THURBER ENGINEERING LTD.

January 6, 2017 Project No.: 14178

McIntosh Perry Consulting Engineers Limited
1-1329 Gardiners Road
Kingston, Ontario, K7P 0L8

Attention: Marc McIntosh, P.Eng.

FOUNDATION ENGINEERING SERVICES
HIGHWAY 11 REHABILITATION MISSINAIBI RIVER TO HYUNDAI ROAD
HAMILTON CREEK CULVERT REPLACMENT, SITE NO. 39W-230/C
CONTRACT DB 2016-5012

Geocres No.: 42G-65

Dear Mr. McIntosh:

As part of the Foundation Engineering component to support the design team for the above captioned assignment, Thurber Engineering Limited (Thurber) has reviewed the Foundation Investigation and Design Report (Geocres No.: 42G-56) previously completed by Englobe. The report, dated February 2016, includes the results of a site investigation and provides geotechnical design recommendations for the replacement of the Hamilton Creek culvert. It must be noted that Englobe is solely responsible for the accuracy and quality of the subsurface information provided in their report. A copy of the report is appended.

It is understood that the replacement culvert will consist of a 5.4 m span by 2.7 m rise precast concrete box culvert with precast concrete cut-off walls. The culvert is to be installed along a new alignment west of the existing culvert with an invert approximately 0.3 m below that of the existing culvert. To facilitate installation, a highway centerline roadway protection system will be utilized in addition to a protection system running parallel between the new and existing culverts.

In general, the Englobe report presents adequate borehole information on which to base geotechnical design recommendations for the culvert replacement. Please refer to the recommendations in the attached report augmented with the following additional recommendations and/or clarifications.

5.3 Culvert Design, Bedding and Embedment

Since the proposed culvert will be on a new alignment through existing fill, no significant settlement is expected as there will be a net unloading due to the removal of fill material required to place the new box culvert.

Settlement is expected however in the existing culvert alignment as fill material will be required after removal of the existing culvert to reinstate the embankment. Additional loading is expected to be less than 50 kPa over the length of the culvert which is expect to cause 20 to 50 mm of settlement, with approximately 90% of this settlement expected to occur during construction. Placement of the final lift of asphalt should be delayed for at least a month.

Foundation settlement outside the embankment footprint is anticipated to be negligible provided fill and stockpiling of materials is not placed above the current grades.

A settlement monitoring plan will be developed as per Section 2.4.9.10 of the RFP. The Contractor shall be prepared to install the monitoring points and benchmarks to implement the monitoring plan prior to start of construction. This may include installation of monitoring points at the adjacent rail alignment based on the limits of the proposed construction activities.

5.3.1 Rigid Concrete Culvert

Given the loose saturated silt subgrade conditions anticipated at the founding level of the replacement culvert, construction equipment should not be permitted to travel on the exposed subgrade. In addition, compaction of granular bedding directly above the subgrade is likely to result in disturbance of the material with pumping of fines into the granular bedding and difficulty achieving the specified degree of compaction. Protection of the subgrade should include over excavation to allow placement of a mud slab 100 mm thick beneath the 300 mm thick Granular A bedding layer.

Cover material and structural backfill should consist of Granular A or Granular B Type II material placed as indicated on OPSD 803.010

5.4.2 Protection System

Temporary Roadway Protection (TPS) will be required during various stages of construction and must be implemented in accordance with OPSS.PROV 539 designed for Performance Level 2. The pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the shoring system. The TPS design is the responsibility of the Contractor and must be carried out by an experienced Professional Engineer.

The protection system to be installed parallel to the alignment of the culverts should be installed at a sufficient distance away from the new culvert to limit the disturbance to subgrade associated with removal of the protection system following completion of construction. Alternatively, the sheet piles could be left in place and cut off at or below 2.6 m beneath the finished pavement grade.

5.5 Excavation, Dewatering and Embankment Construction

The depth of frost penetration at this site is 2.6 m and frost treatment should follow the recommendations provided within the Pavement Design Report.

It should be noted that the mud slab and bedding materials should be placed as soon as practical to protect the subgrade from disturbance during construction. Organic soils, alluvial deposits, soft or loose deposits, disturbed soils and deleterious materials must be removed from the footprint of the foundation to expose competent native subgrade material at or below the desired founding elevation. The exposed subgrade must be inspected by a qualified geotechnical personnel retained by the Contractor to confirm that the subgrade is suitable and uniformly competent. Any soft or organic materials should be sub-excavated and backfilled and compacted as per OPSS.PROV 501 with granular fill consisting of OPSS.PROV 1010.

Where new embankment fill is placed against existing embankment slopes or on a sloping ground surface steeper than 3H:1V, benching of the existing slope should be carried out in accordance with OPSD 208.010.

We concur with Geocres Report No.: 42G-56 that construction dewatering is critical given the silt subgrade. In addition to creek diversion, dewatering is the Contractor's responsibility. The dewatering design should be completed by an experienced specialist and must consider the soil and groundwater conditions as well as the Temporary Protection Systems. The dewatering system must lower groundwater to at least 0.5 m below the excavation base and must remain operational until the culvert is backfilled.

5.6 Lateral Earth Pressures

The earth pressure coefficients in the table provided in the Preliminary FIDR correspond to full mobilization of active and passive earth pressure and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design can be assessed from Figure C6.16 of the Commentary to the CHBDC.

Where ground surfaces are sloped behind the walls, the appropriate earth pressure coefficients which include the inclination of the ground surface should be used. Applicable parameters for cohesionless soils are included in the table below:

Soil Type	Active Earth Pressure Coefficient (K_A) for a Sloping Surface Behind a Wall Inclined at 2H:1V
Granular A	0.42
Granular B Type I	0.44
Granular Fill	0.54
Mixed Fill	See page 13 of report
Silt	0.55
Clay Tills	See page 13 of report
Silt Tills	0.47

5.8 Seismic Considerations (*New Section*)

5.8.1 Spectral and Peak Acceleration Hazard Values

The seismic hazard data for the CHBDC is based on the fifth generation seismic model developed by the Geological Survey of Canada (GSC). Seismic hazard data for this site has been obtained from the GSC's seismic hazard calculator. The data includes peak ground acceleration (PGA), peak ground velocity (PGV), and the 5% damped spectral response acceleration values (Sa(T)) for the reference ground condition (Site Class C) for a range of periods (T) and for a range of return periods including the 475-year, 975-year and 2475-year events. The GSC seismic hazard calculation data sheet for this site is attached.

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The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class and the reference peak ground acceleration (PGA_{ref}).

5.8.2 CHBDC Seismic Site Classification

In accordance with the CHBDC, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy. The Seismic Site Class for this culvert is a Site Class E in accordance with Table 4.1 of the CHBDC.

5.8.3 Seismic Liquefaction

The potential for liquefaction of the foundation soils has been assessed using both the Bray et al. (2004) criteria for liquefaction assessment of fine grained soils and by comparing Cyclic Stress Ratio to Cyclic Resistance Ratio generated from the SPT N-values. Using these methods, the results indicate that an adequate Factor of Safety against liquefaction under earthquake loading exists for this site using the site-specific PGA value factored for Site Class E.

Closure

We trust this letter is sufficient for your purposes at this time; however, should you have any questions, or require additional information, please feel free to contact our offices.

Yours truly,
Thurber Engineering Ltd.

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Attachments

1. GSC Seismic Hazard Calculation
2. Englobe Foundation Investigation and Design Report, Hamilton Creek, Geocres No. 42G-56

2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

November 18, 2016

Site: 49.5935 N, 83.171 W   User File Reference: Hamilton Creek Culvert

Requested by: Chris Murray, Thurber Engineering

National Building Code ground motions: 2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.05)	Sa(0.1)	**Sa(0.2)**	Sa(0.3)	**Sa(0.5)**	**Sa(1.0)**	**Sa(2.0)**	**Sa(5.0)**	**Sa(10.0)**	**PGA (g)**	**PGV (m/s)**
0.067	0.090	**0.083**	0.067	**0.052**	**0.030**	**0.015**	**0.0034**	**0.0015**	**0.049**	**0.039**

Notes. Spectral (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s. Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are specified in **bold** font. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. ***These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.***

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.0049	0.021	0.036
Sa(0.1)	0.0082	0.031	0.051
Sa(0.2)	0.0096	0.031	0.049
Sa(0.3)	0.0086	0.027	0.041
Sa(0.5)	0.0064	0.021	0.033
Sa(1.0)	0.0032	0.012	0.019
Sa(2.0)	0.0012	0.0050	0.0086
Sa(5.0)	0.0003	0.0011	0.0018
Sa(10.0)	0.0003	0.0006	0.0009
PGA	0.0045	0.017	0.028
PGV	0.0036	0.014	0.023

References

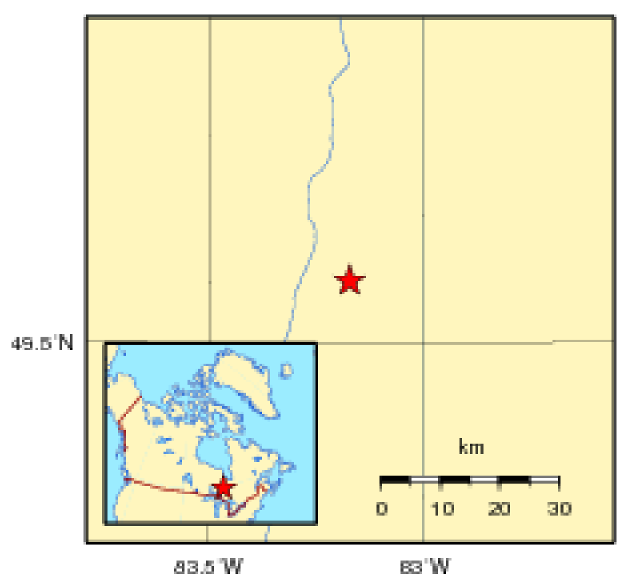
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

User's Guide - NBC 2015, Structural Commentaries NRCC no. xxxxxx (in preparation)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites *www.EarthquakesCanada.ca* and *www.nationalcodes.ca* for more information

Aussi disponible en français



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 11 – Unknown Creek Culvert (Hamilton Creek)
Site No. 39W-230/C
Station 18+063 – Township of Eilber
GWP 5145-05-00

FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

Date: February 16, 2016
Ref. №: 15/05/15059-F4

Geocres No. 42G-56

Englobe

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Culvert Replacement
Highway 11 - Unknown Creek Culvert (Hamilton Creek)
Site No. 39W-230/C
Station 18+063 – Township of Eilber
GWP 5145-05-00

Final Foundation Investigation and Design Report

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Property and Confidentiality

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REVISION AND PUBLICATION REGISTER		
Revision N°	Date	Modification And/Or Publication Details
00	2015-11-30	DRAFT FIDR Issued
01	2016-02-16	FINAL FIDR Issued

REPORT DISTRIBUTION	
2 hard copies	AECOM
5 hard copies and 1 electronic copy	MTO Project Manager
1 hard copy and 1 electronic copy	MTO Pavement and Foundations Section, Foundation Group
1 hard copy	File

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 culvert site. The site has been identified as Site No. 39W-230/C and is located on Highway 11 at Station 18+063 in the Township of Eilber, some 5.8 km east of the intersection between Highway 11 and Gagnon Road.

The foundation investigation location was specified by the MTO in the Terms of Reference for work under Agreement No. 5014-E-0001: GWP 5145-05-00. The terms of reference for the scope of work are outlined in Englobe's Proposal P-14-178 dated February 18, 2015. The purpose of this investigation was to determine the subsurface conditions in the area of the existing culvert. 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

The existing Corrugated Steel Pipe (CSP) culvert is located on Highway 11 at Station 18+063 in the Township of Eilber. The topography of this site is generally flat. 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 supporting on an embankment consisting of granular fills overlying mixed fills, some 3.5 m in height, with centerline elevation of 233.1 m at the culvert location. The existing embankment slopes in the area of the culvert have been built between angles ranging from approximately 4.0H:1V to 4.3H:1V. The culvert at this location has been described as a 3.4 m diameter Corrugated Steel Pipe (CSP) culvert, some 24.5 m long in the RFP, however the current survey has indicated the culvert is a 3860x2460 mm Corrugated Steel Pipe Arch (CSPA) culvert some 24.5 m in length. For the purpose of this report the culvert will be described as a 3860x2460 mm CSPA culvert, some 24.5 m in length. The flow through the culvert is from the south to the north (right to left).

Infrastructure at this site consists of overhead communication lines running parallel to the highway embankment to the north and the south of the embankment. An Ontario Northland Rail Line runs to the south of the highway embankment.

2.1 SITE PHYSIOGRAPHY AND SURFICIAL GEOLOGY

This project is located in the Geomorphic Sub-province known as the Cochrane Clay Plain. The topography on this section of Highway 11 is generally flat. Significant layers of earth overlay the bedrock. Within the project area native overburden primarily consists of fine grained silts overlying a till deposit.

