



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 – Holledge Creek Culvert
Highway 11
Station 15+735 – Township of Owens
Site No. 39W-107
GWP 163-98-00**

FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

Date: February 23, 2016
Ref. N^o: 15/05/15059-F1

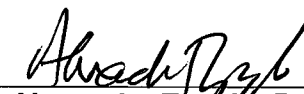
Geocres No. 42G-60

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 – Holledge Creek Culvert
Highway 11
Station 15+735 – Township of Owens
Site No. 39W-107
GWP 163-98-00

Final Foundation Investigation and Design Report

Prepared by:



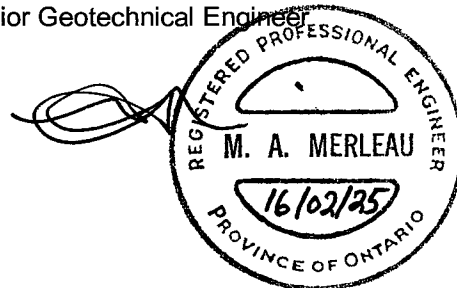
Alexander Teplov, P. Eng.

Englobe – Project Engineer



Sen Hu, P. Eng.

Englobe – Senior Geotechnical Engineer



Reviewed by:

M.A. Merleau, P. Eng.

Englobe – Principal Engineer
MTO Designate

TABLE OF CONTENTS

1 INTRODUCTION	1
2 SITE DESCRIPTION	1
2.1 Site Physiography and Surficial Geology	1
3 INVESTIGATION PROCEDURES	2
4 SUBSURFACE CONDITIONS	3
4.1 Culvert Station 15+735, Twp of Owens	3
4.1.1 Pavement Structure	3
4.1.2 Granular Fill	3
4.1.3 Organic Soils	4
4.1.4 Mixed Fills	4
4.1.5 Sandy Silt	4
4.1.6 Silty Clay	4
4.1.7 Silt	5
4.1.8 Till	5
4.2 Groundwater Data	6
5 DISCUSSION AND RECOMMENDATIONS	7
5.1 General	7
5.2 Foundation Considerations	7
5.2.1 Slope Stability	8
5.3 Culvert Design, Bedding, and Embedment	9
5.3.1 Rigid Concrete Culvert	9
5.3.2 Flexible Culvert	10
5.4 Culvert Installation and Construction Considerations	10
5.4.1 Staged Construction	11
5.4.2 Protection System	11
5.5 Excavation, Dewatering, and Embankment Construction	12
5.6 Lateral Earth Pressures	13
5.7 Construction Concerns	14
6 STATEMENT OF LIMITATIONS	15

Appendices

Appendix 1	Key Plan
Appendix 2	Subsurface Data
Appendix 3	Borehole Plan and Laboratory Data
Appendix 4	Photo Essay
Appendix 5	Design Data

Property and Confidentiality

"This engineering document is the work and property of Englobe Corp. and, as such, is protected under Copyright Law. It can only be used for the purposes mentioned herein. Any reproduction or adaptation, whether partial or total, is strictly prohibited without having obtained Englobe's and its client's prior written authorization to do so.

Test results mentioned herein are only valid for the sample(s) stated in this report.

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

Client:

AECOM Canada Ltd.

189 Wyld Street, Suite 103

North Bay, Ontario

P1B 1Z2

Attention: **Mr. Al Rose**

REVISION AND PUBLICATION REGISTER		
Revision N°	Date	Modification And/Or Publication Details
00	2015-11-20	DRAFT FIDR Issued
01	2016-02-23	FINAL FIDR Issued

REPORT DISTRIBUTION	
2 hard copies	AECOM
5 hard copies and 1 digital copy	MTO Project Manager
1 hard copy, 1 digital 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 described as the Holledge Creek Culvert, Site No. 39W-107. The site is located on Highway 11 at Station 15+735 in the Township of Owens, some 0.6 km west of the intersection between Highway 11 and Owens Road North.

The foundation investigation location was specified by the MTO in the Terms of Reference for work under Agreement No. 5014-E-0001: GWP 163-98-00. The terms of reference for the scope of work are outlined in Englobe's Proposal Reference No. 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.

Following completion of the field investigation, as outlined in the RFP, the MTO indicated that the proposed work at the culvert location would be changed from replacement to rehabilitation, based on the result of structural review. During September 2015, MTO instructed Englobe to proceed with the full foundation investigation and design report as outlined in the RFP.

2 SITE DESCRIPTION

The Corrugated Steel Pipe (CSP) culvert is located on Highway 11 at Station 15+735 in the Township of Owens. 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 constructed on a granular fill embankment some 5.9 to 7.1 m in height, with centerline elevation of 215.1 m at the culvert location. The existing embankment slopes in the area of the culvert have been constructed at an angle of approximately 1.5H:1V. The culvert at this location is a 3.9 m diameter Corrugated Steel Pipe (CSP) culvert, some 30.5 m in length, as surveyed by others. The flow through the culvert is from the south to the north (right to left).

Infrastructure at this site consists of overhead and underground communication lines running parallel to the highway embankment. An Ontario Northland Rail Line runs adjacent 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 soil overlay the bedrock. Within the project area native overburden primarily consists of silty clays, silts and tills.

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 during the period between July 22nd and July 26th, 2015 during which time four (4) sampled boreholes were advanced. Two (2) boreholes were advanced through the embankment at the location of the culvert, and a single borehole was advanced adjacent to each of the inlet (south) and outlet (north) ends of the culverts.

The field investigation was carried out using a 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. 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-8 and Table No. L-9).

The location of the individual boreholes was determined in the field using highway chainage (established by others) 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 13, NAD 83 CSRS. The borehole elevations are based on coordinating the borehole locations with the Highway survey carried out by Callon Dietz Inc. 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 15+735, TWP OF OWENS

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 adjacent to the culvert and Borehole Nos. 3 and 4 advanced adjacent to the culvert inlet and outlet, respectively. At the time of the subsurface investigation, the ground surface elevations at Boreholes Nos. 1 to 4, inclusive, were recorded at elevations 214.9, 215.0, 211.4, and 211.2 m, respectively.

4.1.1 Pavement Structure

Borehole No. 1 and 2 were advanced through the embankment shoulder where a layer of crushed gravel some 205 and 255 mm thick was penetrated, respectively.

4.1.2 Granular Fill

Underlying the pavement structure at Borehole Nos. 1 and 2, a layer of granular fill consisting of brown sand, trace to with gravel, trace to some silt and clay was penetrated. A mixture of brown sand and grey silty clay, trace gravel, was encountered at the bottom interface between the fill layer and the native soils at Borehole Nos. 1 and 2. The natural moisture content measured on samples of this deposit was in the order of 4 to 21%. Gradation analyses were carried out on five (5) samples of this deposit, the results of which indicated 4 to 23% gravel size particles, 67 to 87% sand size particles, and 7 to 11% silt and clay size particles (Figure No. L-1, Appendix 3). Based on SPT 'N' values of 5 to 31 blows per 300 mm penetration, the compactness of this

deposit was described as loose to dense, generally compact. This granular fill layer was encountered to depths of 5.9 and 7.1 m below grade at Borehole Nos. 1 and 2, respectively (elevations 209.0, and 207.9 m, respectively).

4.1.3 **Organic Soils**

At ground surface at Borehole No. 3, a layer of silty organic soils was penetrated. This organic soil layer was encountered to an approximate depth of 0.2 m below ground surface at Borehole No. 3 (elevation 211.2 m).

4.1.4 **Mixed Fills**

Underlying the organic soils at Borehole No. 3, a layer of mixed fills consisting of a mixture of brown silty sands and grey silty clay, trace gravel, trace sand, containing organic soils, rootlets, and wood was penetrated. The natural moisture content measured on samples of this deposit was in the order of 3 to 38%. A gradation (hydrometer) analyses was carried out on one (1) sample of this deposit, the results of which indicated 0% gravel size particles, 19% sand size particles, 51% silt size particles and 30% clay size particles (Figure No. L-2, Appendix 3). Based on in-situ shear strengths of 80 kPa to greater than 100 kPa, the consistency of this deposit was described as stiff to very stiff. This fill layer was encountered to a depth of 2.9 m below grade at Borehole No. 3 (elevation 208.5 m).

4.1.5 **Sandy Silt**

Underlying the granular fills at Borehole No. 2 a deposit of grey sandy silt trace clay was penetrated. The natural moisture content measured on one sample of this deposit was in the order of 17%. A gradation (hydrometer) analysis was carried out on one (1) sample of this deposit, the results of which indicated 0% gravel size particles, 37% sand size particles, 54% silt size particles, and 9% clay size particles (Figure No. L-3, Appendix 3). Based on a SPT 'N' values of 49 blows per 300 mm penetration, the compactness state of this deposit was described as dense. This deposit was encountered to a depth of 9.4 m below grade at Borehole No. 2 (elevation 205.6 m).

4.1.6 **Silty Clay**

Underlying the granular fills at Borehole No. 1, underlying the sandy silt at Borehole No. 2, and underlying the mixed fills at Borehole Nos. 3, and at surface at Borehole No. 4, a deposit of grey silty clay, trace to some gravel, trace sand, was penetrated. Organic soils, rootlets and decayed wood were encountered in this deposit at Borehole No. 1 and 4. The natural moisture content measured on samples of this deposit was in the order of 18 to 55%. Gradation (hydrometer) analysis were carried out on two (2) samples of this deposit, the results of which indicated 0% gravel size particles, 6 to 13% sand size particles, 58 to 62% silt size particles, and 25 to 36% clay size particles (Figure No. L-4, 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 13 to 14% and a Liquid Limit in the order of 23 to 30% (Figure No. L-8, Appendix

3). Based on in situ shear strengths of 52 to greater than 100 kPa, the consistency of this deposit was described as stiff to very stiff, generally very stiff. This deposit was encountered to depths of 8.6, 3.8, and 5.7 m below grade at Borehole Nos. 1, 3, and 4, respectively (elevations 206.3, 207.6, and 205.5 m, respectively). Sampling was terminated in this deposit at a depth of 9.8 m below grade at Borehole No. 2 (elevation 205.2 m).

A layer of silty clay was also encountered between silt layers at Borehole No 3. This silty clay deposit was encountered between depths of 5.6 to 7.2 m below grade (elevations 205.8 to 204.2 m). Based on in situ shear strengths of 52 kPa, the consistency of this layer was described as stiff.

4.1.7 Silt

Underlying/interbedded in the silty clay deposit at Borehole Nos. 1 and 3, a deposit of grey silt trace gravel trace to some sand trace clay was penetrated. The natural moisture content measured on samples of this deposit was in the order of 14 to 29%. A gradation (hydrometer) analysis was carried out on one (1) sample of this deposit, the results of which indicated 0% gravel size particles, 13% sand size particles, 80% silt size particles, and 7% clay size particles (Figure No. L-5, Appendix 3). Based on SPT 'N' values of 14 to 37 blows per 300 mm penetration, the compactness state of this deposit was described as compact to dense. At Borehole No. 1, sampling was terminated in this deposit at a depth of 9.8 m below grade (elevation 205.1 m). Two layers of the silt deposit were encountered at Borehole No. 3, from depths of 3.8 to 5.6 m below grade (elevations 207.6 to 205.8 m) and from depths of 7.2 to 8.6 m below grade (elevations 204.2 to 202.8 m).

4.1.8 Till

Underlying the silt at Borehole No. 3, and underlying the silty clay at Borehole No. 4, a deposit of grey clayey silt till, trace gravel, sandy was penetrated. The natural moisture content measured on samples of this deposit was in the order of 14 to 17%. Gradation (hydrometer) analysis were carried out on two (2) samples of this deposit, the results of which indicated 3 to 5% gravel size particles, 24 to 31% sand size particles, 54% silt size particles, and 12 to 17% clay size particles (Figure No. L-6, 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 11 to 12% and a Liquid Limit in the order of 16 to 18% (Figure No. L-8, Appendix 3). Sampling was terminated in this deposit at a depth of 9.8 m below grade at Borehole No. 3 (elevation 201.6 m).

A transition from clayey silt till to sandy silt till was observed at a depth of some 7.1 m below grade at Borehole No. 4 (elevation 204.1 m). The natural moisture content measured on samples of the sandy silt deposit was in the order of 11 to 12%. Gradation (hydrometer) analysis were carried out on one (1) sample of this deposit, the results of which indicated 5% gravel size particles, 26% sand size particles, 61% silt size particles, and 8% clay size particles

(Figure No. L-7, Appendix 3). Sampling was terminated in this deposit at a depth of 9.8 m below grade at Borehole No. 4 (elevation 201.4 m).

4.2 GROUNDWATER DATA

During the period of investigation (July 22nd to 26th, 2015), the creek water level was measured at an elevation of some 210.6 m at the culvert outlet. The creek flows in a northerly direction.

Measurements of the water levels 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 3 to obtain post borehole completion water levels.

These levels are recorded on the individual Record of Borehole Log Sheets (Appendix 2). The water levels were measured in the standpipes (between July 22th and 28th, 2015) and recorded at elevations 211.8 m and 207.2 m at Borehole Nos. 1 and 3, respectively. The water level in Borehole No. 3 may not have stabilized.

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 CSP culvert as identified in the RFP. Following completion of the field investigation, as outlined in the RFP, the MTO indicated that the proposed work at the culvert location would be changed from replacement to rehabilitation, based on the result of structural review. During September 2015, MTO instructed Englobe to proceed with the full foundation investigation and design report as outlined in the RFP

The existing culvert, located at Station 15+735, in the Township of Owens, is a 3900 mm diameter CSP culvert some 30.5 m long. The culvert invert is established at elevation 208.8 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 data from this foundation investigation, the embankment supporting the existing pavement structure at this site has been constructed using a granular pavement structure overlying granular and mixed fills. The native material, underlying the embankment fill, generally consisted of very stiff to stiff silty clays, compact silts, as well as clayey silt and sandy silt tills.

