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+219 - Twp. of Canisbay
GWP 5178-12-00

FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

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Final Foundation Investigation and Design Report

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1 INTRODUCTION

Englobe Corp. (Englobe), formerly LVM-Merlex, a Division of Englobe Corp., has been retained by AECOM Canada Ltd., on behalf of the Ministry of Transportation of Ontario (MTO), to carry out a foundation investigation at an existing centerline culvert site. The site is located at Station 14+219 in the Township of Canisbay on Highway 60, some 1.8 km east of Canisbay Lake Road.

The foundation investigation location was specified by the MTO in the Terms of Reference for work under Agreement No. 5014-E-0004. The terms of reference for the scope of work are outlined in Englobe's Proposal P-14-199-R2, dated January 15, 2015. The purpose of this investigation was to determine the subsurface conditions in the area of the existing culvert for the contract preparation of the Detailed Design package. 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

A 750 mm diameter Corrugated Steel Pipe (CSP) culvert is located on Highway 60 at Station 14+219 in the Township of Canisbay. 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 on a sand mixed with rock fill embankment some 3.3 m in height above the culvert invert, with centerline elevation of 457.2 m at the culvert location. At the north slope, the maximum height of embankment fill is some 2.8 m above the culvert invert. The maximum height of embankment fill is some 4 m above the culvert invert at the south slope. The existing embankment slopes, in the area of the culvert, have been generally established at an inclination angle of some 1.8H:1V at the north slope and at an inclination angle of approximately 1H:1.15V at the south slope. The culvert at this location is a 750 mm diameter Corrugated Steel Pipe (CSP) culvert, some 26.9 m in length. Flow through the culvert is from the north to the south (left to right).

Visual observation indicates that the infrastructure at the culvert location consists of overhead wires to the right (south) side of the highway embankment.

2.1 SITE PHYSIOGRAPHY AND SURFICIAL GEOLOGY

This project is located in the Geomorphic Sub-province known as the Muskoka Ridges and Pockets. The topography on this section of Highway 60 is generally rolling. Layers of earth overlay bedrock. Organic materials were also observed in the region. Within the project area native overburden consists primarily of sands overlying bedrock.

Bedrock in the area, as indicated on OGS Map MRD-126, bedrock in the area consists of migmatitic rocks and gneisses of undetermined protolith.

3 INVESTIGATION PROCEDURES

The fieldwork for this investigation was carried out during the period between June 24th and August 17th, 2015 during which time four (4) sampled boreholes, were advanced. Two (2) boreholes were advanced through the embankment. A single borehole was advanced at each of the inlet (north) and outlet (south) ends of the culvert, respectively.

The field investigation was carried out using a truck and bombardier mounted CME drilling rig 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 D-1586). 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 advancement of the augers was encountered within the proposed depth of borehole, the borehole was advanced further with N size casing 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 selected open boreholes 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 general order 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(s) 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, Mr. 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 our North Bay laboratory, plus overall drill supervision. All samples received a visual confirmatory inspection in our laboratory. Laboratory testing of select samples included routine 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 results presented on the laboratory sheets in Appendix 3 (Figures Nos. L-1 to L-2 and Table No. L-3).

The location of the individual boreholes was determined in the field using highway chainage established by Callon Dietz Inc. (Callon Dietz) and offset relative to highway centerline. 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 a geodetic datum.

4 SUBSURFACE CONDITIONS

Details of the subsurface conditions revealed by the investigation program are presented on the enclosed Records of Borehole Logs (Appendix 2) and on Drawing No. 2 (Appendix 3). Please note that stratigraphic delineation presented on the borehole logs and soil strata plot are the results of non-continuous sampling, response to drilling progress, the results of SPT, 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+219, TOWNSHIP OF CANISBAY

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, four (4) sampled boreholes were put down at this site, with Borehole Nos. 1 and 2 advanced through the embankment, Borehole No. 3 advanced adjacent to the culvert inlet, and Borehole No. 4 advanced adjacent to the culvert outlet. At the time of the subsurface investigation, the ground surface elevations at Boreholes Nos. 1 to 4 were recorded at elevations 457.4, 457.0, 454.7, and 453.3 m, respectively.

4.1.1 Pavement Structure

Borehole No. 1 was advanced through the embankment where a pavement structure consisting of 51 mm asphalt and 203 mm crushed gravel was penetrated. Borehole No. 2 was advanced through the embankment where a pavement structure consisting of 76 mm asphalt and 76 mm crushed gravel was penetrated.

4.1.2 Embankment Fill

Underlying the pavement structure at Borehole Nos. 1 and 2, a layer of embankment fill consisting of brown sand trace to some gravel, trace to some silt, to gravelly sand, some silt, mixed with rock fill, was penetrated. Gravel to cobble/boulder sized rock pieces were encountered in this fill layer, between elevations 455.2 and 456.6 m. Auger refusal was encountered at Elevations 455.4 and 456 m, respectively, during borehole advancement in the deposit at Borehole Nos. 1 and 2. Below this depth, the boreholes were advanced using N size coring equipment. The natural moisture content measured on retrieved samples of this deposit was generally in the order of 3 to 16%. Gradation (sieve and hydrometer) analyses were carried out on four (4) samples of this deposit, the results of which indicated 6 to 39% gravel size particles, 44 to 78% sand size particles, and 10 to 17% silt and clay size particles (Figure No. L-1, Appendix 3). Based on SPT 'N' values of 14 to 46 blows per 300 mm penetration and 20 blows per zero mm penetration, the compactness of this deposit was described as compact to very dense, generally compact. This deposit was encountered to a depth of 4.1 and 2.7 m below grade at Borehole No. 1 and 2, respectively (elevations 453.3 and 454.3 m, respectively).

4.1.3 Topsoil

At ground surface at Borehole Nos. 3 and 4, a layer of dark brow to black silty topsoil was penetrated. This topsoil layer was encountered to an approximate depth of 0.2 m below ground surface at Borehole Nos. 3 and 4 (elevations 454.5 and 453.1 m, respectively).

4.1.4 Sands

Underlying the embankment fill at Borehole Nos. 1 and 2, underlying the topsoil at Borehole Nos. 3 and 4, a deposit of brown to grey sand, trace to with gravel, trace to with silt and clay was penetrated. The natural moisture content measured on samples of this deposit was in the order of 2 to 28%. Gradation (sieve) analyses were carried out on three (3) samples of this deposit, the results of which indicated 8 to 21% gravel size particles, 67 to 72% sand size particles, and 7 to 22% silt and clay size particles (Figure No. L-2, Appendix 3). Based on SPT 'N' values of 8 to 52 blows per 300 mm penetration to 55 blows per 76 mm penetration, this deposit was described as loose to very dense, generally compact. This deposit was encountered to depths of 7.3, 4.3, 0.8, and 1.5 m below grade at Borehole Nos. 1 to 4, respectively (elevations 450.1, 452.7, 453.9, and 451.8 m, respectively).

4.1.5 Bedrock

Underlying the above described sands at Borehole Nos. 1 to 4, the bedrock was proven by diamond core drilling. The bedrock was described as black gneiss with pink granite bedrock. Based on RQD values of 68 to 89% the bedrock was described as fair to good quality. Based on visual review, the bedrock generally showed negligible weathering. Sampling in the bedrock was terminated at depths of 10.3, 7.3, 3.8, and 4.6 m below grade at Borehole Nos. 1 to 4, respectively (elevations 447.1, 449.7, 450.9, and 448.7 m, respectively). It should be noted that, when encountered, the underlying bedrock surfaces in this area can be very erratic in nature, varying substantially in elevation over short horizontal distances.

4.2 GROUNDWATER DATA

At the time of this investigation (June 24th to August 17th, 2015), surface water was not observed at the culvert.

Measurements of the groundwater 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 3 to obtain post borehole completion water levels. These levels are recorded on the individual Record of Borehole Log Sheets (Appendix 2).

The stabilized groundwater levels were measured at elevations 453.3 m and 454.0 m at Borehole Nos. 1 and 3, respectively, during the periods of foundation investigation. The water level reading at elevation 456.4 m measured at Borehole No. 2 had probably not yet stabilized since it was taken upon completion of borehole advancement on June 24, 2015. The groundwater level was measured at elevation 453.1 m at Borehole No. 4 upon completion of borehole advancement on August 17, 2015.

The groundwater and surface water levels will fluctuate seasonally/yearly.

5 DISCUSSION AND RECOMMENDATIONS

5.1 GENERAL

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

The existing culvert, located at Station 14+219, in the Township of Canisbay, is a 750 mm diameter CSP culvert some 26.7 m long. The existing culvert invert, at centerline, is estimated at a depth of some 3.3 m (elevation 453.9 m). The culvert inverts at the inlet at the outlet are estimated at elevations 454.4 and 453.2 m, respectively. The existing highway embankment currently supports two undivided lanes of highway, running in a west-east direction. The water flow through the culvert is from the left to the right (the north to the south). Based on data from this foundation investigation, the embankment supporting the existing pavement structure at this site has been constructed using a granular pavement structure overlying sand fills mixed with rock fill. The native material, underlying the embankment fill, generally consisted of compact to very dense sands overlying the bedrock.

The type of culvert (concrete, CSP, or High Density Polyethylene (HDPE)) to replace the existing culverts is currently not finalized; however, it is understood that a concrete pipe culvert or CSP are the preferred replacements. It is understood that the new culvert will be constructed along a similar skew and alignment. It is further understood that the final vertical alignment of the highway will remain essentially the same.

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, as such, will not require frost treatments.

5.2 FOUNDATION CONSIDERATIONS

The founding native sands 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 natural bearing surface is not disturbed during construction and groundwater is controlled throughout construction, as discussed in Section 5.6.

Based on the characteristics of the native sand subgrade present below the culverts, the response of the existing embankment, and a founding elevation similar to that of the existing culvert, a factored bearing resistance at ULS of 160 kPa are considered for the open culverts (i.e. concrete frame open culverts, with wall footings, or pipe arch culverts on footings) and the flexible culverts (i.e. CSP/SPCSP/HDPE) and a geotechnical reaction at SLS of 110 kPa, a minimum 0.5 m in width and established at a depth of 1.5 m below creek bed, founded on the native sands, can be used for design, in consideration of 25 mm settlement and taking into consideration the limited depth of overburden and smaller footing width.

