Englobe

Soils Materials Environment

Submitted to AECOM Canada Ltd.
189 Wyld Street Suite 103, North Bay, Ontario P1B 1Z2
On Behalf of the Ontario Ministry of Transportation

Culvert Replacement
Highway 60
Station 14+450 - Twp. of Franklin
GWP 5333-11-00

FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

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TABLE OF CONTENTS

TABLE OF CONTENTS

Appendices

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Englobe's subcontractors who may have accomplished work either on site or in laboratory are duly qualified as stated in our Quality Manual's procurement procedure. Should you require any further information, please contact your Project Manager."

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1 INTRODUCTION

Englobe Corp. (Englobe) has been retained by AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation of Ontario (MTO) to carry out a foundation investigation at an existing culvert site. The site is located at Station 14+450 in the Township of Franklin on Highway 60, about 1 km west of South Portage Road (Muskoka District Road 9), approximately at Latitude 45.338902 degrees, and Longitude:-79.033326 degrees, as shown in Drawing No. 1 in Appendix 1.

The foundation investigation for the culvert at this location was requested by email from AECOM dated March 27, 2017, and authorized to be carried out in addition to the MTO Terms of Reference for work outlined in Englobe's Proposal Reference No. 2017-P152-053-F9, dated April 17, 2017, under Agreement No. 5013-E-0032: GWP 5333-13-00. The terms of reference for the scope of work are outlined in Englobe's Proposal 2017-P152-053-F9, dated April 17, 2017. The purpose of this investigation was to determine the subsurface conditions in the area of the existing culvert to provide baseline information for use by the Design-Build Contractor. Englobe investigated the foundation area by the drilling of boreholes, carrying out in-situ tests, and performing laboratory testing on select samples.

2 SITE DESCRIPTION

An 800 mm diameter Corrugated Steel Pipe (CSP) culvert is located on Highway 60 at Station 14+450 in the Township of Franklin, Ontario. The topography in the area of this site is generally rolling. The existing highway embankment currently supports two undivided lanes of highway running in a west-east direction. The existing highway at the culvert location is constructed through an embankment fill that is about 5.2 m in height above the culvert invert (at centreline), with pavement centreline at Elevation 336.4 m at the culvert location. The existing embankment slopes in the area of the culvert have been generally established at an inclination angle of approximately 1.9H:1V at the south slope and 2H:1V at the north slope. Cobble and boulder size rock pieces of were observed on the existing north side slope of embankment during the site investigation field work, as shown on the Enclosure No. 5 in Appendix 4. A review of the existing condition of the pavement surface at the culvert location revealed some asphalt cracking, however, in general, the embankment appears to have performed satisfactorily.

The culvert at this location is an 800 mm diameter Corrugated Steel Pipe (CSP) culvert, about 30 m in length. Flow through the culvert is from the north to the south (left to right); see Photo Essay, Appendix 4.

There are no known underground services at the culvert location.

2.1 SITE PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The topography on this section of Highway 60 is generally rolling. Layers of earth overlie bedrock. Organic materials were also observed in the region. Within the project area, the native overburden consists primarily of sands and silts overlying bedrock.

Based on Ontario Geologic Survey (OGS) Map MRD-126, bedrock in the area consists of felsic igneous rocks and/or magmatic rocks and gneisses of uncertain protolith.

3 INVESTIGATION PROCEDURES

The fieldwork for this investigation was carried out from September 5th to 8th, 2017, during which time three (3) sampled boreholes were advanced. One (1) borehole was advanced through the embankment and one (1) borehole was advanced adjacent to the inlet (north) and outlet (south) ends of the culvert.

The field investigation was carried out using a truck and a bombardier mounted CME drilling rigs equipped with hollow stem augers, standard augers, casing equipment 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 "N" value. If refusal to further advance of the augers was encountered within the proposed depth of borehole, the drilling was continuously advanced through obstacles and/or cored into bedrock using the wash boring technique and associated diamond drilling, using NQ size coring equipment. All samples taken during this investigation were stored in labeled airtight containers for transport to our North Bay laboratory for visual examination and select 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 was installed in Borehole Nos. 1 and 2 prior to backfilling to allow for further monitoring of the shallow groundwater levels. All open boreholes were backfilled upon completion with compacted auger cuttings in the same general order in which 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. At the borehole through the embankment, the upper portion of the hole, where necessary, was backfilled with an asphalt cold patch to seal the existing asphalt surface.

The fieldwork for this investigation was under the full time direction of a senior member of the Englobe engineering staff (Jame Lavigne), 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 North Bay laboratory, plus overall drill supervision. All samples received a visual confirmatory inspection in the laboratory. Laboratory testing of select samples included routine geotechnical testing for natural moisture content determination and particle size analysis. The results of the laboratory testing are presented on the individual Record of Borehole Sheets (Appendix 2), with a summary of testing results presented on the laboratory sheets in Appendix 3 (Figures Nos. L-1 to L-5 and Table No. L-6).

The location of the individual boreholes was determined in the field using highway chainage (established by Callon Dietz Inc. (Callon Dietz)) and offsets relative to highway centreline. The MTO co-ordinates, northing and easting, were then established for the boring locations using coordinates from MTM Zone 10, NAD 83 CSRS. The borehole elevations are based on coordinating the borehole locations with the highway survey carried out by Callon Dietz. 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 borehole logs (Enclosure Nos. 2 to 4, Appendix 2) and on Drawing No. 2 (Appendix 3). It should be noted that the stratigraphic delineations presented on the borehole logs and the interpreted soil strata plot are the results of non-continuous sampling, response to drilling progress, the results of SPT, plus 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 adjacent boreholes and beyond any specific boring location, and are shown on the drawings for illustration purposes only.

4.1 CULVERT STATION 14+450, TWP. OF FRANKLIN

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. 1 advanced through the embankment, Borehole No. 2 advanced adjacent to the culvert inlet, and Borehole No. 3 advanced adjacent to the culvert outlet. At the time of the subsurface investigation, the ground surface elevations at Boreholes Nos. 1 to 3 were recorded at Elevations 336.2, 333.1 and 331.3 m, respectively.

4.1.1 Pavement Structure

Borehole No. 1 was advanced through the embankment. Borehole No. 1 confirmed the pavement structure consisted of 150 mm asphalt overlying a layer of crushed gravel base approximately 150 mm thick.

4.1.2 Embankment Fill

4.1.2.1 *Upper Sand Fill*

Underlying the pavement structure at Borehole No. 1, the embankment fill was encountered and described as brown sand, with gravel to gravelly, trace silt. The natural moisture contents of samples recovered from this sand fill layer were in the order of 2 to 3%. A gradation (sieve) analysis was carried out on one (1) sample of this layer, the results of which indicated 33% gravel size particles, 61% sand size particles, and 6% silt and clay size particles (Figure No. L-1, Appendix 3). According to results of gradation testing and the criteria for Frost-susceptibility and Erodibility of soils stated in MTO *Pavement Design and Rehabilitation Manual* (2013), the upper sand fill is classified as low susceptibility to frost heave (LSFH) and non-erodible. Based on SPT ‘N’ values of 11 to 35 blows per 300 mm penetration, the relative density/compactness of this deposit was described as compact to dense. This upper sand fill was encountered to a depth of 1.5 m below grade at Borehole No. 1 (Elevation 334.7 m).

BOREHOLE NO.	ELEVATION AT TOP OF LAYER (m)	ELEVATION AT BOTTOM OF LAYER (m)	THICKNESS OF LAYER (m)
1	335.9	334.7	1.2

4.1.2.2 *Rock Fill Mixed with Gravelly Sand*

Underlying the upper embankment sand fill at Borehole No. 1, a layer of rock fill mixed with gravelly sands, trace silt was penetrated. During advance of the borehole, boulder sized rock pieces were encountered at depths of 1.5 and 3.6 m below grade. Based on auger response in Borehole No. 1, it appears that this mixed rock fill layer contained voids at depths of 1.7 and 3.6 m below grade. The natural moisture content measured on a sample of this layer was about 4%. Based on SPT ‘N’ values of 14 to 17 blows per 300 mm penetration, the compactness of this layer was described as compact. Auger refusal was encountered at an approximate depth of 3.6 m below grade, therefore borehole advancement was continued, using the wash boring technique and associated equipment, below the depth of 3.6 m below grade. The mixed rock fill layer was penetrated to a depth of 3.7 m below grade at Borehole No. 1 (Elevation 332.5 m).

BOREHOLE NO.	ELEVATION AT TOP OF LAYER (m)	ELEVATION AT BOTTOM OF LAYER (m)	THICKNESS OF LAYER (m)
1	334.7	332.5	2.2

4.1.2.3 *Lower Sand Fill*

Underlying the mixed rock fill layer at Borehole No. 1, a lower embankment fill layer was encountered and described as brown sand, some gravel, some silt. The natural moisture content measured on one (1) sample of this layer was approximately 22%. Based on SPT 'N' values of 8 blows per 300 mm penetration, the compactness of this layer was described as loose. This lower sand fill was encountered to a depth 4.4 m below grade at Borehole No. 1 (Elevation 331.8 m).

BOREHOLE NO.	ELEVATION AT TOP OF LAYER (m)	ELEVATION AT BOTTOM OF LAYER (m)	THICKNESS OF LAYER (m)
1	332.5	331.8	0.7

4.1.3 Upper Sand

Underlying the embankment Fill at Borehole No. 1 and at surface at Borehole Nos. 2 and 3, a deposit of dark brown sand, trace gravel, trace silt to silty, trace clay was penetrated. Organics (grass rootlets, decayed wood, etc.) were encountered within this deposit. Occasional cobbles and boulders were encountered within this deposit at Borehole No. 2. The natural moisture contents measured on samples of this deposit ranged from about 21 to 54%. A gradation (hydrometer) analysis was carried out on one (1) sample of this deposit, and the results indicated 1% gravel size particles, 80% sand size particles, 17% silt size particles, and 2% clay size particles (Figure No. L-2, Appendix 3). Based on SPT 'N' values of 0 (sampler advanced solely by the static weight of hammer and rods) to 13 blows per 300 mm penetration, the compactness of this deposit was described as very loose to compact, generally compact. This deposit was encountered extending to depths of 5.2, 1.4, and 2.1 m below ground surface at Borehole Nos. 1, 2, and 3, respectively (Elevations 331.0, 331.7 and 329.2 m, respectively).

BOREHOLE NO.	ELEVATION AT TOP OF LAYER (m)	ELEVATION AT BOTTOM OF LAYER (m)	THICKNESS OF LAYER (m)
1	331.8	331.0	0.8
2	333.1	331.7	1.4
3	331.3	329.2	2.1

4.1.4 Silt

Underlying the upper sand at Borehole No. 1, a deposit of brown silt, trace sand, trace clay, was penetrated. The natural moisture content measured on a sample of this deposit was in the order of 22%. A gradation (hydrometer) analysis was carried out on one (1) sample of this deposit, and the results indicated 0% gravel size particles, 6% sand size particles, 88% silt size particles, and 6% clay size particles (Figure No. L-3, Appendix 3). Based on SPT ‘N’ values of 28 blows per 300 mm penetration, the compactness of this deposit was described as compact. This deposit was encountered to a depth of 5.9 m below ground surface at Borehole No. 1 (Elevation 330.3 m).

BOREHOLE NO.	ELEVATION AT TOP OF LAYER (m)	ELEVATION AT BOTTOM OF LAYER (m)	THICKNESS OF LAYER (m)
1	331.0	330.3	0.7

4.1.5 Silty Sand

Underlying the Upper Sand at Borehole No. 3, a deposit of silty sand, trace gravel, trace clay, was penetrated. The natural moisture contents measured on samples of this deposit were in the order of 22 to 23%. A gradation (hydrometer) analysis was carried out on one (1) sample of this deposit, and the results indicated 4% gravel size particles, 59% sand size particles, 36% silt size particles, and 1% clay size particles (Figure No. L-4, Appendix 3). Based on SPT ‘N’ values of 7 to 11 blows per 300 mm penetration, the compactness of this deposit was described as loose to compact. This deposit was encountered to a depth of 3.7 m below ground surface at Borehole No. 3 (Elevation 327.6 m).

BOREHOLE NO.	ELEVATION AT TOP OF LAYER (m)	ELEVATION AT BOTTOM OF LAYER (m)	THICKNESS OF LAYER (m)
3	329.2	327.6	1.6

4.1.6 Lower Sand

Underlying the Silt at Borehole No. 1, the Upper Sand at Borehole No. 2, and the Silty Sand at Borehole No. 3, a deposit of sand, with to trace gravel, some to trace silt, trace clay was penetrated. The natural moisture contents measured on samples of this deposit were in the order of 13 to 24%. Gradation (sieve) analyses were carried out on two (2) samples of this deposit, and the results indicated 17 to 26% gravel size particles, 71 to 78% sand size particles, and 3 to 5% silt and clay size particles (Figure No. L-2, Appendix 3). Based on SPT ‘N’ values of 5 to 65 blows per 300 mm penetration, the compactness of this deposit ranges from loose to very dense, and is generally compact as average. This deposit was encountered to depths of 8.1, 2.9, and 5.9 m below grade at Borehole Nos. 1 to 3, respectively (Elevations 328.1, 330.2 and 325.4 m, respectively).

BOREHOLE NO.	ELEVATION AT TOP OF LAYER (m)	ELEVATION AT BOTTOM OF LAYER (m)	THICKNESS OF LAYER (m)
1	330.3	328.1	2.2
2	331.7	330.2	1.5
3	327.6	325.4	2.2

4.1.7 Gravelly Sand

Underlying the Lower Sand at Borehole No. 2, a deposit of gravelly sand was encountered. The natural moisture content measured on a sample of this deposit was in the order of 12%. Gradation (sieve) analyses were carried out on one (1) sample of this deposit, and the results indicated 32% gravel size particles, 57% sand size particles, and 11% silt and clay size particles (Figure No. L-5, Appendix 3). Based on a SPT ‘N’ value of 47 blows per 300 mm penetration, compactness of this deposit was described as dense. This deposit was encountered to a depth of 3.7 m below grade at Borehole No. 2 (Elevation 329.4 m).

BOREHOLE NO.	ELEVATION AT TOP OF LAYER (m)	ELEVATION AT BOTTOM OF LAYER (m)	THICKNESS OF LAYER (m)
2	330.2	329.4	0.8

4.1.8 Bedrock

Underlying the sands at Borehole Nos. 1 to 3, bedrock was proven by diamond core drilling, at Elevations 328.1, 329.4, and 325.4 m, respectively. The bedrock was described as black gneiss. Based on RQD values of 78 to 100% the bedrock was described as good to excellent quality. Based on visual review, the bedrock was sound, generally exhibiting negligible weathering. Sampling in the bedrock was terminated at depths of 11.1, 6.6 and 9.1 m below grade at Borehole Nos. 1 to 3, respectively (Elevations 325.1, 326.5 and 322.2 m, respectively). This demonstrates that the underlying bedrock surfaces in this area can be very erratic in nature and vary substantially in elevation over short horizontal distances.

BOREHOLE NO.	ELEVATION ENCOUNTERED AT TOP OF BEDROCK (m)
1	328.1
2	329.4
3	325.4

4.2 GROUNDWATER DATA

At the time of this investigation, surface water was encountered at Elevation 331.2 m at the culvert outlet.

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 Nos. 1 and 2 to obtain post borehole completion water levels. These levels are recorded on the individual borehole logs (Appendix B).

The groundwater levels, measured at Elevations 331.4 and 333.1 m at Borehole Nos. 1 and 2, respectively, appeared stabilized for the period of time during which the field work was carried out. The groundwater level was encountered at Elevation 331.3 m at Borehole No. 3 upon completion of sampling at the borehole.