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

5.2 FOUNDATION CONSIDERATIONS

The founding native very stiff to silty clays, dense sandy silts to compact silts present below the existing embankment are considered adequate for support of a culvert and for a conventional highway embankment of this height. 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 a boiling condition or heave and disturbance of subgrade at the founding level.

Based on the characteristics of the native very stiff to silty clays, dense sandy silts to compact silts subgrades 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 260 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 220 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 210 kPa, and a geotechnical reaction at SLS of 180 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 5.5 m. The angles of existing slopes are some 1.5H:1V. 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 side slopes with existing inclinations in the embankment 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)	SHEAR STRENGTH (KPA)
Granular Fill	19.0	32	-
Mixed Fill (undrained)	17.0	-	50
Mixed Fill (drained)	17.0	28	5
Sandy Silt	18.0	30	-
Silty Clay (undrained)	16.5	-	100
Silty Clay (drained)	16.5	28	8
Silt	17.5	28	-
Clayey Silt Till (undrained)	18.5	-	100
Clayey Silt Till (drained)	18.5	28	8
Sandy Silt Till	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 results of the analyses indicate factors of safety in the order of 0.9 to 1.0 on the existing embankment slopes, against minor surficial slippage on the embankment (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. The factor of safety against deep seated failures is in the order of 1.3 to 1.4 with the existing slopes. Lower factors of safety will occur during excavation and backfilling as discussed in Section 5.5. Short term stability during excavation 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 and mixed fills. The results of this investigation indicate that, below the culvert invert, the native soils encountered at Boreholes No. 1 to 4 consisted of very stiff to stiff silty clays, and dense to compact silts overlying 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 fairly. 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.

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 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/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 fills, 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 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 CONSIDERATIONS

The culvert invert has been established at a depth of some 6.3 m below centreline (i.e. elevation 208.8 m). Therefore, a minimum 6.6 m deep excavation (i.e. to elevation 208.5 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 14.0 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 1.8 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 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 213.3 m.
- 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 15 m in length of new culvert.
- Reconstruct the embankment on the right (south), 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 (north).
- As the width of the platform increases on the left, the vertical alignment can be raised, and 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/extent of this foundation investigation, as outlined in the RFP, only two boreholes were advanced through the embankment. It is unknown what type of protection system will be employed by the contractor and considering the possibility of variations in subsurface conditions up and down chainage from the culvert, the contractor should be afforded the opportunity to further investigate if they feel that the conditions could adversely impact their chosen protection system design.

The installation of a protection system for use in the culvert replacement operation will require penetration through some 6.6 m of embankment fills. The embankment fill is generally underlain by very stiff to stiff silty clays, and dense to compact silts, overlying compact tills. Considering the embankment generally consists of granular fills, 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 fills into the underlying native soils. Conceptual shoring locations and sections are illustrated on Figure Nos. SK-4 and SK-5, Appendix 5.

Considering the cohesionless nature of the embankment fills (granular pavement structure over granular and mixed 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 $0.65 \cdot K_a \cdot \gamma \cdot H$, 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.

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 geotechnical 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 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 and/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.

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 210.6 m at the culvert outlet during the period of this investigation and the groundwater level in Borehole No. 1 had stabilized at elevation 211.8 m 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, 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 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 for the bedding/embedment and backfill materials are as follows:

PARAMETER	GRANULAR A	GRANULAR B TYPE I	GRANULAR FILL	MIXED FILL	SANDY SILT
Unit Weight (kN/m^3)	22	21	19	17.0	18.0
Angle of Internal Friction	34°	33°	32°	-	30
Shear Strength (kPa)	-	-	-	50	-
Coefficient of Active Earth Pressure (K_a)	0.28	0.29	0.31	-	0.30
Coefficient of Passive Earth Pressure (K_p)	3.54	3.39	3.23	-	3.00
Coefficient of Earth Pressure at Rest (K_o)	0.44	0.46	0.47	-	0.50

PARAMETER	SILTY CLAY	SILT	CLAYEY SILT TILL	SANDY SILT TILL	
Unit Weight (kN/m^3)	16.5	17.5	18.5	19.0	
Angle of Internal Friction	-	28	-	32	
Shear Strength (kPa)	100	-	100	-	
Coefficient of Active Earth Pressure (K_a)	-	0.36	-	0.31	
Coefficient of Passive Earth Pressure (K_p)	-	2.77	-	3.23	
Coefficient of Earth Pressure at Rest (K_o)	-	0.53	-	0.47	

For rigid structures, such as a precast concrete culvert, 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.

5.7 CONSTRUCTION CONCERNS

Considering the nature of the granular fill 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.

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

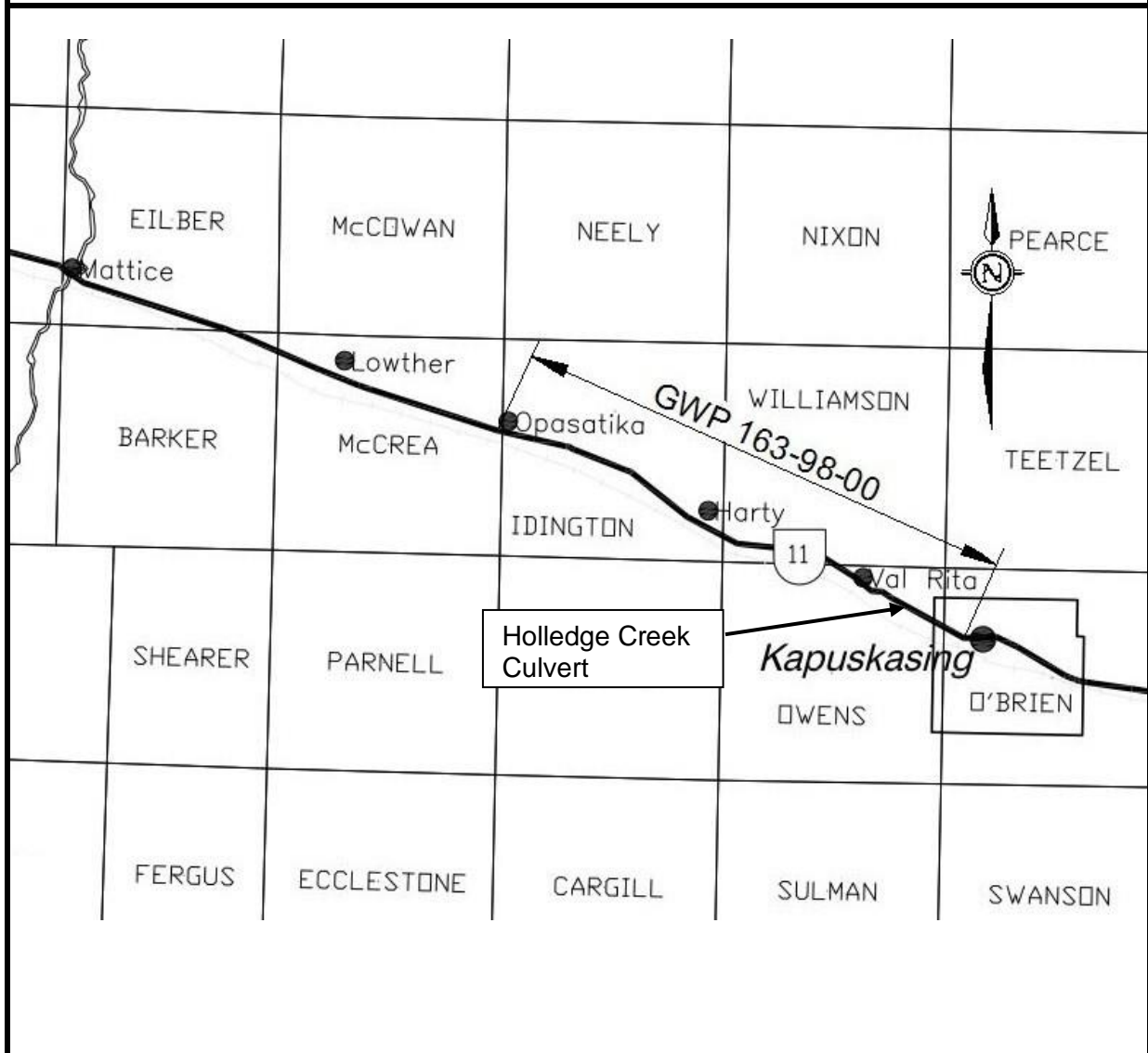
Drawing No. 1

Key Plan

MACRO KEY PLAN

Drawing No. 1

NOT TO SCALE



FOUNDATION INVESTIGATION

AND DESIGN REPORT

GWP 163-98-00

Highway 11

Station 15+735 Culvert

Township of Owens



Reference No: 15/05/15059-F1

February 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.

METRIC

RECORD OF BOREHOLE NO. 1



REFERENCE 15/05/15059-F1 DATUM Geodetic LOCATION N 5477452.3 E 414722.9 - Owens Twp., Station 15+732 ORIGINATED BY JL
 PROJECT GWP 163-98-00, Highway 11 BOREHOLE TYPE Track Mounted CME 45 - Hollow Stem Augers COMPILED BY AT
 CLIENT AECOM DATE (Started) 22 July 2015 TIME 1:45:00 PM DATE (Completed) 22 July 2015 CHECKED BY MAM

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION (see Enclosure No. 1)	STRATA PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					
214.9	Ground Surface												
0.0	205 mm Crushed Gravel GRANULAR FILL- sand, trace to with gravel, trace to some silt brown, moist (dense/loose)		1	SS	26								
			2	SS	23								23 67 (10)
			3	SS	31								
			4	SS	13								
			5	SS	5								4 87 (9)
			6	SS	8								
			7	SS	15								17 72 (11)
209.3			8A	SS	7								
5.6			8B										
209.0	mixture of brown sand and grey silty clay, trace gravel												
5.9	silty CLAY - some sand, trace grass rootlets seams of sand brown to grey (very stiff/stiff)		9	SS	5								
			10	SS	WH								0 13 62 25
206.3													
8.6	SILT - trace silt trace clay (compact) grey												
205.1			11	SS	28								
9.8	End of Sampling End of Borehole												
COMMENTS							+ 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) 22/7/15 1:45:00 PM		9.2		-		
							2) 26/7/15 10:00:00 AM		3.1		-		
							3)		-		-		

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





MEL-GEO 15059 - F1 BOREHOL LOGS.GPJ MEL-GEO.GDT 12/2/16

METRIC

RECORD OF BOREHOLE NO. 2



REFERENCE	15/05/15059-F1	DATUM	Geodetic	LOCATION	N 5477442.3 E 414723.5 - Owens Twp., Station 15+737	ORIGINATED BY	JL
PROJECT	GWP 163-98-00, Highway 11			BOREHOLE TYPE	Track Mounted CME 45 - Hollow Stem Augers	COMPILED BY	AT
CLIENT	AECOM			DATE (Started)	22 July 2015	TIME	
				DATE (Completed)	22 July 2015	(Completed) 4:45:00 PM	CHECKED BY
							MAM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)			
ELEV DEPTH	DESCRIPTION (see Enclosure No. 1)	STRATA PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)		
								○ UNCONFINED		+ FIELD VANE									
215.0	Ground Surface																		
0.0	255 mm Crushed Gravel		1	SS	26											11 78 (11)			
	GRANULAR FILL- sand, trace to some gravel, trace to some silt																		
	brown, moist		2	SS	15														
	(compact/loose)		3	SS	19														
			4	SS	11														
			5	SS	9														
			6	SS	8														
			7	SS	8														
209.1			8	SS	8												8 85 (7)		
5.9	mixture of brown sand and grey silty clay, trace gravel																		
207.9																			
7.1	sandy SILT, trace clay (dense)		10	SS	49										0 37 54 9 (NP)				
205.6																			
9.4	silty CLAY - trace sand, seams of silt		11	SS	28														
205.2	grey (very stiff)																		
9.8	End of Sampling End of Borehole																		
COMMENTS							+ 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/yyyy)/Time				Water Depth (m)		Cave In (m)						
							1) 22/7/15 4:45:00 PM				Dry		4.4						
							2)				-		-						
							3)				-		-						
The stratification lines represent approximate boundaries. The transition may be gradual																			

MEL-GEO 15059 - F1 BOREHOL LOGS.GPJ MEL-GEO.GDT 12/2/16

METRIC

RECORD OF BOREHOLE NO. 3



REFERENCE 15/05/15059-F1 DATUM Geodetic LOCATION N 5477436.5 E 414709.3 - Owens Twp., Station 15+727 ORIGINATED BY JL
 PROJECT GWP 163-98-00, Highway 11 BOREHOLE TYPE Track Mounted CME 45 - Hollow Stem Augers COMPILED BY AT
 CLIENT AECOM DATE (Started) 26 July 2015 TIME (Completed) 10:00:00 AM CHECKED BY MAM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION (see Enclosure No. 1)	STRATA PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)	
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL							× LAB VANE
211.4	Ground Surface																
210.2	Topsoil- silty brown, wet		1	SS	3												
0.2	MIXED FILL - mixture of brown silty sand and grey silty clay, trace gravel, with grass rootlets and decayed wood silty clay, with grass rootlets and decayed wood, trace sand dark grey to grey (stiff/very stiff)		2	SS	5												
			3	SS	4												
		4A	SS	8													
		4B															
208.5																	
2.9	silty CLAY - trace gravel, trace sand moist (very stiff)		5	SS	5												
207.6																	
3.8	SILT - some sand, trace clay grey wet (dense/compact)		6	SS	37												
			7	SS	21												
205.8																	
5.6	silty CLAY - trace sand (stiff)		8	SS	WH												
204.2																	
7.2	SILT - trace gravel, trace clay grey wet (compact)		9	SS	14												
202.8																	
8.6	clayey SILT TILL - trace gravel, with sand grey (stiff)		10	SS	7												
201.6																	
9.8	End of Sampling End of Borehole																
COMMENTS								+ 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) 26/7/15 10:10:00 AM		Dry	▽ -			
											2) 28/7/15 8:00:00 AM		4.25	▽ -			
											3)		-	▽ -			

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

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

EnGlobe Corp.