5.2.1 Slope Stability

The maximum height of the embankment above the culvert invert at this location is some 3.3 m at the centreline, and up to some 4 m at the south slope of the embankment. Stability analyses, using the GEO-SLOPE computer program, Slope/W (GeoStudio 2007, version 7.17, Geo-Slope International Ltd.), were carried out at this location with the existing embankment slopes of the sand and rock fills at inclination angles ranging from some 1.8H:1V at the north slope to some 1H:1.15V at the south slope. For the purposes of these analyses, the materials were modeled using the following parameters;

PARAMETER	MATERIAL			
	EMBANKMENT FILL ABOVE ELEVATION 456 M	EMBANKMENT FILL BELOW ELEVATION 456 M	SAND	TOPSOIL
Unit Weight (kN/m^3)	19.0	21.0	19.0	10.0
Effective Friction Angle (degrees)	30	40	32	-
Cohesion (kPa)	-	-	-	50

The unit weights and friction angles for the slope calculations are based on general representative values for the various soil types, obtained through laboratory testing and tactile analysis. The groundwater levels used for the analyses are shown on Figure Nos. F-1 to F-4, Appendix 5. The results of the analyses indicate the marginal factor of safety in the order of 0.8 on the existing south embankment slope on an inclination of some 1H:1.15V, against the minor surficial slippage on the embankment (see Figure No. S-1, Appendix 5). The factor of safety against long term deep seated failures is in the order of 1.6 with the existing slopes (see Figure No. S-2, Appendix 5). It's recommended that the existing south embankment slope be flattened to an inclination angle of 1.25H:1V or flatter to increase the factor of safety against the surficial slippage. With the embankment slope at an inclination angle of 1.25H:1V, the factor of safety against minor surficial slippage and long term deep seated failure is 1.0 and 1.6, respectively (see Figure Nos. S-3 and S-4). The surficial slippage can be prevented after placing adequate rock protection stated in Section 5.3. Lower factors of safety will occur during excavation and backfilling as discussed in Section 5.5. 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 and sand and silt fills. The results of this investigation indicate that, below the culvert invert, the native subgrade soils at Borehole Nos. 1 to 4 consisted of generally compact to very dense sands. A review of the condition of the pavement surface, at the culvert locations, revealed that the embankment appears to have performed well. The existing embankment has preloaded the soils at the culvert locations and since there will be no change in the height of the embankment, and therefore no increases in embankment load, no appreciable settlement of the embankment is anticipated. As such, installing the culverts 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. 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 per OPSS.PROV 1004 should be used, which would aid in dewatering operations. During backfilling, the material of bedding and cover shall be placed in uniform layers not exceeding uncompacted thickness of 200 mm. The elevation difference of backfilling on either side of the rigid pipe shall be limited to a maximum 200 mm per OPSS.PROV 401. Cover material for concrete pipes can consist of Granular A and placed to the dimensions as shown on OPSD 802.031. If circular concrete pipes are used, compaction of the haunch is critical and should be constructed in accordance with OPSS.PROV 501.

Considering the size of the culvert, a precast concrete rigid frame box culvert is not recommended at this site.

The inlet and outlet stream bed shall be protected with a rip-rap (R-50 size as per OPSS.PROV 1004) apron. The apron shall be 3 m in length, a minimum 400 mm thick and extend across the stream bed to 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/granular embedment. In consideration of the culvert size and anticipated flow, the 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.

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 OPS.PROV 1010 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. The material in the haunch area must be compacted to 100% Standard Proctor Maximum Dry Density prior to placing the remainder of the embedment material. During backfilling, the embedment material shall be placed in uniform layers not exceeding uncompacted 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. 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.

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) apron. The apron shall be 3 m in length, a minimum 400 mm thick and extend across the stream bed to 3 m beyond the outside edges of the culvert.

5.4 CULVERT INSTALLATION AND CONSTRUCTION STAGING CONSIDERATIONS

The invert of the existing culvert is located at elevation 453.9 m, with the top of the embankment at elevation 457.2 m, at the centerline. The culvert inverts at the inlet and the outlet are established at elevations 454.4 and 453.2 m, respectively. As such, the embankment at this location is some 3.3 m in height above the culvert invert at the centerline. Therefore, a minimum 3.6 m deep excavation (i.e. to elevation 453.6 m) will be required (at centerline) in consideration of a 300 mm thick layer of bedding/embedment material. At the inlet and the outlet of the culvert, the excavations will be required to depths of some 3.1 and 4.3 m, respectively (elevations 454.1 and 452.9 m, respectively). The present platform width at this location is some 20 m as can be seen on the cross section on Drawing No. 2. The platform width at this location, as is, will not be sufficient to carry out an open excavation using staged construction unless local lowering of the grade and/or sliver widening is undertaken. In general, an open cut excavation can be considered if the platform is temporarily lowered by some 0.4 m to 0.6 m. If this lowering cannot be accommodated then consideration can be given to a combination of lowering and widening or to constructing a temporary vertical shoring wall for use as a protection system.

5.4.1 Staged Construction

As noted, the platform at this location, as is, is of insufficient width to carry out an open excavation using staged construction, unless temporarily lowering 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 456.8 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 14 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 Protection System

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

The installation of a protection system for use in the culvert replacement operation will require penetration through some 3.3 m of fills (at centerline) of sand mixed with rock fills. The embankment fill is generally underlain by compact to very dense sands. As cobble and boulder size rock pieces 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 may be problematic. A notice to Contractor indicating the presence of the cobble/boulder size rock fill in the embankment has been included in Appendix 5. Several approaches to constructing a protection system are described in Table A in Appendix 5 for advantages and disadvantages for the different type of protection system considered for this site. Conceptual shoring locations are illustrated on Figure No. SK-4, Appendix 5.

One method to construct a protection system would be to penetrate the embankment fill with H piles (soldier piles) extending into the underlying compact sands and/or into bedrock and install lagging with the required dewatering system as discussed in Section 5.6. Pre-drilling may likely be required to advance the H piles through the embankment fills, if oversized obstacles are encountered, and into the underlying bedrock to allow sufficient toe resistance. The H piles would be installed at an interval of 2 to 3 m apart and the lagging would be installed as the excavation progresses. Alternatively, a caisson wall or a drilled micropile system with an intermediate support system of reinforced shotcrete, to act as lagging, could be considered for roadway protection at this site; however these shoring systems are generally more costly.

If tiebacks are required, the resistance (R) for grouted anchors, located outside the active failure wedge, in cohesionless soils can be estimated from the following equation as supplied in the Canadian Foundation 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

For tieback design, a triangular earth pressure distribution over the height of the cut would be appropriate for design.

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.

A table outlining 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 Table A in Appendix 5. A Conceptual shoring location and a schematic cross section are illustrated on Figures Nos. SK-4 and SK-5 in 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 over sand fills mixed with 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 coefficient, as described in Section 5.5,

γ = unit weight, as described in Section 5.5, and

H = height of wall above the base of excavation.

Surcharge loads from the active lane of traffic must also be considered during design of the temporary shoring system.

The contractor's shoring/protection system design must be carried out by a geostructural engineer with appropriate experience.

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

5.5 LATERAL EARTH PRESSURES

Lateral earth pressures should be computed in accordance with the Canadian Highway Bridge Design Code (CHBDC). 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	EMBANKMENT FILL ABOVE ELEVATION 456 M	EMBANKMENT FILL BELOW ELEVATION 456 M	SANDS
Unit Weight (kN/m^3)	22.8	21.2	19	21	19
Angle of Internal Friction	34°	31°	30°	40°	32°
Coefficient of Active Earth Pressure (K_a)	0.28	0.32	0.33	0.22	0.31
Coefficient of Passive Earth Pressure (K_p)	3.54	3.12	3.0	4.55	3.23
Coefficient of Earth Pressure at Rest (K_o)	0.44	0.48	0.5	0.36	0.47

For rigid structures, such as a precast concrete culverts, deflection cannot occur, 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.

5.6 EXCAVATION, DEWATERING, AND EMBANKMENT RECONSTRUCTION

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 a Type 3 soil as defined in the Occupational Health and Safety Act and Regulations for Construction Projects. Temporary open excavations above the groundwater table, could be cut back at an angle of 1H:1V, provided they are monitored continuously; however, below the groundwater table, the side slopes in fill an/or native materials will have to be cut back to an angle of 2H:1V, possibly shallower, dependent upon the Contractors’ chosen method of controlling the groundwater.

The excavation backfill above the culvert bedding/cover should consist, at a minimum, a granular fill meeting OPSS for Select Subgrade Material (SSM).

Final (permanent) rockfill embankment side slopes should be established as per OPSD 201.010. Final slopes should be treated with a seed and mulch to prevent ravelling.

Bedrock was not encountered at the borehole locations within the anticipated depth of excavation, therefore bedrock excavation and/or blasting operations are not anticipated.

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 and 518, will be required to maintain a stable subgrade during culvert installation.

At the time of investigation, no surface water was encountered at locations of the culvert invert and outlet. The stabilized water levels were measured at elevations 453.3 and 454.0 m at Borehole Nos. 1 and 3, respectively. Excavations to minimum elevations 454.1 and 452.9 m at the culvert inlet and outlet, respectively, will likely be required to install the culvert and bedding. As such dewatering may not be required during excavation and culvert installation; however seasonal and yearly fluctuations of the groundwater and the surface water shall be considered at the time of excavation and construction.

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 some 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.

A Permit to take Water is required by the MOE when more than 50,000 litres/per day will be removed for consumptive use.

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, the generally shallow bedrock ranging from 0.8 to 1.5 m below the culvert invert (i.e. elevation 453.9 m at location adjacent to the inlet and elevation 451.8 m at location adjacent to the outlet) may limit the penetration of a steel sheet pile type cofferdam. For base design, sheet piles should extend a minimum depth below base of proposed excavation equal to the height of water above the base of excavation. 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.

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, no major construction concerns are anticipated if construction is carried out in general conformance with the above discussion. However, auger refusal was encountered at Borehole Nos. 1 and 2 in the embankment fill, and the bedrock was encountered at relatively shallow depths. The Contractor must be prepared to excavate and install protection systems considering these materials. A special provision addressing this issue is included in Appendix 5. As noted in Section 5.6 the culvert subgrade must be adequately dewatered to maintain the bearing resistance of the foundation subgrade. The seasonal and yearly fluctuations of the groundwater and the surface water shall be considered for excavation and construction.