Bedrock in the area, as indicated on OGS Map 2506, is of the Early Precambrian felsic igneous and metamorphic rocks consisting of granitic, metasedimentary, and minor metavolcanic migmatite.

3 INVESTIGATION PROCEDURES

The fieldwork for this investigation was carried out between the period of July 25th and August 14th, 2015 during which time three (3) sampled boreholes were advanced. One (1) borehole was advanced through the embankment at the location of the culvert, and one (1) borehole was advanced adjacent to each of the inlet (south) and outlet (north) ends of the culvert.

The field investigation was carried out using 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 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. When cohesive deposits were encountered, the in-situ strength was measured using an “N” size field vane, vane collar, and calibrated torque meter. 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 single 19 mm diameter standpipe was installed in selected open boreholes prior to backfilling to allow for post borehole completion 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 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, 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-6 and Table No. L-7).

The location of the individual boreholes was determined in the field using highway chainage (established by Callon Dietz Inc.) and offset relative to highway centerline. The MTO co-ordinates, northing and easting, were then established for the boring locations. Elevations contained in this report are referenced to a geodetic datum. The borehole elevations are based on a survey carried out by Callon Dietz Inc..

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 18+063, TWP OF EILBER

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 adjacent to the culvert, 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, inclusive, were recorded at elevations 232.8, 232.5, and 231.9 m, respectively.

4.1.1 Pavement Structure

Borehole No. 1 was advanced through the embankment shoulder where a layer of crushed gravel some 150 mm thick was penetrated.

4.1.2 Granular Fill

Underlying the pavement structure at Borehole No. 1, a layer of fill consisting of brown sand trace gravel, some silt was penetrated. The natural moisture content measured on samples of this deposit was in the order of 4 to 20%. Gradation analyses were carried out on one (1) sample of this deposit, the results of which indicated 2% gravel size particles, 85% sand size particles, and 13% silt and clay size particles (Figure No. L-1, Appendix 3). Based on SPT ‘N’ values of 7 to 17 blows per 300 mm penetration, the compactness of this deposit was described as loose to compact. This granular fill layer was encountered to a depth of 2.1 m below grade at Borehole No. 1 (elevation 230.7 m, respectively).

4.1.3 Mixed Fills

Underlying the granular fills at BH No. 1 and at surface at Borehole Nos. 2 and 3, layers of fills consisting of a mixture of brown sand and grey silty clay, trace to some gravel, trace sand, trace organics (i.e. rootlets, wood, etc.) to silty clay was penetrated. The natural moisture content measured on samples of this deposit was in the order of 6 to 40%. Gradation (hydrometer) analyses were carried out on two (2) samples of this deposit, the results of which indicated 0% gravel size particles, 2 to 3% sand size particles, 30 to 77% silt size particles, and 20 to 68% clay size particles (Figure No. L-2, Appendix 3). Atterberg Limits testing was carried out on two (2) samples of this deposit the results of which indicated a Plastic Limit in the order of 18 to 28% and a Liquid Limit in the order of 26 to 55%, indicating a silty clay of low to high plasticity (Figure No. L-6, Appendix 3). Based on an in-situ shear strength of greater than 100 kPa, and SPT 'N' values of 2 to 11 blows per 300 mm penetration, the consistency of this deposit was described as firm to very stiff, very stiff. This fill layer was encountered to depths of 2.6, 2.9, and 2.9 m below grade at Borehole Nos. 1, 2, and 3, respectively (elevations 230.2, 229.6, and 229.0 m, respectively).

4.1.4 Silt

Underlying the mixed fills at Borehole Nos. 1, 2, and 3, a deposit of brown to grey silt, trace sand, trace clay, was penetrated. The natural moisture content measured on samples of this deposit was in the order of 21 to 27%. Gradation (hydrometer) analyses were carried out on two (2) samples of this deposit, the results of which indicated 0% gravel size particles, 0 to 1% sand size particles, 92 to 93% silt size particles, and 6 to 8% clay size particles (Figure No. L-3, Appendix 3). Atterberg Limits testing was attempted on two (2) samples of this deposit, however, was found to be non-plastic. Based on the SPT 'N' values of 6 to 13 blows per 300 mm penetration, the compactness of this deposit was described as loose to compact, generally loose. This deposit was encountered to depths of 4.6, 3.7, and 4.3 m below grade at Borehole No. 1, 2, and 3, respectively (elevations 228.2, 228.8, and 227.6 m, respectively).

4.1.5 Clay Till

Underlying the silt at Borehole Nos. 1 to 3, a deposit of glacial till described as silty clay to clayey silt, trace to some gravel, with sand was penetrated. The natural moisture content measured on samples of this deposit was in the order of 8 to 15%. Gradation (hydrometer) analyses were carried out on three (3) samples of this deposit, the results of which indicated 3 to 8% gravel size particles, 23 to 25% sand size particles, 55 to 58% silt size particles, and 14% clay size particles (Figure No. L-4, Appendix 3). Atterberg Limits testing was carried out on three (3) samples of this deposit, the results of which indicated a Plastic Limit in the order of 12 to 14% and a Liquid Limit in the order of 16 to 25% (Figure No. L-6, Appendix 3). Based on in situ shear strengths of 48 to greater than 100 kPa, the consistency of this deposit was described as firm to very stiff, generally stiff. This deposit was encountered to depths of 8.6, 9.3, and 8.6 m below grade at Borehole Nos. 1 to 3, respectively (elevations 224.2, 223.2, and 223.3 m, respectively).

4.1.6 Silt Till

Underlying the clay till at Borehole Nos. 1 to 3, a deposit of till described as grey sand and silt to sandy silt, some gravel trace clay was penetrated. The natural moisture content measured on samples of this deposit was in the order of 8 to 10%. Gradation (hydrometer) analyses were carried out on two (2) samples of this deposit, the results of which indicated 11 to 13% gravel size particles, 35 to 40% sand size particles, 41 to 46% silt size particles, and 6 to 8% clay size particles (Figure No. L-5, Appendix 3). Atterberg Limits testing was carried out on two (2) samples of this deposit, the results of which indicated a non-plastic silt to a Plastic Limit in the order of 13% and a Liquid Limit in the order of 15% (Figure No. L-6, Appendix 3). Based on SPT 'N' values of 16 to 27 blows per 300 mm penetration, the compactness of this deposit was described as compact. Sampling was terminated in this deposit at a depth of 9.8 m below grade at Borehole Nos. 1, 2, and 3 (elevations 223.0, 222.7, and 223.1 m, respectively).

4.2 GROUNDWATER DATA

During the period of investigation (July 25th to August 14th, 2015), the creek water level was measured at an elevation of some 231.2 m on August 13th, 2015.

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. Standpipes were installed in Borehole Nos. 1 and 2 to obtain post borehole completion water levels. These levels are recorded on the individual Record of Borehole Log Sheets (Appendix 2).

The groundwater levels were measured at elevations 231.5 and 230.2 m at Borehole Nos. 1 and 2, respectively, during the period of foundation investigation.

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

5 DISCUSSION AND RECOMMENDATIONS

5.1 GENERAL

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

The existing culvert, located at Station 18+063, in the Township of Eilber, has been described as a 3860x2460 mm diameter CSPA some 24.5 m long. The culvert invert elevation is at approximately 229.8 m. The existing highway embankment currently supports two undivided lanes of highway, running in a west-east direction. The flow through the existing culvert is from the south to the north (right to left). Based on the data from this foundation investigation, the embankment supporting the existing pavement structure at this site has been constructed using a granular pavement structure overlying predominately granular fills overlying mixed fills. The native material, underlying the embankment fill, generally consisted of loose to compact silts underlain by silty clay tills and silt tills.

The type of culvert (concrete, CSP, or High Density Polyethylene (HDPE)) that will replace the existing culverts is currently unknown. It is assumed that the new culvert(s) will be constructed along a similar skew and vertical alignment as the existing condition.

5.2 FOUNDATION CONSIDERATIONS

The founding native loose to compact silt 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 unduly disturbed during construction and groundwater is controlled throughout construction, as discussed in Section 5.5. Adequate dewatering is required to avoid the potential development of boiling conditions or heave and disturbance of subgrade at the founding level.

Based on the characteristics of the native silt subgrade present below the culvert, the response of the existing embankment, and a founding elevation similar to that of the existing culverts, a factored bearing resistance at ULS of 200 kPa can be used for a closed culvert (i.e. precast concrete box culvert or CSP culvert). In consideration of the width of the culvert, depth of overburden, and response of the existing embankment, a geotechnical reaction at SLS of 150 kPa can be used for design, in consideration of 25 mm settlement.

If open culverts (i.e. concrete frame open culverts, with wall footings, or pipe arch culverts on footings) are considered, then a factored bearing resistance at ULS of 125 kPa, and a geotechnical reaction at SLS of 100 kPa would apply 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 stream bed at this location is some 3.3 m. The angles of existing slopes ranging from approximately 4.0H:1V to 4.3H:1V (locally steepened). 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 for the north and the south slopes with existing inclinations in the granular fill. For the purposes of these analyses, the materials were modeled using the following parameters;

MATERIAL	PARAMETER		
	UNIT WEIGHT (KN/M3)	EFFECTIVE FRICTION ANGLE (DEGREES)	UNDRAINED SHEAR STRENGTH (KPA)
Granular Fill	19.0	30	-
Mixed Fill (undrained)	17.0	-	75
Mixed Fill (drained)	17.0	28	5
Silt	18.0	29	-
Clay Tills (undrained)	18.0	-	75
Clay Tills (drained)	18.0	28	5
Silt Tills	19.0	32	-

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 factor of safety against deep seated failure is in the order of 6.8 (short term) and 3.0 (long term) with the existing slopes (see Figure Nos. S-1 and S-2, Appendix 5). It is recommended that the finished slopes of embankment be established at 2H:1V or shallower. 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 consists of granular fills overlying mixed fills. The results of this investigation indicate that, below the culvert invert, the native soils encountered at Boreholes No. 1 to 3 consisted of loose to compact silts, firm to very stiff clayey silt to silty clay tills and compact sand and silt to sandy silt tills. A review of the condition of the pavement surface, at the culvert locations, revealed minor asphalt cracking; however, in general, 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 long term 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. 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 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 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 501. See Section 5.5 for trench backfilling requirements.

A precast concrete rigid frame box culvert can also be considered for culvert replacement at this site. Bedding for a rigid frame box culvert shall consist of Granular A with a thickness of 300 mm. The bedding under the middle third of the box unit base should be loosely placed and upcompacted. The upper 75 mm portion of the Granular A bedding should be uncompacted throughout the length/width of the box and incorporated as the top levelling course in conformance with OPSS 422. 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 applications. During backfilling, the material of bedding, cover and backfill shall be placed in uniform layers not exceeding uncompacted thickness of 200 mm. Backfilling shall be placed in a balanced manner in layers not exceeding 200 mm in thickness on each side of the box unit. The elevation difference of backfilling on either side of the box unit shall be limited to a maximum 400 mm as per OPSS 422. Backfilling and construction of pre-cast concrete box culverts shall be in accordance with OPSS 422. Cover material for concrete box culverts can consist of Granular A, placed to the dimensions as shown on MTOD-803.021.

The joints between precast box units should be covered with a strip of Non-Woven Class II Geotextile (per OPSS 1860) 600 mm in width, centered over the joint, covering the top of the culvert and extending down the sides of the culvert to prevent the infiltration of fines.

Apron (cut-off) walls, 1.2 m deep, must be added to the ends of the rigid frame box culvert in accordance with the MTO Concrete Culvert Design Manual.

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 minimum 3 m in length, minimum 400 mm thick and extend across the stream bed to a 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. Considering the head difference between the inlet and outlet, it is recommended that clay seals not be used at this culvert location.

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 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 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 401.

Considering the porous nature of the embankment fill, inlet clay seals along the culvert or outlet cut-off walls are not required; however, 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 minimum 3 m in length, minimum 400 mm thick and extend across the stream bed to a minimum 3 m beyond the outside edges of the culvert.

5.4 CULVERT INSTALLATION AND CONSTRUCTION CONSIDERATIONS

The culvert invert has been established at a depth of some 3.3 m below centreline (i.e. elevation 229.8 m). Therefore, a minimum 3.6 m deep excavation (i.e. to elevation 229.5 m) will be required in consideration of a 300 mm thick layer of bedding/embedment material.

The present platform width at this location is some 17 m as can be seen on the cross sections on Drawing No. 2. The platform width at this location, as is, will be sufficient to carry out an open excavation using staged construction. Consideration can be given to widening or to constructing a temporary vertical wall for use as a protection system.

5.4.1 Staged Construction

As noted, the platform at this location, as is, will be of sufficient width to carry out an open excavation using staged construction. To carry out an open cut excavation, staged construction using staged sequencing and limiting traffic flow to one lane would be required (see Figure No. SK-3, Appendix 5). Sliver widening will be required to carry out open cut excavations and local lowering of the groundwater level in the embankment will be required in order to consider the embankment fill as a Type 3 soil.