The groundwater and surface water levels should be expected to fluctuate, possibly significantly, seasonally/yearly.

5 DISCUSSION AND RECOMMENDATIONS

5.1 GENERAL

A foundation investigation was carried out for the proposed replacement of a CSP culvert as identified by the MTO.

Located at Station 14+450 in the Township of Franklin, the existing culvert is an 800 mm diameter CSP culvert about 30 m long. The existing culvert invert is estimated at a depth of 5.2 m below the roadway centreline (Elevation 331.2 m). Flow through the culvert is from the north to the south (left to right). The existing highway embankment currently supports two undivided lanes of highway running in a west-east direction. Based on data from this foundation investigation, the embankment at this site has been constructed using a flexible (asphalt over granular base and subbase) pavement structure overlying sand fills mixed with rock fill. The native material underlying the embankment generally consists of very loose to very dense sands, silty sands, silts, and gravelly sands overlying bedrock.

At this time, the type of culvert (concrete, CSP or High Density Polyethylene (HDPE)) being proposed to replace the existing culvert has yet to be determined. However, in consideration of the existing traffic conditions on Highway 60, trenchless construction methods are being considered for the culvert replacement at this site. Considering the size of the existing culvert, it is our understanding that replacing the culvert with an open culvert (i.e. non-rigid open frame culvert) is not practical unless an increased flow is required based on the results of a hydrological study. It is assumed that the new culvert will be constructed along a similar skew and alignment. It is also assumed that the final vertical alignment of the highway will remain essentially the same as current culvert.

5.1.1 Frost Penetration

Generally, culverts within the depth of frost penetration below the pavement structure are included in the pavement structure frost treatment (see OPSD 803.010 and OPSD 803.030). However, closed culverts are not designed in consideration of frost penetration below the culvert. Culverts with footings, (i.e. open culverts, culvert retaining walls, etc.) require the footings to be designed for frost penetration.

At this site, the frost penetration depth below cleared pavement surfaces is approximately 1.8 m. The culvert at this location is not located within the depth of frost penetration below the pavement surface and, as such, will not require frost treatments.

5.2 FOUNDATION CONSIDERATIONS

The founding native sand to silt soils present below the existing embankment are considered adequate for support of a culvert and for a conventional highway embankment of this height. Geotechnical bearing resistance should not be a major issue provided the native soils at the recommended foundation level are not disturbed during construction, and groundwater is controlled throughout construction, as discussed in Section 5.6.

Based on the characteristics of the native sand to silty sand to silt subgrade below the existing culvert, and the response of the existing embankment, a factored geotechnical resistance at ULS of 250 kPa is applicable for a closed culvert (i.e. precast rigid frame box culvert, precast concrete pipe or CSP culvert) with an invert level at Elevation 331.2 m below the centreline of highway. In consideration of the width of the culvert, depth of overburden, and condition of the existing embankment slopes, a geotechnical reaction at SLS of 150 kPa can be used for design, in consideration of 25 mm total settlement, and 19 mm of differential settlement depending on structure rigidity.

The geotechnical resistance for a closed culvert assumes a founding elevation and culvert size the same as that of the existing culvert (i.e. 800 mm diameter CSP, invert (foundation) level at Elevation 331.2 m below centreline). Additionally, the bearing resistances provided assume that the subgrade and bedding is properly prepared as per Sections 5.3 and 5.6 of this report.

5.2.1 Slope Stability

The maximum height of the embankment above the stream bed at this location is some 5.2 m at centreline, and up to about 5.9 m at the south side of the embankment. A stability analysis was carried out using the GEO-SLOPE computer software, Slope/W (GeoStudio 2007, Version 7.17, Geo-Slope International Ltd.) for this location with slopes of 1.9H:1V embankment slopes assumed in the embankment fills. For the purposes of these analyses, the materials were modeled using the following parameters;

PARAMETER	MATERIAL			
	EMBANKMENT FILL	SAND	SILTY SAND	SILT
Unit Weight (kN/m^3)	21.0	18.5	18.0	18.0
Effective Friction Angle (degrees)	34	32	30	30
Cohesion (kPa)	-	-	-	-

The above unit weights and friction angles for the slope stability analyses are assumed values considered by Englobe to be representative for the various soil types, based on general laboratory characterization and tactile analysis. The groundwater levels used for the analyses are shown on Figure No. S-1, Appendix 5. The results of the analyses indicate factors of safety against long-term failures (shallow failure mode) are in the order of 1.4 for the embankment side slopes at an inclination angle of 1.9H:1V (see Figure No. S-1, Appendix 5). Lower factors of safety will occur during excavation and backfilling as discussed in Section 5.6. Short term stability should not be an issue if construction is carried out as described herein.

5.3 CULVERT DESIGN, BEDDING, AND EMBEDMENT

The embankment generally consists of sand fills with gravel to gravelly overlying rock fills mixed with sands and gravels. The results of this investigation indicate that the native subgrade soils below the culvert invert generally consisted of sands, silty sands to silts, and gravelly sands overlying bedrock. A review of the condition of the pavement surface at the culvert locations revealed that the existing embankment appears to have performed satisfactorily. The existing embankment has preloaded the soils at the culvert locations, and since there will be no appreciable change in the height of the embankment and correspondingly, no increase in embankment load, no appreciable settlements of the embankment are anticipated. As such, installing the culvert on a camber will not be required at this site.

5.3.1 Rigid Concrete Culvert

Concrete pipes can be considered for culvert replacement at this site. A Class B Bedding for the concrete pipes shall consist of Granular A with a thickness of 300 mm. Alternatively, specifically if construction is carried out under wet conditions, a bedding and levelling course consisting of 19 mm clear stone (Type 2) per OPSS.PROV 1004 (Material Specification for Aggregates - Miscellaneous) should be used, which would aid in dewatering operations. During backfilling, the bedding material (including haunches) and cover shall be placed in uniform layers not exceeding loose thickness of 200 mm, as per OPSS.PROV 401 (Construction Specification for Trenching, Backfilling, and Compacting). The elevation difference of backfilling on either side of the rigid pipe shall be limited to a maximum 200 mm per OPSS.PROV 401 (Construction Specification for Trenching, Backfilling, and Compacting). Cover material for concrete pipes can consist of Granular A and placed to the dimensions as shown on OPSD 802.031 (Rigid Pipe Bedding, Cover, and Backfill, Type 3 Soil - Earth Excavation). If circular concrete pipes are used, compaction of the haunch is critical and should be constructed and compacted in accordance with OPSS.PROV 501 (Construction Specification for Compacting).

As noted, considering the size of the existing culvert, a precast concrete rigid frame box culvert or a concrete rigid frame open culvert are likely not practical at this site, unless increased flow is required, based on the results of a hydrological study.

The inlet and outlet stream bed shall be protected with a rip-rap (R-50 size as per OPSS.PROV 1004 (Material Specification for Aggregates - Miscellaneous)) apron. The apron shall be minimum 3 m in length, a minimum 400 mm thick and extend across the stream bed to minimum 3 m beyond the outside edges of the culvert. Clay seals are generally used only where significant head differences exist between the inlet and outlet of the culverts to prevent flow through the bedding/embedment granulars. In consideration of the culvert size and anticipated flow, clay seals are not considered necessary at this location, provided embedment/bedding materials are properly compacted in the haunch area and rip rap over a Class II geotextile is placed around the inlet end of the culvert. The embankment fills and native sands are considered to have a low erodibility. At a minimum, the inlet and outlet must be protected with layer of rock protection.

5.3.2 Flexible Culvert

Flexible culverts (i.e. CSP/SPCSP/HDPE) can also be considered for culvert replacement at this site. If flexible pipes are used for replacement, embedment material should consist of Granular B Type I per OPSS.PROV 1010 (Material Specification for Aggregates - Base, Subbase, Select Subgrade, and Backfill Material) provided the maximum size of stone inclusions is limited to 25 mm or less in size and placed in accordance with OPSD 802.010 for a Type 3 soil. A minimum 150 mm to a maximum 300 mm in thickness for a new 800 mm diameter flexible pipe of embedment material is required below the culvert invert per OPSD 802.010 (Flexible Pipe, Embedment and Backfill, Earth Excavation). The material in the haunch area must be compacted to 100% Standard Proctor Maximum Dry Density (SPMDD) prior to placing the remainder of the embedment material. During backfilling, the embedment material shall be placed in uniform layers not exceeding loose thickness of 200 mm. The elevation difference of the embedment fill on either side of the flexible pipe must be limited to a maximum 200 mm per OPSS.PROV 401 (Construction Specification for Trenching, Backfilling, and Compacting). The backfill should be placed to a minimum depth of 900 mm above the crown of the pipe before power tractors or rolling equipment can be used for compacting per OPSS.PROV 401 (Construction Specification for Trenching, Backfilling, and Compacting).

In consideration of the culvert size and anticipated flow, clay seals are not considered necessary at this location, provided embedment/bedding materials are properly compacted in the haunch area and rip rap over a Class II geotextile is placed around the inlet end of the culvert. The inlet and outlet stream bed shall be protected with a rip-rap (R-50 size as per OPSS.PROV 1004 (Material Specification for Aggregates - Miscellaneous)) apron. The apron shall be minimum 3 m in length, a minimum 400 mm thick and extend across the stream bed to minimum 3 m beyond the outside edges of the culvert.

5.4 CULVERT INSTALLATION AND CONSTRUCTION STAGING CONSIDERATIONS

The invert elevation of the existing culvert at centreline is at 331.2 m, with the top of the embankment at Elevation 336.4 m at the centreline of highway. The culvert inverts at the inlet and outlet are at Elevations 331.7 and 330.7 m, respectively. As such, the embankment at this location is approximately 5.2 m in height above the culvert invert at the centreline of highway. Considering the height of the embankment, open cut excavations are not considered feasible unless local lowering of the grade is undertaken or a protection system (temporary vertical wall) is used for excavation support.

In general, an open cut excavation can be considered if the platform is temporarily lowered by approximately 1.4 to 1.6 m below grade. If this lowering cannot be accommodated then consideration can be given to a combination of lowering and widening, or constructing a temporary vertical wall for excavation support.

5.4.1 Staged Construction

As noted, the existing platform at this location, not sufficiently wide to carry out an open excavation using staged construction unless temporarily lowering of the vertical alignment is carried out. To carry out an open cut excavation, locally lowering the grade to allow for staged construction using staged sequencing and limiting traffic flow to one lane would be required (see Figure No. SK-3, Appendix 5).

A possible staging plan for a continuous open cut excavation under a 24/7 traffic control operation, as shown on Figure No. SK-3, Appendix 5, is as follows:

- Locally lower the grade at the culvert to an elevation of approximately 324.5 m.
- Limit traffic to a single lane on the left, with a minimum platform width of 6 m, under 24/7 traffic control.
- Open cut excavate, to the right, and install approximately 16 m of new culvert.
- Reconstruct the embankment on the right, with a minimum platform width of 6 m for traffic.
- Divert the single lane of traffic to the right and continue open excavation to install the remainder of the culvert on the left.
- As the width of the platform increases on the right, the vertical alignment can be raised, and the traffic can revert back to two lanes when sufficient width permits.

It should be noted that additional subsurface information may be required if widening beyond the existing embankment toe is required.

5.4.2 Temporary Protection System

As noted above, consideration could be given to constructing a vertical wall, along centreline, for use as a temporary protection system.

The installation of a protection system for use in the culvert replacement operation will require penetration through approximately 5.2 m of granular fills mixed with rock fill. The embankment fill is generally underlain by compact to dense silts, silty sands and sands. As noted, a layer of rock fill consisting of boulder sized rock pieces mixed with sands and gravels was encountered in the embankment. Considering the presence of rock fill in the embankment, advancing a temporary retaining system (i.e. driven sheet piles) through the rock fill will be challenging. A suggested Notice to Contractor indicating the presence of the cobble/boulder sized rock pieces in the embankment has been included in Appendix 5.

Several approaches to constructing a protection system are described below and in Table A, Appendix 5. A comparison of advantages and disadvantages for the different types of protection systems considered for this site are presented in Table A, Appendix 5. Conceptual shoring locations are illustrated on Figure No. SK-4, Appendix 5.

One method to construct a protection system would be to penetrate the mixed rock fill in the embankment with H-piles (soldier piles) extending into the underlying native soils and/or into bedrock and install lagging. Pre-drilling will likely be required to advance the H-piles through the embankment fill and into the underlying native soils. 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. A waler and raker system or tie back anchor system would have to be installed as the excavation advances. The contractor must be prepared to address large pieces of rock and control groundwater as the excavation progresses, without compromising the adjacent active lane of traffic.

The resistance (R) for grouted anchors (used in a tie-back system), located outside the active failure wedge, in cohesionless soils can be estimated from the following equation as supplied in Section 26.12.4.1 of the Canadian Foundation Engineering Manual (4th Edition):

$R = \sigma'_z * A_s * L_s * \alpha_g$ Where: σ'_z = effective vertical stress at the midpoint of the load carrying length

A_s = effective unit surface area of the anchor

L_s = effective embedment length of the anchor

α_g = anchorage coefficient, use 1.0 for granular backfill

Unless the pull-out resistance (capacity) of the anchor is proven with a load test program, the allowable anchor load (as suggested by the Canadian Foundation Engineering Manual, 4th Edition), is commonly obtained by dividing the computed capacity of the anchor by a factor of safety of 3. Alternatively, proprietary anchor systems can be used.

Alternatively, a caisson wall or drilled micropile system with an intermediate support system of reinforced shotcrete, to act as lagging, could be considered for roadway protection at this site. One method of constructing this system would be to drill in micropiles, advanced on either side of the culvert below the invert and extending several metres into the compact to very dense sands to silty sands to silts or bedrock, depending upon the size and capacity of the micropiles. Above the culvert, the piles would be installed down to top of culvert grade followed by bracing, with a suitably sized waler and anchorage system, tied into the full depth piling at the culvert sides, in order to provide support at the top of the piling over the culvert barrel. Depending on the section properties of the retaining structure, walers and bracing struts or ground anchor support systems will probably be required. As the excavation progresses downward in 1 to 1.2 m lifts, a reinforced shotcrete, tied into the piles, is applied. Once one half of the culvert construction is complete, a system of buried anchors could be installed to tie back the micropiles as the highway fill is brought up to grade. When the excavation on the opposite side reaches the anchor depths, a support waler, if required, can be placed and tensioned to support the shotcrete as specified in the contractor's approved shoring design. However, these shoring system are generally more costly, as such are not recommended at this site.

Table A outlines the possible temporary excavation protection/flexible retaining systems and their relative advantages, disadvantages and costs, as well as comments on the viability of the methods is provided in Appendix 5. Conceptual shoring locations are illustrated on Figure No. SK-4, Appendix 5.

The protection system can be designed using the lateral earth pressure parameters as outlined in Section 5.5.

Considering the cohesionless nature of the embankment fills (granular pavement structure overlying granular fills and mixed rock fills), a rectangular apparent pressure distribution over the height of the cut would be appropriate for design of the temporary shoring. The width of the apparent rectangular pressure distribution, over the height of excavation, can be considered equal to $0.65*K_a*\gamma*H$, where:

K_a = active earth pressure,

γ = unit weight, and

H = height of wall above the base of excavation.

The temporary protection system should be designed and constructed to comply with OPSS.PROV 539 (Construction Specification for Temporary Protection Systems). In consideration of the location of the protection system and traffic volume, a Performance Level 2 is considered appropriate.