6 STATEMENT OF LIMITATIONS

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

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

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

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

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

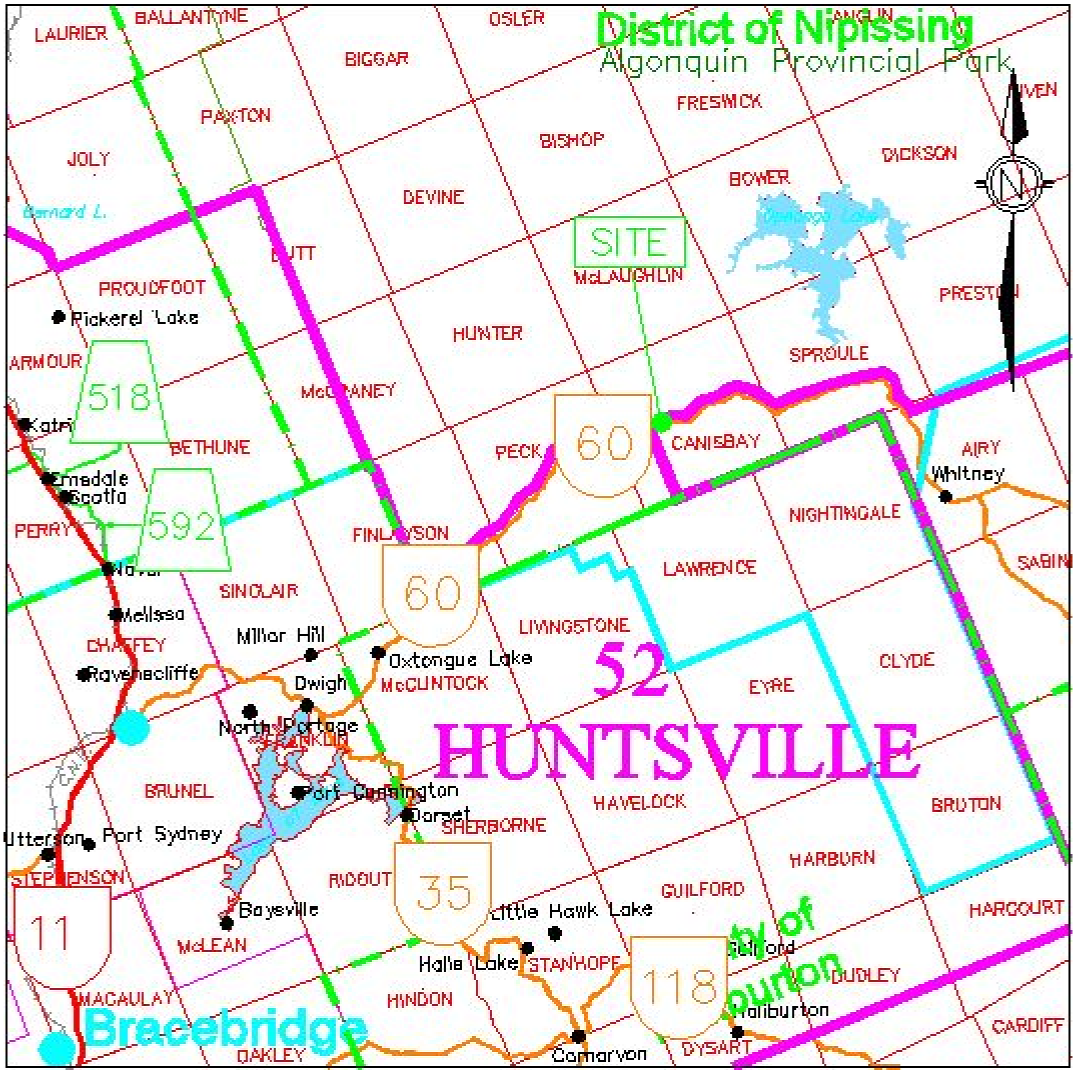
Appendix 1 Key Plan

Drawing No. 1	Key Plan

MACRO KEY PLAN

Drawing No.1

NOT TO SCALE



FOUNDATION INVESTIGATION AND DESIGN REPORT
GWP 5178-12-00
Highway 60

Station 14+219 Culvert

Township of Canisbay

Reference No: 15/04/15020-F1 May 2016

Appendix 2 Subsurface Data

Enclosure No. 1	List of Abbreviations and Symbols
Enclosure Nos. 2 to 5	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)	*Relative Density*
0 to 4	very loose
4 to 10	loose
10 to 30	compact
30 to 50	dense
over 50	very dense

b) *Cohesive Soils:*

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

3. SOIL DESCRIPTION (Cont'd)

c) *Bedrock:*

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

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

+ 3.2 - Field Vane test in borehole. The number denotes the sensitivity to remoulding.

D - Laboratory Vane Test

.. - Compression test in laboratory

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

e) *Soil Moisture:*

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

4. TERMINOLOGY

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

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

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

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

SAMPLE DESCRIPTION NOTES:

1. **FILL:** The term fill is used to designate all man-made deposits of natural soil and/or waste materials. The reader is cautioned that fill materials can be very heterogeneous in nature and variable in depth, density and degree of compaction. Fill materials can be expected to contain organics, waste materials, construction materials, shot rock, rip-rap, and/or larger obstructions such as boulders, concrete foundations, slabs, abandoned tanks, etc.; none of which may have been encountered in the borehole. The description of the material penetrated in the borehole therefore may not be applicable as a general description of the fill material on the site as boreholes cannot accurately define the nature of fill material. During the boring and sampling process, retrieved samples may have certain characteristics that identify them as 'fill'. Fill materials (or possible fill materials) will be designated on the Borehole Logs. If fill material is identified on the site, it is highly recommended that testpits be put down to delineate the nature of the fill material. However, even through the use of testpits defining the true nature and composition of the fill material cannot be guaranteed. Fill deposits often contain pockets or seams of organics, organically contaminated soils or other deleterious material that can cause settlement or result in the production of methane gas. It should be noted that the origins and history of fill material is frequently very vague or non-existent. Often fill material may be contaminated beyond environmental guidelines and the material will have to be disposed of at a designated site (i.e. registered landfill). Unless requested or stated otherwise in this report, fill material on this site has not been tested for contaminants however, environmental testing of the fill material can be carried out at your request. Detection of underground storage tanks cannot be determined with conventional geotechnical procedures.

2. **TILL:** The term till indicates a material that is an unstratified, glacial deposit, heterogeneous in nature and, as such, may consist of mixtures and pockets of clay, silt, sand, gravel, cobbles and/or boulders. These heterogeneous deposits originate from a geological process associated with glaciation. It must be noted that due to the highly heterogeneous nature of till deposits, the description of the deposit on the borehole log may only be applicable to a very limited area and therefore, caution must be exercised when dealing with a till deposit. When excavating in till, contractors may encounter cobbles/boulders or possibly bedrock even if they are not indicated on the borehole logs. It must be appreciated that conventional geotechnical sampling equipment does not identify the nature or size of any obstruction.

3. **BEDROCK:** Auger refusal may be due to the presence of bedrock, but possibly could also be due to the presence of very dense underlying deposits, boulders or other large obstructions. Auger refusal is defined as the point at which an auger can no longer be practically advanced. It must be appreciated that conventional geotechnical sampling equipment does not differentiate between nature and size of obstructions that prevent further penetration of the boring below grade. Bedrock indicated on the borehole logs will be labeled 'possibly' or 'probable' etc. based on the response of the boring and sampling equipment, surrounding topography, etc. Bedrock can be proven at individual borehole locations, at your request, by diamond core drilling operations or, possibly, by testpits. It must also be appreciated that bedrock surfaces can be, and most times are, very erratic in nature (i.e. sheer drops, isolated rock knobs, etc.) and caution must be used when interpreting subsurface conditions between boreholes. A bedrock profile can be more accurately estimated, at the clients' request, through a series of closely positioned unsampled auger probes combined with core drilling.

4. **GROUNDWATER:** Although the groundwater table may have been encountered during this investigation and the elevation noted in the report and/or on the record of boreholes, it must be appreciated that the elevation of the groundwater table will fluctuate based upon seasonal conditions, localized changes, erratic changes in the underlying soil profile between boreholes, underlying soil layers with highly variable permeabilities, etc. These conditions may affect the design and type and nature of dewatering procedures. Cave-in levels recorded in borings give a general indication of the groundwater level in cohesionless soils however, it must be noted that cave-in levels may also be due to the relative density of the deposit, drilling operations etc.

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

METRIC

RECORD OF BOREHOLE NO. 1

Englobe

REFERENCE 15/04/15020 DATUM Geodetic LOCATION N 5046866.9 E 376490.3 - Canisbay Twp., Station 14+222.5 ORIGINATED BY JL

PROJECT GWP 5178-12-00, Highway 60 - F1 BOREHOLE TYPE Truck Mounted CME 45 - Hollow Stem Augers and NW casings COMPILED BY SH

CLIENT AECOM DATE (Started) 2015 June 24 DATE (Completed) 2015 June 24 TIME (Completed) 2:30:00 PM CHECKED BY MAM

ELEV DEPTH	DESCRIPTION (see Enclosure No. 1)	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
457.4	Ground Surface				
0.0	51 mm asphalt 203 mm crushed gravel EMBANKMENT FILL- sand, trace gravel to gravelly, trace to some silt Rock pieces of gravel to cobble sizes encountered at depths from 0.8 m to 2 m. Auger refual encountered at depth of 2 m. gravelly sand, some silt and clay brown, moist wet (compact/dense)	1	SS	17	
		2	SS	23	
		3	SS	46	35 51 (14)
		4	SS	31	
		5	SS	10	
		6	SS	22	39 44 (17)
453.3 4.1	SAND- trace to some gravel, some silt and clay brown to grey boulder and cobble encountered at depths of 4.6 m and 5.8 m, respectively (compact/very dense)	7	SS	17	
		8	SS	34/203m	19 67 (14)
		9	SS	52	
450.1 7.3	Start Bedrock Coring Bedrock - black gneiss Fair to good quality	10	RC	Rec.=95% RQD=71	
		11	RC	Rec.=100% RQD=87%	
447.1 10.3	End of Sampling End of Borehole				

Graph headings: STRATA PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (457, 456, 455, 454, 453, 452, 451, 450, 449, 448); 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
Advance borehole with N size casing and coring equipment below 2 m depth

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 120 kPa
○ 3% STRAIN AT FAILURE

WATER LEVEL RECORDS

Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
1) 15/6/24 2:30:00 PM	3.9	-
2) 15/6/24 2:35:00 PM	3.1	-
3) 15/8/7 7:50:00 AM	4.1	-

MEL-GEO 15020 - BOREHOL LOGS - F1.GPJ MEL-GEO.GDT 16/4/27

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

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

METRIC

RECORD OF BOREHOLE NO. 2

Englobe

REFERENCE 15/04/15020 DATUM Geodetic LOCATION N 5046862.4 E 376478 - Canisbay Twp., Station 14+212 ORIGINATED BY JL

PROJECT GWP 5178-12-00, Highway 60 - F1 BOREHOLE TYPE Truck Mounted CME 45 - Hollow Stem Augers and NW casings COMPILED BY SH

CLIENT AECOM DATE (Started) 2015 June 24 DATE (Completed) 2015 June 24 TIME (Completed) 6:20:00 PM CHECKED BY MAM

ELEV DEPTH	DESCRIPTION (see Enclosure No. 1)	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
457.0	Ground Surface						
0.0	76 mm asphalt 76 mm crushed gravel EMBANKMENT FILL- sand to gravelly sand, trace to some silt Rock pieces of gravel to cobble sizes encountered at depths from 0.9 m to 1.8 m. Auger refual encountered at depth of 1 m. cobble penetrated at depth of 1.5 m brown, wet (compact/very dense)	1	SS	29			12 78 (10)
		2	SS	20/0mm	456		
		3	SS	14	455		
		4	SS	30			6 77 15 2 NP
454.3 2.7	dark brown sand - trace gravel, some silt, trace clay, trace grass rootlets SAND - trace to some gravel, some silt and clay occasional rock pieces of cobble size encountered brown to greyish brown (compact/very dense)	5	SS	13	454		
		6	SS	55/76mm	453		
452.7 4.3	wet Start Bedrock Coring Bedrock - black gneiss good quality	7	RC	Rec.=95% RQD=79%	452		
		8	RC	Rec.=100% RQD=87%	451 450		
449.7 7.3	End of Sampling End of Borehole						

Column headings: SOIL PROFILE; STRATA PLOT; SAMPLES; GROUND WATER CONDITIONS; 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/m^3

COMMENTS
Advance borehole with N size casing and coring equipment below 1 m depth

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 120 kPa
○ 3% STRAIN AT FAILURE

WATER LEVEL RECORDS

Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
1) 15/6/24 6:20:00 PM	0.6	0.8
2)	-	-
3)	-	-

MEL-GEO 15020 - BOREHOL LOGS - F1.GPJ MEL-GEO.GDT 16/4/27

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

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

METRIC

RECORD OF BOREHOLE NO. 3

Englobe

REFERENCE 15/04/15020 DATUM Geodetic LOCATION N 5046875.3 E 376476.7 - Canisbay Twp., Station 14+222 ORIGINATED BY JL

PROJECT GWP 5178-12-00, Highway 60 - F1 BOREHOLE TYPE Track Mounted CME 45 - Hollow Stem Augers and NW casings COMPILED BY SH

CLIENT AECOM DATE (Started) 2015 August 7 DATE (Completed) 2015 August 7 TIME (Completed) 10:30:00 AM CHECKED BY MAM

ELEV DEPTH	DESCRIPTION (see Enclosure No. 1)	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
454.7	Ground Surface						
454.6 0.0	TOPSOIL - silty, with grass rootlets						
0.2	Dark brown SAND - with gravel, trace silt brown (compact)	1	SS	9		~19	21 72 (7)
453.9 0.8	Auger Refusal Start Bedrock Coring	2	SS	25/25mm	454		
	Bedrock - black gneiss with pink granite Fair to good quality	3	RC	Rec.=83% RQD=68%	453		
		4	RC	Rec.=97% RQD=88%	452		
450.9 3.8	End of Sampling End of Borehole				451		

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

Advance borehole with N size casing and coring equipment below 0.8 m depth

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 120 kPa

○ 3% STRAIN AT FAILURE

WATER LEVEL RECORDS

	Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
1)	15/8/7 10:30:00 AM	0.1	-
2)	15/8/17 4:00:00 PM	0.7	-
3)		-	-

MEL-GEO 15020 - BOREHOL LOGS - F1.GPJ MEL-GEO.GDT 16/4/27

EnGlobe Corp.