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:

- Sliver widen the existing roadway, raising the grade to elevation 233.0 m, or higher, as required to carry out the excavation.
- Limit traffic to a single lane on the left (north), with a minimum platform width of 6 m, under 24/7 traffic control.
- Open cut excavate, to the right (south), and install approximately 11 m in length of new culvert.
- Reconstruct the embankment on the right (south), allowing for 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 (north).
- As the width of the platform increases on the left, the traffic can revert back to two lanes when sufficient width permits.

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.

Considering the nature of this foundation investigation, as outlined in the RFP, only one borehole was advanced through the embankment. Depending upon the type of protection system proposed by the contractor, additional borehole information, beyond the existing embankment borehole, may be required, if the variation in elevation of the silty clay till deposit could impact their design of protection system.

The installation of a protection system for use in the culvert replacement operation is estimated to require penetration through some 3.6 m of embankment fills at the centerline of highway. The embankment fill is generally underlain by loose to compact silts, overlying very stiff silty clay to clayey silt tills. The recommended method of constructing a temporary vertical wall for a protection system along the centreline of the highway alignment would be to drive steel sheet piles through the embankment fill into the underlying native soils. Conceptual shoring locations and cross sections are illustrated on Figure Nos. SK-4 and SK-5, Appendix 5.

The granular pavement structure over granular fills are considered cohesionless, as such, a rectangular apparent pressure distribution over the height of the cut would be appropriate for design of the temporary shoring in granular fills. 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 5.6,

γ = unit weight, as described in Section 5.6, and

H = height of wall above the base of excavation.

The existing mixed fill, underlying the granular fill at Borehole No. 1, is largely composed of cohesive materials (silty clay). This material will be replaced with granular fill during the backfilling of Stage 1. As such, the rectangular apparent pressure distribution would apply. However, the presence of the cohesive backfill during Stage 1 may require that the load acting on the protection system be checked using the "layered strata" method, as outlined in the Canadian Foundation Engineering Manual, 4th Edition, Section 26.10.7.

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.

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 is illustrated on Figure No. SK-4 in Appendix 5.

The protection system can be designed using the lateral earth pressure parameters as outlined in Section 5.6. The temporary protection system should be designed and constructed to comply with OPSS.PROV 539. In consideration of the location of the protection system and traffic volume, a Performance Level 2 is considered appropriate. The protection system should be removed upon completion of the work.

5.5 EXCAVATION, DEWATERING, AND EMBANKMENT CONSTRUCTION

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 of granular fill as per OPSS.Prov 1010, at a minimum, up to the underside of the pavement structure. Frost tapers should be constructed at 10H:1V on both sides of the trench, see Englobe's Pavement Design Report Reference No. 15/05/15059-P2, provided under a separate cover.

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

The water levels in the creek were recorded at elevations some 231.2 m at the culvert outlet during the period of this investigation and the groundwater levels at Borehole Nos. 1 and 2 had stabilized at elevations of 231.5 and 230.2 m, respectively, at the time of this investigation. All excavations extending below the groundwater table, present at the time of construction, will have to be maintained in a dewatered condition. 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 cofferdam, constructed of earth fill, sand bags, or water filled bag (i.e. aquadam) can be considered at this site for controlling stream flow. For base design, shoring 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. Temporary erosion control should be carried out in accordance with OPSS 805 requirements.

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.

5.6 LATERAL EARTH PRESSURES

Lateral earth pressures should be computed in accordance with the Canadian Highway Bridge Design Code (CHBDC). The design parameters to be considered for the bedding/embedment and backfill materials are as follows:

PARAMETER	GRANULAR A	GRANULAR B TYPE I	GRANULAR FILL	MIXED FILL	SILT
Unit Weight (kN/m^3)	22	21	19	17	18
Angle of Internal Friction	34°	33°	30°	-	29°
Undrained Shear Strength (kPa)	-	-	-	75	-
Coefficient of Active Earth Pressure (K_a)	0.28	0.29	0.33	-	0.35
Coefficient of Passive Earth Pressure (K_p)	3.54	3.39	3.00	-	2.88
Coefficient of Earth Pressure at Rest (K_o)	0.44	0.46	0.50	-	0.52
PARAMETER	CLAY TILLS	SILT TILLS			
Unit Weight (kN/m^3)	18	19			
Angle of Internal Friction	-	32°			
Undrained Shear Strength (kPa)	75	-			
Coefficient of Active Earth Pressure (K_a)	-	0.31			
Coefficient of Passive Earth Pressure (K_p)	-	3.23			
Coefficient of Earth Pressure at Rest (K_o)	-	0.47			

For rigid structures, such as a precast rigid frame box culvert, the “at-rest” condition (K_o) applies. For flexible structures, such as CSP/HDPE culverts, 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).

5.7 CONSTRUCTION CONCERNS

Considering the nature of the granular fills and mixed fills in the embankment, no major construction concerns are anticipated if construction is carried out in general conformance with the above discussion. As noted in Section 5.5 the culvert subgrade must be adequately dewatered to maintain the bearing resistance of the foundation subgrade. Sufficiently robust sheet piles will be required due to the compact/very stiff till deposits.

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

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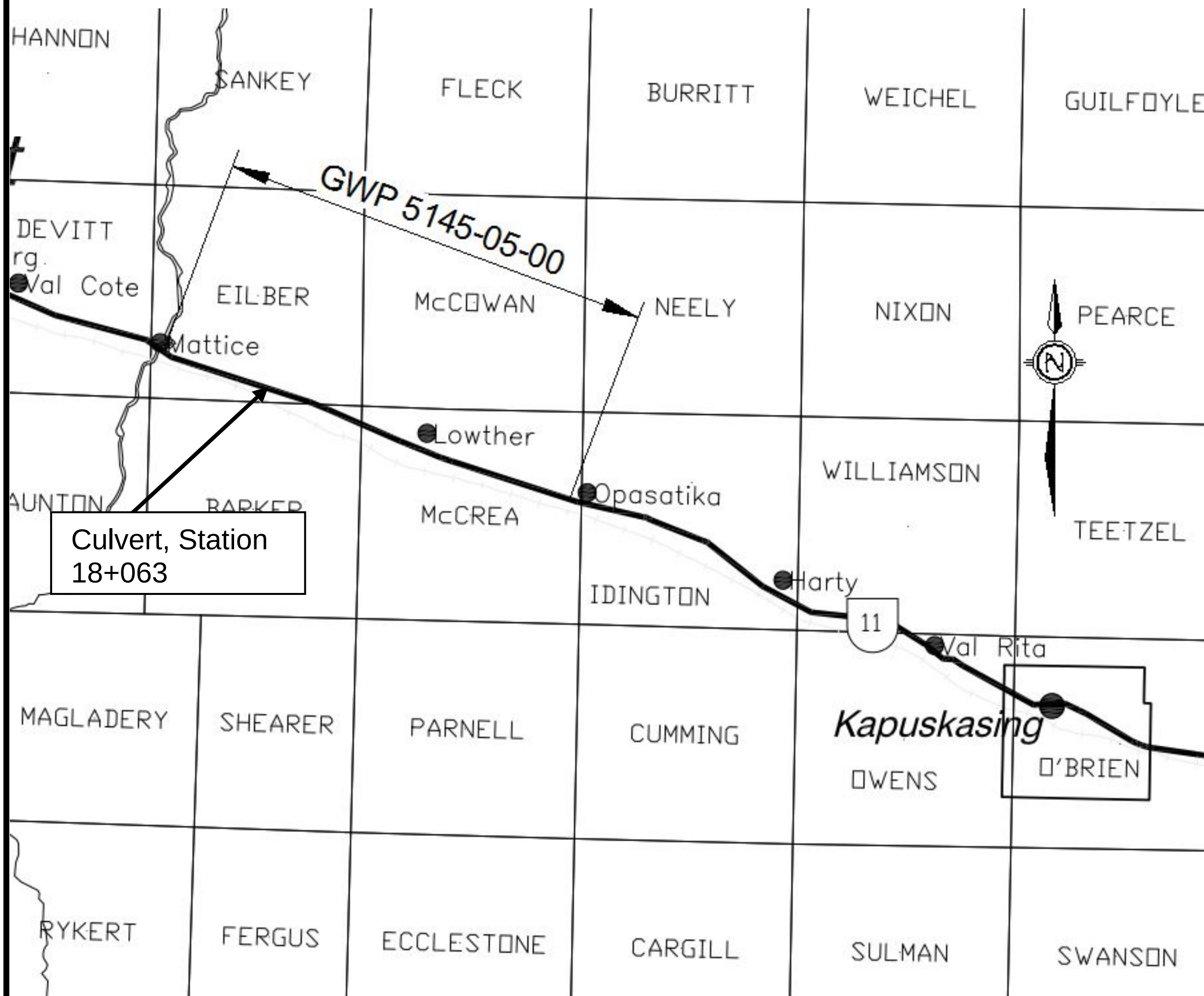
MACRO KEY PLAN

Drawing No.1

NOT TO SCALE



FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT
GWP 5145-05-00

Highway 11

Station 18+063 Culvert

Township of Eilber

Reference No: 15/05/15059-F4 February 2016

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)	*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: 15/05/15059-F4	DATUM: Geodetic	LOCATION: N 5495421.8 E 364736.0 - Eilber Twp., Station 18+066	ORIGINATED BY: JL
PROJECT: GWP 5145-05-00, Highway 11		BOREHOLE TYPE: Track Mounted CME 45 - Hollow Stem Augers	COMPILED BY: SH
CLIENT: AECOM		DATE (Started): 25 July 2015; DATE (Completed): 25 July 2015; TIME (Completed): 12:30:00 PM	CHECKED BY: MAM

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION (see Enclosure No. 1)
232.8	Ground Surface
0.0	150 mm Crushed Gravel Granular FILL- sand, trace gravel, some silt and clay brown, moist (compact/loose) wet
230.7 / 2.1	Mixed FILL - silty clay, trace sand brown
230.2 / 2.6	SILT - trace clay brown to grey (compact/loose) occasional seams of silty clay
228.2 / 4.6	CLAY TILL - silty clay to clayey silt, trace to some gravel, with sand moist (firm/very stiff) brown
224.2 / 8.6	SILT TILL - sand and silt, some gravel, trace clay grey (compact)
223.0 / 9.8	End of Sampling End of Borehole

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
1	SS	17	
2	SS	9	2 85 (13)
3	SS	7	
4	SS	11	
5	SS	13	0 (NP) 0 92 8
6	SS	8	
7	SS	WH	
8	SS	WH	3 25 58 14
9	SS	WH	
10	SS	19	
11	SS	24	13 (NP) 40 41 6

Field vane values (shear strength plot): >100 (approx. elev. 228.6), 2 (approx. elev. 227.7), 4 (approx. elev. 227.1), >100 (approx. elev. 226.3).