5.4.3 Trenchless/Tunnelling Techniques

The borehole through the embankment indicated that cobble to boulder sized rock pieces are present within the existing embankment at this location. The embankment is approximately 5.2 m in height above the invert level of existing culvert at the centreline of highway. A trenchless approach to culvert replacement would eliminate the need for open cuts, roadway protection systems, and associated traffic delays. Several trenchless technologies are available for consideration, as outlined in the following table. However, the cobble/boulder size rock encountered in the embankment may limit the type of trenchless method that can be used at this site. As noted, rock fill was encountered within the embankment and large diameter rock pieces were also observed on the embankment slopes, in close proximity to the culvert. As such, the Contractor must be prepared to advance through cobble and boulder size obstructions within the embankment.

The following table contains the advantages and disadvantages of the different trenchless techniques, ranked from the most suitable to the least suitable methods considered at this site.

METHOD	ADVANTAGES	DISADVANTAGES	PROPOSED RANKING OF SUITBILITY
Pipe Ramming	• Minimal groundwater control required along the installation route (unless required to remove obstruction/old pipe) • Can penetrate soils containing cobbles/boulders if obstruction less than casing diameter • New culvert size within the practical construction limit of 2 m	• Installation problems can occur in dense to very dense soils with cobble/boulders • Requires staging construction shafts • Groundwater control will be required at staging construction shafts • Possible ground displacement/heaving in the soils above the crown • Presence of cobbles or boulders can potentially affect the productivity and effectiveness of construction	Recommended provided sufficient dewatering and trenchless equipment (e.g. "culvert swallowing replacement" method) used to drill through cobbles and boulders in embankment fills
Pipe Jacking/Micro-Tunneling	• Shield face can accommodate high groundwater conditions • Can accommodate cobble/boulders with appropriate shield • Alignment can be altered during boring	• Groundwater control will be required at construction shafts • Requires thrust block of sufficient mass to jack pipe • Presence of cobbles or boulders can potentially affect the productivity and effectiveness of construction	Considered as an alternative for trenchless construction; however higher cost
Horizontal Directional Drilling	• Can be used in most ground condition • Generally does not require staging pits therefore minimal ground water control required • Alignment can be adjusted to avoid obstructions • New culvert size within the practical construction limits between 140 and 1200 mm	• Site grades may require longer bore or staging pits • Larger drilling equipment may be required • Requires drilling fluid to maintain the bore, which could result in heave • Presence of cobbles or boulders can potentially affect the productivity and effectiveness of construction	Feasible using special equipment and drilling fluid to drill through cobbles/boulders in embankment fills

METHOD	ADVANTAGES	DISADVANTAGES	PROPOSED RANKING OF SUITBILITY
Jack-and-Bore	• Good contractor availability • Good for shorter tunnel length (less than 120 m) • Good gradient control • New culvert size within the practical construction limits between 200 and 1500 mm	• Requires construction shafts • Groundwater control will be required for the bore and construction shafts • Elevated potential for ground subsidence • Larger boring diameter required to allow removal occasional cobbles/boulders • Presence of cobbles or boulders can potentially affect the productivity and effectiveness of construction • Not well suited for use in rock fills or if there is a high concentration of large obstructions	Least suitable due to dewatering requirement and risk of obstacles to be encountered in embankment fills

As noted, obstructions due to the presence of cobble/boulder sized rock pieces were encountered within the embankment fills. These obstructions could limit the feasibility of some of trenchless installation methods at this site. As such, it is recommended that additional subsurface information be obtained along the proposed alignment of the replacement culvert if trenchless technologies are used to confirm the constructability of the proposed construction method.

Pipe Ramming could be considered for advancing a heavily reinforced casing through embankment fills including obstructions. However, to advance the pipe, the casing diameter must be large enough to allow hand mining operations to be carried out at the face to remove large pieces of rock that cannot be swallowed into the advancing casing. Generally, a minimum 1.2 m diameter is required to have sufficient room to hand mine rock pieces.

Jack-and-Bore is a common trenchless construction method for advancing a culvert. However, considering the presence of cobble and boulder sized obstructions and requirements for dewatering along the alignment during construction, Jack-and-Bore is not considered to be a suitable method for culvert installation at this site. As such, Jack-and-Bore will not be discussed further.

The preferred method of trenchless culvert replacement considered for this site is to install a new culvert along the same alignment using Pipe Ramming methods (e.g. the "culvert swallowing replacement" method to swallow and crush the existing culvert using specialized equipment) or by Pipe Bursting. The pipe swallowing method involves ramming a larger size steel casing around the existing culvert, following which the existing culvert is then removed using the specialized equipment. Pipe Bursting involves ramming a bursting tool to split the existing culvert, while pulling a new culvert of the same diameter to replace the existing. It should be noted that boulder sized rock pieces having voids were encountered between Elevations 334.7 and 332.6 m in the embankment fill. Cobble and boulder sized rock pieces were also observed on the existing north side slope of embankment during the fieldwork for this investigation, as shown on the Enclosure No.5 in Appendix 4. Pipe Bursting can be difficult through the existing CSP culvert and may result in significant vibrations and possible displacement/heaving of the soils above the crown of culvert; however, the Pipe Bursting method may be possible depending on the equipment and methodology proposed by the Contractor.

The ground movement due to trenchless/tunnelling construction could occur and result in a settlement trough along the trenchless/tunnelling alignment. Based on the Gaussian distribution curve and empirical methods, the estimated ground surface settlements may approximately range from 1 to 4 mm, assuming the new 800 mm culvert is to be constructed along a similar alignment and the ground loss ranging from 1 to 3%. During construction of the culvert using trenchless/tunnelling techniques, the settlement of the roadway must be monitored to meet the MTO requirements 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.

Staging pits will be required for Pipe Ramming operations. Groundwater levels were encountered between Elevations 331.4 and 333.1 m at Borehole Nos. 1 to 3 during the site investigation period; therefore construction dewatering will be required for the proposed excavations at construction shafts per Section 5.6. It should be noted that the ground water/surface water levels will fluctuate seasonally/yearly. The trenchless construction should meet requirements of the NSSP for Pipe Installation by Trenchless Method (see Appendix 5).

5.5 LATERAL EARTH PRESSURES

Lateral earth pressures should be computed in accordance with the CSA S6-14 Canadian Highway Bridge Design Code (CHBDC)) published by Canada Standard Association Group (CSA Group) in December 2014, and “Exceptions to the Canadian Highway Bridge Design Code CSA S6-14 for Ontario, January 1, 2016” published by MTO in 2016. The parameters for bedding, cover, embedment and backfill materials are based on compaction levels of 100% Standard Proctor Maximum Dry Density (SPMDD). The design parameters for the bedding/embedment and backfill materials are as follows:

PARAMETER	GRANULAR A	GRANULAR B TYPE I	EXISTING GRANULAR FILL	EXSISTING EMBANKMENT FILL
Unit Weight (kN/m^3)	22.8	21.2	19.0	21.0
Angle of Internal Friction	35°	33°	32°	34°
Coefficient of Active Earth Pressure (K_a)	0.27	0.30	0.31	0.28
Coefficient of Passive Earth Pressure (K_p)	3.69	3.33	3.23	3.57
Coefficient of Earth Pressure at Rest (K_o)	0.43	0.46	0.47	0.44
PARAMETER	**NATIVE SANDS**	**SILTY SAND**	**SILT**	
Unit Weight (kN/m^3)	18.5	18.0	18.0	
Angle of Internal Friction	32°	30°	30°	
Coefficient of Active Earth Pressure (K_a)	0.31	0.33	0.33	
Coefficient of Passive Earth Pressure (K_p)	3.23	3.00	3.00	
Coefficient of Earth Pressure at Rest (K_o)	0.47	0.33	0.33	

For rigid structures such as a precast concrete culverts, deflection cannot occur, and as such, the “at-rest” condition (K_o) applies. For flexible structures, such as CSP/HDPE culverts, deflection can occur, as such the “active” condition (K_a) applies. The “passive” condition (K_p) applies when the wall is in compression (in a direction opposite to the wall loading).

5.6 EXCAVATION, DEWATERING, AND EMBANKMENT RECONSTRUCTION

As noted, culvert installation using trenchless/tunneling techniques will require excavation and dewatering for the staging construction shafts. Other open cut excavations may also require dewatering depending on the locations and depths of excavation.

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 material, above the water table, is considered as a Type 3 soil and the native material at the culvert ends, when wet, is considered Type 3 to 4 soils as defined in the Occupational Health and Safety Act and Regulations for Construction Projects. Temporary open excavations below the groundwater table in fill and/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.

Bedrock was not encountered at the borehole locations within the anticipated depth of trenchless boring and/or excavations for staging pits/open cut, therefore bedrock excavation and/or blasting operations are not anticipated.

Final (permanent) embankment side slopes in granular fills should be established to match the existing slopes or as per OPSD 200.010. Final slopes should be treated with a seed and mulch to prevent ravelling.

Excavations must be maintained in a dewatered condition during excavation and foundation construction, and every reasonable effort must be made to prevent disturbing (piping/boiling) at the founding subgrade. Groundwater control, in accordance with OPSS 517 (Construction Specification for Dewatering) and SP 517F01 (Amendment to OPSS 517), will be required to maintain a stable subgrade during trenchless/tunneling construction.

At the time of investigation, surface water was encountered at Elevation 331.2 m at the culvert outlet. Groundwater was measured between Elevations 331.3 and 333.1 m at Borehole Nos. 1 to 3 during the site investigation period. As such, dewatering will likely be required during excavation and culvert installation and/or for staging construction shafts for trenchless culvert replacement.

During construction, installation of filtered sumps and pumping from the base of the excavation will, at a minimum, be required to maintain the excavation in a dewatered condition during subgrade preparation and culvert installation. The effectiveness of this method of groundwater control would be limited to conditions where the prevailing groundwater table is less than about 1 m above the final excavation depth. If the excavation must penetrate to a greater depth below the prevailing groundwater table, a more effective groundwater control method such as a vacuum well point system or sheet pile cut-off wall should be considered by the contractor to maintain a stable excavation base. Considering the native sand subgrades, piping may result in disturbed subgrades. The Contractor's dewatering method must be designed to prevent piping.

A cofferdam constructed of earth fill, sand bags, or water-filled bag (i.e. aquadam) can be considered at this site. Steel sheet piles may also be considered for controlling stream flow, however their use may be limited at the culvert inlet due to shallow bedrock. By-pass pumping can be carried out to divert the stream flow at the time of construction. It is recommended that by-pass pumping through a temporary culvert installed through the embankment be carried out to divert the stream flow past the work area isolated with the cofferdam system.

A Permit to take Water (PTTW) is required by the MOECC when more than 50,000 litres/per day will be removed. Considering the existing water levels, culvert replacement using a closed end system and bypass pumping as needed, with an invert Elevation of 331.2 m (at centerline), a PTTW is not anticipated to be required, however, this will depend upon the Contractors proposed methodology and schedule.

Ultimately, the method of excavation, dewatering and stream flow diversion will be the choice of the contractor; however the importance of maintaining the subgrade in a dewatered stable condition during excavation and construction operations cannot be stressed enough.

5.7 CONSTRUCTION CONCERNS

Considering the nature of the embankment fills (granulars and boulder/cobble sized rock pieces), no major construction concerns are anticipated if construction is carried out in general conformance with the above discussion. However, it is recommended that the potential to encounter oversized boulders requiring removal or pre-drilling be anticipated in the Contract documents. The Contractor must be prepared to excavate and advance protection and dewatering systems through these materials.

As noted in Section 5.6, the culvert subgrade must be adequately dewatered to maintain the adequate bearing resistance of the foundation subgrade. The Contractor must also be prepared to deal with potentially significant seasonal and yearly fluctuations of ground/surface water.

A suggested Notice to Contractor is included in Appendix 5.

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

KEY PLAN

Drawing No. 1

NOT TO SCALE

FOUNDATION INVESTIGATION AND DESIGN REPORT

GWP 5333-11-00

Highway 60

Culvert 14+450, Twp of Franklin

Reference No: P-0014193-0-00-100-04-F9

November 2017

Englobe

Appendix 2 Subsurface Data

Enclosure No. 1	List of Abbreviations and Symbols
Enclosure Nos. 2 to 4	Record 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)	*Compactness Condition*
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.

ENCLOSURE NO.: 2 (Pg. 1 of 2)

METRIC

RECORD OF BOREHOLE NO. 1

Englobe

REFERENCE P-0014193-0-00-100-04-F9 DATUM Geodetic
LOCATION N 5022216.3 E 341375.4 - Twp of Franklin , Station 14+449
ORIGINATED BY JL

PROJECT GWP 5333-11-00, Hwy 60
BOREHOLE TYPE Truck Mounted CME 45 - Hollow Stem Augers
COMPILED BY DM

CLIENT AECOM
DATE (Started) 5 September 2017
DATE (Completed) 6 September 2017
TIME (Completed)
CHECKED BY AT

ELEV / DEPTH (m)	SOIL PROFILE – DESCRIPTION (see Enclosure No. 1)	SAMPLE NUMBER	TYPE	"N" VALUES	NATURAL MOISTURE CONTENT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
336.2	Ground Surface					
0.0	150 mm asphalt 150 mm crushed gravel EMBANKMENT FILL - sand, with gravel to gravelly, trace silt brown (compact/dense)	1	SS	35	o	
		2	SS	11	o	33 61 (6)
334.7 1.5	EMBANKMENT FILL - rockfill mixed with gravelly sand, trace silt brown (compact) rock fragments encountered at depths of 1.5 and 3.6 m based on auger response, voids encountered at depths of 1.7 and 3.0 m	3	SS	10/0 mm		
		4	SS	17	o	
		5	SS	14		
332.5 3.7	auger refusal at depth of 3.6 m, start advancing casing EMBANKMENT FILL - sand some gravel, some silt brown (loose)	6	SS	8	o	
331.8 4.4	SAND - trace gravel, some silt, trace grass rootlets dark brown (compact)	7	SS	13	o	
331.0 5.2	SILT - trace sand, trace clay brown (compact)	8	SS	28	o	0 6 88 6
330.3 5.9	SAND - with to some gravel, trace silt, trace clay brown (very dense)	9	SS	65	o	26 71 (3)
		10	SS	56	o	
328.1 8.1	BEDROCK - black gneiss good to excellent quality	11	RC	REC= 97% RQD= 89%		
	Continued Next Page					

Ground water level symbols shown at approx. elevation 331.4 (depth 4.8 m).

Elevation scale: 336, 335, 334, 333, 332, 331, 330, 329, 328, 327

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60
UNIT WEIGHT γ kN/m³

COMMENTS
Northing and Easting based on MTM Zone 10 NAD83 CSRS

The stratification lines represent approximate boundaries. The transition may be gradual.