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

MEL-GEO 15059 - F1 BOREHOL LOGS.GPJ MEL-GEO.GDT 12/2/16

METRIC

RECORD OF BOREHOLE NO. 4



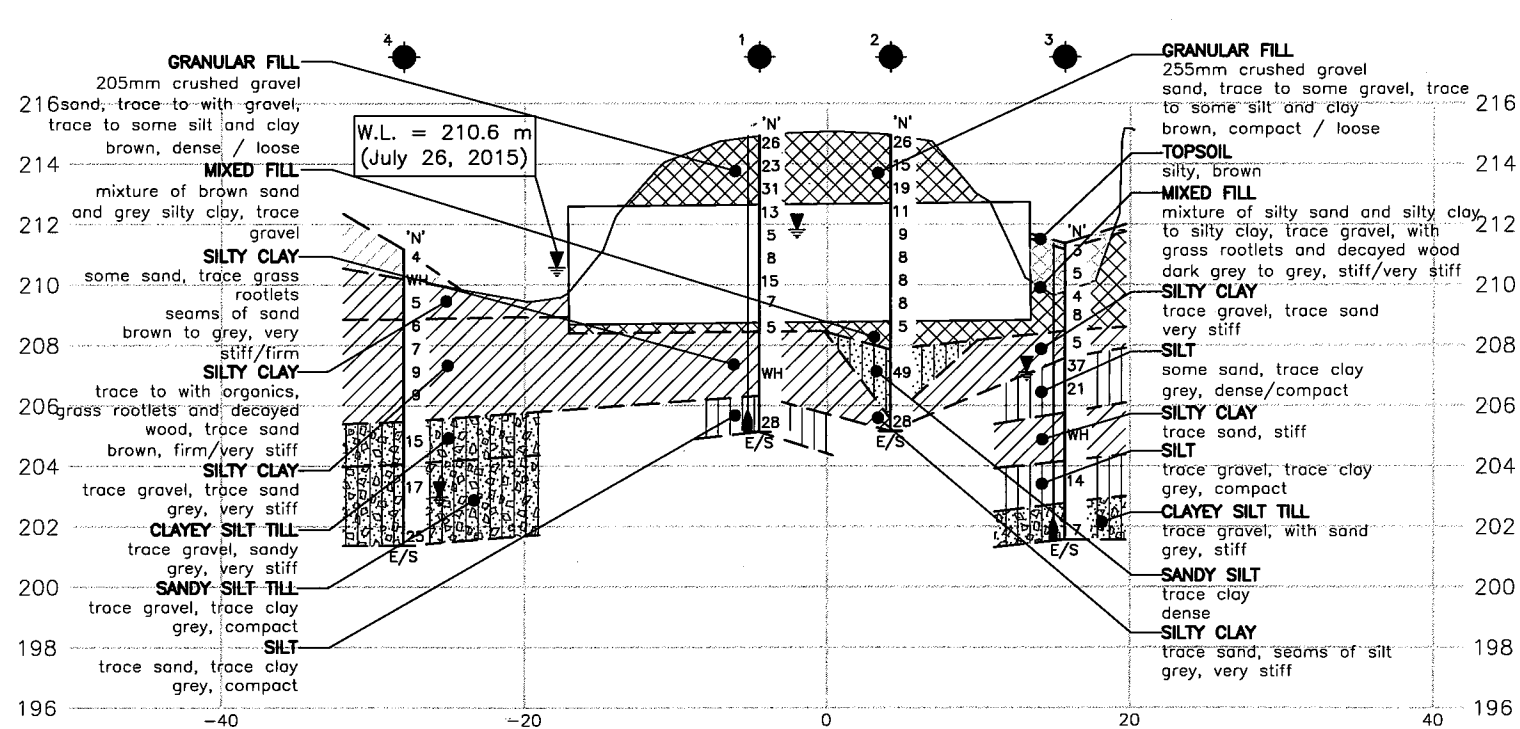
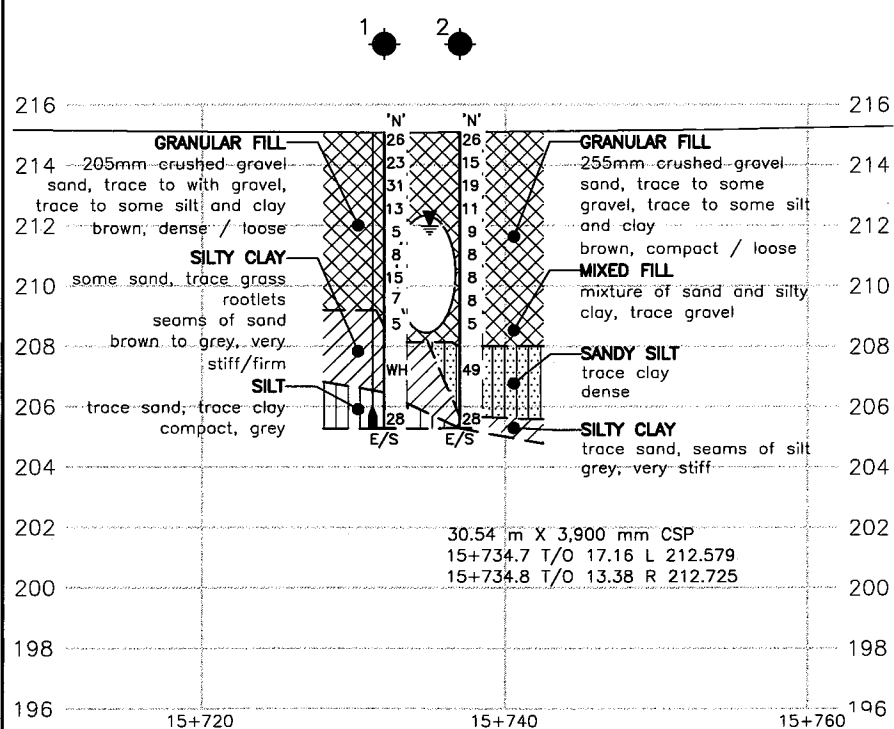
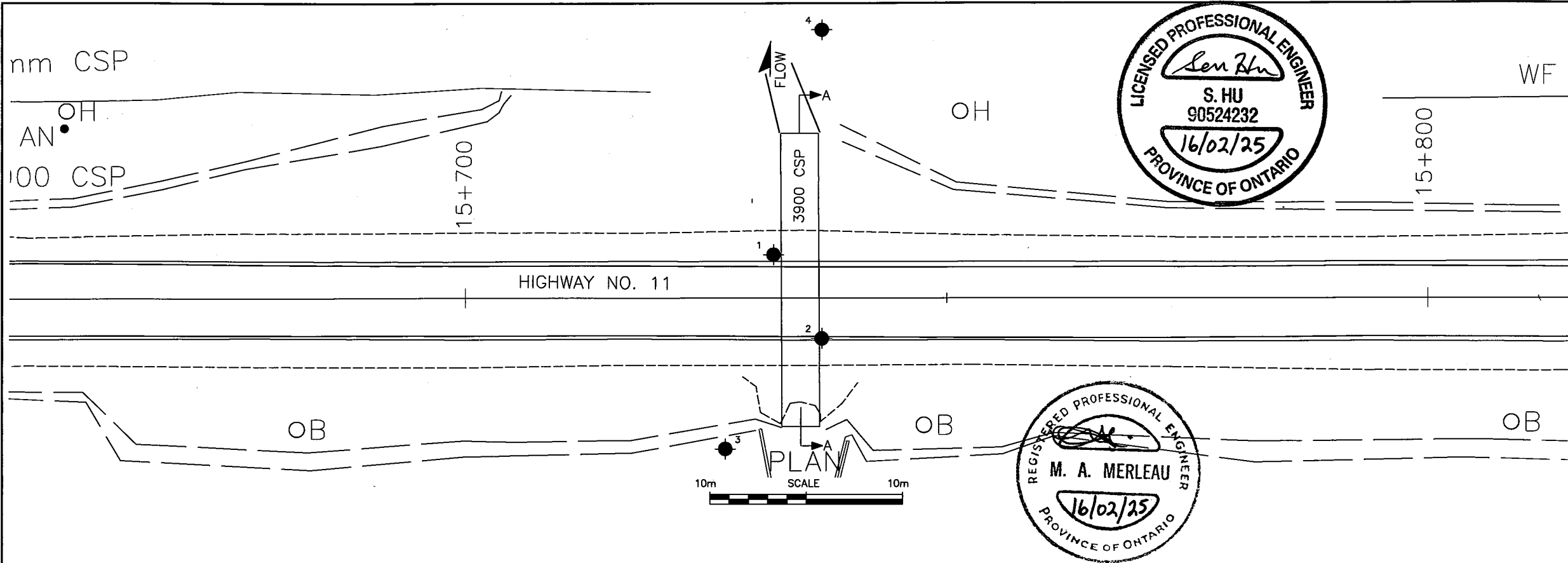
REFERENCE 15/05/15059-F1 DATUM Geodetic LOCATION N 5477471.0 E 414737.9 - Owens Twp., Station 15+737 ORIGINATED BY JL
 PROJECT GWP 163-98-00, Highway 11 BOREHOLE TYPE Track Mounted CME 45 - Hollow Stem Augers COMPILED BY AT
 CLIENT AECOM DATE (Started) 26 July 2015 TIME
 DATE (Completed) 26 July 2015 (Completed) 5:20:00 PM CHECKED BY MAM

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)												
ELEV DEPTH	DESCRIPTION (see Enclosure No. 1)	STRATA PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa						WATER CONTENT (%)											
211.2	Ground Surface																								
0.0	silty CLAY - trace to with organics, grass rootlets and decayed wood, trace sand		1	SS	4																				
	brown, moist																								
	(firm/very stiff)		2	SS	WH																				
			3	SS	5																				
208.9																									
2.3	silty CLAY - trace gravel, trace sand		4	SS	6																				
	grey, moist																								
	(very stiff)		5	SS	7																				
			6	SS	9																				
			7	SS	9																				
205.5																									
5.7	clayey SILT TILL - trace gravel, sandy																								
	grey		8	SS	15																				
	(very stiff)																								
204.1																									
7.1	sandy SILT TILL - trace gravel, trace clay																								
	grey		9	SS	17																				
	moist																								
	(compact)																								
201.4			10	SS	25																				
9.8	End of Sampling End of Borehole																								
COMMENTS							+ 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 <table border="1"> <thead> <tr> <th>Date (dd/mm/yy)/Time</th> <th>Water Depth (m)</th> <th>Cave In (m)</th> </tr> </thead> <tbody> <tr> <td>1) 26/7/15 5:20:00 PM</td> <td>8.2</td> <td>8.7</td> </tr> <tr> <td>2)</td> <td>-</td> <td>-</td> </tr> <tr> <td>3)</td> <td>-</td> <td>-</td> </tr> </tbody> </table>					Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)	1) 26/7/15 5:20:00 PM	8.2	8.7	2)	-	-	3)	-	-
Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)																							
1) 26/7/15 5:20:00 PM	8.2	8.7																							
2)	-	-																							
3)	-	-																							
The stratification lines represent approximate boundaries. The transition may be gradual.																									