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

ENCLOSURE NO.:5 (Pg. 1 of 1)

METRIC

RECORD OF BOREHOLE NO. 4

Englobe

REFERENCE 15/04/15020 DATUM Geodetic LOCATION N 5046856.8 E 376502.8 - Canisbay Twp., Station 14+221 ORIGINATED BY JL

PROJECT GWP 5178-12-00, Highway 60 - F1 BOREHOLE TYPE Track Mounted CME 45 - Hollow Stem Augers and NW casings COMPILED BY SH

CLIENT AECOM DATE (Started) 2015 August 17 DATE (Completed) 2015 August 17 TIME (Completed) 4:10:00 PM CHECKED BY MAM

ELEV DEPTH	SOIL PROFILE DESCRIPTION (see Enclosure No. 1)	STRATA PLOT	SAMPLE 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)
453.3	Ground Surface										
453.0 / 0.0	TOPSOIL - silty, with grass rootlets										
0.2	Black		1	SS	8	∇	453		○		
	SAND - trace gravel, with silt and clay										
	brown		2	SS	37				○		8 70 (22)
451.8	(loose/dense)						452				
1.5	Auger Refusal Start Bedrock Coring										
	Bedrock - pink granite/black gneiss		3	RC	Rec.=97% RQD=89%		451				
	Good quality						450				
			4	RC	Rec.=100% RQD=84%		449				
448.7 / 4.6	End of Sampling End of Borehole										

COMMENTS
Advance borehole with N size casing and coring equipment below 1.5 m depth

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 120 kPa
○ 3% STRAIN AT FAILURE

WATER LEVEL RECORDS

	Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
1)	15/8/17 4:10:00 PM	0.2	4.6
2)		-	-
3)		-	-

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

Appendix 3 Borehole Plan and Lab Data

Drawing No. 2:	Borehole Location and Soil Strata
Figure Nos. L-1 and L-2:	Grain Size Distribution Curves
Table No. L-3:	Lab Test Summary Sheet

Englobe

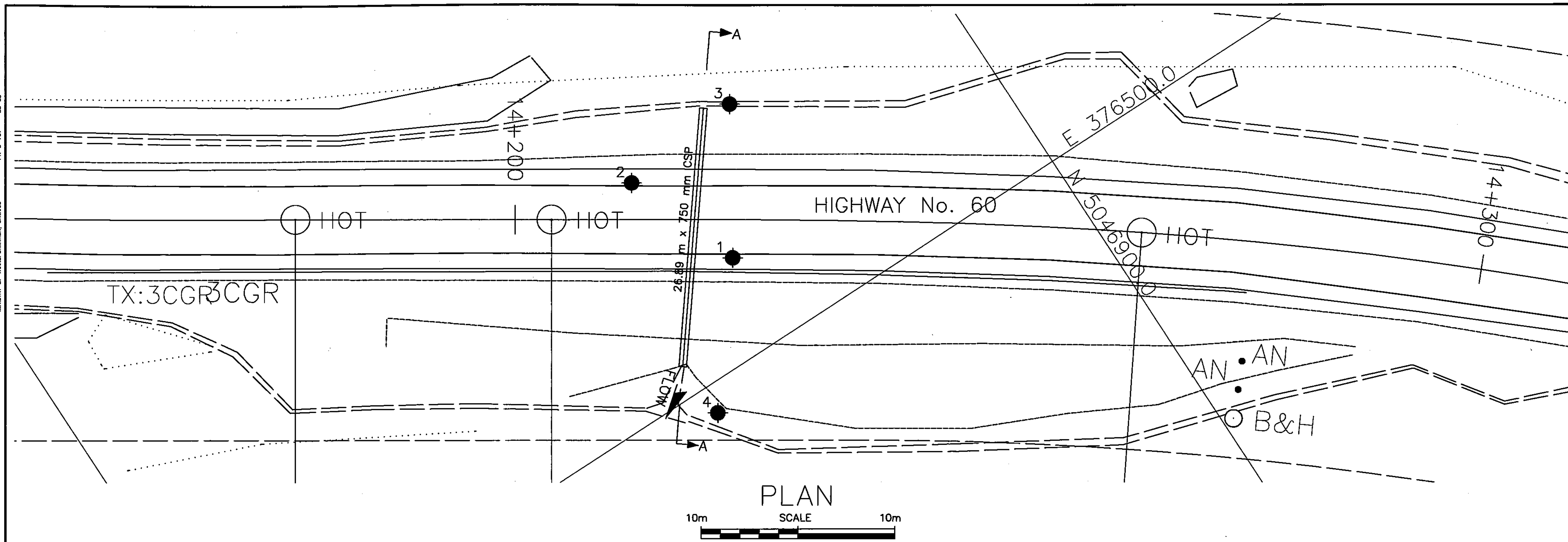
DISTRICT
CONT. No.
GWP No. 5178-12-00

HWY 60
CULVERT AT STA 14+219
TOWNSHIP OF CANISBAY

BOREHOLE LOCATIONS
AND SOIL STRATIGRAPHY

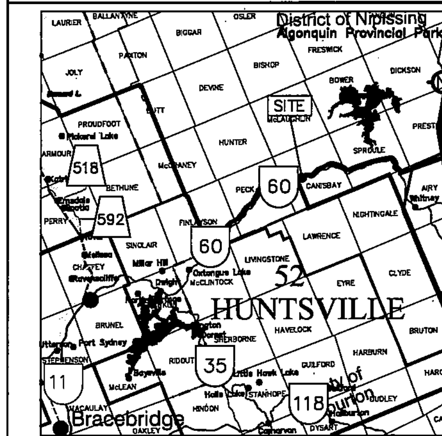
SHEET 2

Englobe



PLAN

10m SCALE 10m



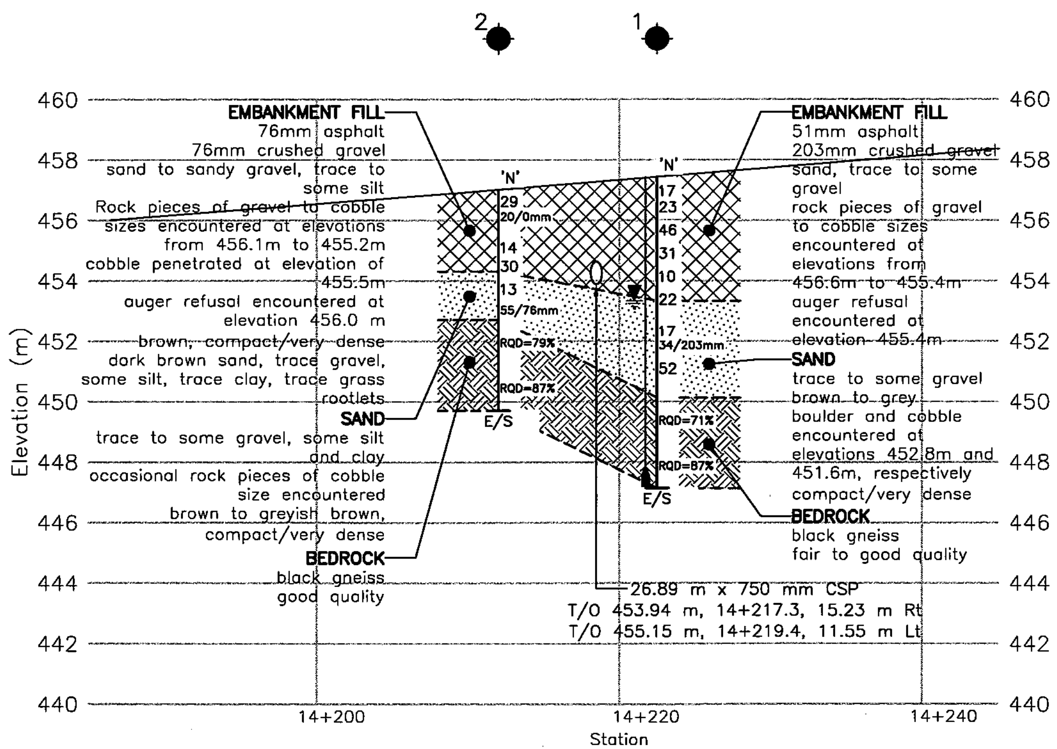
KEY PLAN

N.T.S.

LEGEND

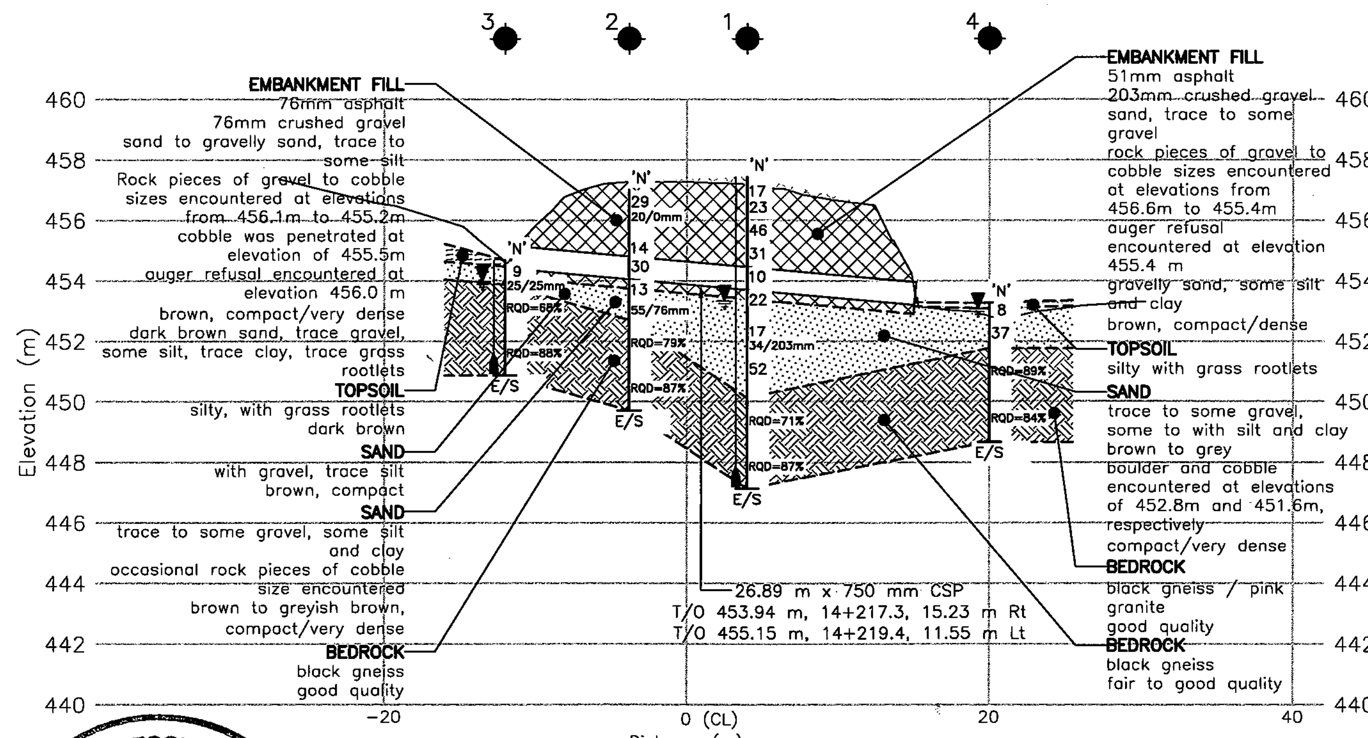
●	Borehole
N	Blows/0.3 m (Std Pen Test, 475 J/blow)
▼	Water Level at Time of Investigation
E/S	End of Sampling
	Piezometer

BOREHOLE No.	ELEVATION	O/S	NORTHING	EASTING
1	457.4	4.0m Rt	5046866.9	376490.3
2	457.0	3.8m Lt	5046862.4	376478.0
3	454.7	12.0m Lt	5046875.3	376476.7
4	453.3	20m Rt	5046856.8	376502.8



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

LICENSED PROFESSIONAL ENGINEER
S. HU
90524232
16/05/06
PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER
M. A. MERLEAU
16/05/06
PROVINCE OF ONTARIO

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.