+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) 7/9/17 7:30:00 AM	4.8	-
2) 7/9/17 2:30:00 PM	4.8	-
3) 8/9/17 9:00:00 AM	4.8	-

MEL-GEO P-0014193 - BOREHOLE LOGS.GPJ MEL-GEO.GDT 29/11/17

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 BOREHOLE NO. 1

Englobe

REFERENCE	P-0014193-0-00-100-04-F9 DATUM Geodetic	LOCATION	N 5022216.3 E 341375.4 - Twp of Franklin , Station 14+449	ORIGINATED BY	JL
PROJECT	GWP 5333-11-00, Hwy 60	BOREHOLE TYPE	Truck Mounted CME 45 - Hollow Stem Augers	COMPILED BY	DM
CLIENT	AECOM	DATE (Started) / DATE (Completed)	5 September 2017 / 6 September 2017; TIME (Completed)	CHECKED BY	AT

ELEV DEPTH	SOIL PROFILE: DESCRIPTION (see Enclosure No. 1) Continued from Previous Page	STRATA PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L / WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
			12	RC	REC= 100% RQD= 98%		326				
325.1 / 11.1	End of Borehole End of Sampling										

MEL-GEO P-0014193 - BOREHOLE LOGS.GPJ MEL-GEO.GDT 29/11/17

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ENCLOSURE NO.: 3 (Pg. 1 of 1)

METRIC

RECORD OF BOREHOLE NO. 2

Englobe

REFERENCE P-0014193-0-00-100-04-F9 DATUM Geodetic
LOCATION N 5022225.4 E 341382.0 - Twp of Franklin, Station 14+449
ORIGINATED BY JL

PROJECT GWP 5333-11-00, Hwy 60
BOREHOLE TYPE Truck Mounted CME 45 - Hollow Stem Augers
COMPILED BY DM

CLIENT AECOM
DATE (Started) 7 September 2017 TIME
DATE (Completed) 7 September 2017 (Completed)
CHECKED BY AT

ELEV DEPTH (m)	DESCRIPTION (see Enclosure No. 1)	Sample No.	Type	"N" Values	Elevation Scale	Natural Moisture Content w (%)	Remarks & Grain Size Distribution (%) GR SA (SI CL)
333.1	Ground Surface				333		
0.0	SAND - trace gravel, some silt to silty, with black organics, trace grass rootlets; occasional cobbles/boulders; (loose/very dense)	1	SS	6		~32	
		2	SS	25/75 mm	332	~20	
331.7 / 1.4	SAND - some gravel, trace silt; brown; (compact)	3	SS	20		~19	17 78 (5)
		4	SS	23	331	~19	
330.2 / 2.9	GRAVELLY SAND - trace silt; brown; (dense)	5	SS	47	330	~13	32 57 (11)
329.4 / 3.7	Auger Refusal; Start Rock Coring; BEDROCK - black gneiss; good to excellent quality	6	RC	REC=100% RQD=78%	329		
		7	RC	REC=95% RQD=95%	328, 327		
326.5 / 6.6	End of Sampling; End of Borehole						

Dynamic Cone Penetration Resistance Plot: 20 40 60 80 100
Shear Strength kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE — 20 40 60 80 100
Plastic Limit W_P — Natural Moisture Content w — Liquid Limit W_L; Water Content (%) 20 40 60
Unit Weight γ kN/m³

COMMENTS
Northing and Easting based on MTM Zone 10 NAD83 CSRS

The stratification lines represent approximate boundaries. The transition may be gradual.

+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) 7/9/17 11:30:00 AM	0	-
2) 7/9/17 11:45:00 AM	0	-
3) 8/9/17 9:00:00 AM	0	-

MEL-GEO P-0014193 - BOREHOLE LOGS.GPJ MEL-GEO.GDT 29/11/17

ENCLOSURE NO.: 4 (Pg. 1 of 1)

METRIC

RECORD OF BOREHOLE NO. 3

Englobe

REFERENCE P-0014193-0-00-100-04-F9	DATUM Geodetic	LOCATION N 5022197.0 E 341362.8 - Twp of Franklin , Station 14+450	ORIGINATED BY JL
PROJECT GWP 5333-11-00, Hwy 60		BOREHOLE TYPE Truck Mounted CME 45 - Hollow Stem Augers	COMPILED BY DM
CLIENT AECOM		DATE (Started) 8 September 2017 / DATE (Completed) 8 September 2017 / TIME (Completed)	CHECKED BY AT

ELEV / DEPTH (m)	DESCRIPTION (see Enclosure No. 1)	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%) approx.	GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
331.3	Ground Surface						
0.0	SAND - trace gravel, some silt, trace clay some grass rootlets and decayed wood; dark brown; (very loose/compact)	1	SS	WH		○	
		2	SS	3		○	1 80 17 2
	grey	3	SS	13		○	
329.2 / 2.1	SILTY SAND - trace gravel, trace clay, trace grass rootlets; grey; (compact/loose)	4	SS	11		○	
		5	SS	7	Cave-in	○	4 59 36 1
327.6 / 3.7	SAND - some to trace gravel, some silt; grey; (loose/dense)	6	SS	5		○	
		7	SS	38		○	
325.4 / 5.9	Auger Refusal; Start Rock Coring; BEDROCK - black gneiss; excellent quality	8	RC	REC= 100% RQD= 93%			
		9	RC	REC= 100% RQD= 100%			
322.2 / 9.1	End of Sampling; End of Borehole						

Chart headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%). ELEVATION SCALE 331–323.

COMMENTS
Northing and Easting based on MTM Zone 10 NAD83 CSRS

The stratification lines represent approximate boundaries. The transition may be gradual.

+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) 8/9/17 12:00:00 PM	0	3.3
2)	-	-
3)	-	-

MEL-GEO P-0014193 - BOREHOLE LOGS.GPJ MEL-GEO.GDT 29/11/17

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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 Laboratory Data

Drawing No. 2:	Borehole Location and Soil Strata
Figure Nos. L-1 to L-5:	Grain Size Distribution Curves
Table No. L-6:	Laboratory Test Summary Sheet

Englobe

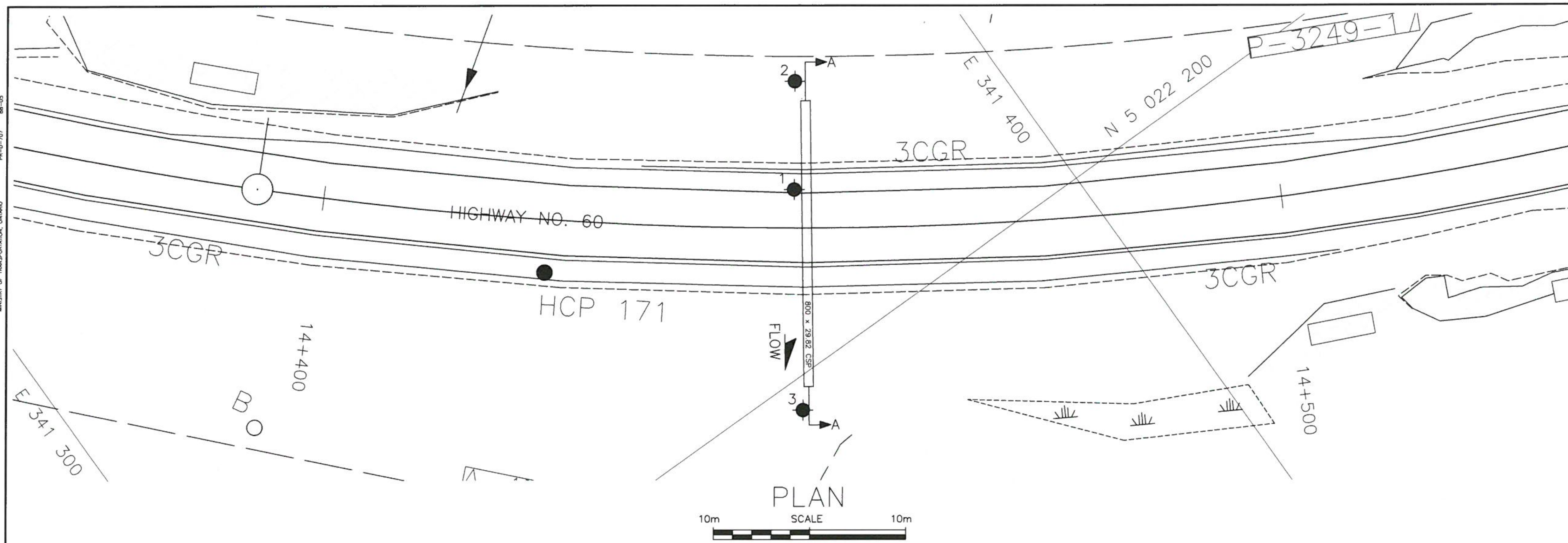
DISTRICT
CONT. No.
GWP No. 5333-11-00

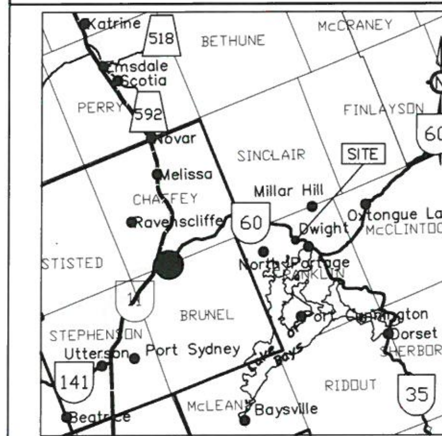
HWY 60 CULVERT
STA. 14+450, FRANKLIN TWP.

DRAWING 2

BOREHOLE LOCATIONS AND SOIL STRATIGRAPHY

Englobe



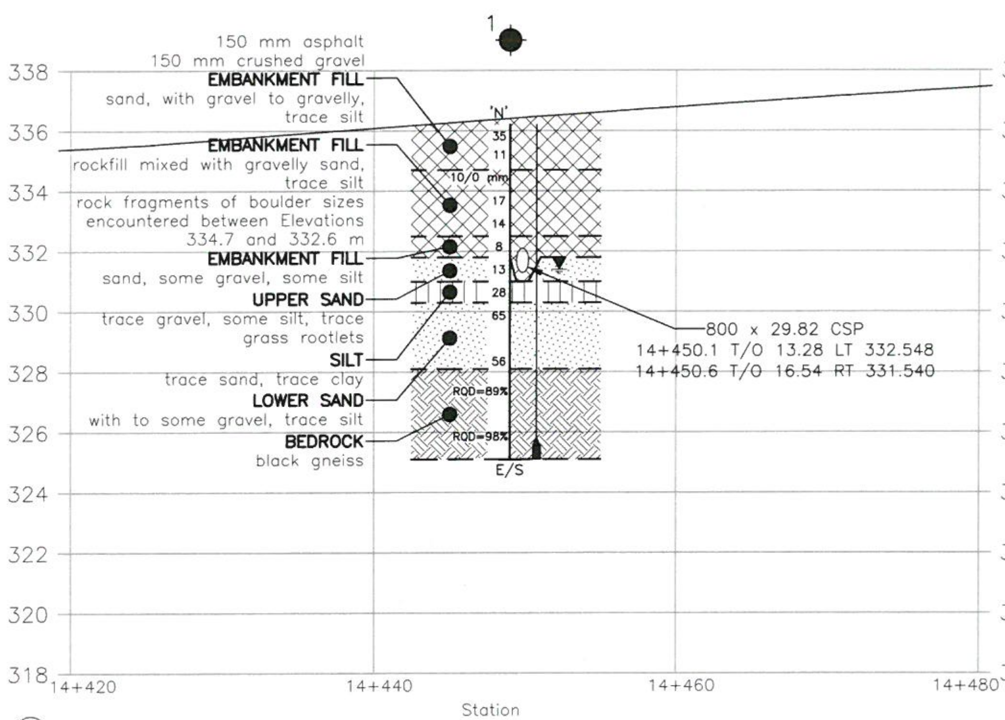


KEY PLAN
N.T.S.

LEGEND

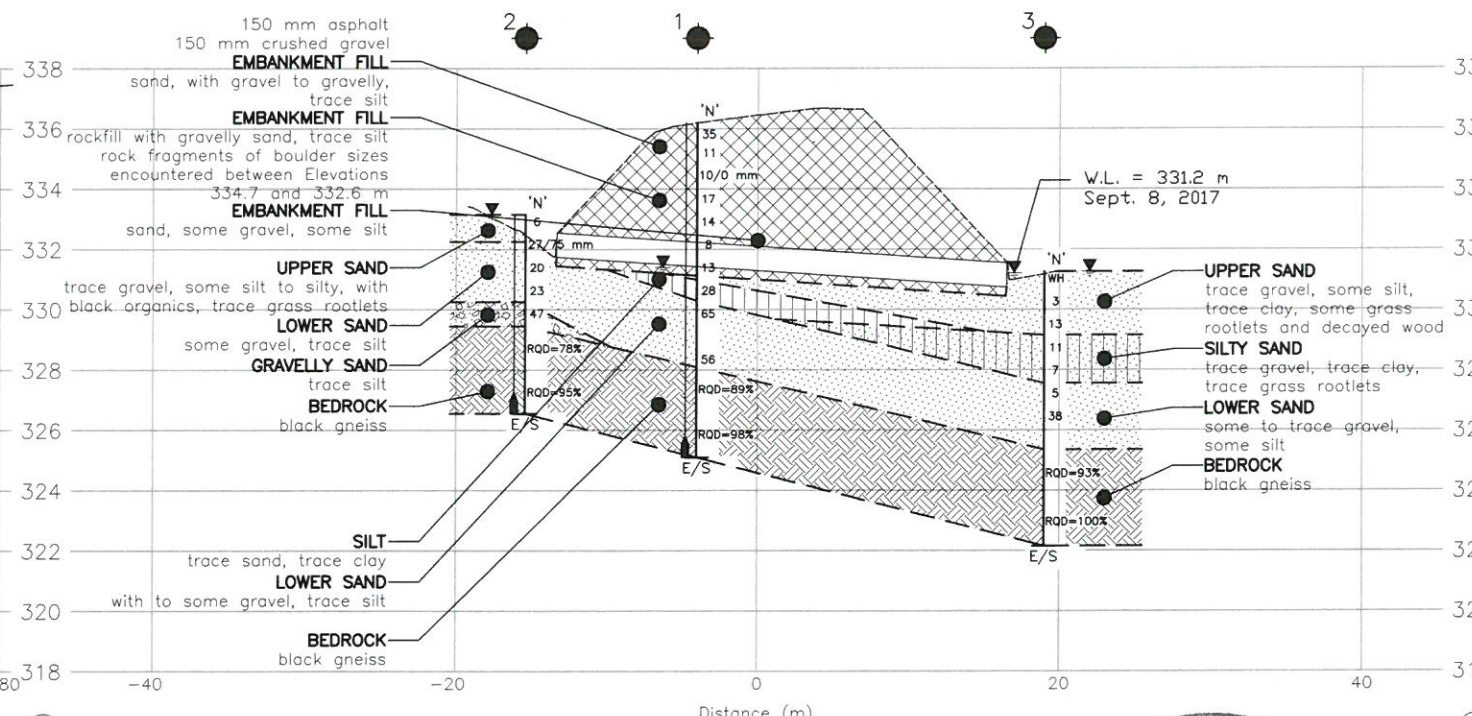
●	Borehole
N	Blows/0.3 m (Std Pen Test, 475 J/blow)
▼	Water Level at Time of Investigation
E/S	End of Sampling
▮	Piezometer

BOREHOLE No.	ELEVATION	O/S	NORTHING	EASTING
1	336.2	4.0m Lt	5022216.3	341375.4
2	333.1	15.3m Lt	5022225.4	341382.0
3	331.3	19.0m Rt	5022197.0	341362.8



C/L PROFILE HWY 60

SCALE
HOR 10 5 0 10 20m
VERT 5 2.5 0 5 10m



CROSS SECTION A-A

SCALE
HOR 10 5 0 10 20m
VERT 5 2.5 0 5 10m

This drawing is for subsurface information only. Surface details and features are for conceptual illustration. The proposed structure location is shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents.