Column headings: STRATA PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (232 – 223); 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

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)	25/7/15 12:40:00 PM	9.3	-
2)	13/8/15 5:00:00 AM	1.3	-
3)		-	-

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

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

METRIC

RECORD OF BOREHOLE NO. 2

Englobe

REFERENCE 15/05/15059-F4 DATUM Geodetic LOCATION N 5495405.0 E 364733.5 - Eilber Twp., Station 18+069 ORIGINATED BY JL

PROJECT GWP 5145-05-00, Highway 11 BOREHOLE TYPE Track Mounted CME 45 - Hollow Stem Augers COMPILED BY SH

CLIENT AECOM DATE (Started) 12 August 2015 DATE (Completed) 12 August 2015 TIME (Completed) 3:40:00 PM CHECKED BY MAM

ELEV DEPTH	DESCRIPTION (see Enclosure No. 1)	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
232.5	Ground Surface				
0.0	Mixed FILL- mixture brown sand and thin layers of silty clay, some to trace gravel, trace grass rootlets moist (compact/loose)	1	SS	15	
		2	SS	6	
231.1 1.4	Mixed FILL - silty clay, trace sand trace grass rootlets thin sand layers encountered at depth of 2.3 m to 2.7 m brown (stiff)	3	SS	6	
		4	SS	8	0 3 77 20
229.6 2.9	SILT - trace sand, trace clay grey (loose)	5	SS	7	0 1 93 6 (NP)
228.8 3.7	CLAY TILL - silty clay to clayey silt, trace to some gravel, with sand thin sand layers encountered at depth of 3.8 m to 4.3 m grey (stiff/very stiff)	6	SS	3	
		7	SS	3	
		8	SS	14	8 23 55 14
		9	SS	11	
223.2 9.3	SILT TILL - sandy silt, some gravel, trace clay grey (compact)	10	SS	16	
222.7 9.8	End of Sampling End of Borehole				

Field vane shear strength (kPa): + 2 at approx. elev. 227.9; + 2 at approx. elev. 227.2

Column headings: SOIL PROFILE; SAMPLES; STRATA PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (232 – 223); 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

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) 12/8/15 3:45:00 PM	6.5	-
2) 13/8/15 5:30:00 PM	2.3	-
3) 14/8/15 5:00:00 PM	2.3	-

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

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

RECORD OF BOREHOLE NO. 3

METRIC

Englobe

REFERENCE 15/05/15059-F4 DATUM Geodetic LOCATION N 5495431.9 E 364760.9 - Eilber Twp., Station 18+058 ORIGINATED BY JL

PROJECT GWP 5145-05-00, Highway 11 BOREHOLE TYPE Track Mounted CME 45 - Hollow Stem Augers COMPILED BY SH

CLIENT AECOM DATE (Started) 12 August 2015 DATE (Completed) 12 August 2015 TIME (Completed) 6:05:00 PM CHECKED BY MAM

ELEV / DEPTH	DESCRIPTION (see Enclosure No. 1)
231.9	Ground Surface
0.0	Mixed FILL- mixture brown sand and grey silty clay, trace sand, trace grass rootlets, decayed wood, organics; moist; (firm/very stiff)
229.6 / 2.3	Mixed FILL - silty clay, trace sand with organics, trace rootlets seams of thin silt encountered (very stiff)
229.0 / 2.9	SILT - trace sand, trace clay; grey; wet; (loose)
227.6 / 4.3	CLAY TILL - silty clay to clayey silt, trace to some gravel, with sand; grey; (very stiff)
223.3 / 8.6	SILT TILL - sandy silt, some gravel, trace clay; grey; (compact)
222.1 / 9.8	End of Sampling; End of Borehole

Sample NUMBER	TYPE	"N" VALUES	Remarks: Grain size GR SA SI CL (%)
1	SS	2	
2	SS	7	
3	SS	5	0 2 30 68
4	SS	5	
5	SS	9	
6	SS	6	
7	SS	7	5 23 58 14
8	SS	9	
9	SS	24	
10	SS	27	11 35 46 8

Dynamic cone penetration: >100 at approx. elev. 229.9, 229.1, 227.6, 226.8

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (223–231); 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)

COMMENTS

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)	12/8/15 6:05:00 PM	DRY	-
2)		-	-
3)		-	-

MEL-GEO 15059 - F4 BOREHOL LOGS.GPJ MEL-GEO.GDT 11/2/16

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

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
Figure No. L-6:	Atterberg Limits
Table No. L-7:	Laboratory Test Summary Sheet

Englobe

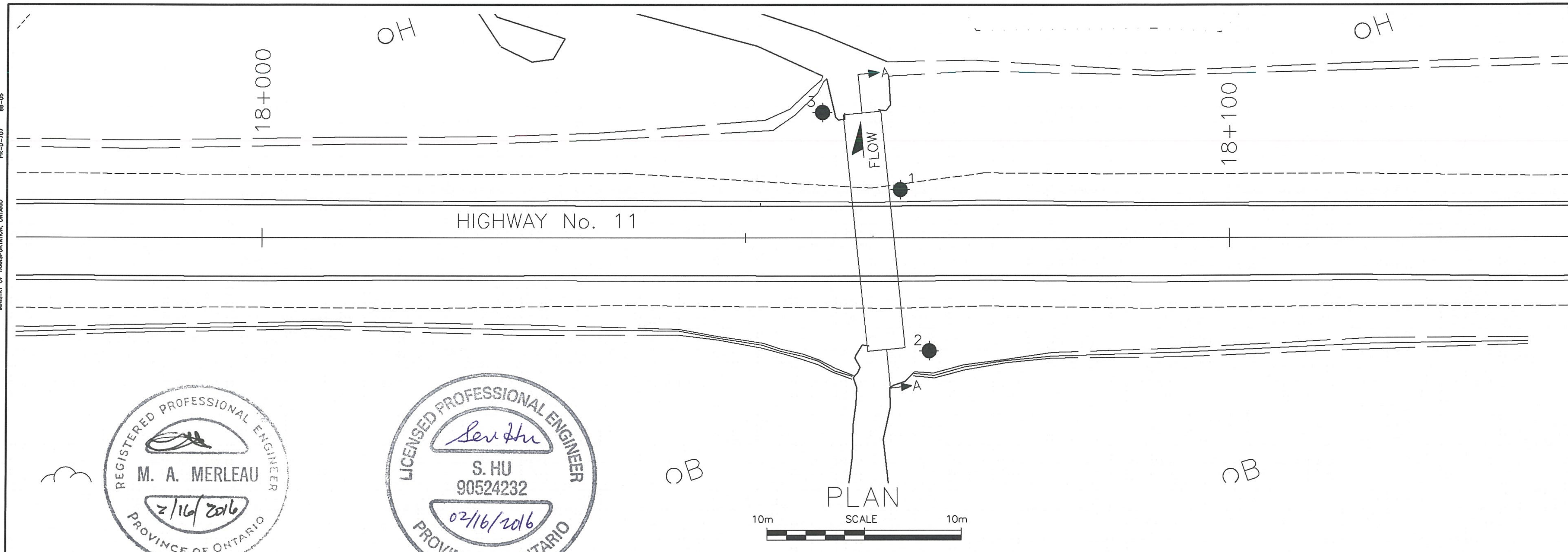
DISTRICT
CONT. No.
GWP No. 5145-05-00

HWY 11 CULVERT
STA. 18+063
SITE NO. 39W-230/C

BOREHOLE LOCATIONS AND SOIL STRATIGRAPHY

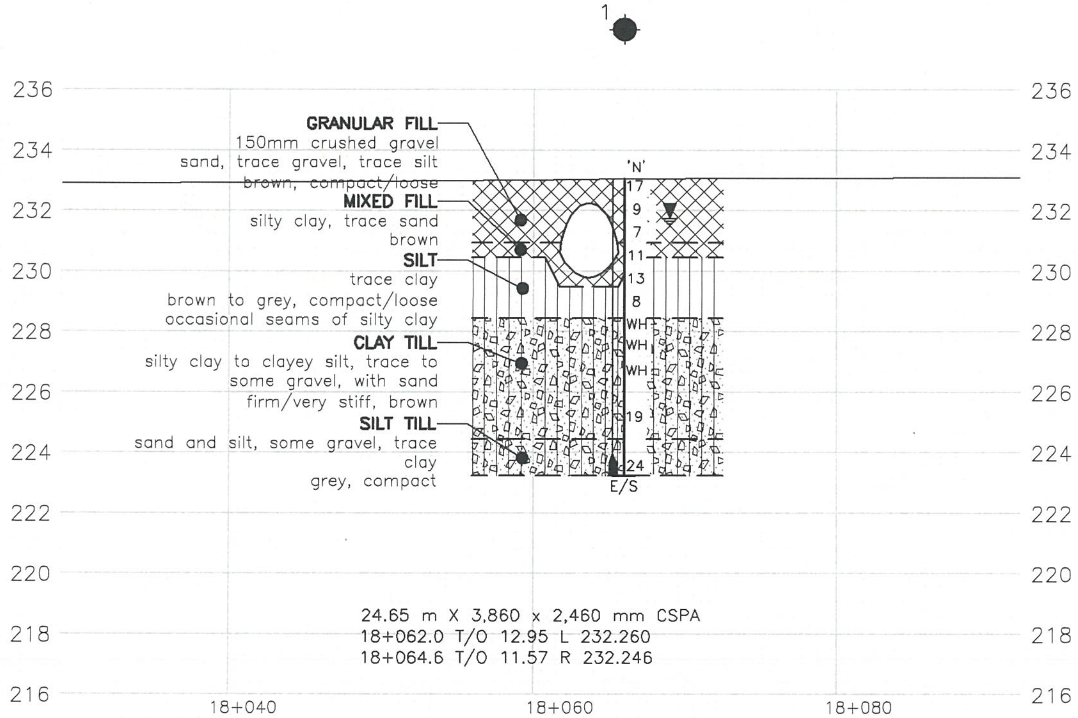
DRAWING 2

Englobe



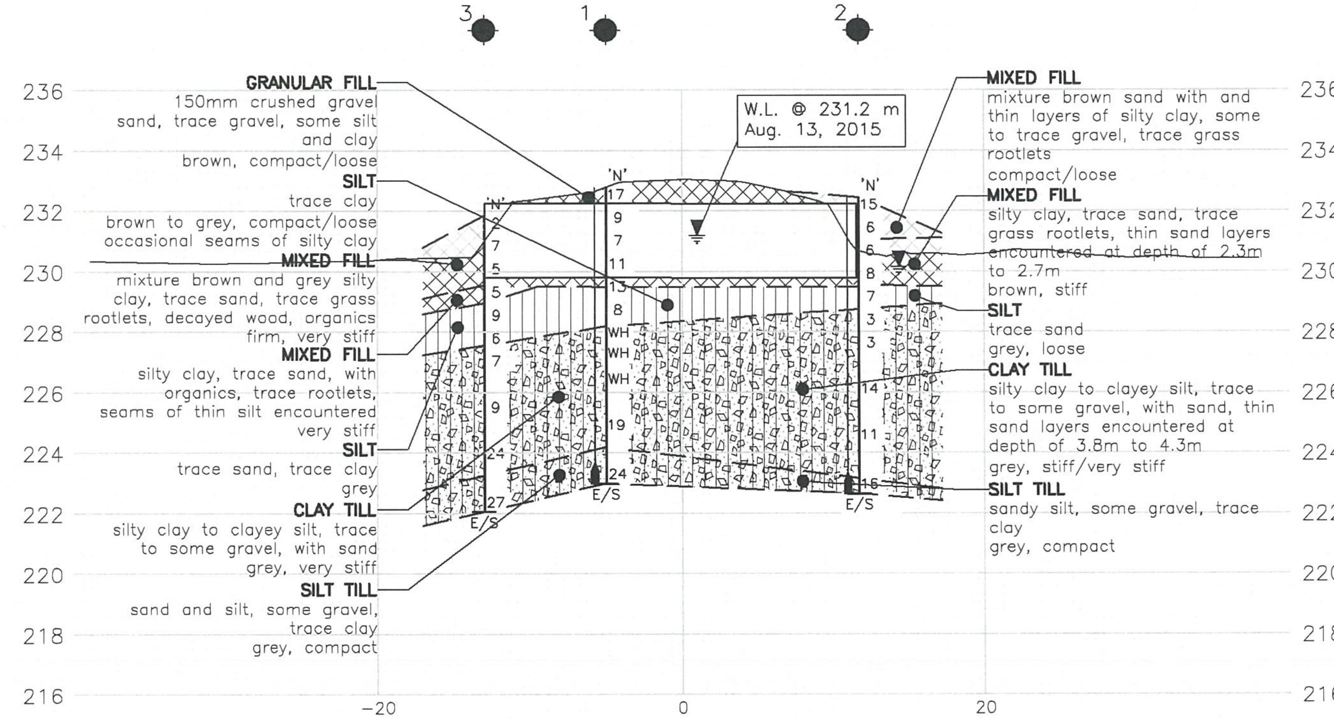
M. A. MERLEAU — REGISTERED PROFESSIONAL ENGINEER — PROVINCE OF ONTARIO — 2/16/2016

S. HU 90524232 — LICENSED PROFESSIONAL ENGINEER — PROVINCE OF ONTARIO — 02/16/2016



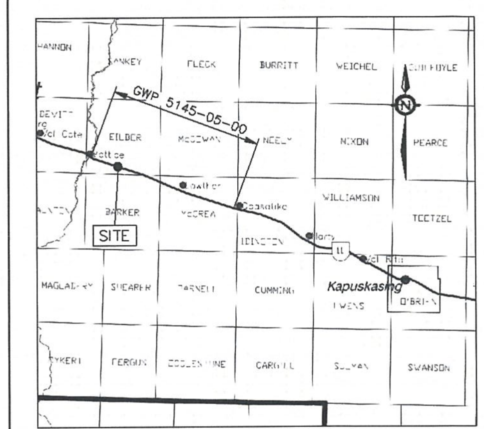
C/L PROFILE of HWY 11

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



KEY PLAN
N.T.S.

