sample No.	Depth	Grain Size Analysis				NMC	Atterberg Limits			SPT 'N'	USCS	Unit Weight (kN/m3)	Remarks
			Gravel Size (%)	Sand Size (%)	Silt Size (%)	Clay Size (%)		LL (%)	PL (%)	IP (%)				
06-16	1	0.3					12.5				N/A			
	2	1.0					12.5				13			
	3	1.8					11.9				6			
	4	2.5					21.9				13			
	5	3.3					34.0				7			
	6	4.0					11.2				22			
	7	4.8					13.5				29			
	8	6.3	4	22	40	34	14.2				43			
07-16	1	0.3					12.4				N/A			
	2	1.0					18.4				33			
	3	1.8					12.9				10			
	4	2.5					41.0				11			
	5	3.3					13.3				18			
	6	4.0					13.2				12			
	7	4.8	6	25	37	32	13.5				21			
	8	6.3					11.7				30			
01-17	1	1.0					6.3				44			
	2	1.8					3.5				91			
	3	2.5	58	37	11		9.0				20			
	4	3.3					17.4				12			
	5	4.0	2	20	68	10	65.2				2			
	6	4.8					27.9				18			
	7	5.6	5	20	50	25	13.1	22.4	13.8	8.6	15			
	8	6.3					14.5				15			
	9	7.1					17.3				20			
	10	7.9					15				24			

## **Appendix 4      Design Data**

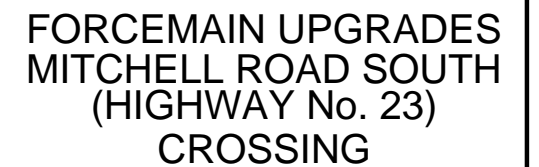
Enclosure No.5                      Encroachment Permit Drawing Figure No. 1  
Enclosure No.6              Guidelines for Foundation Engineering - Tunnelling  
Specialty for Corridor Encroachment Permit Application



900Ø STEEL -  
CASING PIPE

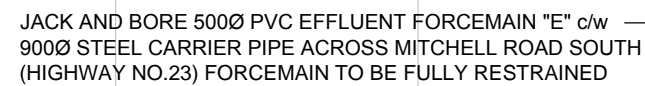


N.T.S.



# ENCROACHMENT PERMIT

Figure No. 1



315047  
JANUARY 2017  
Scale: Horiz.=1:500  
Vert.=1:50

## Guidelines For Foundation Engineering – Tunnelling Specialty For Corridor Encroachment Permit Application

These guidelines specify MTO's minimum requirements for the Foundation Engineering – Tunnelling Specialty component of submissions from proponents of development within the Ministry of Transportation's (MTO) corridor permit control area. The Foundation Engineering – Tunnelling Specialty component of submissions is a requirement for the permit application only and do not cover all the design requirements.

The complexity ratings of Foundations Engineering services are defined in Table 1.

**Table 1: Complexity ratings for tunnelling specialty services**

Highway Classification	Tunnel Excavation Diameter (ϕ)					
	≤ 1 m		>1 m & ≤ 2 m		>2 m	
	Minimum Overburden Cover * (m)					
	≥ 3 ϕ (or 1.5 m whichever is greater)	< 3 ϕ (or 1.5 m whichever is greater)	≥ 3 ϕ	< 3 ϕ (or 1.5 m whichever is greater)	≥ 3 ϕ	< 3 ϕ (or 1.5 m whichever is greater)
Kings Highway	Low	Medium	Medium	High	High	High
400 Series Freeway	Medium	High	High	High	High	High

\*Minimum overburden cover is the vertical distance measured from the lowest ground elevation to the crown of the tunnel.

Foundations Engineering consultants that are registered in the MTO consultant acquisition system (RAQS) at complexity ratings identified in Table 1 are eligible to provide Foundations Engineering services for this project. Alternatively, the proponents may propose a Foundations Engineering consultant that is not registered in RAQS, in which case, the proponent must submit sufficient documentation to demonstrate that the consultant's qualifications meet or exceed the RAQS complexity requirements.

For Engineering Materials Testing and Evaluation, the consultant shall be qualified for Soil and Rock testing of complexity level at least equal to that identified for this project.

Consultant services shall be provided in accordance with the most recent editions of the Canadian Highway Bridge Design Code (CHBDC), and the 'Guideline for Professional Engineers Providing Geotechnical Engineering Services' published by the Professional Engineers of Ontario.