REGISTERED PROFESSIONAL ENGINEER M. H. MacKAY PROVINCE OF ONTARIO

2017-12-07

LICENSED PROFESSIONAL ENGINEER S. HU 90524232 Dec. 7, 2017 PROVINCE OF ONTARIO

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 AECOM on October 23, 2017

Coordinates based on MTM Zone 10 NAD83 CSRS

GEOCRES No. 31E-385

REVISIONS			DESCRIPTION
NOV/17	DM		DRAFT
DEC/17	DM		FINAL

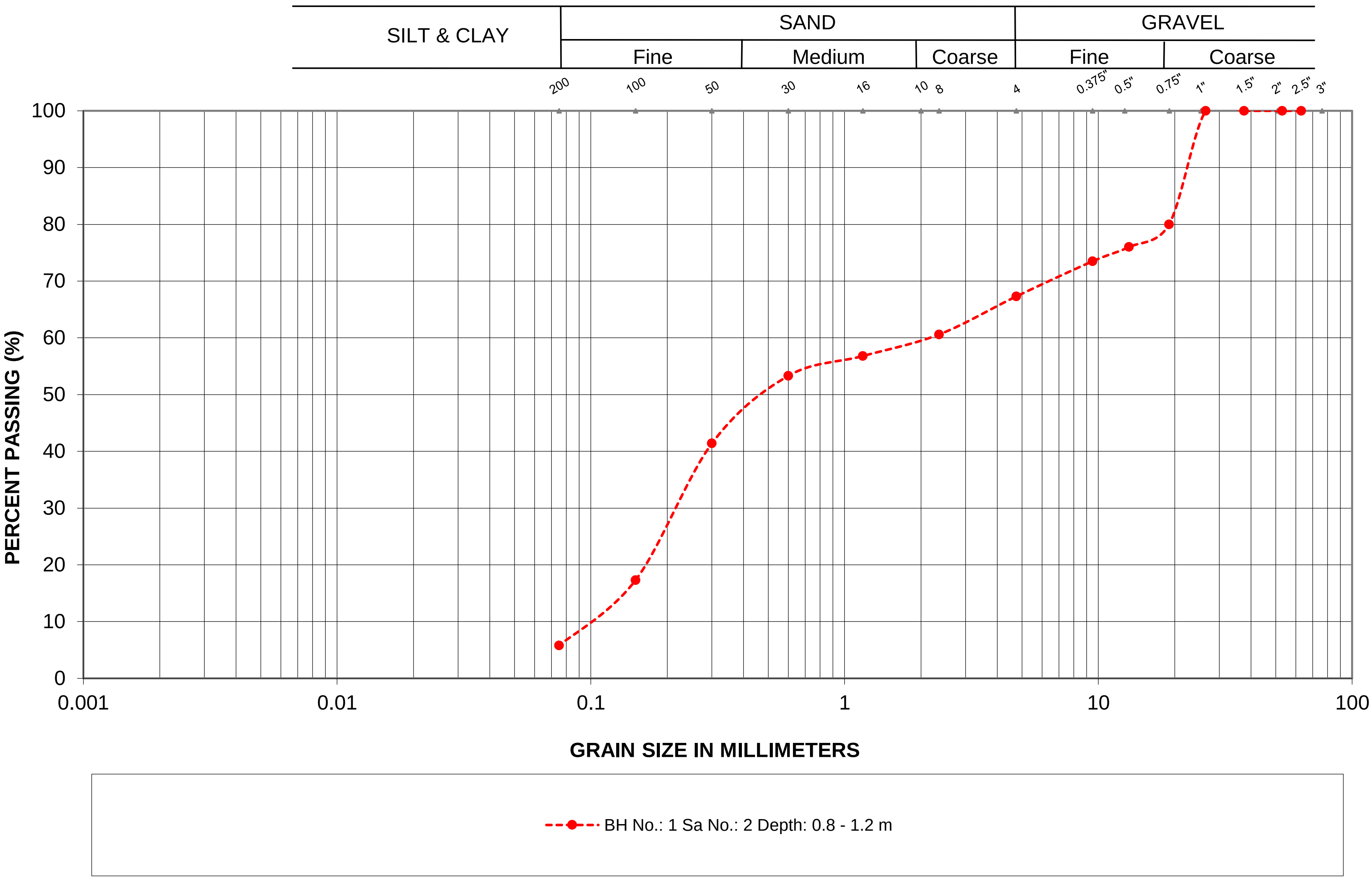
DESIGN AT | CHK | CODE | LOAD | DATE NOV/17
DRAWN DM | CHK SH | SITE | STRUCT | SCHEME | DWG 2

CAD FILE LOCATION AND NAME:\152\P-0014193 - PAV & FDN, Hwy 60 - 14083 - Change Order (Aecom)\Foundation\4_CAD\F9\P-0014193-F9 - Culvert at Station 14+450.dwg
MODIFIED:11/29/2017 4:02:17 PM BY: MITCDU
DATE PLOTTED:11/29/2017 4:04:56 PM BY: DUNCAN MITCHELL

MINISTRY OF TRANSPORTATION, ONTARIO PR-D-707 88-05

Reference No.: P-0014193-0-00-100-04-F9
Date: October, 2017

GRAIN SIZE ANALYSIS



EMBANKMENT FILL

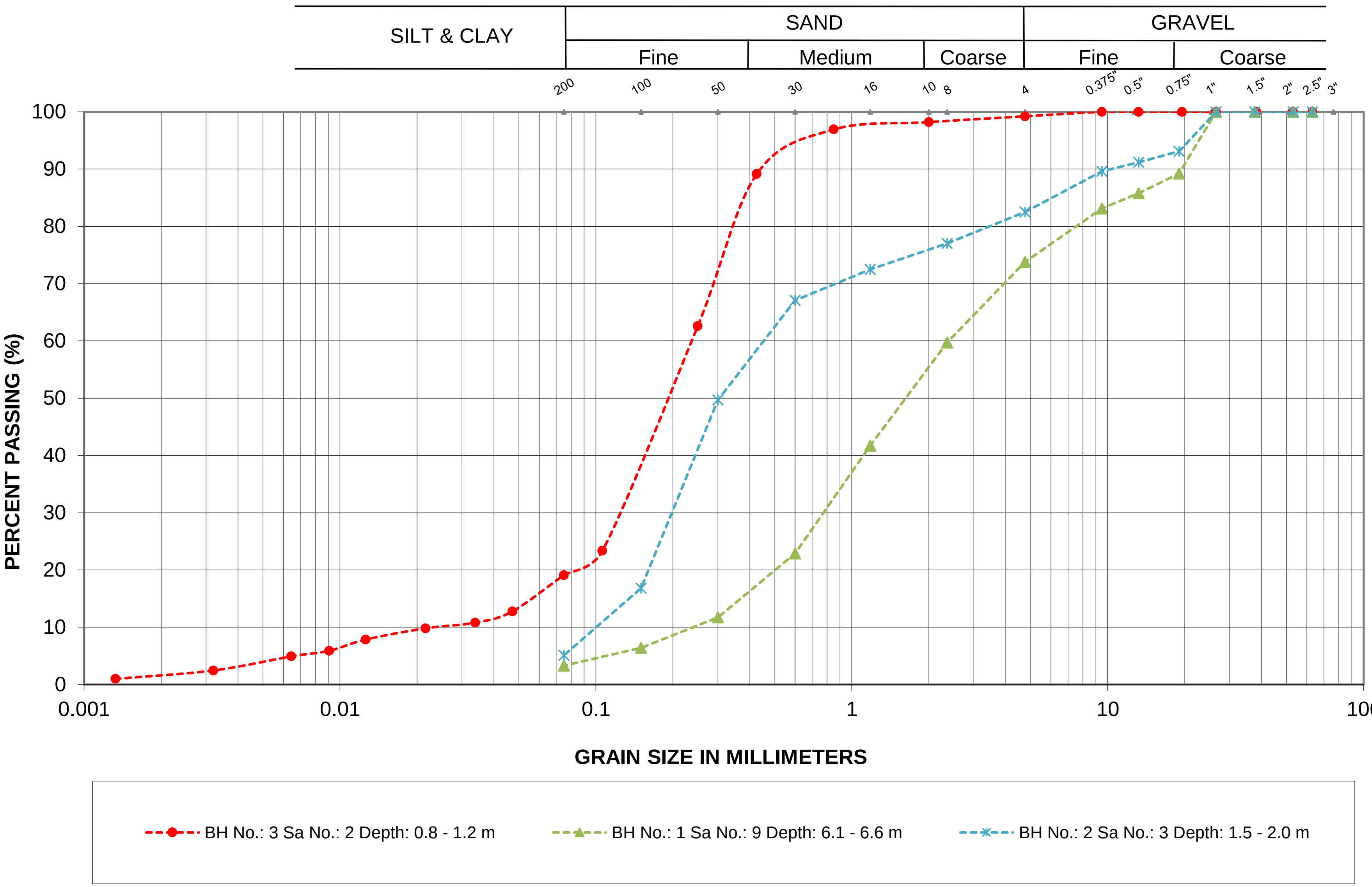
LOCATION: Hwy 60, Culvert Station 14+450
TWP of Franklin

Englobe Corp.

FIGURE L-1

Reference No.: P-0014193-0-00-100-04-F9
Date: October, 2017

GRAIN SIZE ANALYSIS



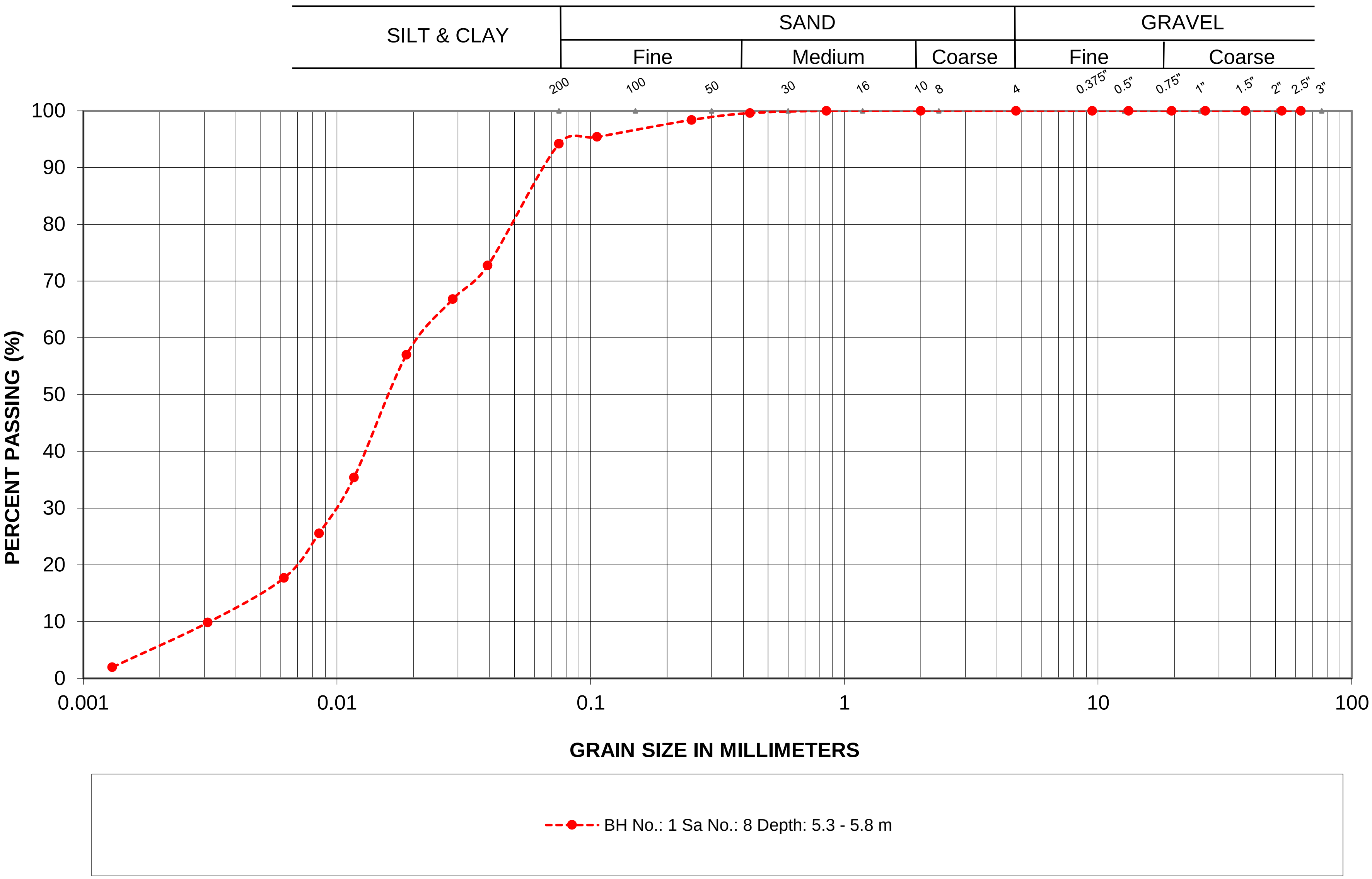
SAND

LOCATION: Hwy 60, Culvert Station 14+450
TWP of Franklin

Englobe Corp.