LEGEND

Symbol	Description
⊕	Borehole w/ DCPT
●	Borehole
N	Blows/0.3 m (Std Pen Test, 475 J/blow)
DCPT	Blows/0.3 m (60° Cone, 475 J/blow)
▼	Water Level at Time of Investigation
A/R	Auger Refusal at Elevation
E/S	End of Sampling
	Piezometer

BOREHOLE No.	ELEVATION	O/S	NORTHING	EASTING
1	232.8	5.0m Lt	5495421.8	364736.0
2	232.5	11.7m Rt	5495405.0	364733.5
3	231.9	13.0m Lt	5495431.9	364760.9

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 Callon Dietz on September 17, 2015

Coordinates based on MTM Zone 13 NAD83 CSRS

GEOCRES No. 42G-56

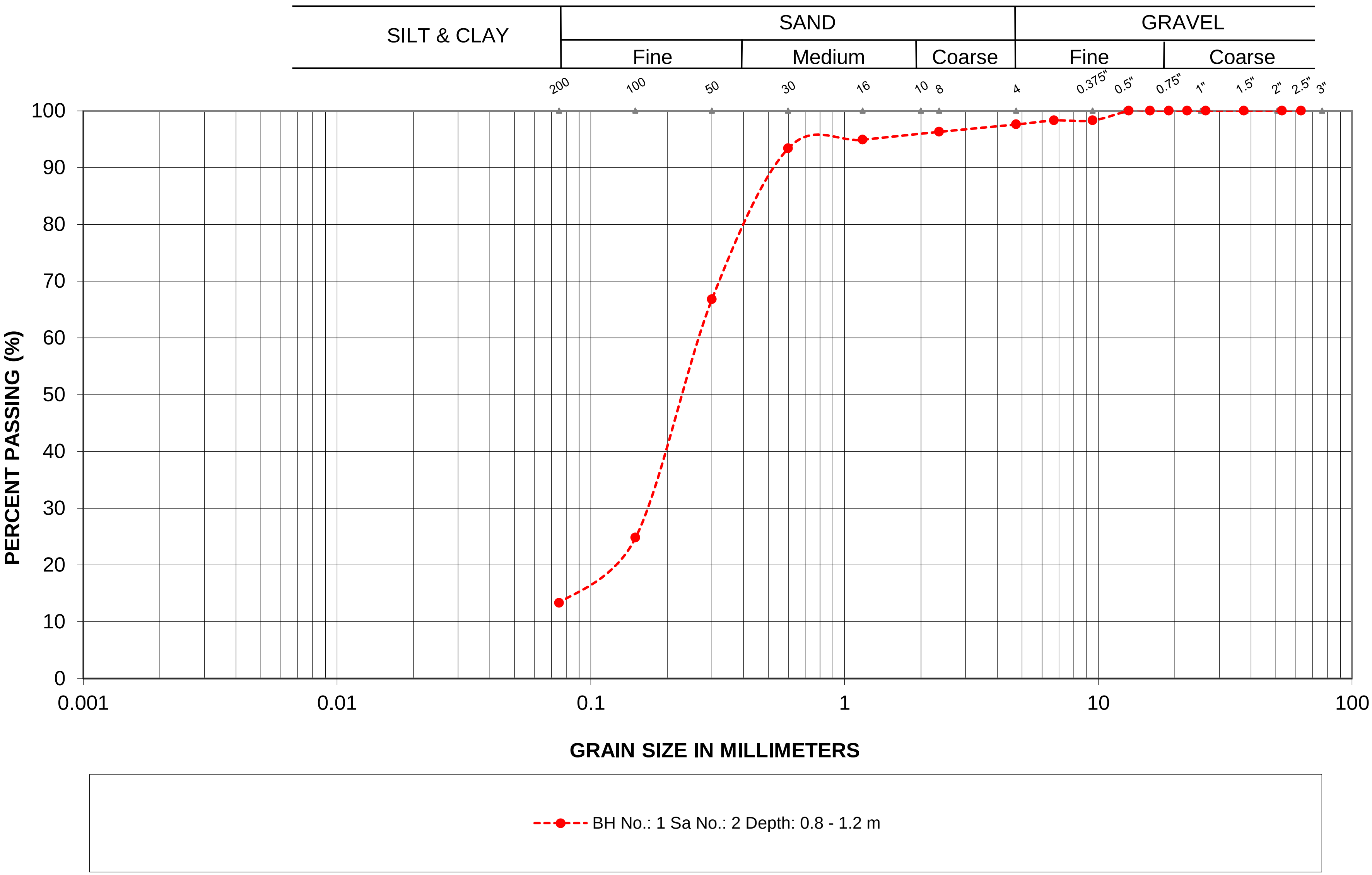
This drawing is for subsurface information only. Surface details and features are for conceptual illustration. The proposed structure location is shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents.

REVISIONS		DESCRIPTION
NOV/15	DM	DRAFT
FEB/16	DM	FINAL

DESIGN	CHK	CODE	LOAD	DATE FEB/16
DRAWN DM	CHK SH	SITE 39W-230/C	STRUCT	SCHEME / DWG 2

Reference No.: 15/05/15059-F4
Date: September, 2015

GRAIN SIZE ANALYSIS



GRANULAR FILL

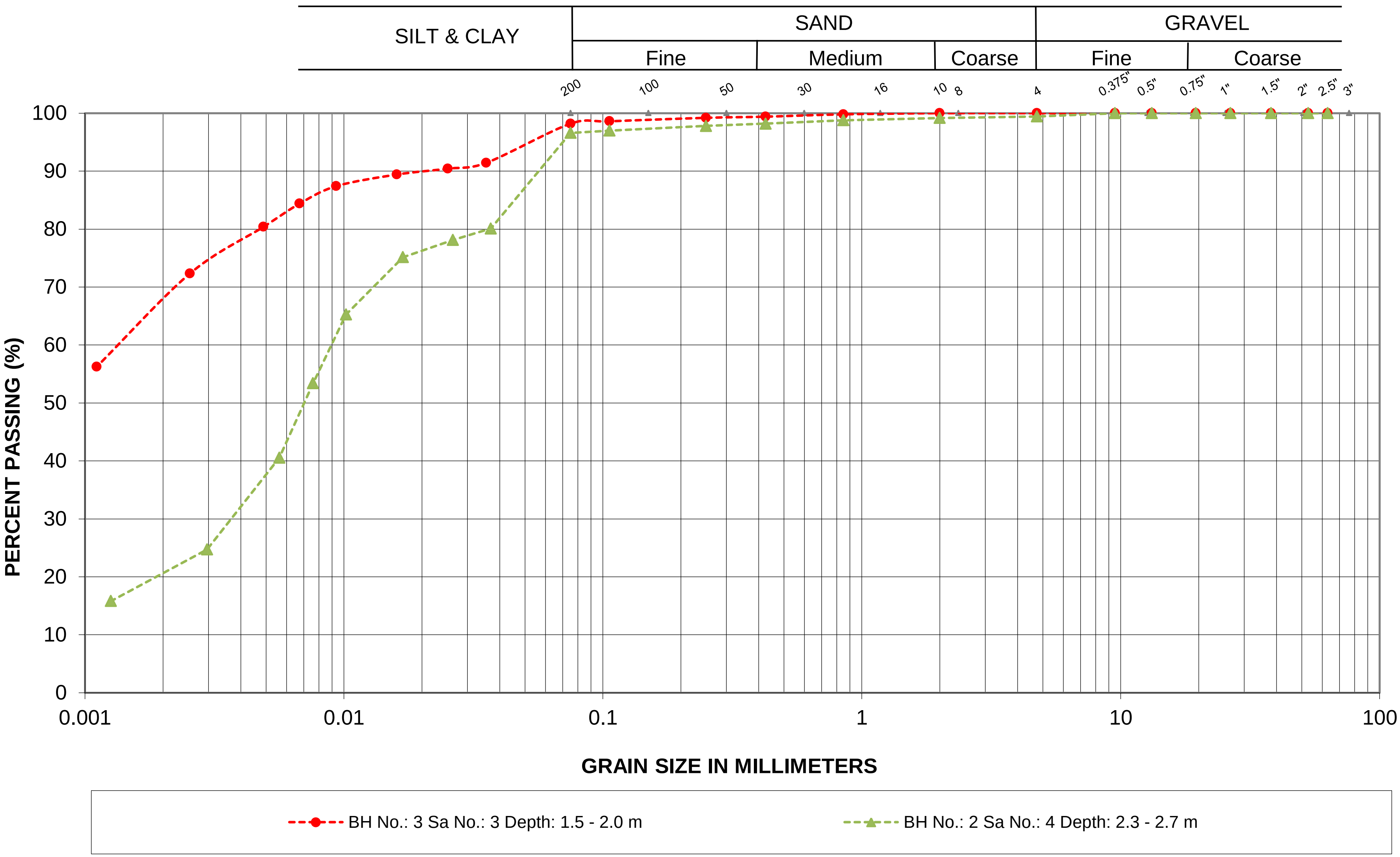
LOCATION: Hwy 11, Station 18+063
TWP of Eilber

Englobe Corp.

FIGURE L-1

Reference No.: 15/05/15059-F4
Date: September, 2015

GRAIN SIZE ANALYSIS



MIXED FILL

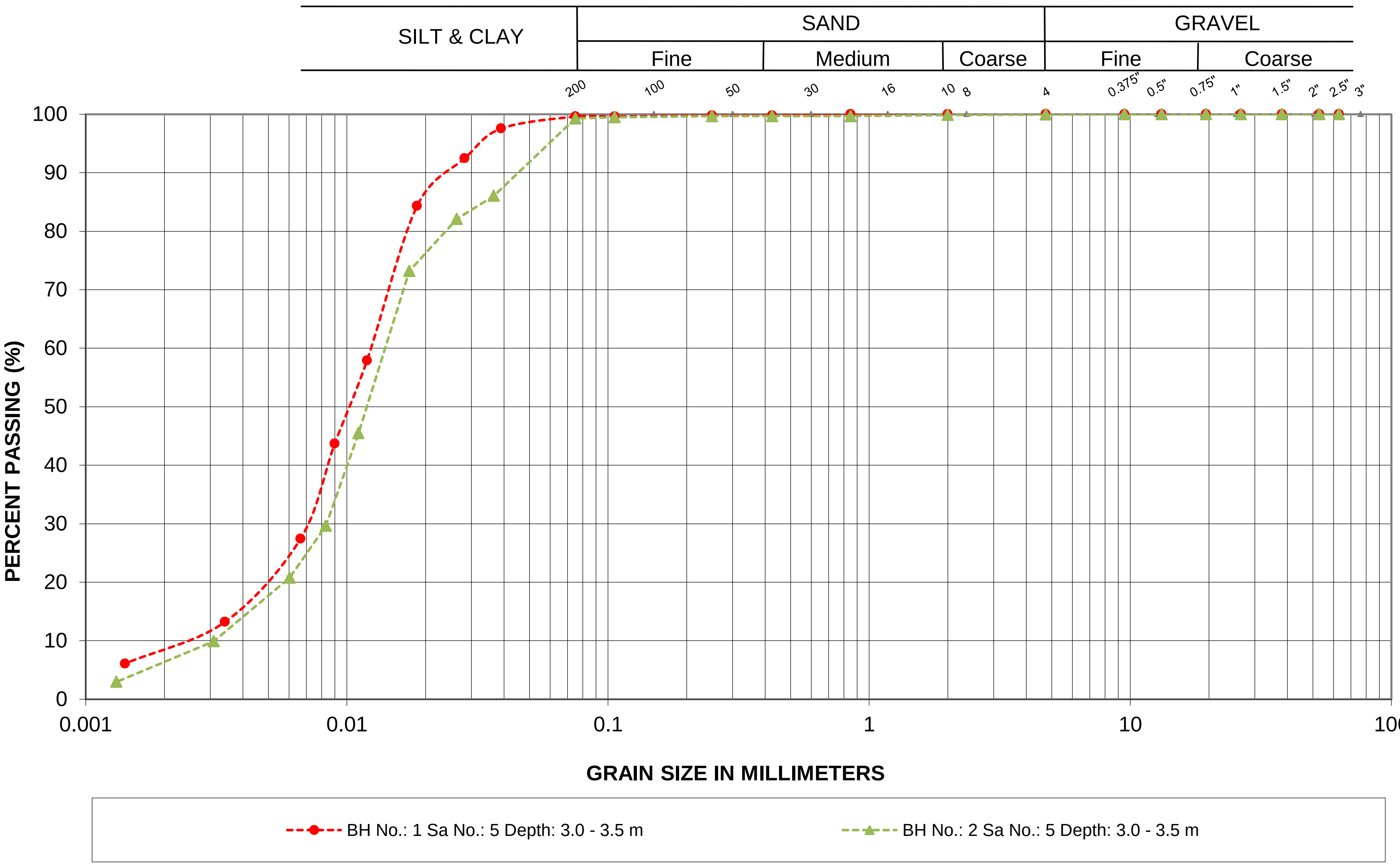
LOCATION: Hwy 11, Station 18+063
TWP of Eilber

Englobe Corp.