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.

The thickness of fill directly below the culvert has been assumed at 300 mm on the cross section.

Base plan and alignment provided in digital format by Callon Dietz on October 1, 2015

Coordinates based on MTM Zone 10 NAD83 CSRS

GEOCRES No. 31E-354

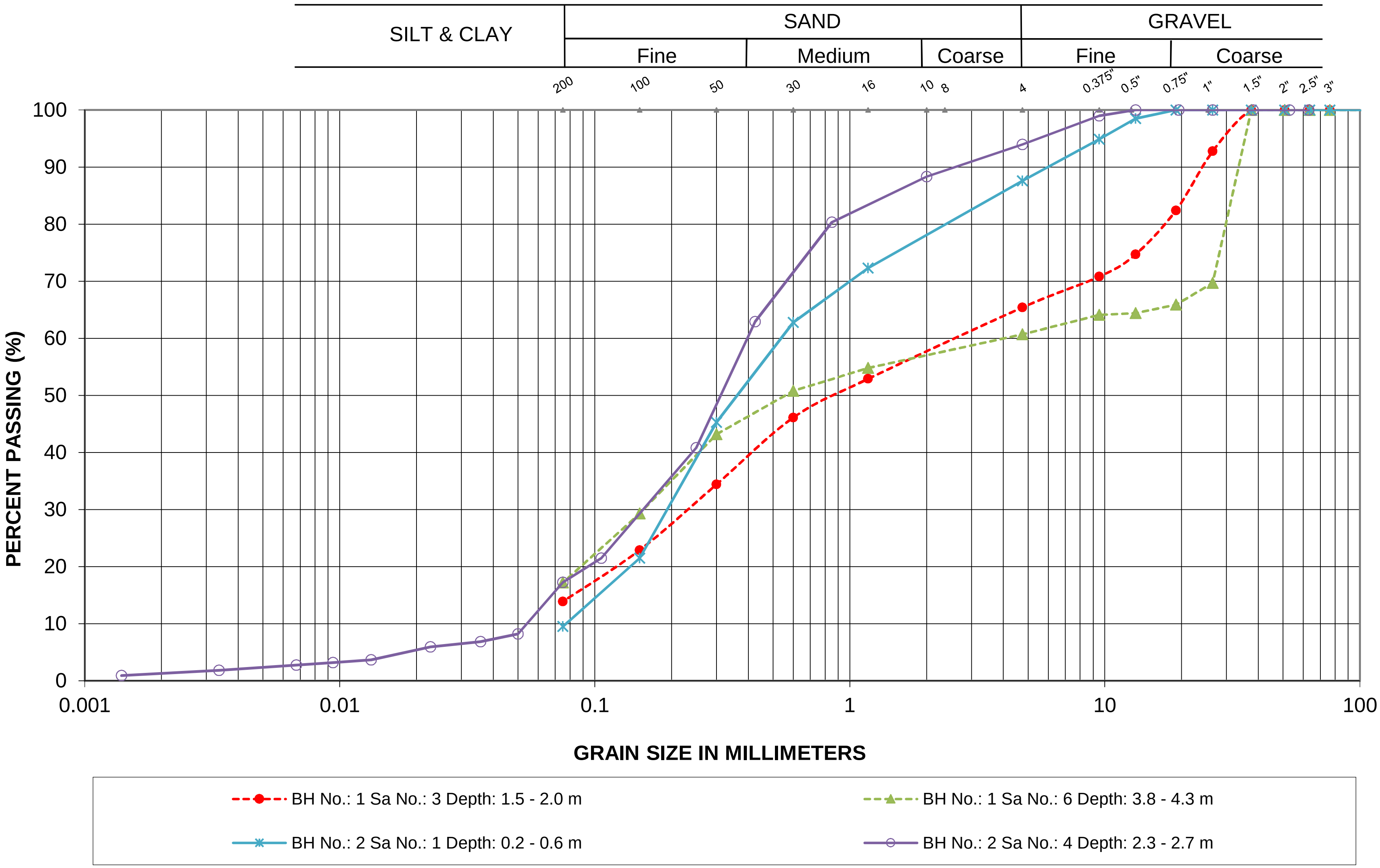
REVISIONS			
DEC/15	DM	DRAFT	
APR/16	DM	FINAL	
		DESCRIPTION	

DESIGN	CHK	CODE	LOAD		DATE APR/16
DRAWN DM	CHK SH	SITE	STRUCT	SCHEME	DWG 2

CAD FILE LOCATION AND NAME:G:\2015\15020 - PAV & FDN, Hwy 60 & 118, 5014-E-0004 (AECOM)\FOUNDATION\Drawings\F1\15020 - F1 - Sta 14+220.dwg
MODIFIED: 4/19/2016 11:57:55 AM BY: MITCOU
DATE PLOTTED: 4/19/2016 1:47:26 PM BY: DUNCAN MITCHELL

Reference No.: 15/04/15020-F1
Date: November, 2015

GRAIN SIZE ANALYSIS



EMBANKMENT FILL

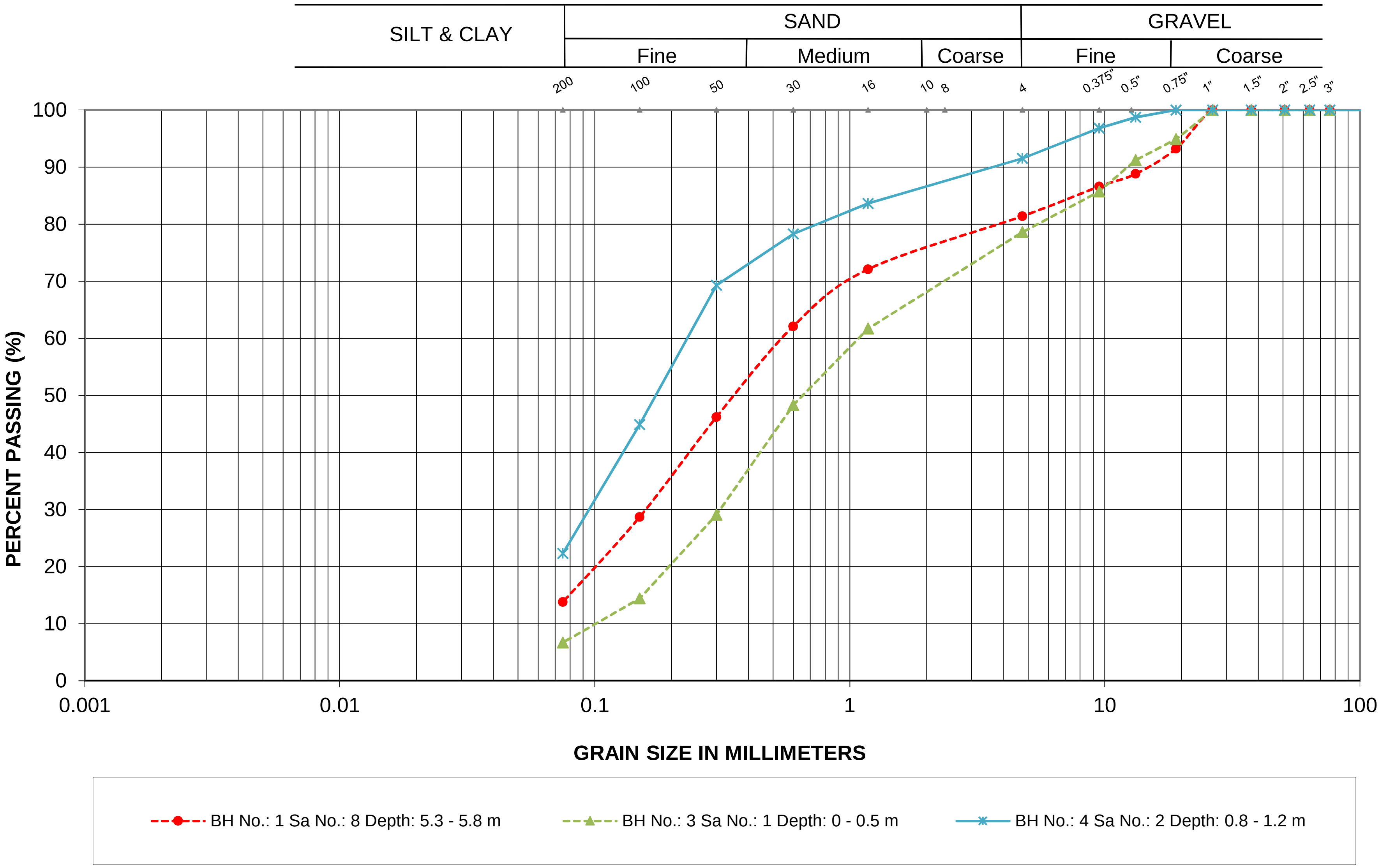
LOCATION: Hwy 60, Culvert Station 14+219
TWP of Canisbay

Englobe Corp.

FIGURE L-1

Reference No.: 15/04/15020-F1
Date: November, 2015

GRAIN SIZE ANALYSIS



SAND

LOCATION: Hwy 60, Culvert Station 14+219
TWP of Canisbay

Englobe Corp.