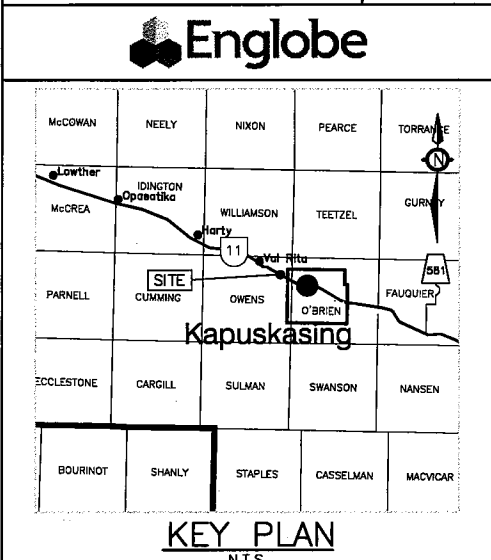
MEL-GEO 15059 - F1 BOREHOLE LOGS.GPJ MEL-GEO.GDT 12/2/16





Appendix 3 Borehole Plan and Laboratory Data

Drawing No. 2:	Borehole Location and Soil Strata
Figure Nos. L-1 to L-7:	Grain Size Distribution Curves
Figure No. L-8:	Atterberg Limits Summary
Table No. L-4:	Laboratory Test Summary Sheet



DISTRICT CONT. No. GWP No. 163-98-00	DRAWING 2
HWY11 HOLLEDGE CREEK CULVERT STA. 15+735 SITE NO. 39W-107	
BOREHOLE LOCATIONS AND SOIL STRATIGRAPHY	



LEGEND	
	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	214.9	4.5m Lt	5477452.3	414722.9
2	215.0	4.2m Rt	5477442.3	414723.5
3	211.4	15.7m Rt	5477436.5	414709.3
4	211.2	28m Lt	5477471.0	414737.9

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 Collon Dietz on August 4, 2015

Coordinates based on MTM Zone 13 NAD83 CSRS

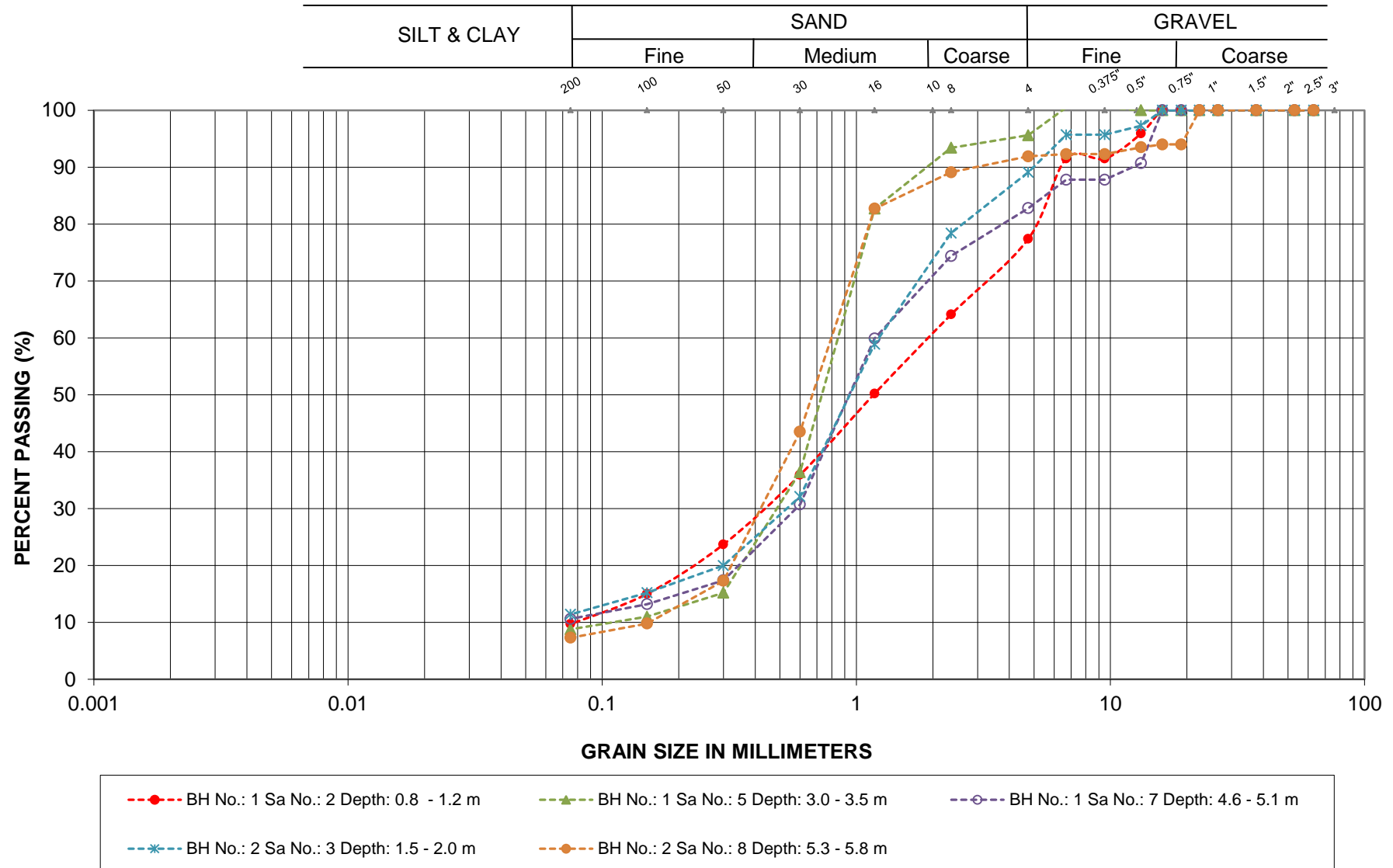
GEOCREs No. 42G-60

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		DATE	
NOV/15	DM	DRAFT			
FEB/16	DM	FINAL			
DESIGN	CHK	CODE	LOAD	DATE	FEB/16
DRAWN	DM	CHK	SH	SITE 39W-107	STRUCT
				SCHEME	DWG 2

CAD FILE LOCATION AND NAME: G:\2015\15059 - PAV & FDN, Hwy 11 - 163-98-00 & 5145-05-00 (ALCOM)\FOUNDATIONS\Drawings\F1\15059 F1 - Holledge Creek Culvert.dwg
MODIFIED: 2/2/2016 4:33:51 PM BY: MITOU
DATE PLOTTED: 2/11/2016 9:47:35 AM BY: DUNCAN MITCHELL

GRAIN SIZE ANALYSIS



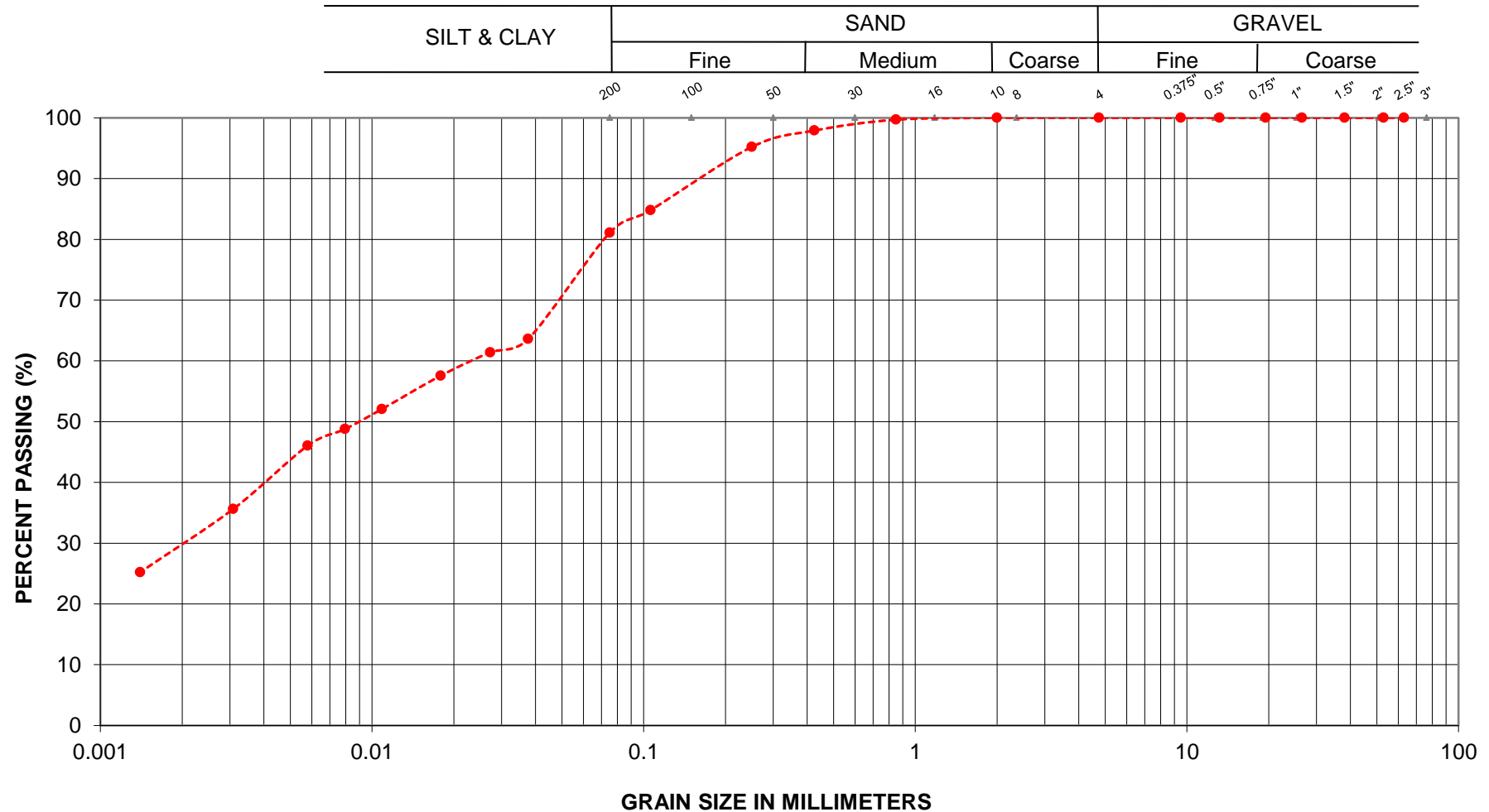
GRANULAR FILL

LOCATION: Hwy 11, Station 15+735
TWP of Owens

Englobe Corp.

FIGURE L-1

GRAIN SIZE ANALYSIS



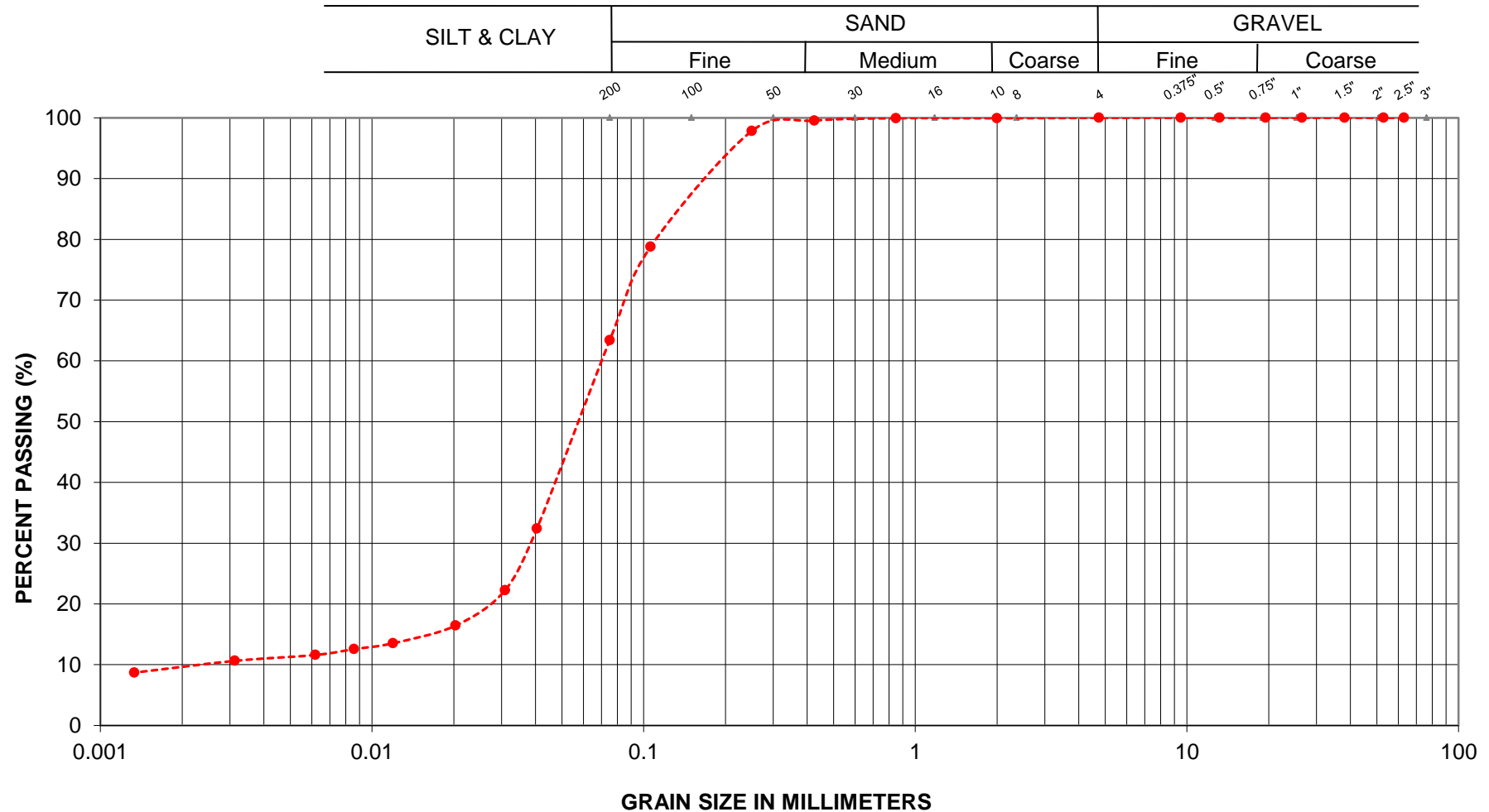
MIXED FILL

LOCATION: Hwy 11, Station 15+735
TWP of Owens

Englobe Corp.