The designated principal contact identified for Foundations Engineering services by MTO shall sign, and where required, seal, all submissions and correspondence that are submitted to MTO.

Services include, but are not restricted to, conducting a site investigation that shall be of sufficient scope to verify design assumptions and to provide the contractor with adequate subsurface information for design and construction planning.

Sufficient subsurface (factual) information is required to determine the vertical and horizontal extent of subsurface materials (including both soil and rock) and their pertinent engineering properties and groundwater conditions.

Subsurface information is usually acquired by advancing boreholes, laboratory testing of soil samples and rock core samples, performing in-situ tests such as standard penetration tests, dynamic cone tests, and piezocone tests (CPTU) and test pits.

### **Minimum requirements for Subsurface Investigation and Recommendations**

A minimum of one borehole shall be advanced at each end of tunnel crossing. The boreholes shall be located outside but within 2 m of the tunnel's excavated footprint.

Spacing between the boreholes shall not exceed 50 m. In case of larger spacing between the boreholes, additional boreholes shall be advanced except where significant traffic disruptions might occur and where consistent conditions are evident.

Boreholes shall be advanced to 3 tunnel diameters (excavated diameters) below invert. If bedrock is encountered earlier, the borehole shall advance to at least 3 m below the invert of tunnel into the bedrock.

The investigations, if required, shall be supplemented with additional and deeper boreholes to verify consistent conditions and existence of boulders within critical foundation zones.

Sampling and testing, consisting of Standard Penetration Test, thin wall tube sample, rock cores, and MTO Field Vane Test where appropriate, shall be conducted to develop a comprehensive subsurface model. Semi-continuous sampling at 0.75m (2.5ft) intervals is required within overburden; whereas, sampling interval of 1.5m (5.0ft) is required below the tunnel invert.

Where encountered, the bedrock-soil interface shall be determined by geological definition and not the by the material properties.

All aspects of implementation of means of subsurface investigations including, but not limited to, planning, licensing, construction, maintenance, abandonment, and reporting, shall be in accordance with Ministry of the Environment Regulation 903 and its amendments (the water well regulation under the OWRA).

Boreholes and piezometer tubes shall be backfilled with a suitable bentonite/cement mixture. Test pits shall be backfilled with suitable material and either re-vegetated or otherwise protected from erosion. Temporary open holes shall be adequately covered.

Holes in roads shall be backfilled as required to prevent future settlement and acceptably patched where pavement surfaces have been damaged. Backfilling requirements shall be described in the Foundation Investigation and Design Report.

Where encountered, artesian groundwater conditions shall be sealed. Details of the artesian condition and the sealing operation shall be included in the Foundation Investigation Report.

Fieldwork shall be carried out in accordance with the Occupational Health and Safety Act.

Traffic protection in accordance with MTO requirements shall be provided during the course of any field investigations. However, where significant traffic disruptions might occur, boreholes may be relocated or numbers reduced with MTO's approval.

The locations and ground surface elevations of all boreholes, test pits and soundings shall be surveyed and referred to fixed reference points and data. Locations are to be identified by co-ordinates (Northing and Easting). The vertical accuracy of survey readings shall be within 0.1m; whereas, horizontal accuracy shall be within 0.5m.

### **Minimum Laboratory Testing Requirements:**

Laboratory testing shall consist of routine testing of 25% of samples. One routine lab test is defined as natural water content plus Atterberg Limit plus grain size distribution tests. Complex laboratory testing is defined by all other tests including compressive strength, shear strength, consolidation, permeability and triaxial testing. Laboratory testing requirements shall be supplemented with additional routine and complex tests if required to verify strata boundaries and properties and behaviour of critical subsurface zones.

### **Borehole Log Preparation and Foundation Drawing:**

Borehole log sheets, figures and drawings shall be prepared in accordance with MTO standards. The Foundation Drawing shall consist of a plan showing the locations of all borings, test pits and soundings and various stratigraphical longitudinal profiles and stratigraphical cross-sections at each tunnel structure foundation element and groundwater levels.

### **Minimum Requirements for the Foundation Investigation and Design Report:**

A Foundation Investigation and Design Report shall consist of the factual subsurface information (including the field and laboratory test information) and the recommendations required for foundation design.

The report shall be signed and sealed by two professional engineers, registered with the Professional Engineers of Ontario, representing the consulting firm; one of them shall be the firm's designated principal contact for MTO's Foundations Engineering projects.