FIGURE L-2

Reference No.: 15/04/15020-F1
Date: November 2015

Laboratory Tests - Summary Sheet

Borehole No.	Sample No.	Depth	Grain Size Analysis				NMC	Atterberg Limits			SPT 'N'	USCS	Unit Weight (kN/m3)	Remarks
			Gravel Size (%)	Sand Size (%)	Silt Size (%)	Clay Size (%)		LL (%)	PL (%)	IP (%)				
1	1	0.3					3.0				17			
	2	1.0					6.0				23			
	3	1.8	35	51	14		9.0				46			
	4	2.5					13.0				31			
	5	3.3					8.0				10			
	6	4.0	39	44	17		16.0				22			
	7	5.1					20.0				17			
	8	5.6	19	67	14		12.0				34/203mm			
	9	6.3					2.0				52			
	10	7.3												Rec= 95%, RQD= 71%
	11	8.8												Rec= 100%, RQD= 87%
2	1	0.3	12	78	10		4.0				29			
	2	0.8					3.0				20/0mm			
	3	1.9					12.0				14			
	4	2.5	6	77	15	2	16.0				30			Non-plastic
	5	3.3					16.0				13			
	6	3.9					8.0				55/76mm			
	7	4.3												Rec= 95%, RQD= 79%
	8	5.8												Rec= 100%, RQD= 87%
3	1	0.2	21	72	7		21.0				9			
	2	0.8									25/25mm			
	3	0.8												Rec= 83%, RQD= 68%
	4	2.3												Rec= 97%, RQD= 88%
4	1	0.2					28.0				8			
	2	1	8	70	22		15.0				37			
	3	1.5												Rec= 97%, RQD= 89%
	4	3												Rec= 100%, RQD= 84%

Project: Hwy 60, Culvert Sta. 14+219, Township of Canisbay

Table No. L-3

Appendix 4 Photo Essay

Enclosure No. 6: Photo Essay

Embankment at Culvert Location – Looking East	Photo: 1

Embankment at Culvert Location – Looking West	Photo: 2

Project: Hwy 60 – Culvert, Station 14+219, Township of Canisbay	Photos Provided By: Englobe Date: June and August 2015

Culvert Outlet – Looking South	Photo: 3
	
View of Culvert Inlet – Looking above inlet	Photo: 4
	
Project: Hwy 60 – Culvert, Station 14+219, Township of Canisbay	Photos Provided By: Englobe Date: June and August 2015

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

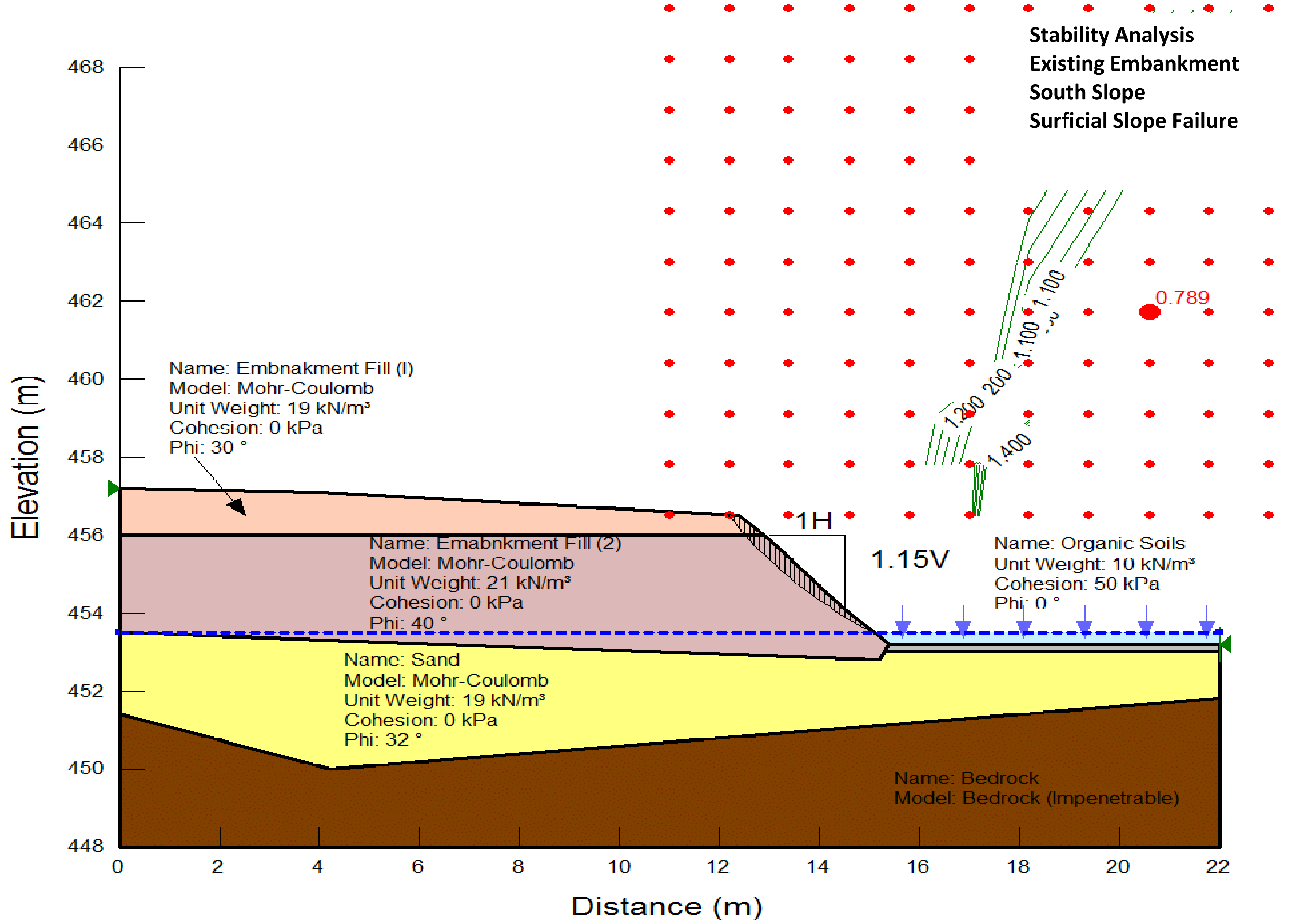
Project: Hwy 60 – Culvert, Station 14+219, Township of Canisbay	Photos Provided By: Englobe Date: June and August 2015

Rock Cores – Borehole 3 (left) and Borehole 4 (right)	Photos: 7 and 8

Project: Hwy 60 – Culvert, Station 14+219, Township of Canisbay	Photos Provided By: Englobe Date: June and August 2015