FIGURE L-2

GRAIN SIZE ANALYSIS



---●--- BH No.: 2 Sa No.: 10 Depth: 7.6 - 8.1 m

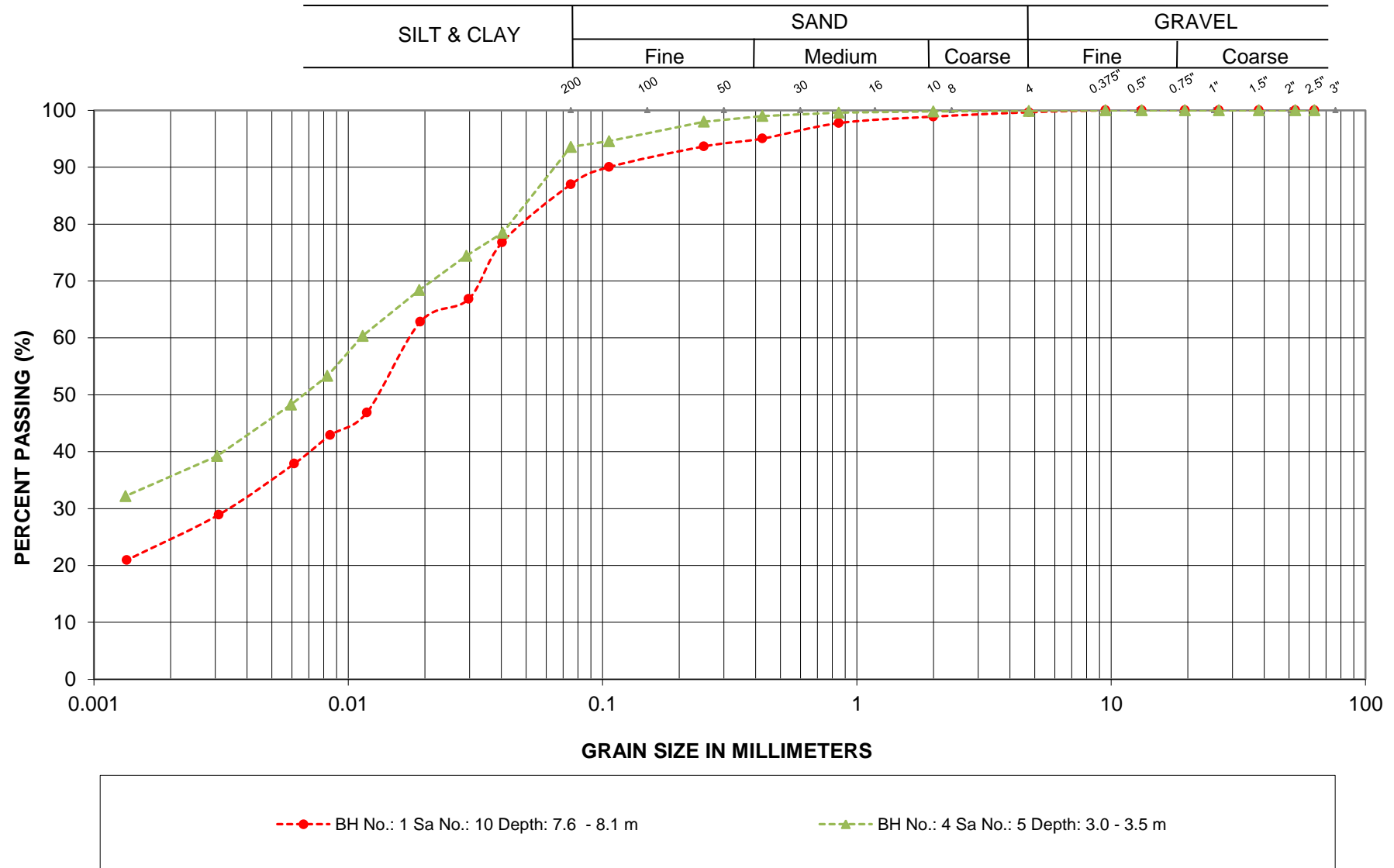
SANDY SILT

LOCATION: Hwy 11, Station 15+735
TWP of Owens

Englobe Corp.

FIGURE L-3

GRAIN SIZE ANALYSIS

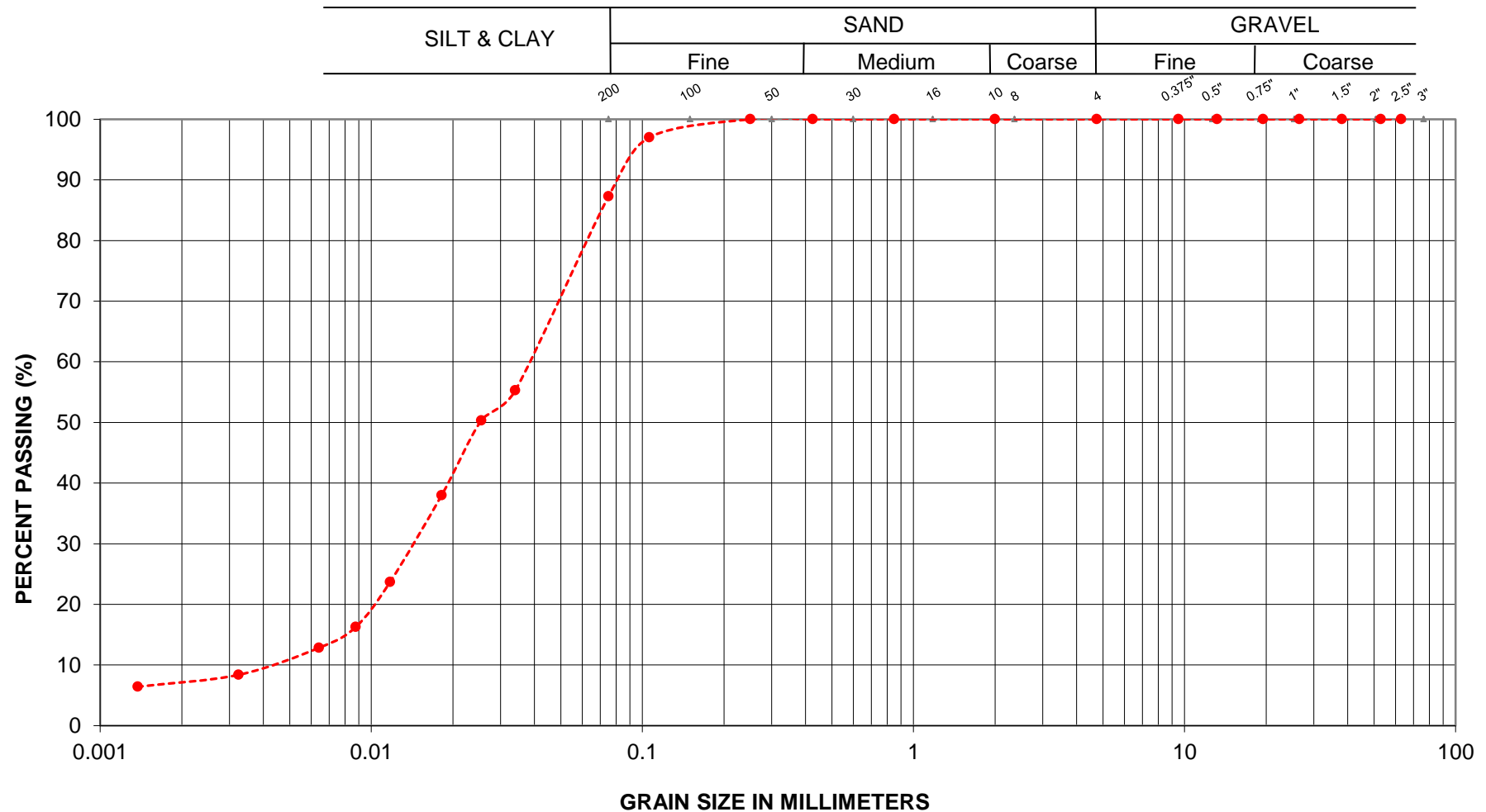


SILTY CLAY

LOCATION: Hwy 11, Station 15+735
TWP of Owens

Englobe Corp.

FIGURE L-4

GRAIN SIZE ANALYSIS

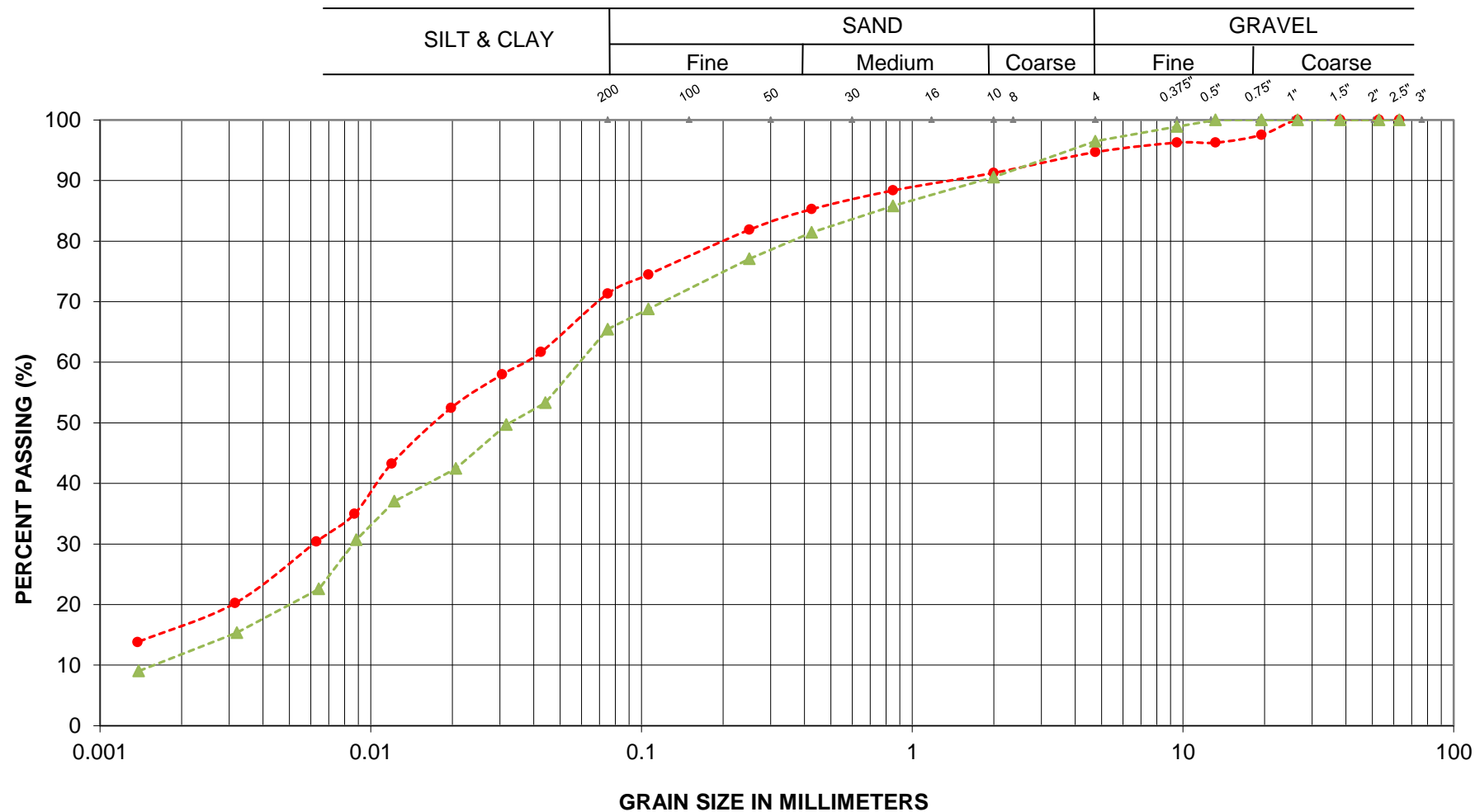
---●--- BH No.: 3 Sa No.: 6 Depth: 3.8 - 4.3 m

SILT

LOCATION: Hwy 11, Station 15+735
TWP of Owens

Englobe Corp.

FIGURE L-5

GRAIN SIZE ANALYSIS

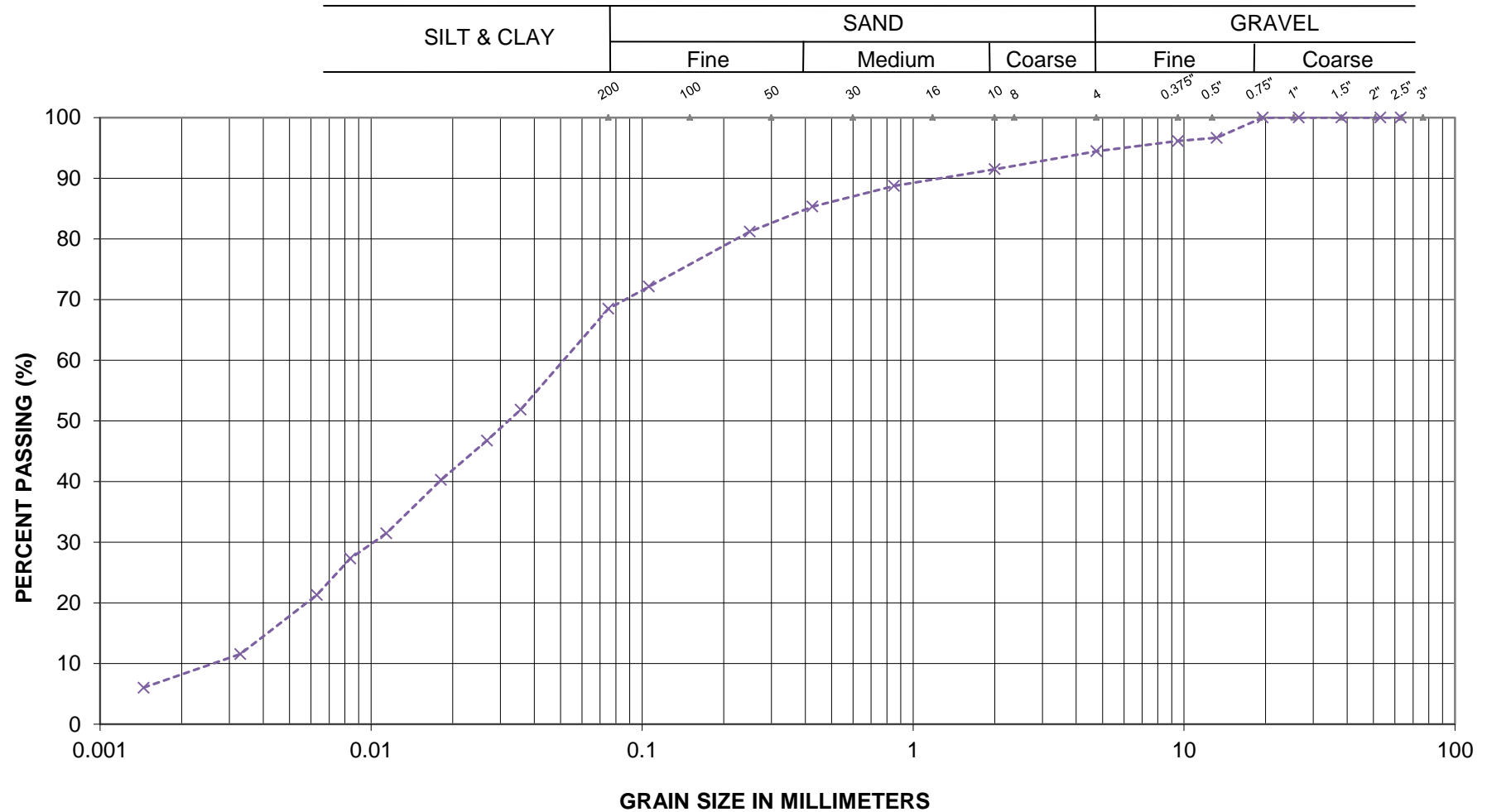
clayey SILT TILL

LOCATION: Hwy 11, Station 15+735
TWP of Owens

Englobe Corp.