FIGURE L-2

Reference No.: 15/05/15059-F4
Date: September, 2015

GRAIN SIZE ANALYSIS



SILT

LOCATION: Hwy 11, Station 18+063
TWP of Eilber

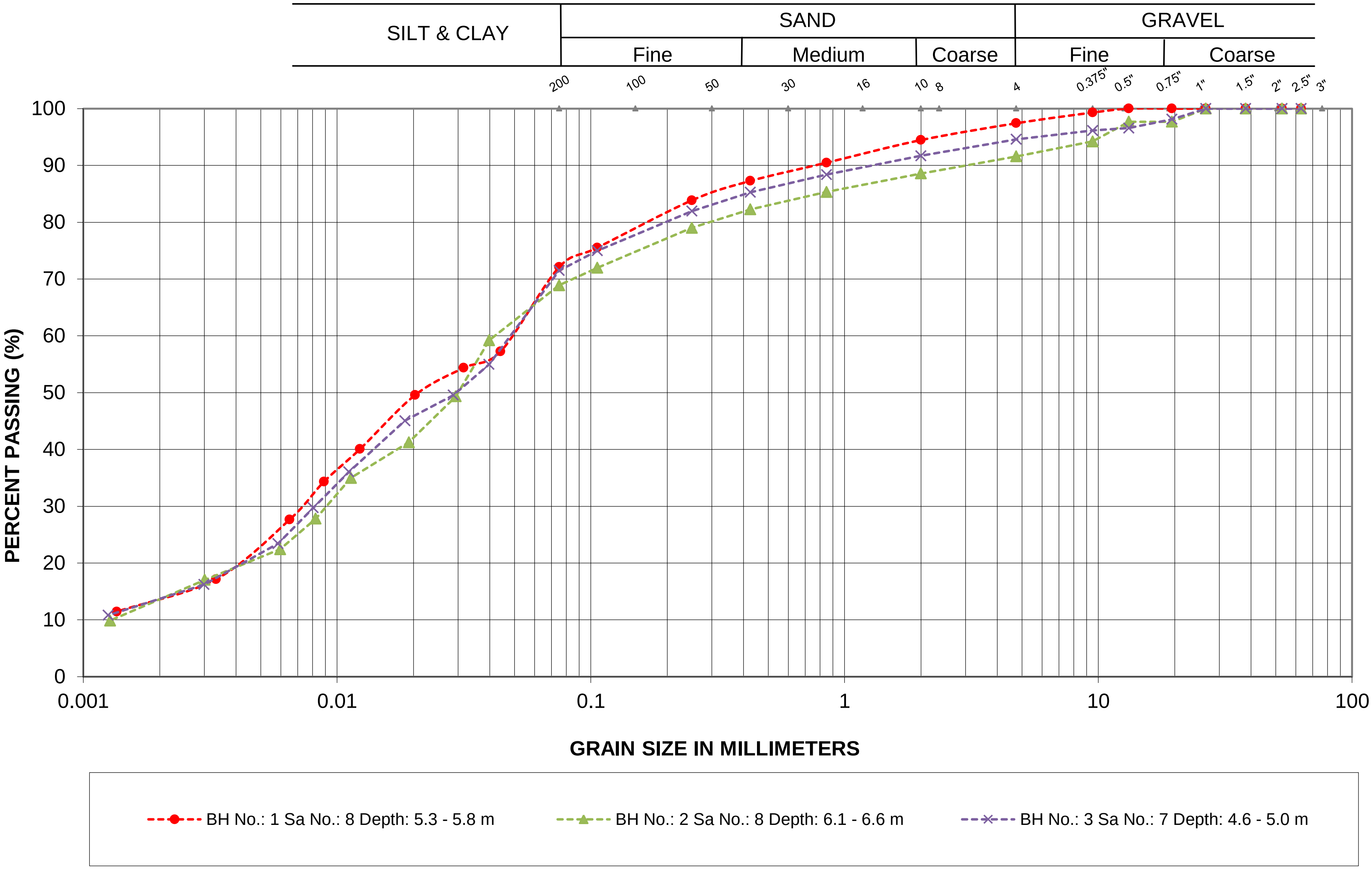
Englobe Corp.

FIGURE L-3

Reference No.: 15/05/15059-F4
Date: September, 2015

Englobe

GRAIN SIZE ANALYSIS



CLAY TILL

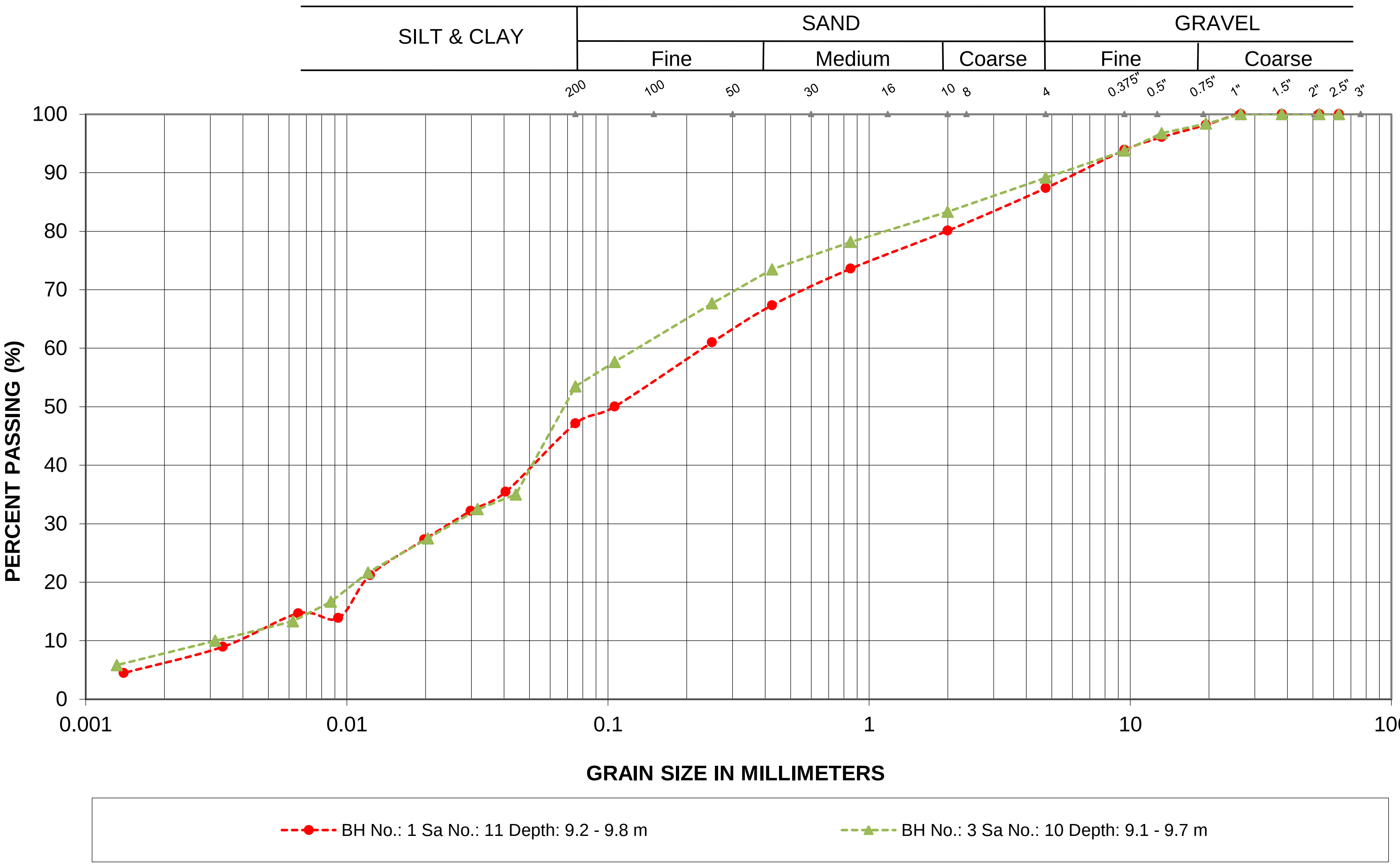
LOCATION: Hwy 11, Station 18+063
TWP of Eilber

Englobe Corp.

FIGURE L-4

Reference No.: 15/05/15059-F4
Date: September, 2015

GRAIN SIZE ANALYSIS



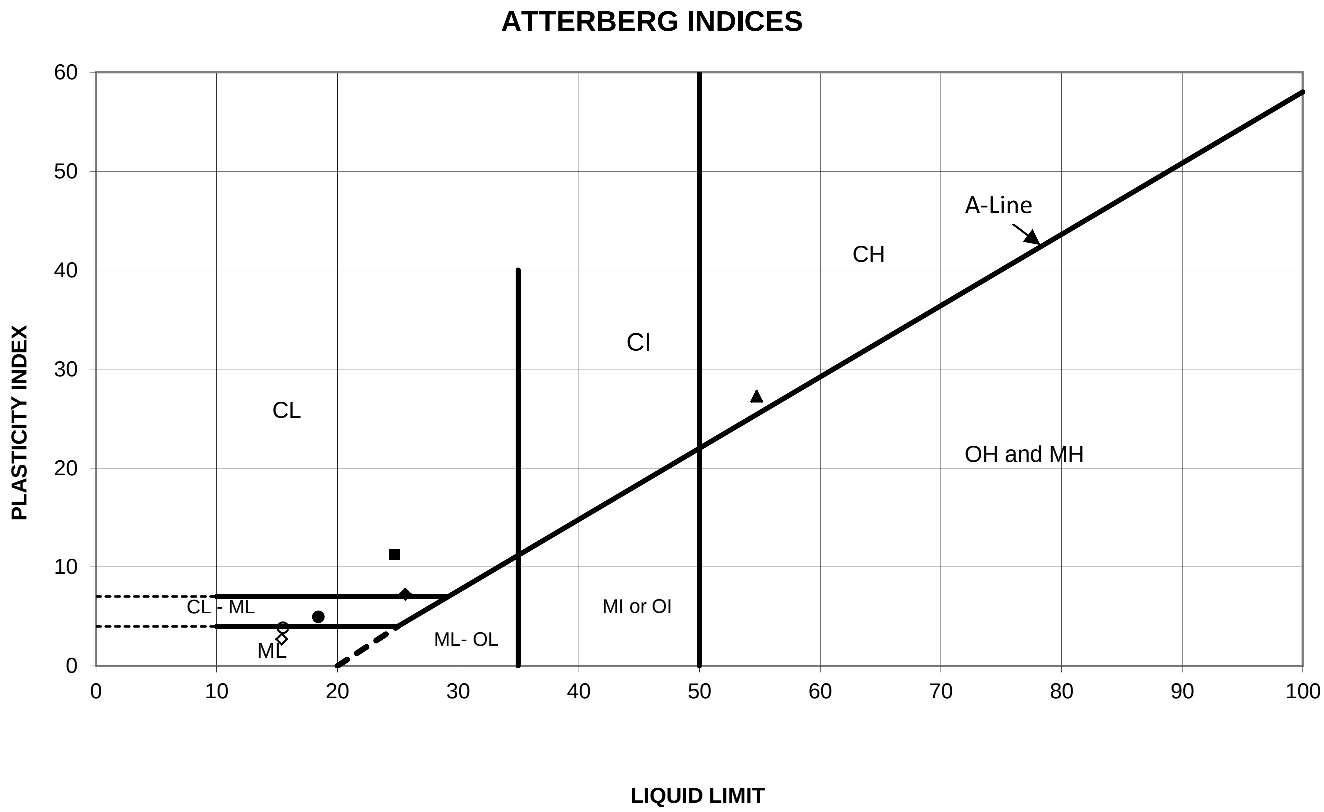
SILT TILL

LOCATION: Hwy 11, Station 18+063
TWP of Eilber

Englobe Corp.

FIGURE L-5

ATTERBERG LIMITS TEST RESULTS	FIGURE L-6



SYMBOL	BH	Sa. No.	Depth(m)	Elev.(m)	Liquid Limit	Plastic Limit	Plasticity Index	NMC %
●	1	8	5.6	227.2	18.4	13.5	4.9	13.7
◆	2	4	2.5	230.0	25.6	18.4	7.2	28.5
■	2	8	6.3	226.2	24.8	13.6	11.2	7.8
▲	3	3	1.8	230.2	54.7	27.5	27.2	38.6
○	3	7	4.8	227.1	15.5	11.7	3.8	13.2
◇	3	10	9.5	222.5	15.4	12.7	2.7	9.8

Date: Sep-15
Project: Hwy 11,
Location: Sta. 18+063, TWP. of Eilber

Prep'd: AT
Chkd: MAM
Ref. No.: 15/05/15059-F4

Englobe Corp.