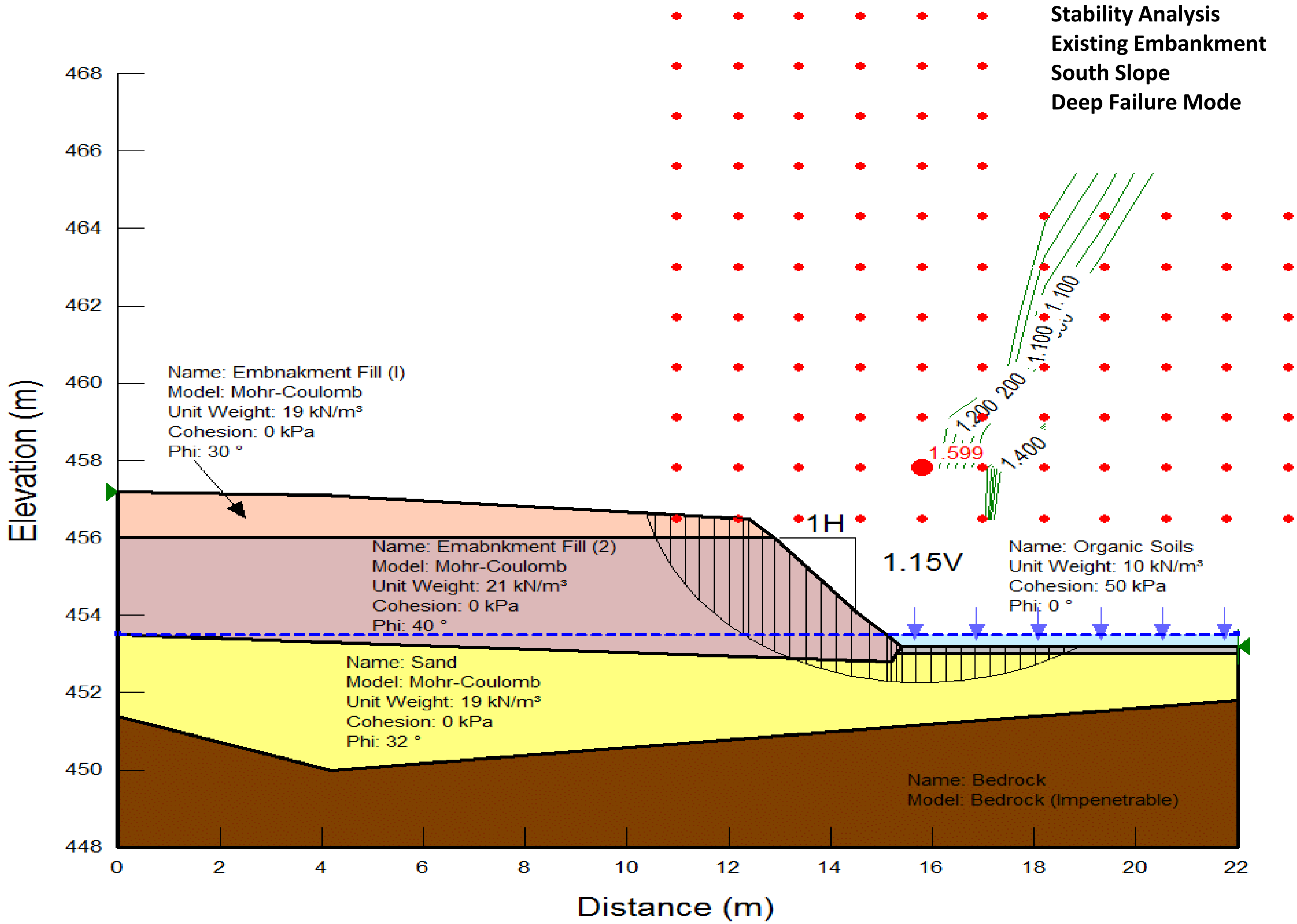
Appendix 5 Design Data

Figure Nos. S-1 to S-4:	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



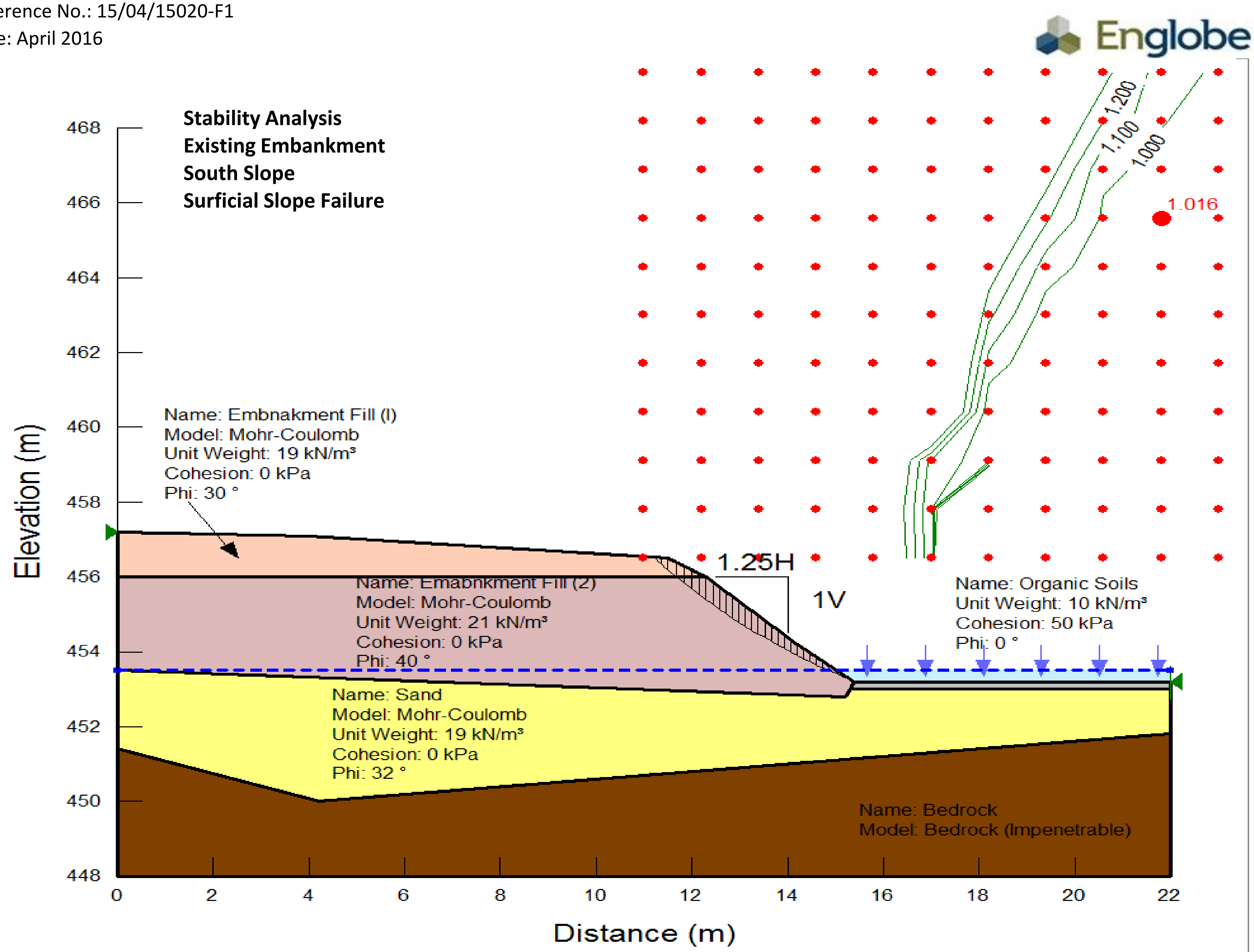
South Slope
Culvert Station 14+219

Stability Analysis
Existing Embankment
South Slope
Deep Failure Mode



South Slope
Culvert Station 14+219

Reference No.: 15/04/15020-F1
Date: April 2016

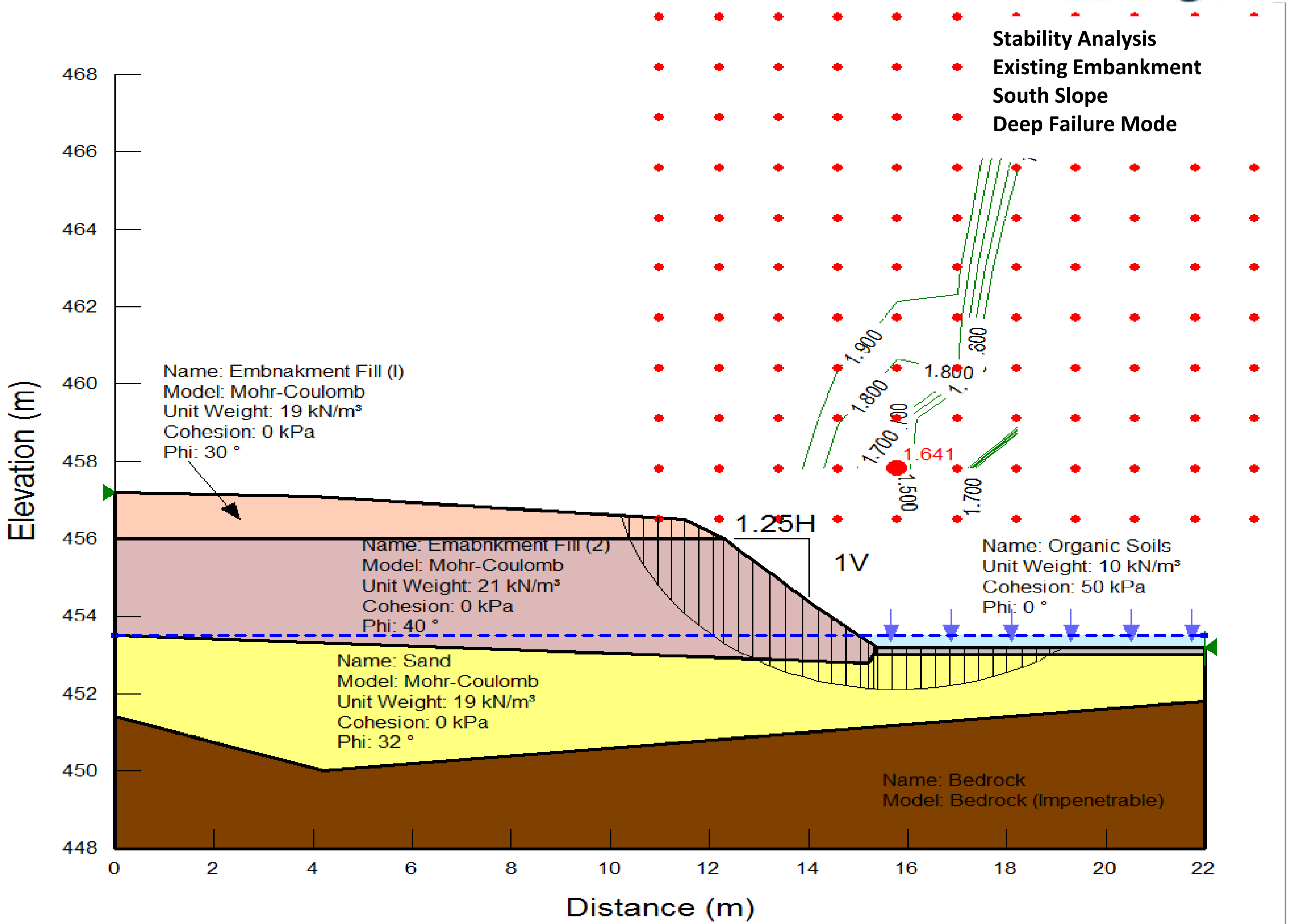


South Slope
Culvert Station 14+219

Project: G.W.P 5178-12-00
Location: Hwy 60, Township of Canisbay

Figure No. S-3

Reference No.: 15/04/15020-F1
Date: April 2016



South Slope
Culvert Station 14+219

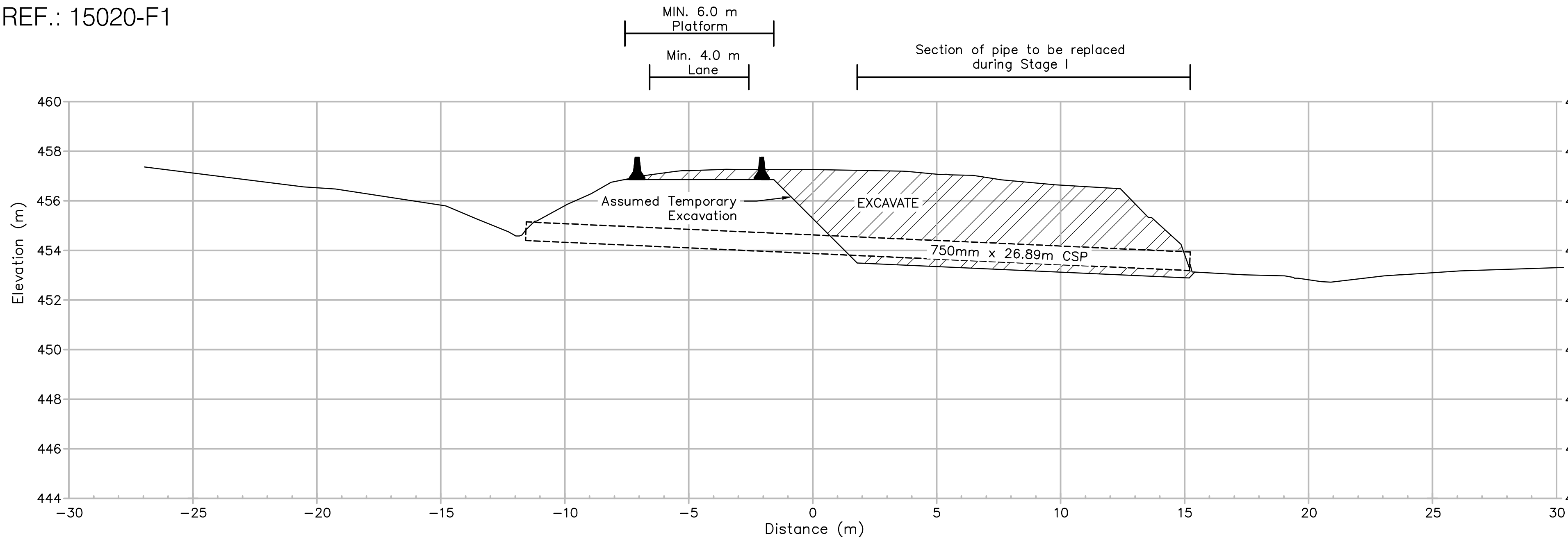
Project: G.W.P 5178-12-00
Location: Hwy 60, Township of Canisbay

Figure No. S-4

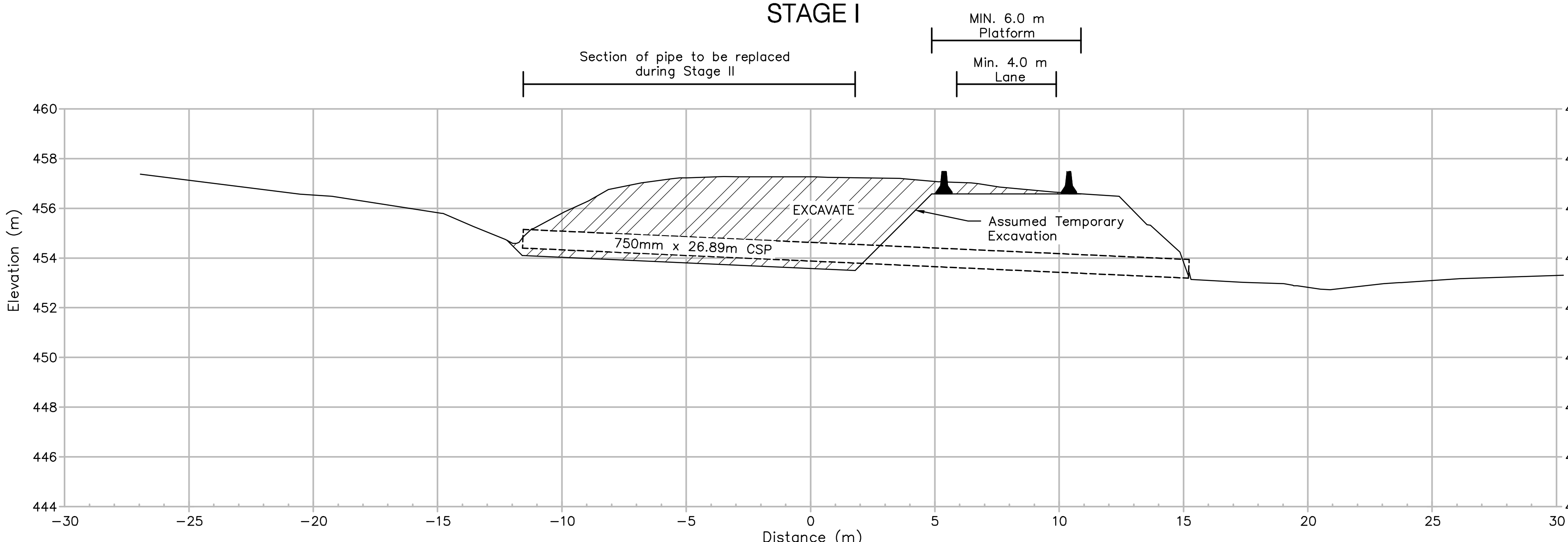
Table A – Comparison of Shoring Alternatives