FIGURE L-6

GRAIN SIZE ANALYSIS



--x-- BH No.: 4 Sa No.: 9 Depth: 7.6 - 8.1 m

clayey SILT TILL

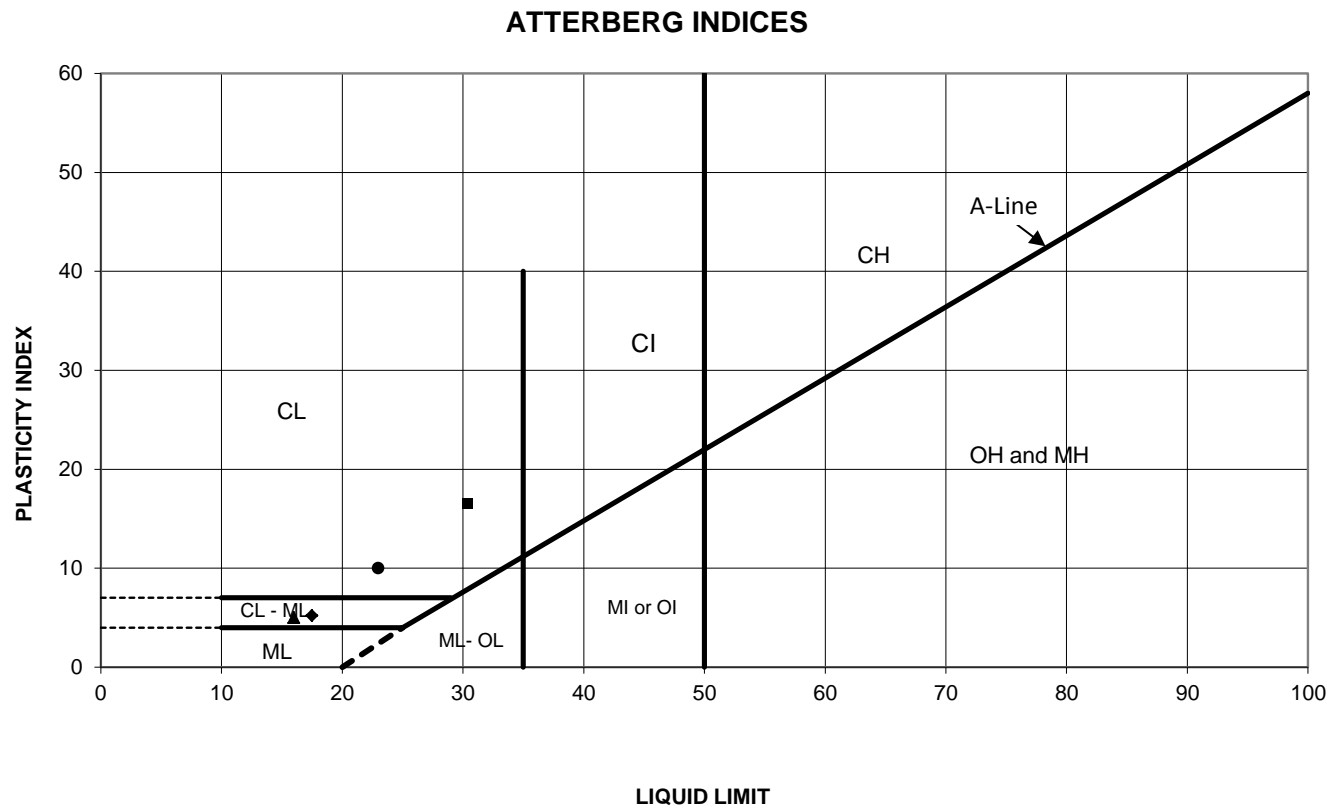
LOCATION: Hwy 11, Station 15+735
TWP of Owens

EnGlobe Corp.

FIGURE L-7

ATTERBERG LIMITS TEST RESULTS

FIGURE L-8



SYMBOL	BH	Sa. No.	Depth(m)	Elev.(m)	Liquid Limit	Plastic Limit	Plasticity Index	NMC %
●	1	10	7.9	207.0	23.0	13.0	10.0	18.1
◆	3	10	9.5	201.9	17.5	12.3	5.2	14.0
■	4	5	3.3	207.9	30.4	13.9	16.5	21.1
▲	4	8	6.3	204.9	16.0	11.0	5.0	17.1

Date: Sep-15
Project: Hwy 11, Holledge Creek Culvert
Location: Sta. 15+735, TWP. of Owens

Prep'd: AT
Chkd: MAM
Ref. No.: 15/05/15059-F1

Englobe Corp.

Laboratory Tests - Summary Sheet



Borehole No.	Sample No.	Depth	Grain Size Analysis				NMC	Atterberg Limits			SPT 'N'	USCS	Unit Weight (kN/m3)	Remarks
			Gravel Size (%)	Sand Size (%)	Silt Size (%)	Clay Size (%)		LL (%)	PL (%)	IP (%)				
1	1	0.0					5.0				26			
	2	0.8	23	67	10		3.9				23			
	3	1.5					4.9				31			
	4	2.3					4.7				13			
	5	3.1	4	87	9		4.6				5			
	6	3.8					4.9				8			
	7	4.6	17	72	11		12.0				15			
	8a	5.3					18.9				7			
	8b	5.6					19.1							
	9	6.1					18.5				5			
	10	7.6	0	13	62	25	18.1	23.0	13.0	10.0	WH			
	11	9.2					15.2				28			
2	1	0.0					4.5				26			
	2	0.8					5.3				15			
	3	1.5	11	78	11		5.2				19			
	4	2.3					5.4				11			
	5	3.1					5.2				9			
	6	3.8					5.6				8			
	7	4.6					17.0				8			
	8	5.3	8	85	7		16.0				8			
	9	6.1					21.4				5			
	10	7.6	0	37	54	9	17.0				49			Non-Plastic (NP)
	11	9.2					34.9				28			

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 (%)				
3	1	0.0					25.9				3			
	2	0.8					30.0				5			
	3	1.5	0	19	51	30	2.8				4			Non-Plastic (NP)
	4a	2.3					37.9				8			
	4b	2.4					23.3							
	5	3.1					16.9				5			
	6	3.8	0	13	80	7	29.0				37			Non-Plastic (NP)
	7	4.6					16.7				21			
	8	6.1					47.7				WH			
	9	7.6					13.7				14			
	10	9.2	5	24	54	17	14.0	17.5	12.3	5.2	7			
4	1	0.0					28.0				4			
	2	0.8					55.2				WH			
	3	1.5					48.4				5			
	4	2.3					19.5				6			
	5	3.1	0	6	58	36	21.1	30.4	13.9	16.5	7			
	6	3.8					17.3				9			
	7	4.6					35.7				9			
	8	6.1	3	31	54	12	17.1	16.0	11.0	5.0	15			
	9	7.6	5	26	61	8	11.8				17			Non-Plastic (NP)
	10	9.2					11.3				25			

Appendix 4 Photo Essay

Enclosure No. 6:

Photo Essay

Embankment at Culvert Location – Looking South

Photo: 1



Culvert Inlet – Looking South

Photo: 2



Project: Hwy 11 – Holledge Creek Culvert

Photos Provided By:Englobe

Date: July 2015

Culvert Outlet – Looking North

Photo: 3



View Through Culvert – Looking South

Photo: 4



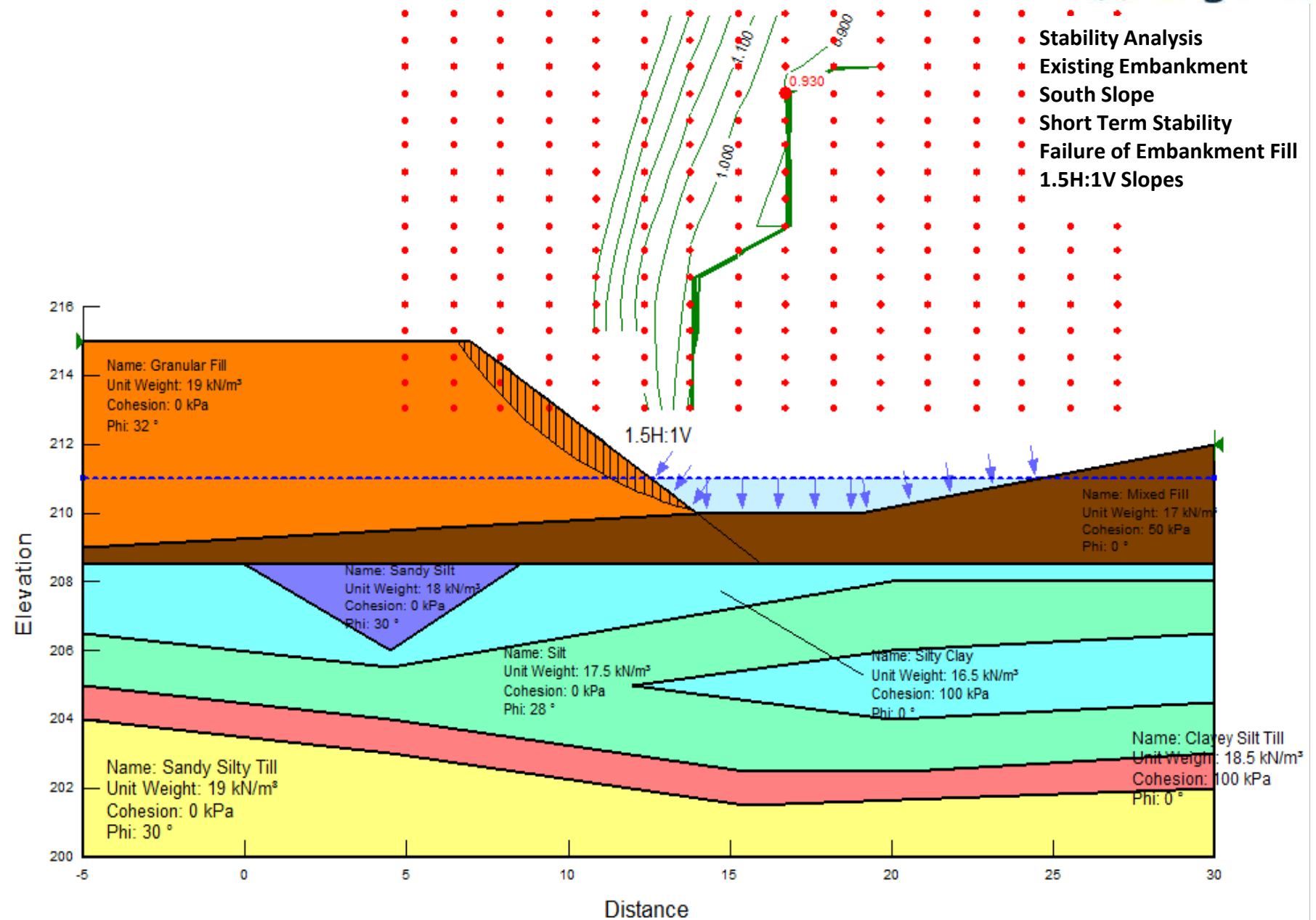
Project: Hwy 11 – Holledge Creek Culvert