- The Foundation Investigation component of the report shall contain:
- Site Description - including topography, vegetation, drainage, existing land use, and structures.
- Investigation Procedures - including site investigation and lab testing procedures.
- Description of Subsurface Conditions - including soil, boulders, rock and groundwater conditions.
- Miscellaneous Section - that identifies the name of the drilling company, the laboratory where testing was performed, the persons who carried out the field supervision, and those who wrote and reviewed the report.

The Foundation Design component of the report shall present discussion and recommendations for design. The consultant shall analyse field data and test results and make comprehensive and practical recommendations pertaining to temporary, interim and permanent conditions at the Project.

The consultant shall identify and evaluate all reasonable and appropriate alternatives for the proposed tunnel crossing. Alternatives may include, but not limited to, jack & bore, pipe jacking using TBM, pipe ramming, micro-tunnelling (if economically feasible), utility tunnelling using TBM (two pass system), Horizontal Directional Drilling (HDD) and cut and cover methods.

The consultant shall identify and present overview assessments of the advantages, disadvantages, costs and risks/consequences of alternative tunnelling methods in a table. The report should conclude a preferred alternative from foundation engineering and cost effectiveness perspective.

In the development and design of the preferred alternative, the Consultant shall, as applicable, address:

- impacts on the land use and property, traffic and transportation, and environment,
- length and diameter constraints
- control of face stability
- capability of boulder excavation
- evaluation of temporary and permanent support
- alignment control
- estimated settlements and heave and management of these deformations
- special access and egress requirements for TBM's and other similar equipment such as those used for the Jack & Bore method including recommendations for vertical shafts and jacking pits;
- shored and un-shored alternatives for open-cut excavation;
- groundwater control & dewatering;
- the long-term stability of the tunnel;

- relative costs; and
- traffic management and contractor access for each alternative.

If borehole logs available from previous projects are included to meet the requirements of field investigations then the accuracy of subsurface information from these boreholes remains the responsibility of consultant except in situations where MTO specify the use of previous boreholes. Borehole logs from previous studies that are appended to the report shall be reformatted to meet the MTO's requirements.

The final foundation recommendations shall detail the geometric, material and strength properties of the new tunnel crossing plus the liner, bedding and backfill requirements, and slope and embankment restoration requirements. The invert elevation should be assessed in view of the subsurface conditions and the anticipated open face stability control.

The consultant is responsible for developing contract documents sufficient to implement the design. This typically includes:

- Contract specifications for materials and specialized construction activities, and
- Recommendations for methods of overcoming anticipated construction problems, in particular, those relating to dewatering, boulder excavation, alignment control and the stability of excavations and embankments. .

The consultant shall develop a detailed instrumentation and monitoring program that meets the requirements of these guidelines. (see Appendix for typical settlement monitoring guidelines).

The consultant is responsible for preparing Traffic Control Plans and to obtain approvals and an Encroachment Permit from the Ministry, which are required for lane closures necessary to install the settlement monitoring points.

The tunnelling consultant shall ensure that the foundations engineering component of the project is adequately reflected in the design drawings, specifications and related contract documents.

Written confirmation is required from the Proponent and the tunnelling consultant that the design package submitted to MTO have been reviewed by the tunnelling consultant and that all recommendations have been satisfactorily incorporated in the contract package.

## **APPENDIX: SETTLEMENT MONITORING GUIDELINES - TUNNELING**

**The purpose of settlement monitoring is to prevent damage to existing utilities and highway structures along the tunnel alignment. Ground settlement include settlement due to lost ground and dewatering/drainage.**