Reference No.: 15/05/15059-F4
Date: September 2015

Laboratory Tests - Summary Sheet

Englobe

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	0.0					4.0				17			
	2	0.8	2	85	13		6.8				9			
	3	1.5					19.8				7			
	4	2.3					25.6				11			
	5	3.1	0	0	92	8	23.5				13			Non-Plastic (NP)
	6	3.8					26.5				8			
	7	4.6					12.5				WH			
	8	5.3	3	25	58	14	13.7	18.4	13.5	4.9	WH			
	9	6.1					13.5				WH			
	10	7.6					10.4				19			
	11	9.2	13	40	41	6	8.9				24			Non-Plastic (NP)
2	1	0.0					6.2				15			
	2	0.8					12.1				6			
	3	1.5					23.0				6			
	4	2.3	0	3	77	20	28.5	25.6	18.4	7.2	8			
	5	3.1	0	1	93	6	23.4				7			Non-Plastic (NP)
	6	3.8					14.6				3			
	7	4.6					12.7				3			
	8	6.1	8	23	55	14	7.8	24.8	13.6	11.2	14			
	9	7.6					12.2				11			
	10	9.1					8.4				16			

Project: Hwy 11, Culvert Sta. 18+063, Township of Eilber

Table No. L-7

Laboratory Tests - Summary Sheet

Englobe

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 (%)				
3	1	0.0					39.9				2			
	2	0.8					37.0				7			
	3	1.5	0	2	30	68	38.6	54.7	27.5	27.2	5			
	4	2.3					25.2				5			
	5	3.1					20.9				9			
	6	3.8					20.5				6			
	7	4.6	5	23	58	14	13.2	15.5	11.7	3.8	7			
	8	6.1					13.3				9			
	9	7.6					9.0				24			
	10	9.1	11	35	46	8	9.8	15.4	12.7	2.7	27			

Appendix 4 Photo Essay

Enclosure No. 5: Photo Essay

Existing Embankment – Looking East	Photo: 1

Culvert Inlet – Looking South	Photo: 2

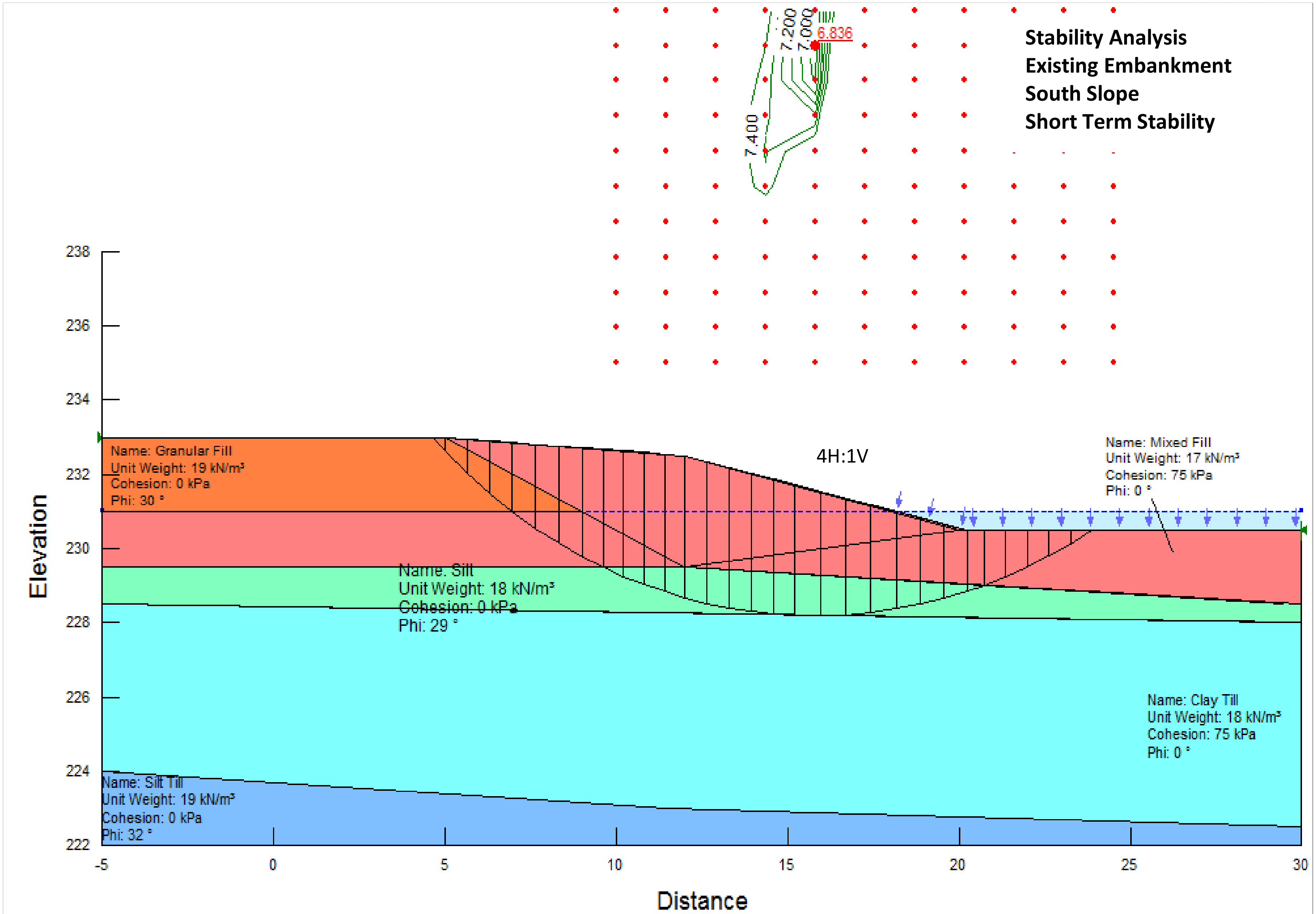
Project: Hwy 11 – Culvert, Station 18+063, Township of Eilber, Ontario	Photos Provided By:Englobe Date: August 2015

Culvert Outlet – Looking North	Photo: 3

View of Culvert Inlet – Looking North	Photo: 4

Project: Hwy 11 – Culvert, Station 18+063, Township of Eilber, Ontario	Photos Provided By:Englobe Date: August 2015

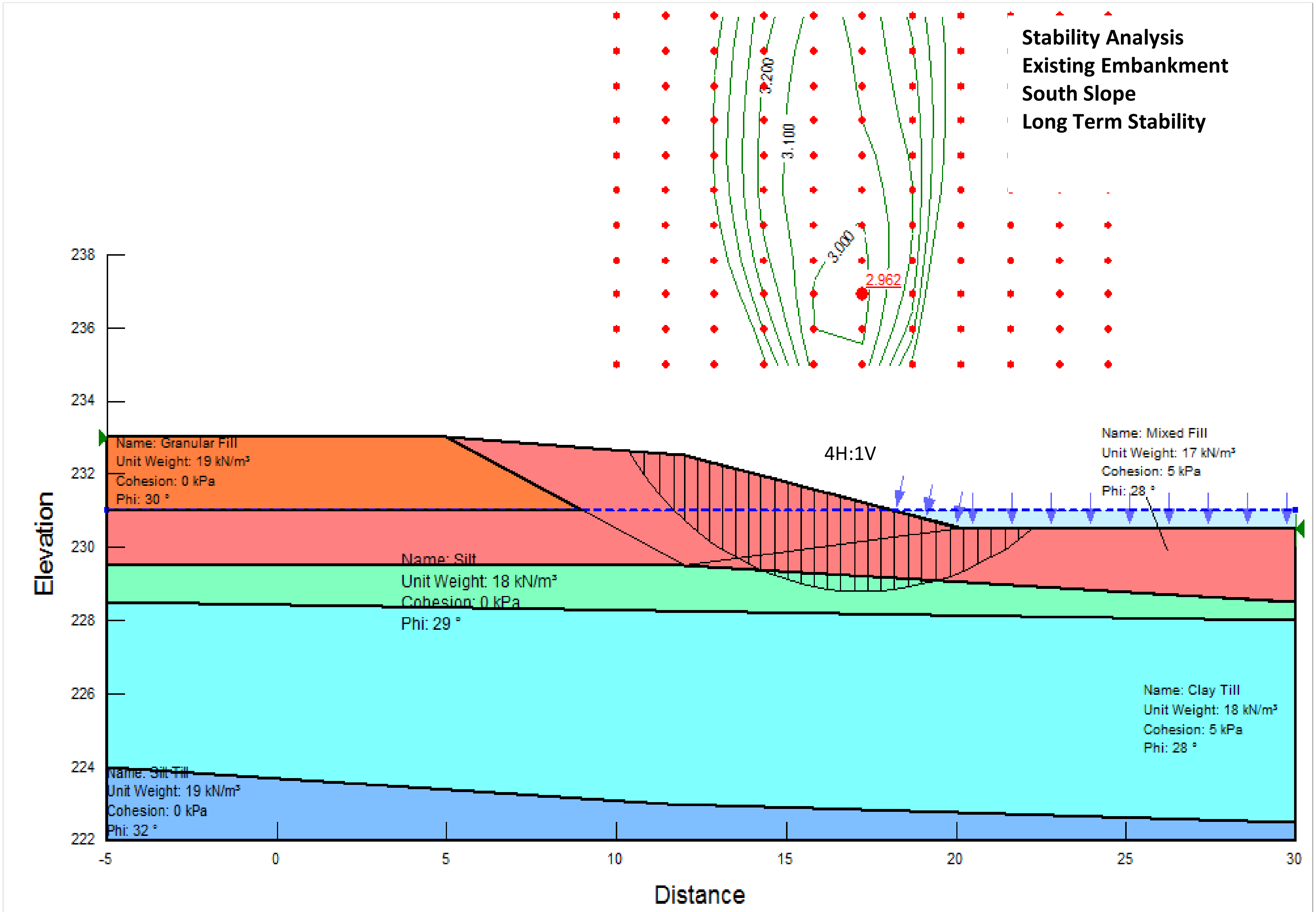
Appendix 5 Design Data



South Slope
Culvert Station 18+063

Reference No.: 15/05/15059-F4
Date: February, 2016

Englobe



South Slope
Culvert Station 18+063

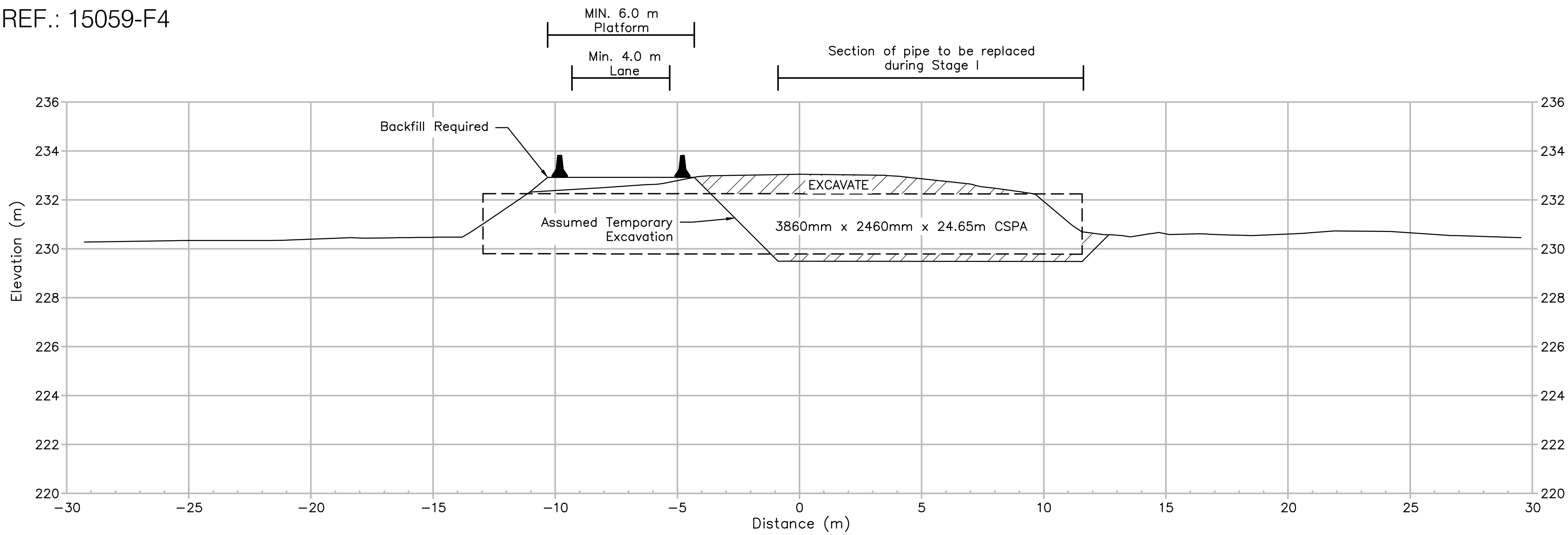
Project: G.W.P 5145-05-00
Location: Hwy 11, Township of Eilber