Photos Provided By:Englobe

Date: July 2015

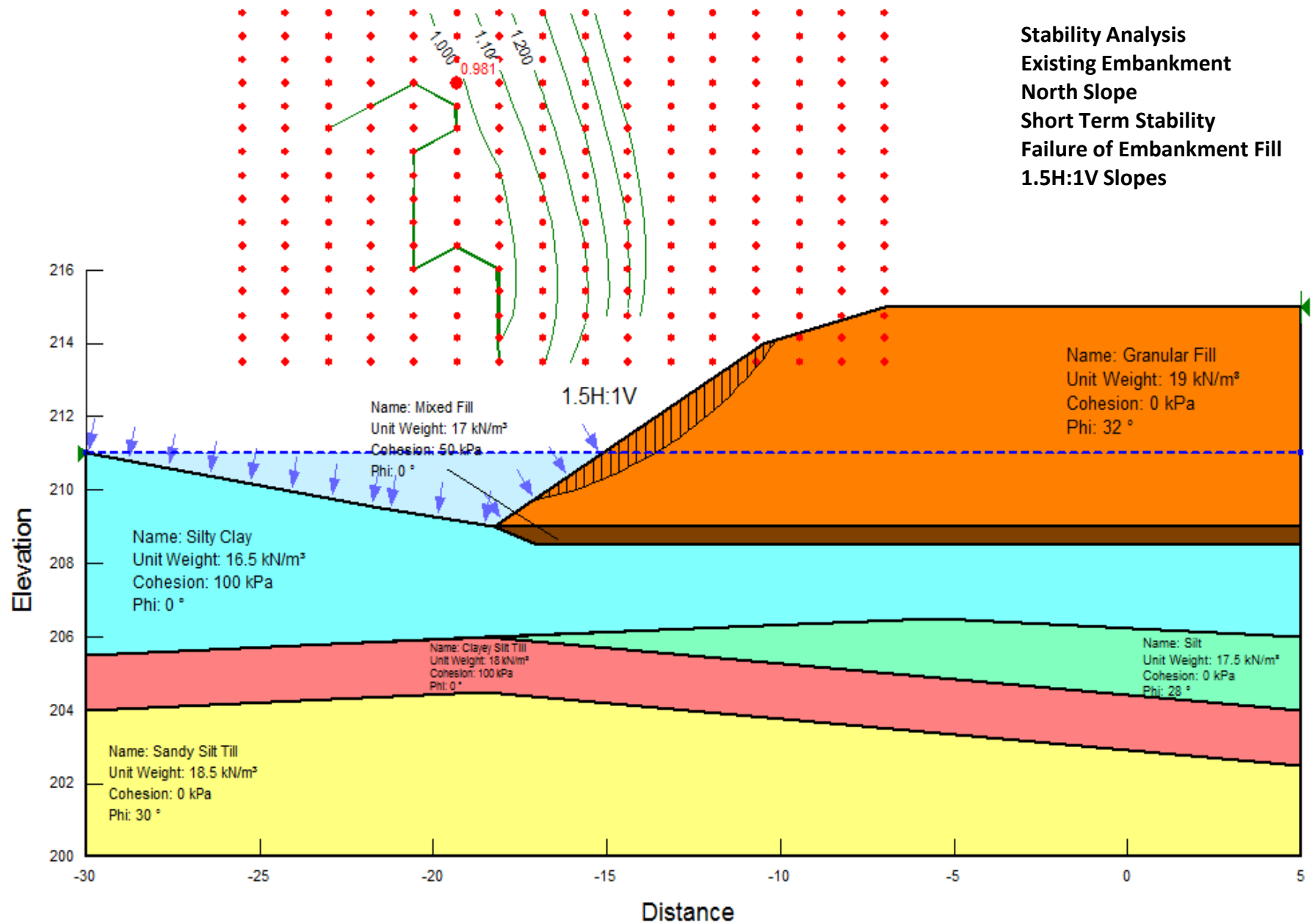
Appendix 5 Design Data

Figure Nos. S-1 to S-4:	Slope Stability Analyses
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

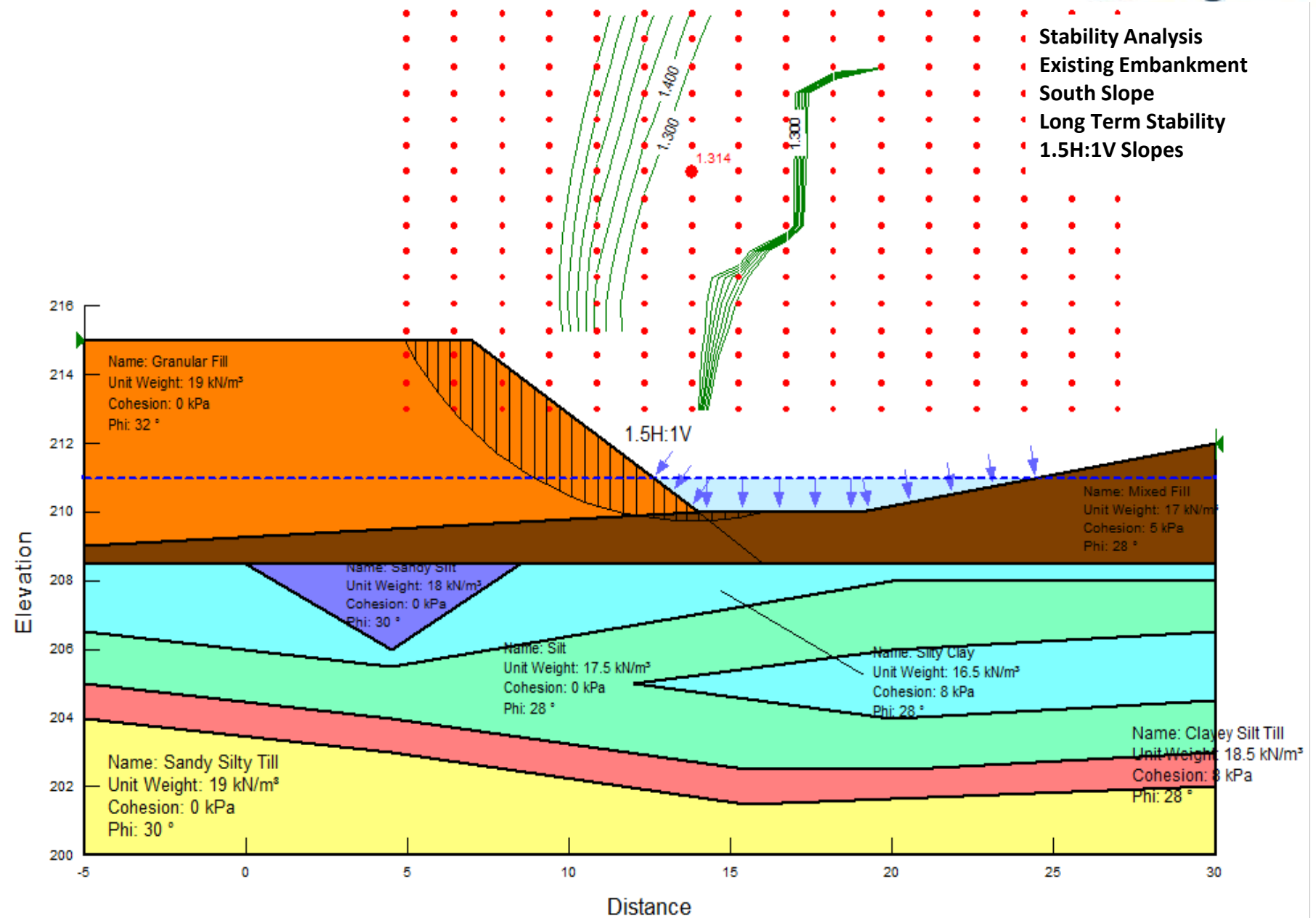


South Slope
 Culvert Station 15+735

Stability Analysis
Existing Embankment
North Slope
Short Term Stability
Failure of Embankment Fill
1.5H:1V Slopes