FIGURE L-2

GRAIN SIZE ANALYSIS

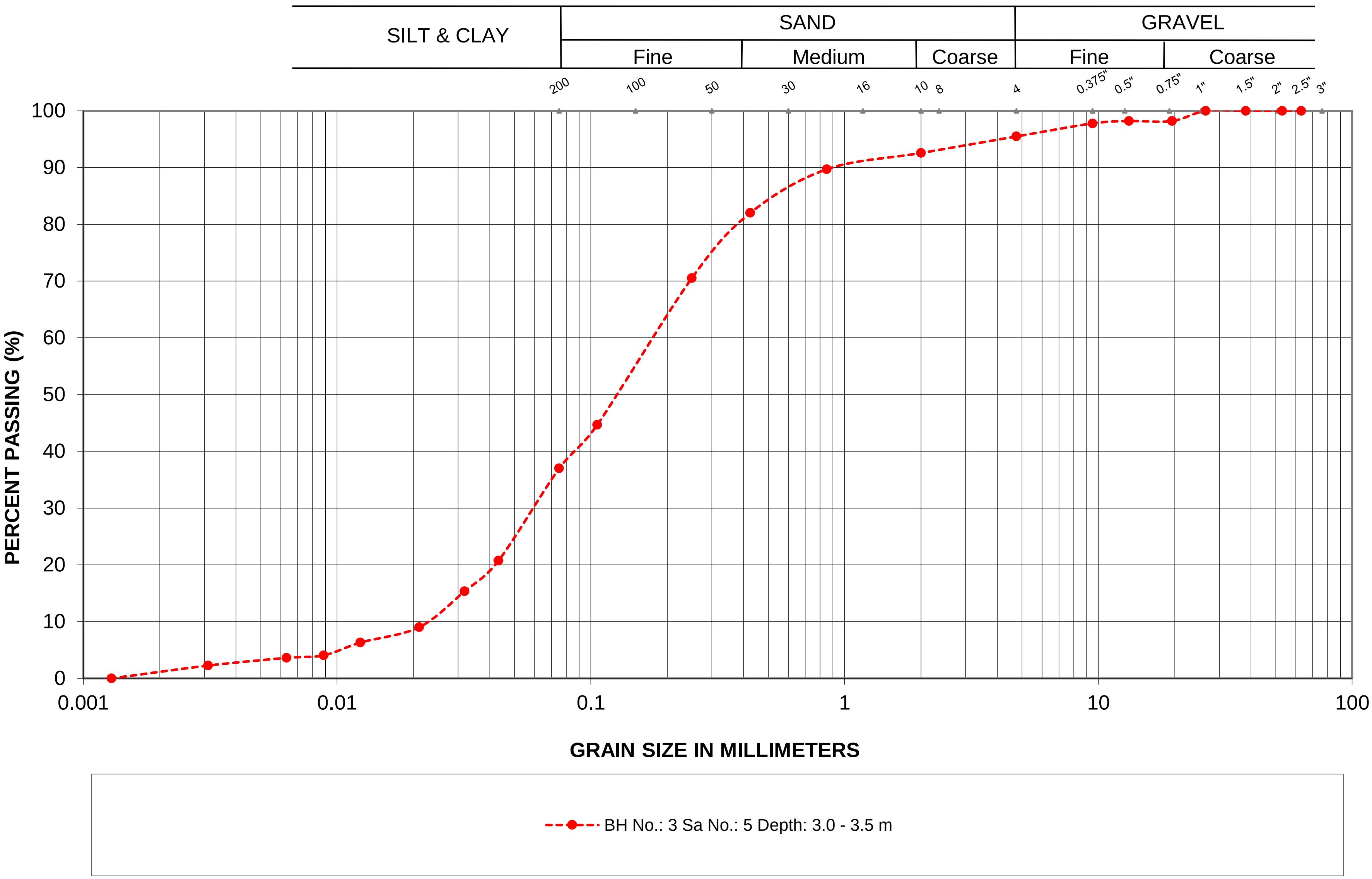


SILT

LOCATION: Hwy 60, Culvert Station 14+450
TWP of Franklin

Reference No.: P-0014193-0-00-100-04-F9
Date: October, 2017

GRAIN SIZE ANALYSIS



SILTY SAND

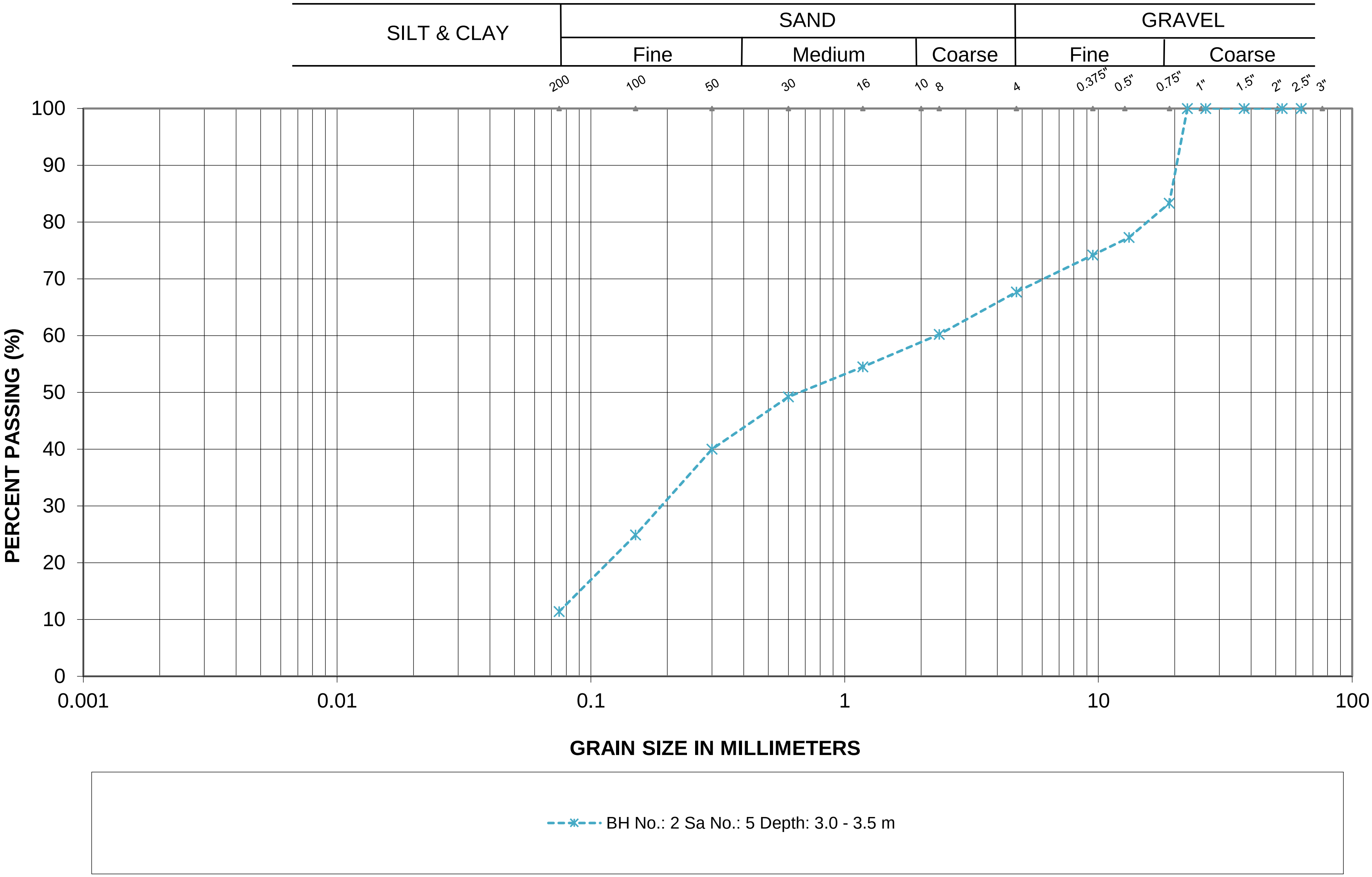
LOCATION: Hwy 60, Culvert Station 14+450
TWP of Franklin

Englobe Corp.

FIGURE L-4

Reference No.: P-0014193-0-00-100-04-F9
Date: October, 2017

GRAIN SIZE ANALYSIS



GRAVELLY SAND

LOCATION: Hwy 60, Culvert Station 14+450
TWP of Franklin

Englobe Corp.

FIGURE L-5

Reference No.: P-0014193-0-00-100-04-F9
Date: November 2017

Laboratory Tests - Summary Sheet

Borehole No.	Sample No.	Depth	Grain Size Analysis: Gravel Size (%)	Sand Size (%)	Silt Size (%)	Clay Size (%)	NMC	Atterberg Limits: LL (%)	PL (%)	IP (%)	SPT 'N'	USCS	Unit Weight (kN/m3)	Remarks
1	1	0.2					3.4				35			
	2	0.8	33	61	6		2.4				11			
	3	1.5									10/0 mm			Sample loss/void
	4	2.3					4.0				17			
	5	3.1									14			Sample loss/void
	6	3.8					21.5				8			
	7	4.6					24.4				13			
	8	5.3	0	6	88	6	21.7				28			
	9	6.1	26	71	3		13.1				65			
	10	7.6					15.3				56			
	11	8.1												Rec= 97%, RQD= 89%
	12	9.6												Rec= 100%, RQD= 98%
2	1	0.0					33.8				6			
	2	0.8					21.1				25/75 mm			
	3	1.5	17	78	5		18.3				20			
	4	2.3					19.0				23			
	5	3.1	32	57	11		11.5				47			
	6	3.7												Rec= 100%, RQD= 78%
	7	5.2												Rec= 95%, RQD= 95%
3	1	0					54.4				WH			
	2	0.76	1	80	17	2	42.7				3			
	3	1.52					24.1				13			
	4	2.29					23.1				11			
	5	3.05	4	59	36	1	21.5				7			
	6	3.8					23.0				5			
	7	4.57					24.2				38			
	8	5.9												Rec= 100%, RQD= 93%
	9	7.5												Rec= 100%, RQD= 100%

Appendix 4 Photo Essay

Enclosure No. 5: Photo Essay

Embankment at Culvert Location – Looking East	Photo: 1
	
Embankment at Culvert Location – Looking West	**Photo: 2**
	
Project: GWP 5333-11-00 - Hwy 60 – Culvert, Station 14+450, Township of Franklin	Photos Provided By: Englobe Date: September 2017

Culvert Inlet – Looking South	Photo: 3

Culvert Outlet – Looking South	Photo: 4

Project: GWP 5333-11-00 - Hwy 60 – Culvert, Station 14+450, Township of Franklin	Photos Provided By: Englobe Date: September 2017

Rock Cores – Borehole Nos. 1 (left) and 2 (right)	Photos: 5 and 6

Project: GWP 5333-11-00 - Hwy 60 – Culvert, Station 14+450, Township of Franklin	Photos Provided By: Englobe Date: September 2017

Rock Cores – Borehole No. 3 (left)	Photos: 7

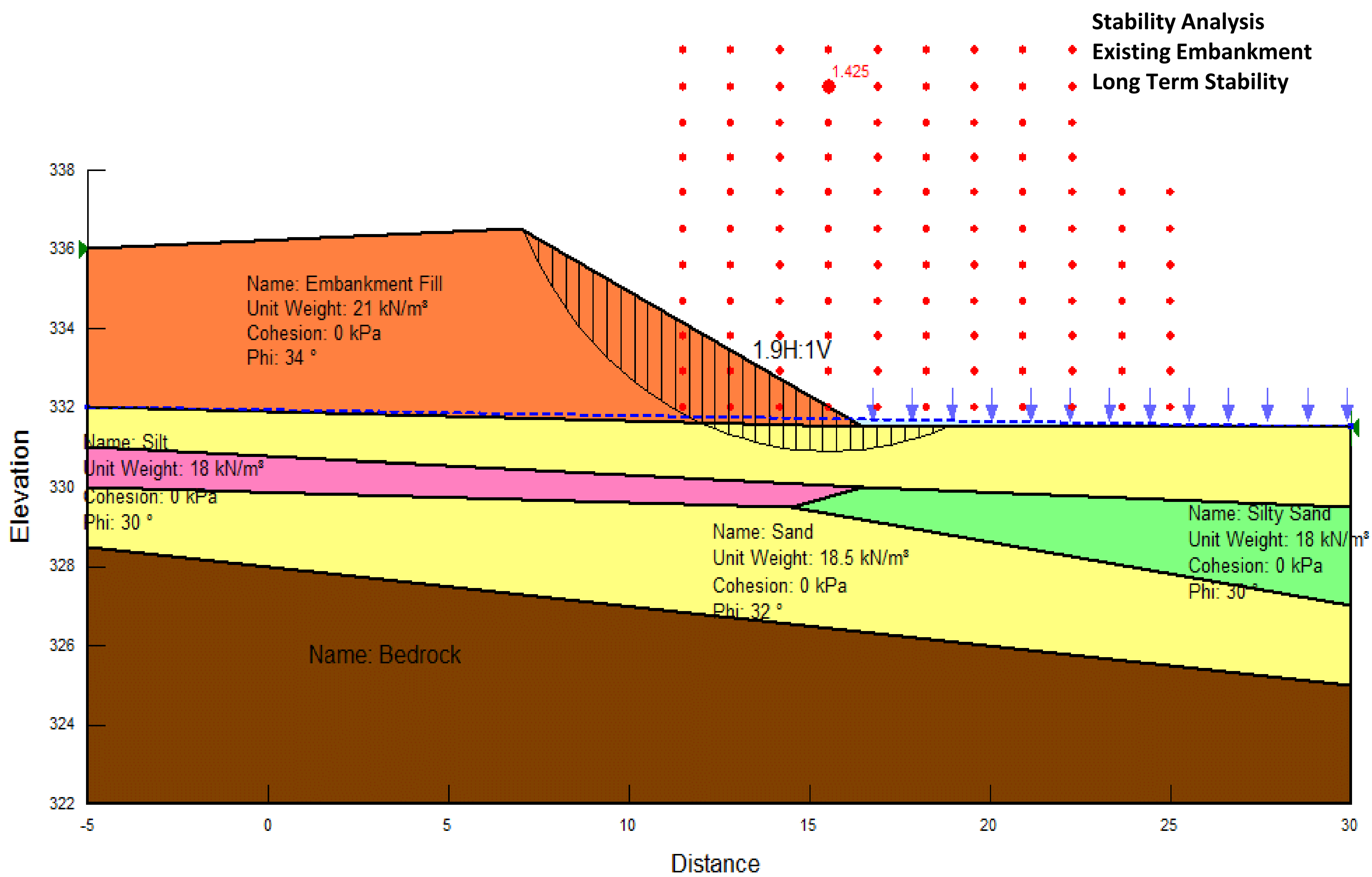
Project: GWP 5333-11-00 - Hwy 60 – Culvert, Station 14+450, Township of Franklin	Photos Provided By: Englobe Date: September 2017

Appendix 5 Design Data

Figure Nos. S-1:	Slope Stability
Table A:	Comparison of Shoring Alternatives
Figure No. SK-3:	Conceptual Staging Plan
Figure No. SK-4:	Conceptual Shoring Locations
Figure No. SK-5	Conceptual Shoring Sections
	Notice to Contractor
	NSSP: Pipe Installation by Trenchless Method
	SP 517F01 Amendment to OPSS 517

Reference No.: P-0014193-0-00-100-04-F9
Date: November 2017

Englobe



Project: G.W.P 5333-11-00
Location: Hwy 60

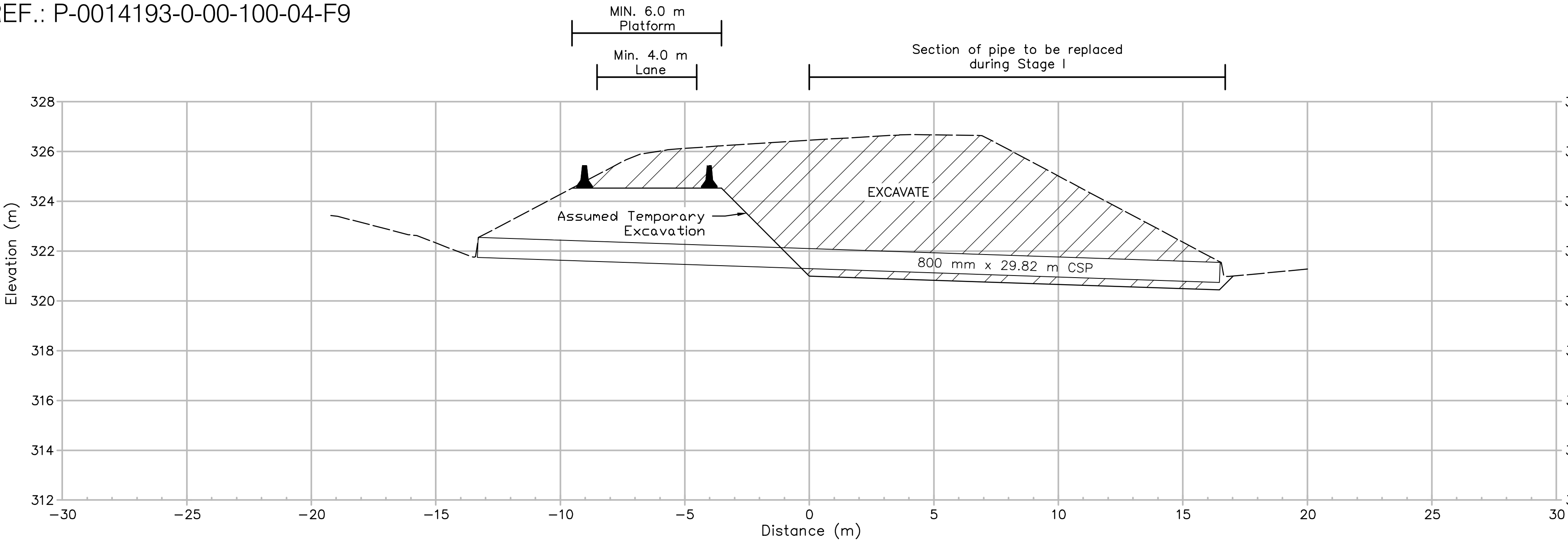
Station 14+450
Township of Franklin

Figure No. S-1

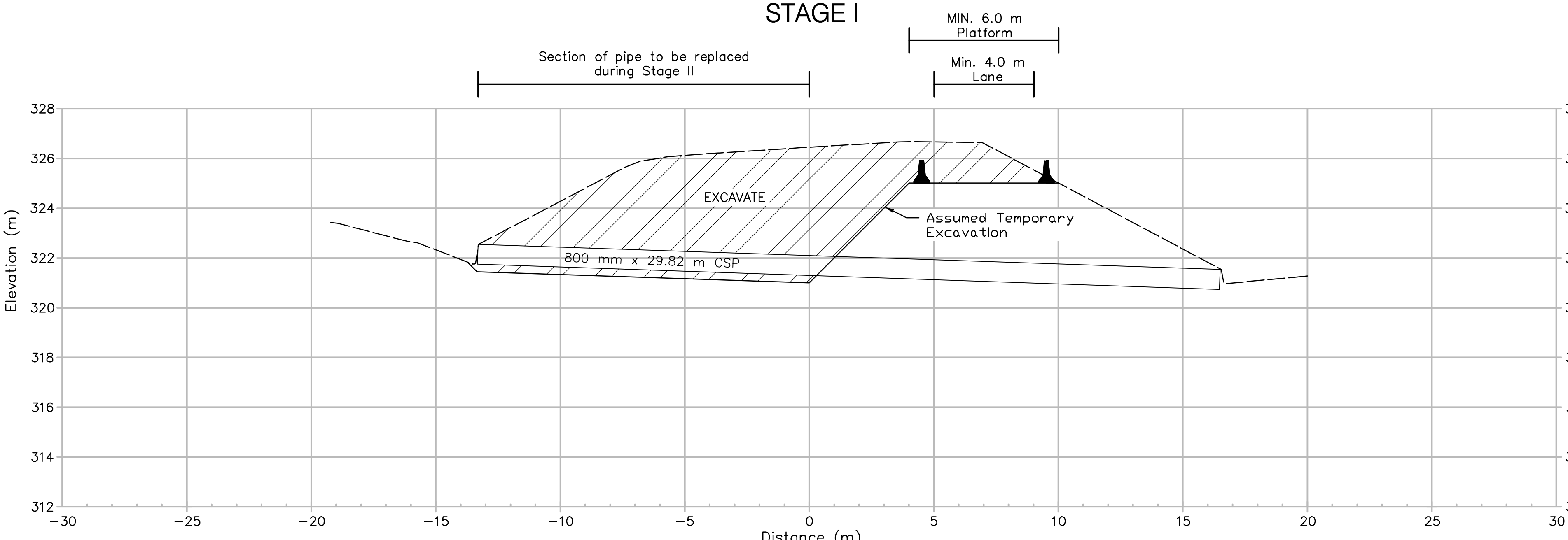
Table A – Comparison of Shoring Alternatives