### **Instrumentation Arrays**

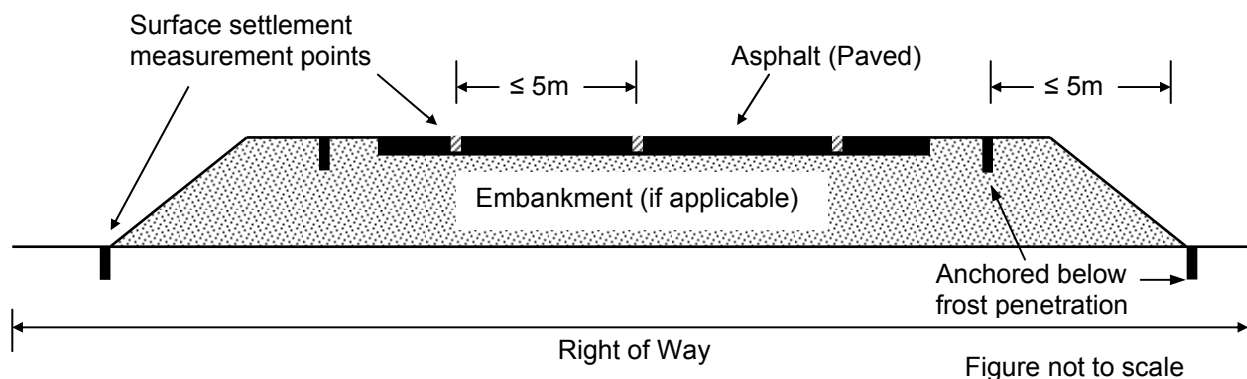
All measurement points shall be installed and surveyed before the start of excavation to establish benchmarks/baseline.

#### **Surface Monitoring Points**

Surface monitoring points will be installed to cover the whole length of the tunnel with in the right of way under the jurisdiction of MTO (Figure 1).

Surface monitoring points will be located at not greater than 5m intervals along the tunnel alignment. The surface monitoring will be identified using paint marks on the pavement. Surface monitoring points installed on the unpaved right of way shall be founded below frost penetration depths. The interval and/or marking of the points should be changed with MTO's approval where traffic disruptions might occur.

The final instrumentation plan should be finalised when Contractor's proposed construction method is available.



**Figure 1:** Typical configuration of surface settlement monitoring points along the tunnel alignment.

## **Condition Survey**

A condition survey for the pavement will be carried out prior to commencement of construction and documented for the purpose of requirement of restoration. The condition survey shall document visible flaws such as cracks, distortions and deviations, heaves, and depressions. This surface survey will be completed during the installation of the monitors and again once the tunnel has been completed.

## **Reading Frequency**

An average of at least two readings shall be taken to establish the initial conditions.

The reading and collection of data from the surface monitoring points shall be read and recorded by the Contractor during the construction period and after construction for period of at least 2 weeks provided that further settlement has stopped.

A minimum of three (3) sets of reading be taken daily, provided that movements are within anticipated limits. Otherwise, the frequencies should increase according to a pre-planned interval.

Monitoring of movements is required during work stoppages, such as during non-operation period (off-shifts) or weekends. A minimum of three (3) sets of readings should be taken daily.

Measurements of the monitoring points shall be reported promptly to MTO for review.

## **Data Collection and Data Transfer**

A procedure is required to be established in consultation with MTO so that the monitoring data and the interpreted data will reach all parties as soon as necessary. The contract administrator/consultant and the Contractor should interpret monitoring data as needed for the purpose of on-going construction. The Foundation Engineer should be contacted for technical support to the prime Consultant in the interpretation of ground movements and review of the Contractor's response when Review and Alert Levels are reached.

## **Criteria for Assessment**

The acceptable surface settlement (or heave) will be according to criteria as specified below.

**Baseline Reading** – A baseline reading of the instrumentation shall be taken prior to commencement of the work. An average of at least two initial readings shall be recorded as baseline reading.

Review Level – A maximum value of 10 mm relative to the baseline readings is suggested for this project. If this level is reached, the method, rate or sequence of construction, or ground stabilization measures should be reviewed or modified to mitigate further ground displacements.

Alert Level – A maximum value of 15mm relative to the baseline readings is suggested for this project. If this level is reached, the Contractor shall cease construction operations and to execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic.

### **Review of Contractor's Proposed Method**

MTO, the Proponent's prime consultant and Foundation Engineer should review the Contractor's proposed method of construction. The proposed method should include a description of the potential loss of ground, and calculation of the maximum settlement in relation to the Contractor's procedure and equipment, alternative/remedial measures when review level of measurement is reached; and contingency/remedial measures when alert level of measurement is reached.

### **Contractor's Responsibility For Restoration and Warranty Provision**

In addition to the monitoring program to assess the adequacy of the construction method to control potential ground movements and groundwater, the Contractor is responsible for reinstatement (such as surface paving) should movements or other surface distress occur, and provide a reasonable warranty period acceptable to MTO. Remedial measures shall be approved by MTO; however, MTO maintains the right to perform the maintenance at the proponent's expense.

### **Construction Monitoring**

The Proponent shall retain a qualified Geotechnical Consultant to supervise the installation of surface settlement points on site and to provide direction, technical input and field inspection on this project.



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