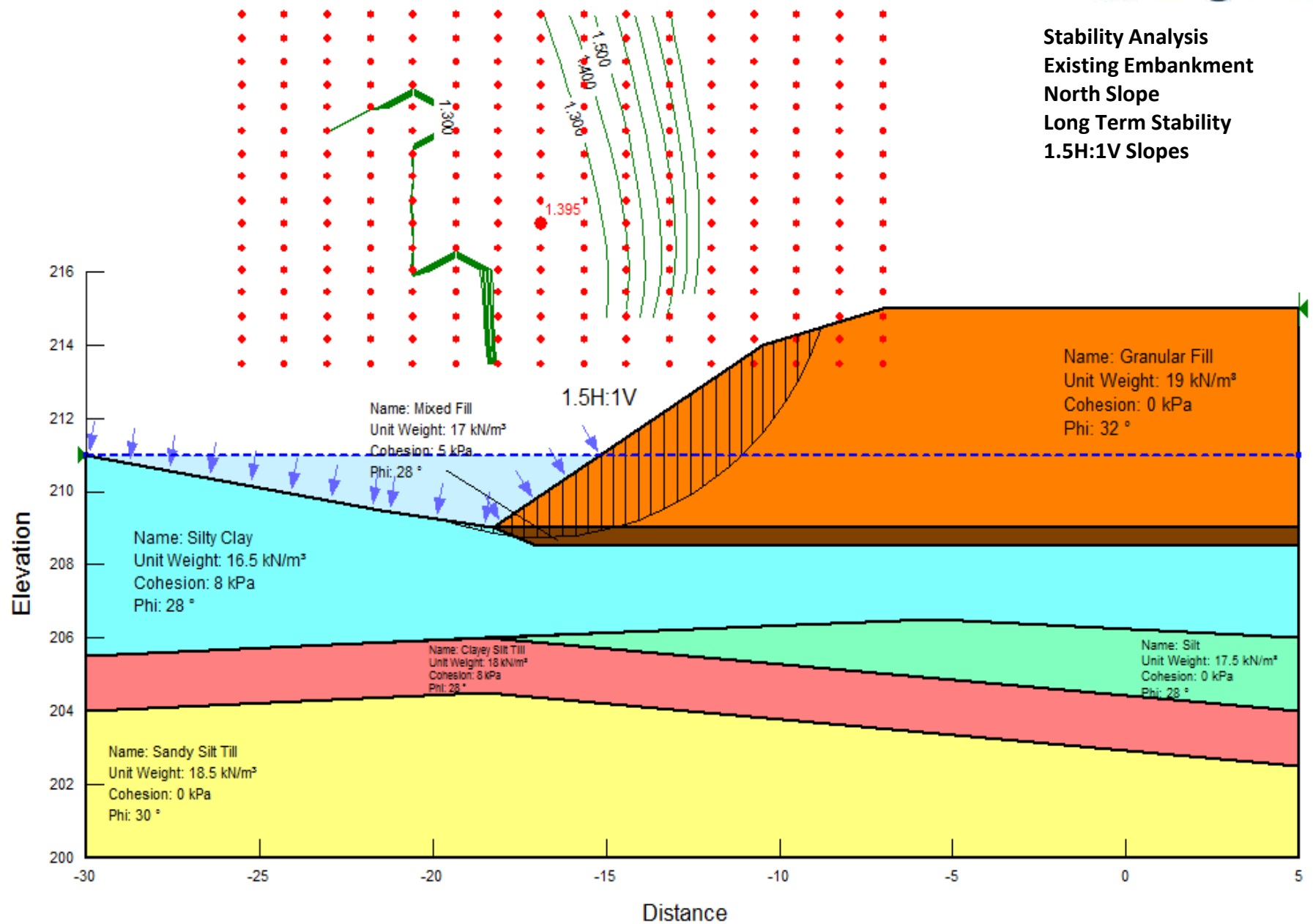


South Slope
 Culvert Station 15+735



North Slope
 Culvert Station 15+735

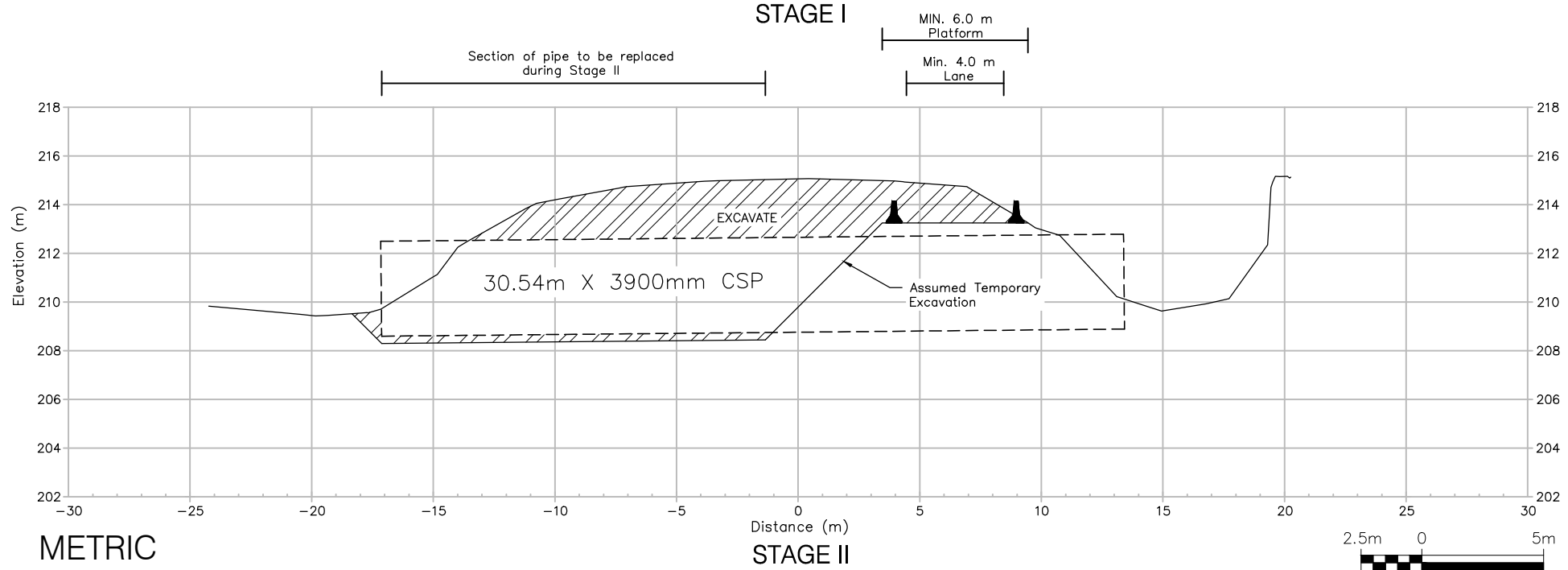
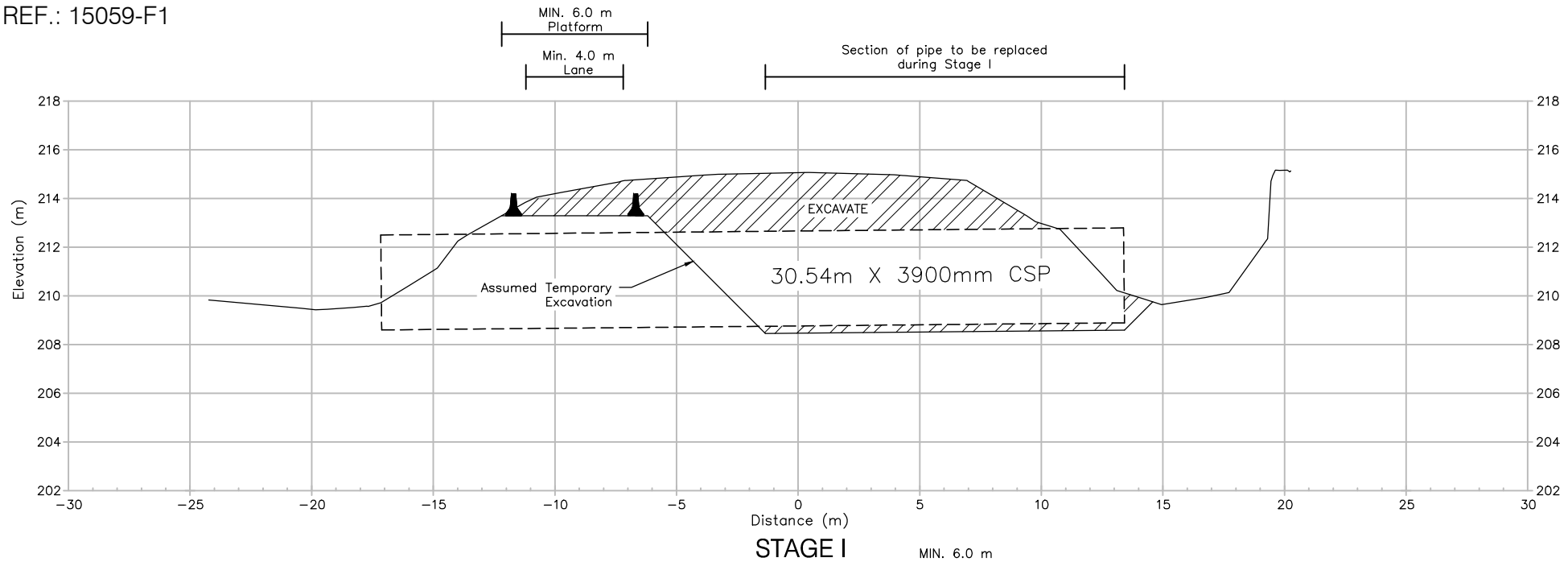
**Stability Analysis
Existing Embankment
North Slope
Long Term Stability
1.5H:1V Slopes**



North Slope
Culvert Station 15+735

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 for protection system.	\$ 650/m ²
Steel Sheet Piles	5 – 21	-High strength, continuous, -Readily available	-Limited by soil conditions (i.e. obstructions)	Recommended for temporary protection.	\$ 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



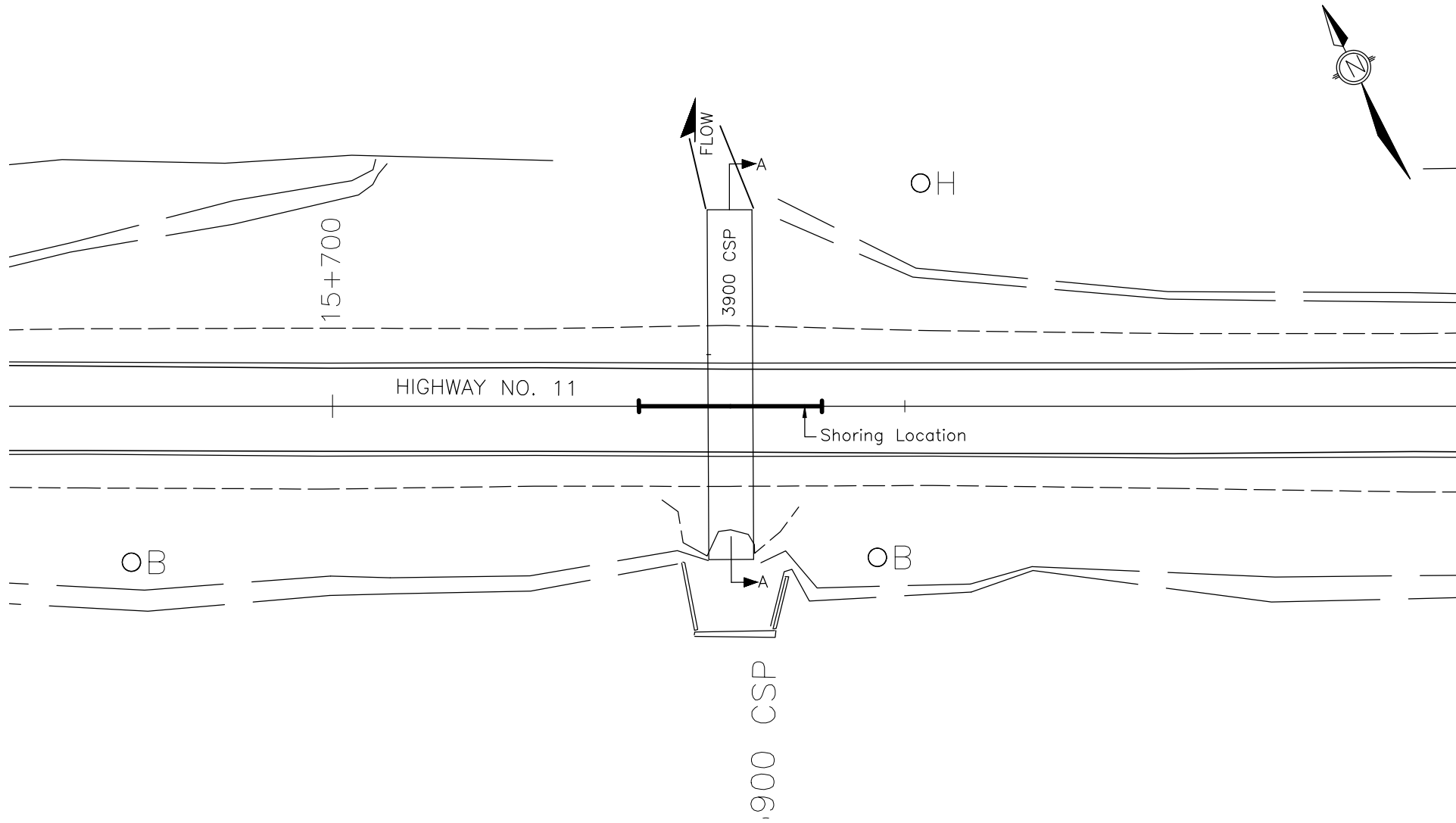
METRIC

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

Highway 11, Township of Owens - Culvert at Station 15+735
Conceptual Shoring Location Plan



FIGURE SK-3



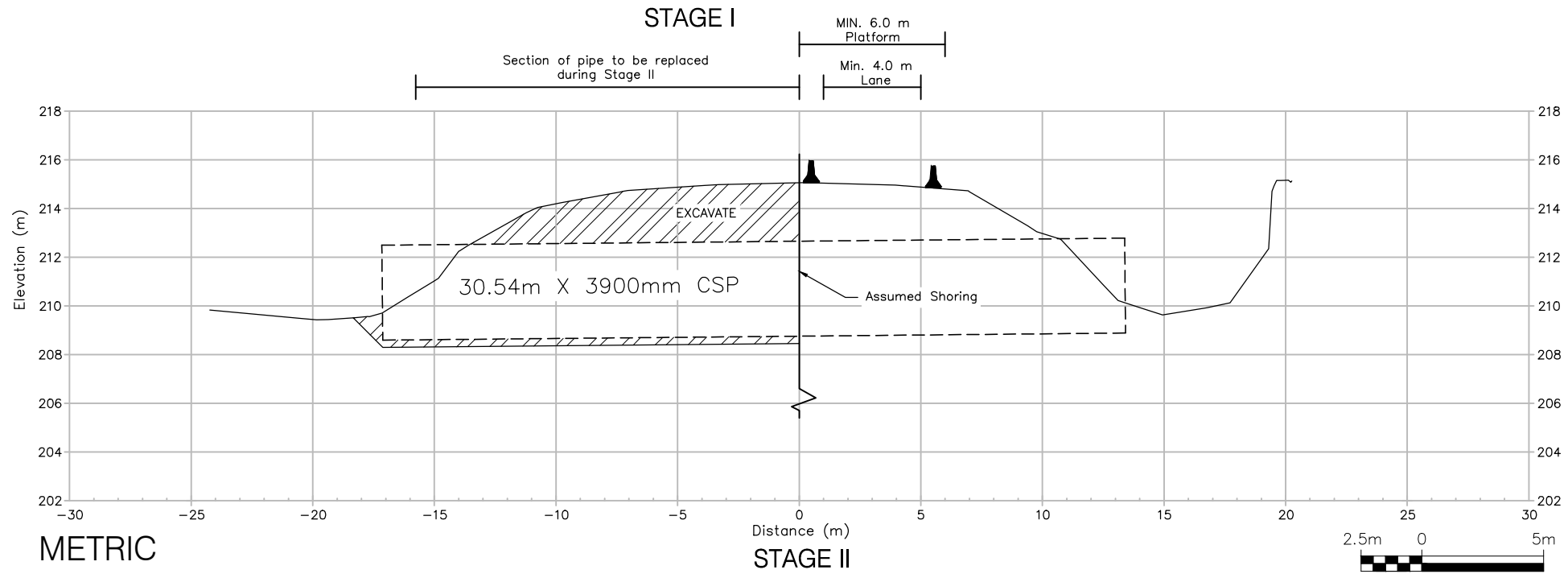
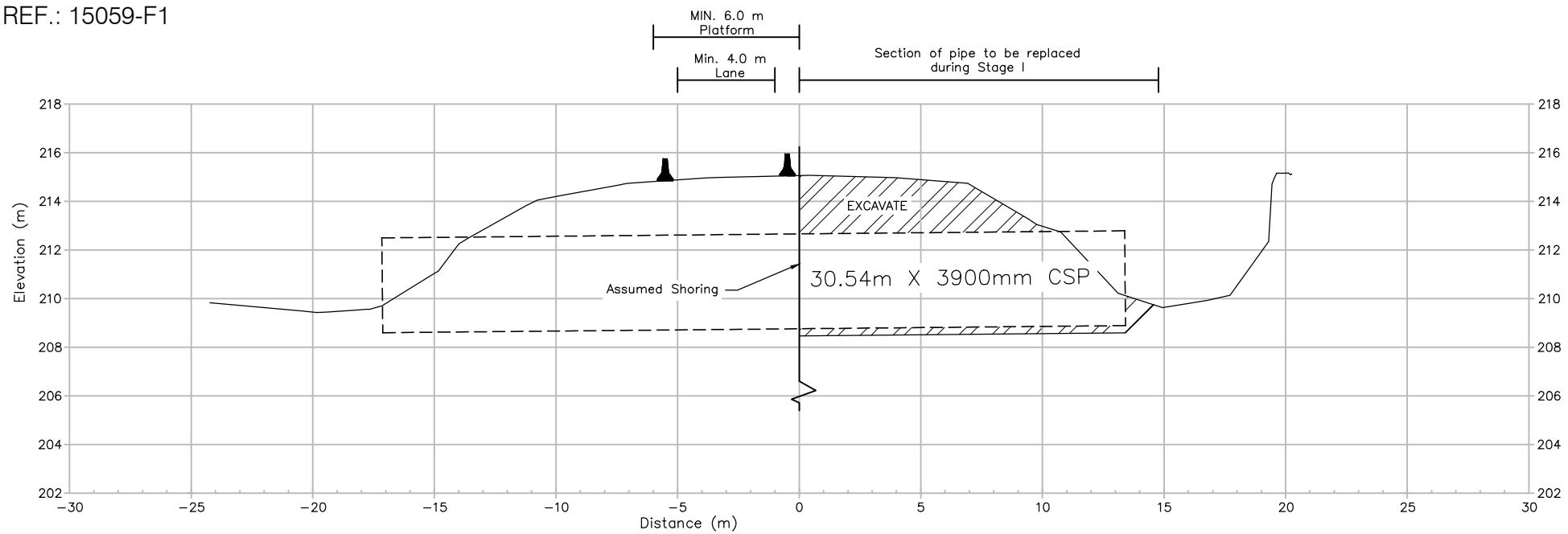
METRIC

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



Highway 11, Township of Owens - Culvert at Station 15+735
Conceptual Shoring Location Plan

FIGURE SK-4



METRIC

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

Highway 11, Township of Owens - Culvert at Station 15+735
Conceptual Shoring Location Plan

FIGURE SK-5