Figure No. S-2

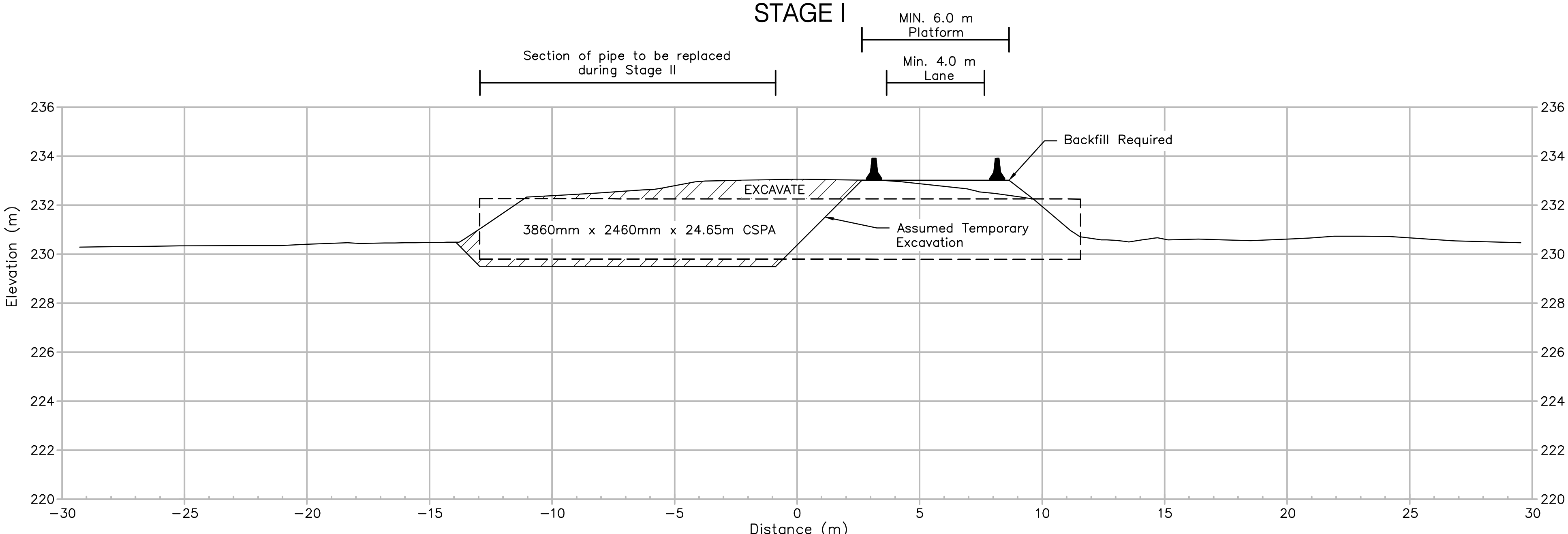
Table A – Comparison of Shoring Alternatives

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	Considered as alternative of protection system	$ 650/m^2
Steel Sheet Piles	5 – 21	-High strength, continuous, -Readily available	-Limited by soil conditions (i.e. obstructions)	Recommended for protection system	$ 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	Not considered due to higher cost	$ 725/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	Not Considered due to higher costs	
Concrete Diaphragm	10 – 30	-High Strength -Durable -Can be permanent	-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	Not Considered due to higher costs	$ 900/m^2

REF.: 15059-F4



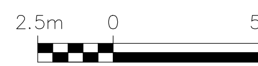
STAGE I



STAGE II

METRIC

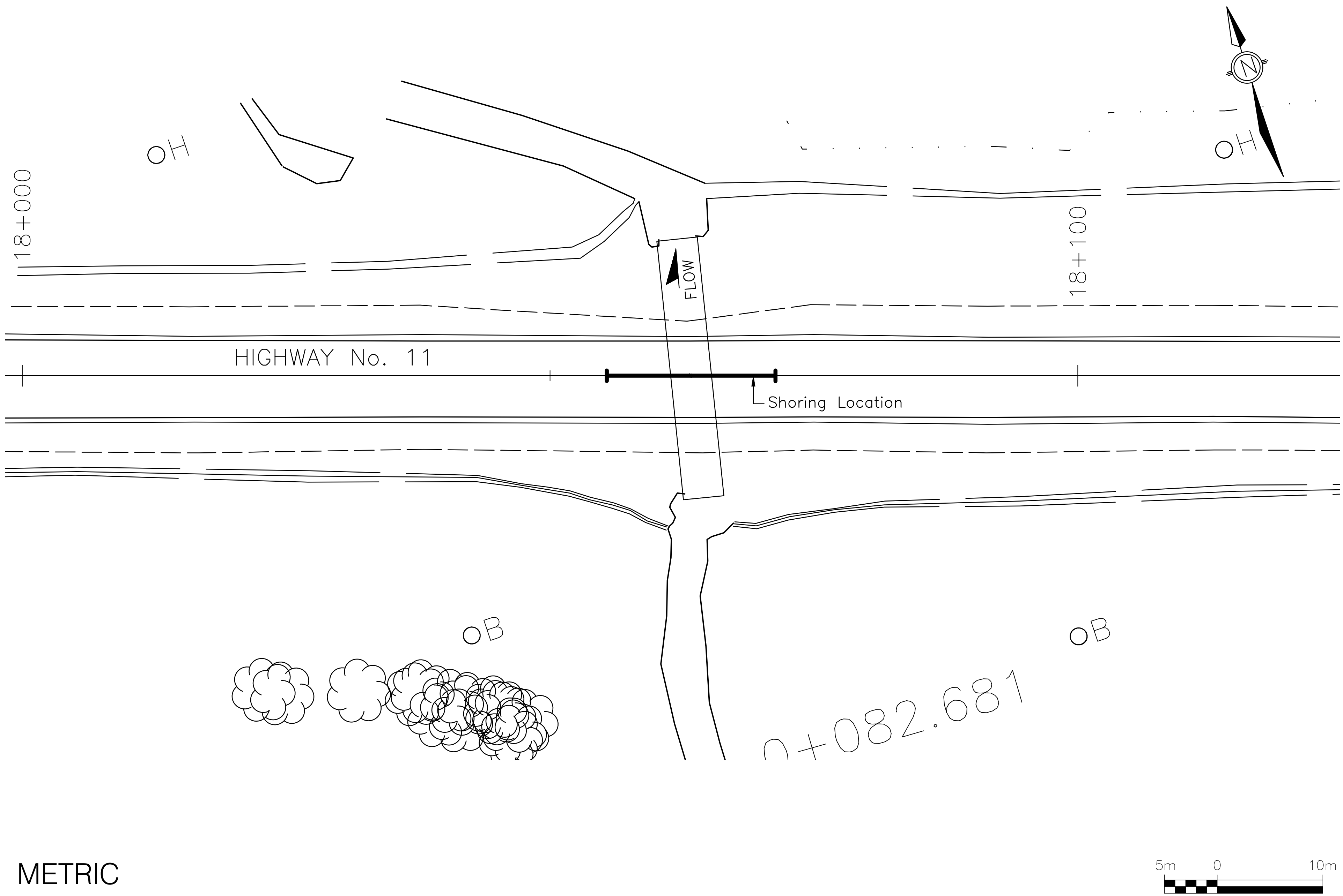
Dimensions are in meters and/or millimeters unless otherwise shown. Stations are in kilometers + meters.



Highway 11, Township of Eilber - Culvert at Station 18+063
Conceptual Shoring Location Plan

FIGURE SK-3

REF.: 15059-F4



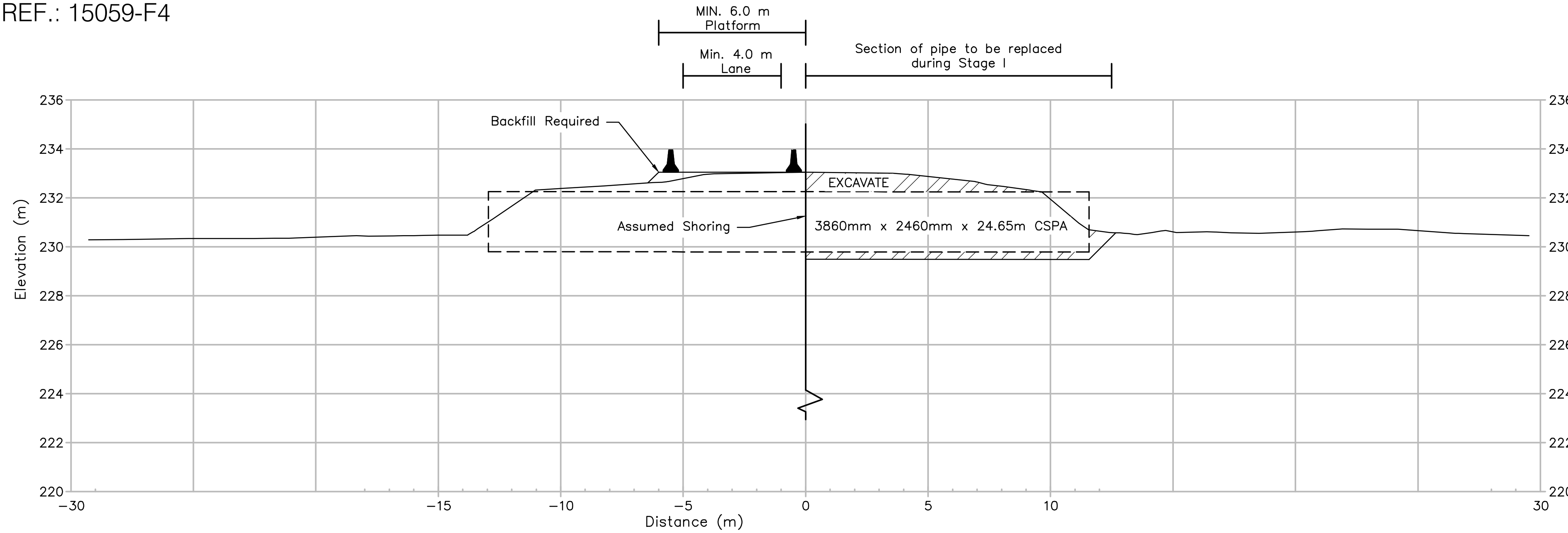
METRIC

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

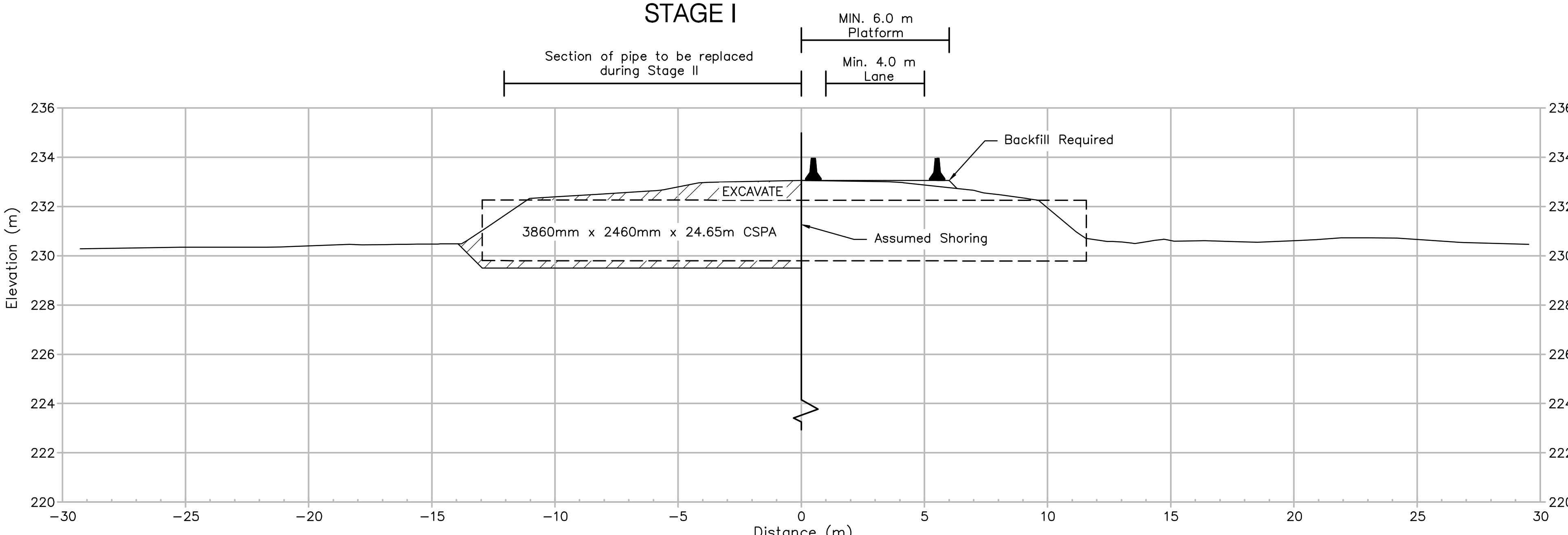
Highway 11, Township of Eilber - Culvert at Station 18+063
Conceptual Shoring Location Plan

FIGURE SK-4

REF.: 15059-F4



STAGE I



STAGE II

METRIC

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

2.5m 0 5m

Highway 11, Township of Eilber - Culvert at Station 18+063
Conceptual Shoring Location Plan

FIGURE SK-5

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