Method	Depth Range (m)	Advantages	Disadvantages	Remarks	Estimated Costs
Wood Sheeting	1.5 – 5	-Low cost, -Easily installed in good ground conditions	-Limited by soil conditions, -Limited depth of installation, -Low lateral resistance, -discontinuous	Not recommended due to rock pieces encountered in embankment fills and native soils	$ 650/m^2
Steel Sheet Piles	5 – 21	-High strength, continuous protection, -Readily available	-Limited by soil conditions (i.e. obstructions)	Not recommended due to rock pieces encountered in embankment fills and native soils	$ 650/m^2
Pre-cast concrete panels	3 – 10	-Durable -Assists in minimizing seepage	-Limited depths -Can be damaged during installation -Limited by soil conditions (i.e. obstructions)	Not considered due to higher cost	
Soldier piles	5 – 25	-Easy installation -Readily available -Adaptable to various ground conditions	-Pre-drilling may be required -Possible ground loss	Recommended provided sufficient dewatering and predrilling is carried out through cobbles/boulders encountered in embankment fills and native soils	$ 725/m^2 Predrilling 1500/m^2
Tangent/ Secant/ Staggered Drilled Piles	10 – 18	-Readily available -Adaptable to various ground conditions	-Possible ground loss and/or seepage -Poor alignment tolerance	Feasible using special equipment drilled through cobbles/boulders encountered in embankment fills and native soils	
Concrete Diaphragm	10 – 30	-High Strength -Durable -Can be left in place permanently	-High cost -Requires specialized equipment/control	Not considered due to higher costs	
Micropiles with reinforced shotcrete face		-Can be installed in various ground conditions -High strength -Good tolerance	-High Cost -Requires specialized equipment	Considered as alternative for protection system, however, higher cost	$ 1200 to 1500/m^2

REF.: P-0014193-0-00-100-04-F9



STAGE I



STAGE II

2.5m 0 5m

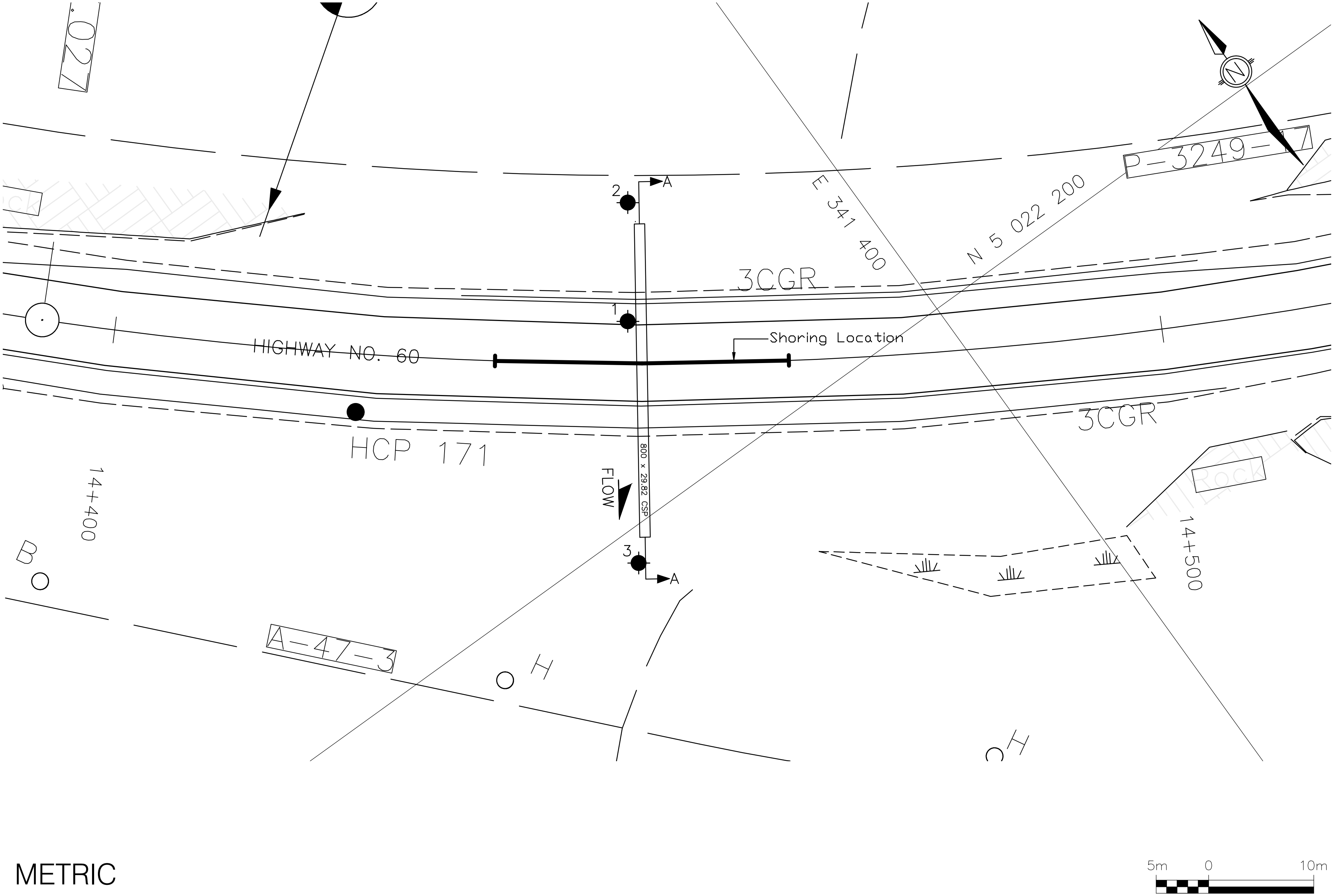
METRIC

Dimensions are in meters and/or millimeters unless otherwise shown. Stations are in kilometers + meters.

Highway 60, Township of Franklin - Culvert at Station 14+450
Conceptual Staging Plan

FIGURE SK-3

REF.: P-0014193-0-00-100-04-F9



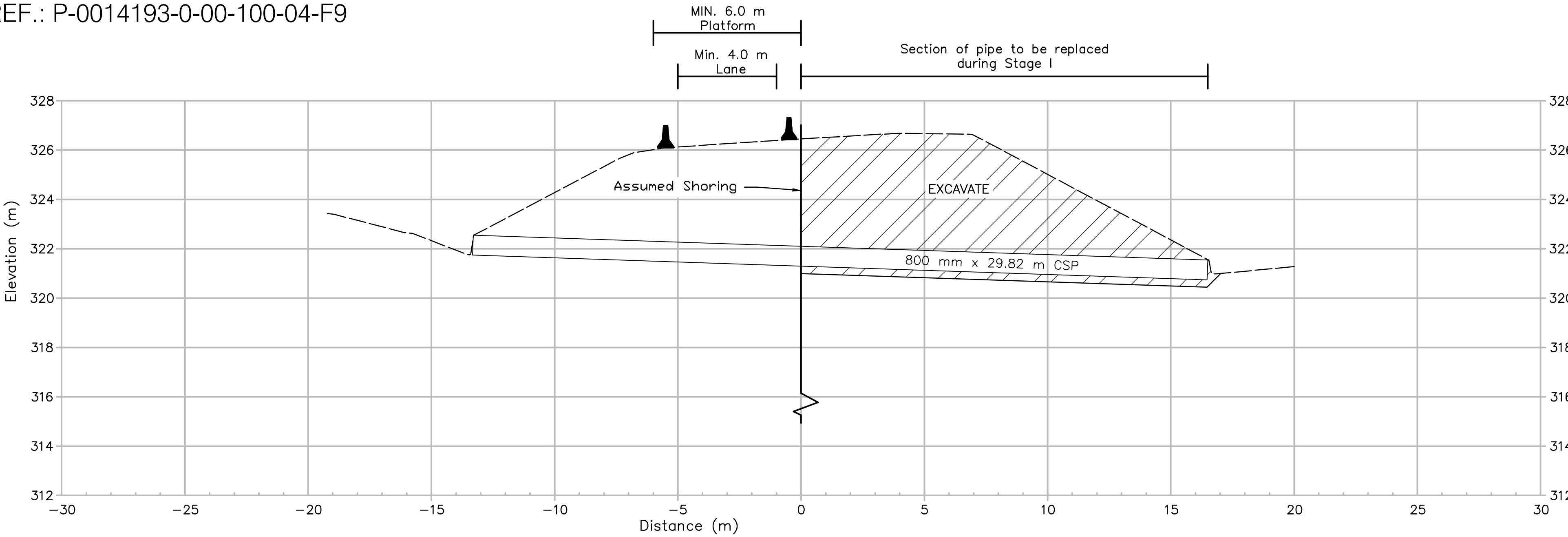
METRIC

Dimensions are in meters and/or millimeters unless otherwise shown. Stations are in kilometers + meters.

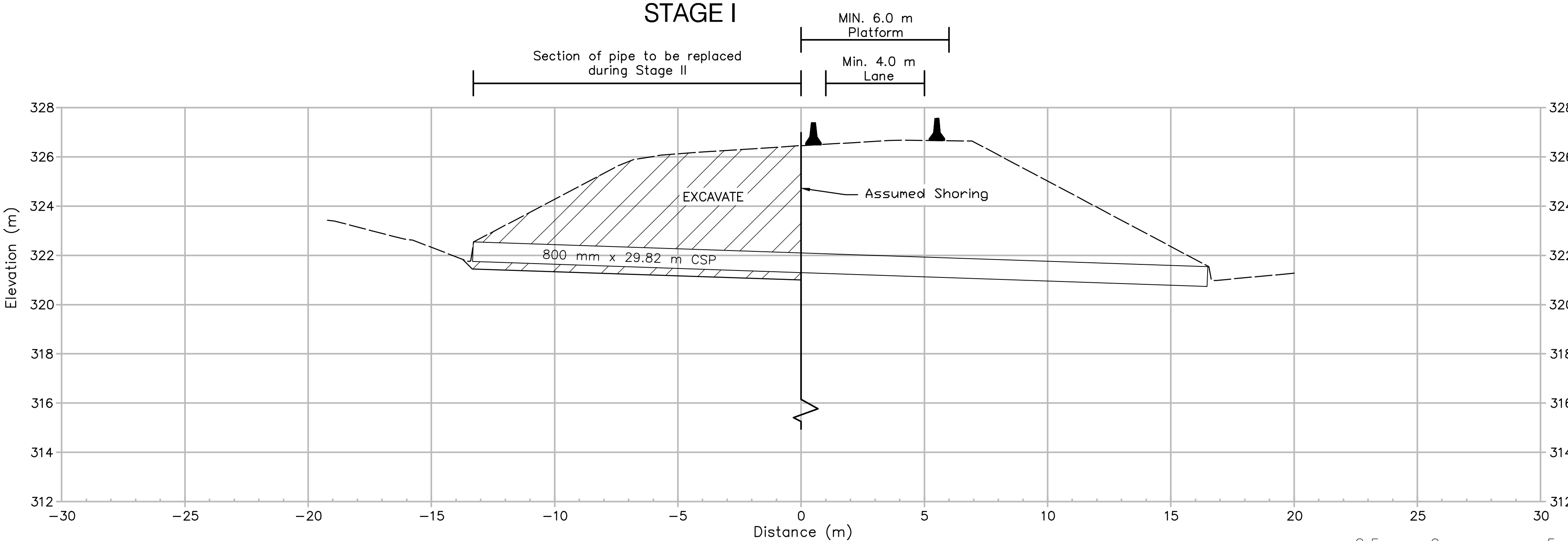
Highway 60, Township of Franklin - Culvert at Station 14+450
Conceptual Shoring Location Plan

FIGURE SK-4

REF.: P-0014193-0-00-100-04-F9



STAGE I



STAGE II

2.5m 0 5m

METRIC

Dimensions are in meters and/or millimeters unless otherwise shown. Stations are in kilometers + meters.

Highway 60, Township of Franklin - Culvert at Station 14+450
Conceptual Shoring Plan

FIGURE SK-5

NOTICE TO CONTRACTOR – Obstructions in Fill and Native Sands

Special Provision

The Contractor is advised that, at the borehole locations, mixed cobble/boulder sized rock fragments were encountered in the embankment fills and native sands overlying bedrock. The contractor should be prepared to deal with these materials for dewatering, temporary protection system and other construction activities. The Contractor must also be prepared to deal with seasonal and yearly fluctuations of ground/surface water.

<u>PIPE INSTALLATION BY TRENCHLESS METHOD</u> – Item No.

Special Provision

1. SCOPE

This specification covers the general requirements for the installation of pipes by trenchless methods, including Jack & Bore, Pipe Ramming, Directional Drilling, and Tunnelling. The Contractor shall determine the most appropriate method of installation for each of the crossing locations.

This specification shall supersede OPSS 415 (Construction Specification for Pipeline Installation by Tunneling), OPSS 416 (Construction Specification for Pipeline and Utility Installation by Jacking and Boring) and OPSS 450 (Construction Specification for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling).

2. REFERENCES

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

Ontario Provincial Standard Specifications, General

OPSS 180	Management and Disposal of Excess Materials

Ontario Provincial Standard Specifications, Construction

OPSS 401	Trenching, Backfilling, and Compacting
OPSS 404	Support Systems
OPSS 491	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 517	Dewatering of Pipeline, Utility, and Associated Structure Excavation
DBSP 539	Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

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

American Society for Testing and Materials (ASTM) International Standards

ASTM A252-93	Welding and Seamless Steel Pipe Piles
ASTM D2657-03	Standard Practice for Heat Fusion Joining of Polyelofin Pipe and Fittings
ASTM D3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
ASTM F894	Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

Canadian Standards Association Standards:

CSA B182.6	Profile Polyethylene Sewer Pipe and Fittings.
CAN/CSA A5-93	Portland Cement
CSA W59	Welded Steel Construction (Metal Arc Welding)

3. DEFINITIONS

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

Auger Jack & Bore: a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead and rotating a cutter head, followed by removal of material from inside the bore by using an auger.