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 strength, -discontinuous	Not considered due to rock fill embankment	\$ 650/m^2
Steel Sheet Piles	5 – 21	-High strength, continuous, -Readily available	-Limited by soil conditions (i.e. obstructions)	Not considered due to rock fill embankment	\$ 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 ground conditions and higher cost	
Soldier piles	5 – 25	-Easy installation -Readily available -Adaptable to various ground conditions	-Pre-drilling may be required -Possible ground loss	Recommended for protection system on the condition of pre-drilling if refusal and bedrock encountered	\$ 725/m^2 Predrilling \$ 1,500/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	Considered as alternative for protection system due to higher cost	
Concrete Diaphragm	10 – 30	-High Strength -Durable -Can be permanent	-High cost -Requires specialized equipment/control	Not considered due to ground conditions and 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 due to higher cost	\$ 1,200 – 1,500/m^2

REF.: 15020-F1



STAGE I



STAGE II

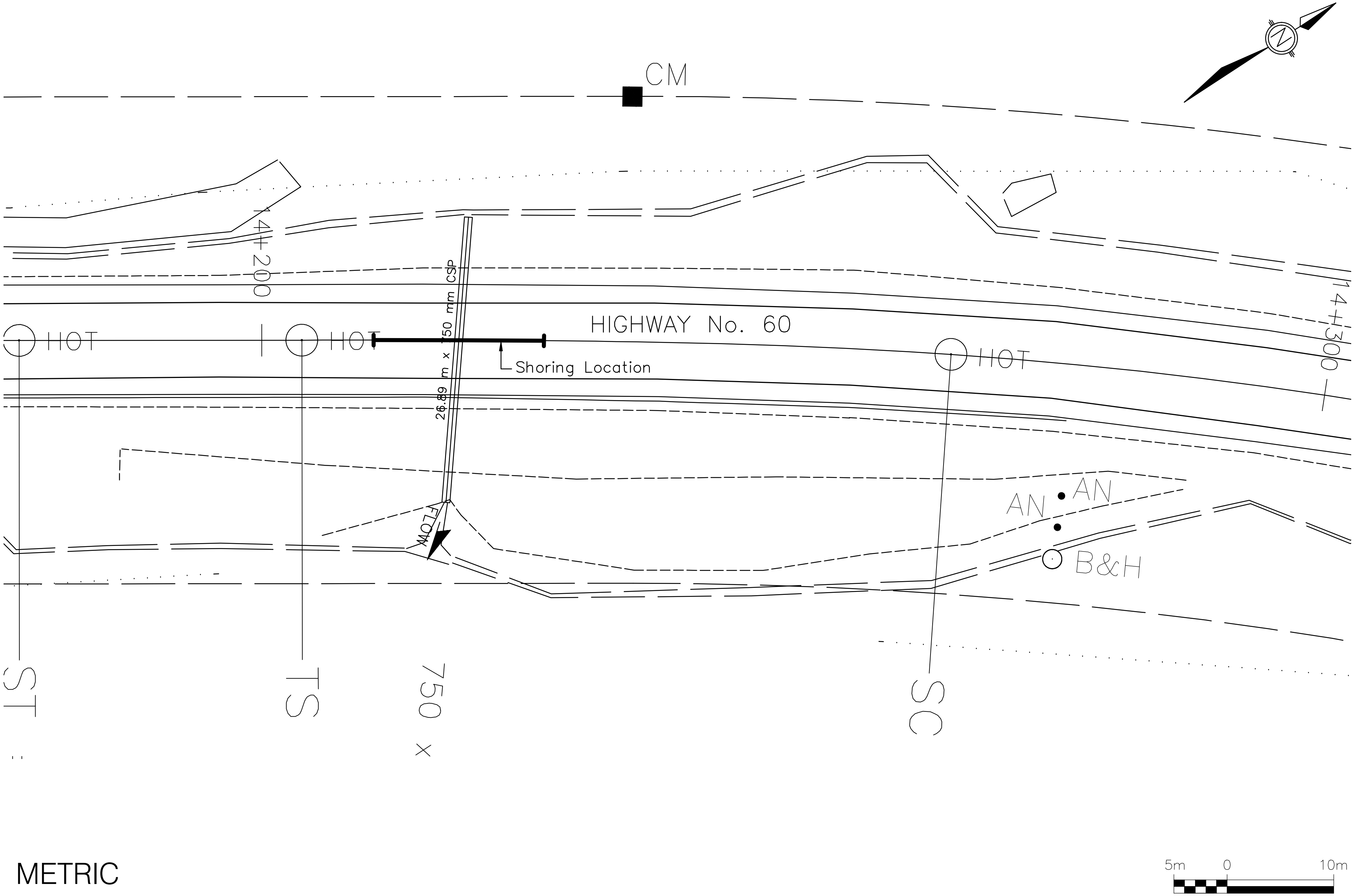
2.5m 0 5m

METRIC

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

Highway 60, Township of Canisbay - Culvert at Station 14+219 Conceptual Shoring Location Plan	FIGURE SK-3

REF.: 15020-F1

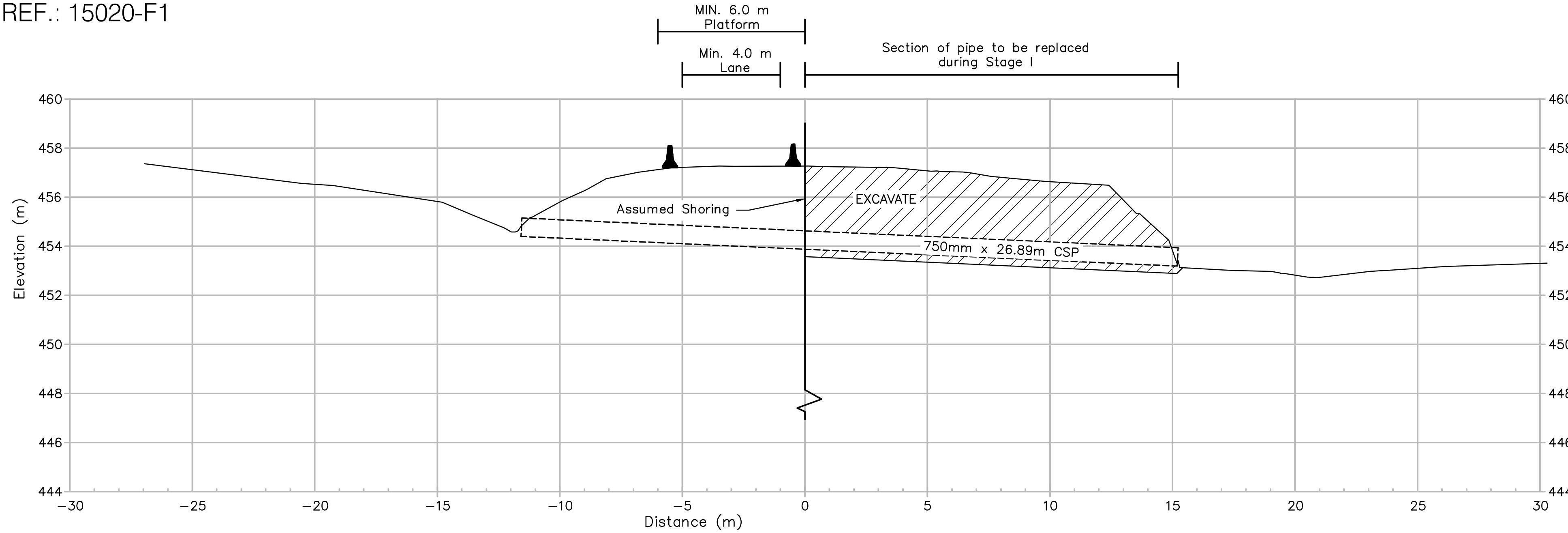


METRIC

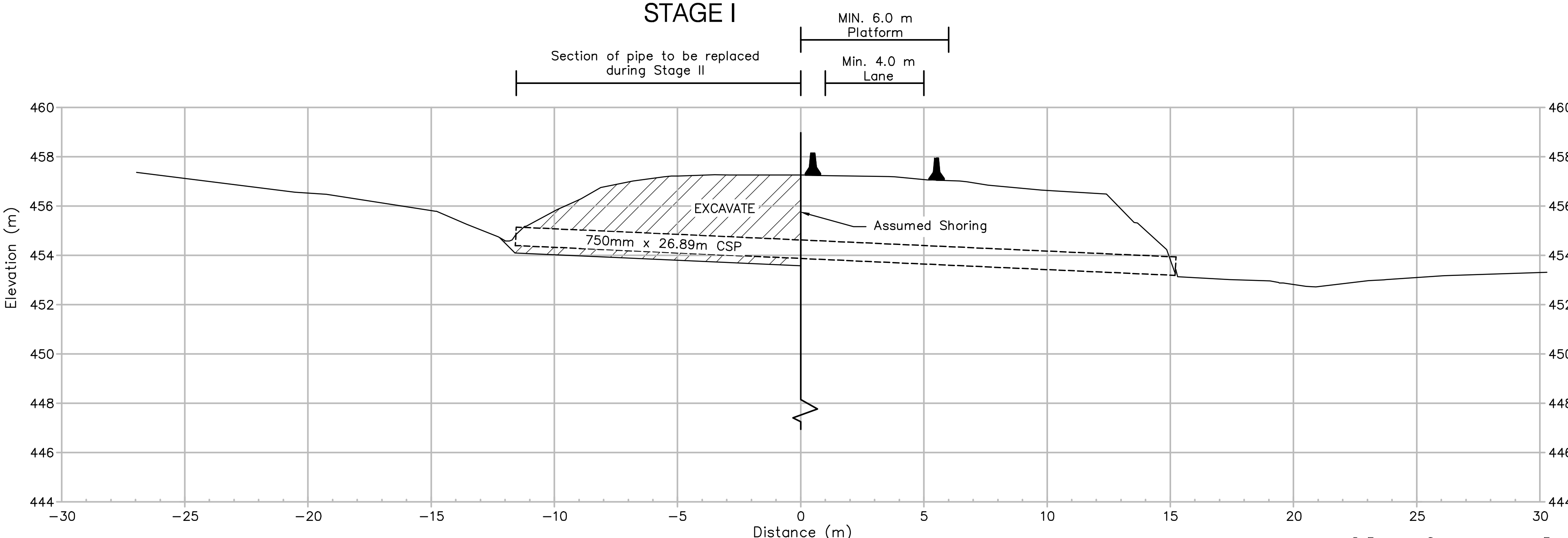
Dimensions are in meters and/or millimeters unless otherwise shown. Stations are in kilometers + meters.

Highway 60, Township of Canisbay - Culvert at Station 14+219 Conceptual Shoring Location Plan	FIGURE SK-4

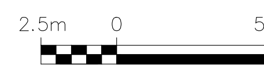
REF.: 15020-F1



STAGE I



STAGE II



METRIC

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

Highway 60, Township of Canisbay - Culvert at Station 14+219
Conceptual Shoring Location Plan

FIGURE SK-5

<u>NOTICE TO CONTRACTOR</u> – Obstructions in Fills and Fluctuations of Ground/Surface Water

Special Provision

The Contractor is notified that, during foundation field investigations for the Structural Culvert at Station 14+219, Township of Canisbay, on Highway 60, cobble/boulder sized rock fill was encountered in the embankment fills. The bedrock was encountered at relatively shallow depths below the embankment fills and native soils at the existing culvert location. The contractor shall take into account these materials as well as the seasonal and yearly fluctuations of ground/surface water when designing and installing the Dewatering and Protection Systems.

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