Backreamer: a cutting head suitably designed for the subsurface conditions that is attached to the end of a drill string to enlarge the pilot bore during a pullback operation.

Bore Path: 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 original design and working drawings. 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.

Digger Shield/Hand Mining: a method of forming a horizontal bore in the subsurface by essentially 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.

Drilling Fluids: 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 Fracture or Frac Out: a condition where the drilling fluid's pressure in the bore is sufficient to overcome the in situ confining stress, thereby fracturing the soil and/or rock materials and allowing the drilling fluids to migrate to the surface at an unplanned location.

Engineer: a Professional Engineer licensed by the Professional Engineers of Ontario to practice in the Province of Ontario.

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

Environmentally Sensitive Area (ESA): areas adjacent to construction that are off limits to the Contractor as specified elsewhere in the Contract.

Fill: man-made mixture of previously placed/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.

Grouting: injection of grout into voids.

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

Directional Drilling (DD): directional boring or guided boring.

HDPE: high density polyethylene.

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

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

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

Pipe Jacking: a method for installing steel casing or concrete pipe in the subsurface utilizing hydraulically operated jacks of adequate number and capacity to ensure smooth and uniform advancement without overstressing the liner/pipe.

Pipe Ramming: 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.

Primary Liner (Support): system installed prior to or concurrent with excavation, to maintain stability of an excavation and to support earth or rock and any structure utilities or other facilities in or on the supported earth or rock mass, until the excavation is completed.

Product: pipe culverts, pipe sewers, watermain pipe and sanitary pipe.

Pullback: that part of the DD method in which the drill string is pulled back through the bore path to the entry point.

Quality Verification Engineer (QVE): an Engineer who has a minimum of five (5) years experience in the field of pipe installation using trenchless methods or alternatively has demonstrated expertise by providing satisfactory quality verification services for the work at a minimum of two (2) projects of similar scope to the contract. The Quality Verification Engineer shall be retained by the Contractor to certify that the work is in general conformance with the contract documents and to issue Certificate(s) of Conformance.

Reaming: a process for pulling a tool attached to the end of the drill string through the bore path to enlarge the bore and mix the cuttings with the drilling fluid. This typically includes multiple passes.

Rock: 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 size equivalent to 0.3 m in diameter or greater.

Secondary Liner: concrete pipe, HDPE pipe or un-reinforced cast-in-place concrete, installed subsequent to tunnel excavation.

Shaft: vertically sided excavation used as entry and/or exit points from which the trenchless method is initiated or directed for the installation of product.

Strike Alert: 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: a mixture of soil and/or rock cuttings, and drilling fluid.

Soil: all materials except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials; includes rock fragments having an equivalent size less than 0.3 m in diameter.

Trenchless Installation: an underground method of constructing a passage open at both ends that involves installing a pipe. For the purpose of this specification, the pipe may be installed by any of the various methods defined herein such as Auger Jack & Boring, Pipe Jacking, Pipe Ramming, Directional Drilling, or using a tunnelling machine or hand mining methods.

Tunnelling: An underground method of constructing a passage using a tunnel boring machine (TBM), a microtunnel boring machine (MTBM) or hand mining using a shield to support the opening.

4. DESIGN AND SUBMISSION REQUIREMENTS

4.01 General

The Contractor's documentation, submission requirements and installation methods shall specifically consider and address the subsurface conditions at each pipe crossing as identified in the Foundation Investigation Report or elsewhere in the Contract Documents.

4.02 Working Drawings

Three copies of stamped working drawings for portal or shaft construction, primary liner, excavation, secondary lining, dewatering and groundwater control and grouting shall be submitted to the Contract Administrator (CA) at least one week prior to the commencement of the work for information purposes. All submissions shall bear the seal and signature of the Design Engineer and Design Checking Engineer. The Contractor shall have a copy of the stamped working drawings at the site during construction.

As a minimum, working drawings/details pertaining to the tunnel design and construction shall include the following (as appropriate):

a) Plans, Elevations and Details:

- A work plan outlining the materials, procedures, methods and schedule to be used to execute the work;
- A list of personnel, including backup personnel, and their qualifications and experience;
- A safety plan including the company safety manual and emergency procedures;
- The work area layout;
- An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail;
- 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;
- Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations; and
- Excavated materials disposal plan.

b) Design Criteria:

- Primary liner design details, if applicable;
- Design assumption and material data when materials other than those specified are proposed for use; and
- Drill path design, details of alignment and alignment control, maximum curvature and reaming stages.

c) Materials:

- 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; and
- Material mixture for filling voids and installation procedures.

d) Upstream/Downstream Portal Installation Procedure:

- The access shaft or entry/exit pit details designed and stamped/signed by the Design Engineer, as applicable; and
- Face support and other temporary support details, if applicable.

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

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

f) Excavation and Dewatering:

- Ground control/dewatering details, as applicable, describing the proposed method for control, handling, treatment, and disposal of water.

g) Monitoring Method:

- The methods to be employed to monitor and maintain the alignment of the installation.

4.03 Site Survey

Prior to commencing the work, the Contractor shall, at each pipe location, lay-out the alignment and install settlement monitoring points.

4.04 Certificate of Conformance

The Contractor shall submit details of the sequence and method of construction to the Quality Verification Engineer for review, prepared and stamped by the Design Engineer. The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer a minimum of one week 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 Certificate of Conformance sealed and signed by the Quality Verification 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 Certificate of Conformance shall state that the work has been carried out in general conformance with the contract documents, specifications and/or stamped working drawings.

In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a final Certificate of Conformance sealed and signed by the Quality Verification 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.

The Design Engineer will not be permitted to carry out the work of the Quality Verification Engineer.

5. MATERIALS

5.01 Product

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

5.02 Concrete

Concrete shall be according to OPSS.PROV 1350. The concrete strength shall be as specified in the Contractor's design submission.

5.03 Concrete Reinforcement

Steel reinforcing for concrete work shall be according to OPSS.PROV 1440.

5.04 Timber

Timber shall be sound, straight, and free from cracks, shakes and large or loose knots.

5.05 Grout

The Contractor shall submit the proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces. Purging grout shall consist of a mixture of one part Portland cement conforming to the requirements of CAN/CSA A5-93 and two parts mortar sand conforming to OPSS.PROV 1004 wetted with only sufficient water to make the mixture plastic.

5.06 Auger Jack & Bore Materials

5.06.01 Pipe Materials

Steel pipe shall conform with ASTM A252-93 welded joints suitable for jacking operations. The Contractor shall select pipe class for pipe jacking.

Concrete pipe as per OPSS.PROV 1820.

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

5.07 Pipe Ramming Materials

5.07.01 Pipe Materials

Steel pipe shall conform with ASTM A 252-93 welded joints.

New steel casing when specified shall be smooth wall carbon steel pipe according to ASTM A252-93 Grade 2.

Used steel casing can be used provided that the steel casing can resist the applicable static and dynamic loadings.

Pipe wall thickness shall be determined by the Contractor based on static and dynamic loads from traffic loading and anticipated ramming forces for selected pipe and driven pipe lengths. The wall thickness shall be increased as required to ensure the casing is not damaged during handling and installation. The pipe minimum wall thickness shall be as per Table 1 of OPSS 1802.

Pipe segments shall be determined by the Contractor.

Steel pipe joints shall be pressure fit type or welded.

All steel casing pipe shall be square cut.

Steel casing pipe shall have roundness such that the difference between the major and minor outside diameters shall not exceed 1% of the specified nominal outside diameter or 6 mm, whichever is less.

Steel casing pipe shall have a minimum allowable straightness of 1.5 mm maximum per metre of length.

5.07.02 Mill Certificates

For permanent casing, the Contractor shall submit to the Contract Administrator at the time of delivery one copy of the mill certificate, indicating that the steel meets the requirements for the appropriate standards for casings.

Where mill test certificates originate from a mill outside Canada or the United States of America the Contractor shall have the information on the mill certificate verified by testing by a Canadian laboratory. The laboratory shall be accredited by a Canadian National Accreditation Body to comply with the requirements of ISO/IEC Guide 25 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 and the signature of an authorized officer of the Canadian testing laboratory.

5.08 Directional Drilling Materials

5.08.01 Drilling Fluids

The drilling fluids shall be mixed according to the manufacturer's recommendations and be appropriate for the anticipated subsurface conditions.

5.08.02 Pipe Materials

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

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

The Contractor shall determine the required dimensional ratio (DR) of the HDPE pipe to support all subsurface conditions and hydrostatic pressures, and to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

The Contractor's submission shall demonstrate, in conjunction with the manufacturer's specifications, that the heat resistance of the pipe material is sufficient to tolerate without damage the heat of hydration generated by grout curing.

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

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

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

5.09 Tunnelling Materials

5.09.01 Primary Liner

Tunnelling methods will require installation of a primary liner. The primary liner shall be designed by the Contractor and the design/drawings shall be stamped/signed by the Design Engineer. The design shall be submitted to the Contract Administrator as specified herein.

5.09.02 Secondary Liner

Concrete or High Density Polyethylene Pipe shall be used according to the following requirements.

5.09.02.01 Concrete Pipe

Concrete pipe as per OPSS.PROV 1820 shall be used. The Contractor shall select the pipe class to withstand grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

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

5.09.02.02 High Density Polyethylene (HDPE)

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

The requirements for fittings shall be according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

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

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

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

6. EQUIPMENT

6.01 Auger Jack & Bore Equipment

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 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 shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.02 Pipe Ramming Equipment

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 drive pit through the existing subsurface conditions at the site.

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 pipe shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.03 Directional Drilling Equipment

6.03.01 General

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

6.03.02 Drilling Rig

The directional drilling rig shall:

- 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;
- contain a guidance system to accurately guide boring operations;
- be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation; and
- 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 Equipment

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

Specific details of the manner in which rock or boulders will be broken and removed from the tunnel face shall be submitted to the Contract Administrator information purposes. 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.

7. CONSTRUCTION

7.01 General

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

Administrator for information purposes prior to commencing the work and shall be subject to the limitations presented in the following subsections.

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 at every 5 m in normal conditions and every 2 m where precise alignment control is necessary;

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

All excavations shall be carried out in accordance with the Occupational Health and Safety Act (OHSA) of Ontario.

For 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 9m 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.

7.01.02 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 DBSP 539. 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 Contract, 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, 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 DBSP 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 Boulders

The Contractor is alerted that cobbles and boulders should be anticipated in the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

7.01.12 Record Keeping

Verification record requirements of the alignment and depth of the installation shall be as specified in the Contract Documents. A copy of the verification records shall be given to the Contract Administrator at the completion of the installation.

7.01.13 Testing

Testing of the product installation shall consist of verifying the specified grade between the two ends of the pipe and passing of water from the inlet end of the pipe to the outlet end to confirm gravity flow conditions.

7.01.14 Management and Disposal of Excess Material

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

7.01.15 Site Restoration

Site restoration shall be according to OPSS 492.

7.01.16 Supervision

A qualified individual, who is experienced in the pipe installation by trenchless methods shall supervise the work at all times.

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:

- Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.
- 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.
- 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 conditions at each pipe crossing.

7.02.02 Pipe Installation

Concrete pipe joints shall be water tight and according to OPSS.PROV 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 excavation shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavation shall be filled with grout.

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. But welding of pipe joints shall conform to CAS W59.

Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement 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.

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 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.

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 DD 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 and re-drill from the location along the bore path before the deviation.

In the event that a drilling fluid fracture, inadvertent returns, or loss of circulation occurs during pilot bore drilling operations, the Contract Administrator shall be advised of the event and action shall be taken in accordance with the Contractor's submitted contingency plan.

At the entry and exit points, there is potential for ravelling of the existing soil, fill and or weathered rock areas along the alignment. This is conventionally addressed by the use of drilling fluid. However, casing may be required. The Contractor's methods shall take into consideration the potential need to install sections of casing to manage ravelling at or near ground surface.

If a drill hole beneath the highway must be abandoned, the hole shall be backfilled with grout or bentonite to prevent future subsidence.

The Contractor shall maintain drilling fluid pressure and circulation throughout the DD 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 Fracture (Frac-Out)

In order to reduce the potential for hydraulic fracturing of the hole during directional drilling, a minimum depth of cover of 5m is normally maintained between the pipe and the ground surface. Sections of the pipe close to the exit pit with less than 5m cover shall be cased. The Contractor shall ensure that drilling fluid pressures are properly set and controlled 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.

Since fluid loss normally occurs in fault zones, fracture zones, or seams of coarse material, fluid migration does not always gravitate to the surface, thus making detection difficult. Once a fluid loss is detected, the Contractor shall halt operations immediately and conduct a detailed examination of the drill path and implement measures to mitigate fluid loss. If no surface migration is evident, resume operation while paying particular attention to fluid monitoring.

In the event of a fluid migration to the surface occurring, the Contractor shall halt all operations immediately, isolate the migration site, and recover fluids. Once the fracture is controlled, continue drilling operations with the operator paying particular attention to the fracture points

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 exceeded.

Product shall be allowed to recover 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 shall be pulled through the bore path. Once the pullback operation has commenced, it shall continue without interruption until the product 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. When specified in the Contract Documents, a weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

The product 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 excavation walls shall be filled with grout.

7. 05 Tunnelling Installation

7.05.01 General

The method of tunnelling shall be selected by the Contractor and shall be submitted to the Contract Administrator prior to commencement of the work for information purposes.

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 advance the ventilation system as a regular part of the normal excavation cycle.

The Contractor shall provide lighting in accordance with OHSA requirements for the entire length of the tunnel.

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.

In the event that excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation. 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 surface of the excavation shall be filled with cement grout. If an unexpanded liner is used, the space outside the liner plates shall be grouted 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.

7.06 Instrumentation Monitoring

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

Surface settlement markers for monitoring ground stability shall be installed at the pavement/ground surface level on the shoulder, side slope and pavement at not greater than 5 m intervals along the tunnel alignment and as an array of three in-ground (1.5 m depth) measurement points on the shoulder of the highway perpendicular to the alignment. The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within ± 1 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).

In general, 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. The assembly shall be placed in a drill hole and backfilled with uniform sand.

The Contractor shall install all surface settlement instruments a minimum of one week prior to the start of works.

The surface settlement instruments shall be clearly labelled for easy 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 recorded at the following time intervals:

- Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);
- Once per shift during tunnelling operations period; and
- 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 Administrative 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 Criteria for Assessment of Roadway Subsidence/Heave

Based on the monitoring of ground movement as specified in Subsections 4.02 and 7.06, the following represents trigger levels that define magnitude of movement and corresponding action:

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

The Contractor shall avoid damaging instrumentation during construction. Instrumentation that is damaged as a result of the Contractor's operation shall be repaired or replaced by the Contractor within one business day. The costs for replacement/repair shall be borne by the Contractor.

At the completion of the job, the Contractor shall abandon all instrumentations installed during the course of the Work.

9. MEASUREMENT FOR PAYMENT

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

10. BASIS OF PAYMENT

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

Payment for the rigid or flexible pipe conduits installed inside the pipe liners shall be paid separately under the appropriate tender items.

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

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

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

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

Payment for removal of boulders/obstructions greater than an equivalent 0.3 m in diameter shall be on a time and materials basis. The Contractor shall inform the Contract Administrator when boulders/obstructions are encountered and prior to removal to allow for proper and accurate tracking of time and material charges.