

**FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT REPLACEMENT AND
RETAINING WALL REMEDIATION
HIGHWAY 9
BERVIE, ONTARIO
G.W.P. No. 3033-14-00**

GEOCRES Number: 41A-236

Report to

Ministry of Transportation Ontario

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) at the proposed culvert replacement and distressed retaining wall sites on Highway 9, located in Bervie, Ontario.

The purpose of this investigation was to obtain subsurface information at the locations of the distressed retaining wall and culverts and, based on the data obtained, to provide borehole location plans, stratigraphic profiles, cross-sections, records of boreholes, laboratory test results, and a written description of the subsurface conditions.

Thurber was retained by the Ministry of Transportation Ontario (MTO) to carry out this foundation investigation under the MTO Agreement Numbers 3012-E-007 and 3012-E-008. The foundations terms of reference indicated that there was a previous investigation carried out at a bridge site near the retaining wall (Geocres Report 41A-159 for the Penetangore River Bridge – Site 2-255). No record is available for any previous foundation investigation carried out at, or near, the subject culvert.

2 SITE DESCRIPTION

The culvert site (Site 1) is located on Highway 9, approximately 3.2 kilometres east of Highway 10 near Bervie Ontario. The retaining wall site (Site 2) is located on Highway 9, approximately 60 m east of Highway 10 near Bervie, Ontario.

The existing culvert structure consists of one 900 x 900 mm concrete box culvert and one 1500 x 1200mm concrete open footing culvert of approximately equal lengths but different invert elevations. The grade of the existing Highway 9 in the vicinity of the culvert is at approximate Elevation 286.6 m resulting in an embankment height above the culverts in the order of 3 to 3.5 m.

The existing gabion retaining wall structure is approximately 55 m long and located at the northeast quadrant of the Highway 9 crossing at Penetangore River. A section of the wall of about 15 m in length has slumped and settled. Emergency repair work was conducted in August 2014 by placing rip

rap at the base of the wall for temporary stabilization. The grade of the existing Highway 9 in the vicinity of the retaining wall is at approximate Elevation 264 m.

The culvert site is located in a rural area surrounded by farmland. Naturally low-lying, swampy areas are present near the inlet and outlet of the culvert, with vegetation consisting of tall grass and shrubs with occasional trees. Local topography is of low relief with no visible bedrock outcrops. The area in the immediate vicinity of the culvert is at a lower grade than the surroundings.

The retaining wall site is located in a rural area, close to light residential development along the highway, within the floodplain of the Penetangore River near a bridge structure. Vegetation within the Penetangore River flood plain consists of tall grass and trees. Local topography is of low relief with no visible bedrock outcrops. Areas surrounding the retaining wall consist of light residential development to the east and west. The area north of the retaining wall is at a lower grade than the surrounding residential areas.

From published geological information, the site is located within the physiographic region known as the Huron Slope which consists of a glacio-lacustrine clay to silty clay plain originated from the glacial Lake Warren. Elsewhere within this region at higher elevations, clayey silt to silty clay glacial till is exposed at ground surface. The Penetangore River made deep trenches into the clay plain. It is anticipated that the floodplain of the river consists of more recent alluvial deposits.

3 SITE INVESTIGATION AND FIELD TESTING

The borehole investigation and field testing program was carried out between October 28 and 30, 2014 and from November 12 to 17, 2014. The program consisted of drilling and sampling seven boreholes (identified as 14-01 through 14-07) and three hand augered holes (HA-01 to HA-03) to depths ranging from 0.6 to 12.8 m (Elev. 275.4 to 251.9 m). Three boreholes were located in the vicinity of the culvert (14-01 to 14-03). Four boreholes and the three hand augered holes were located in the vicinity of the retaining wall (14-04 to 14-07 and HA-01 to HA-03).

The borehole and hand augered hole locations were marked in the field and utility clearances were obtained prior to commencement of drilling operations. The coordinates and elevations of the as-drilled boreholes were subsequently provided by Ron Dore Surveying of Kincardine, Ontario, based on borehole location sketches prepared by Thurber. The locations and elevation of the boreholes are shown on the attached Borehole Locations and Soil Strata Drawing included in Appendix C.

A truck mounted drill rig was used to drill and sample Boreholes 14-01, 14-02, 14-05, 14-07 using hollow stem auger drilling techniques. Boreholes 14-03, 14-04 and 14-06 drilled near the culvert inlet and at the base of the retaining wall, were advanced with a tri-pod rig using a 70 lb.-hammer and wash boring with casing. A hand auger was utilized for HA-01 to HA-03.

Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). It is noted that a 70 lb. hammer was used for the tri-pod rig as

opposed to a standard 140 lb. hammer in conventional drill rigs. SPT 'N' values obtained from the 70lb. hammer were converted to equivalent 'N' values for a 140 lb. hammer.

The drilling and sampling operations were supervised on a full time basis by an experienced member of Thurber's technical staff. The recovered soil samples were logged in the field and processed for transportation to Thurber's MTO approved Toronto area laboratory for further examination and testing.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Two standpipe piezometers were installed in Boreholes 14-01 and 14-03 at the culvert location and two standpipe piezometers were installed in Boreholes 14-04 and 14-05 at the retaining wall location for monitoring of the groundwater level. The details of piezometer installations and borehole completion are summarized in

Table 3-A and Table 3-1B for the culvert and retaining wall locations, respectively.

Table 3-1A. Culvert Borehole Completion and Piezometer Installation Details

Borehole Number	Piezometer Installations			Completion Details
	Sand Screen Depth (m)	Sand Screen Elevation (m)	Sand Filter Stratum	
14-01	8.9 – 10.7	274.8 – 273.0	Silty Clay Till	Bentonite holeplug to 8.8 m, bentonite /cuttings to surface
14-02	None Installed			Bentonite holeplug and cuttings to 0.6 m, concrete to 0.2 m, and asphalt cold patch to surface.
14-03	3.7 – 7.6	279.8 – 275.9	Silty Clay Till	Bentonite holeplug to surface

Table 3-1B. Retaining Wall Borehole Completion and Piezometer Installation Details

Borehole Number	Piezometer Installations			Completion Details
	Sand Screen Depth (m)	Sand Screen Elevation (m)	Sand Filter Stratum	
14-04	3.7 – 7.5	254.0 – 257.8	Silty Clay Till/Silty Sand	Bentonite holeplug to surface
14-05	9.5 – 11.2	253.2 – 254.9	Sand and Silt	Bentonite holeplug to surface
14-06	None Installed			Bentonite holeplug to surface
14-07	None Installed			Bentonite holeplug and cuttings to 0.6 m, concrete to 0.2 m, then asphalt cold patch to surface
HA-01	None Installed			Cuttings to surface
HA-02	None Installed			Cuttings to surface

HA-03	None Installed	Cuttings to surface
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Results of field drilling and sampling are presented on the Record of Borehole sheets in Appendix A.

A site reconnaissance visit was carried out by one of our engineers to observe and document the condition of the wall and its immediate surroundings.

4 LABORATORY TESTING

All recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected soil samples were subjected to grain size distribution analyses (sieve and hydrometer) and plasticity testing (Atterberg Limits). The results of this laboratory testing program are shown on the Record of Borehole sheets in Appendix A and on the figures in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS AT CULVERTS (SITE 1)

5.1 General

Reference is made to the Record of Borehole sheets in Appendix A and the Borehole Locations and Soil Strata Drawings in Appendix C for details of the soil stratigraphy encountered in the boreholes. An overall description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented in the record of boreholes governs any interpretation of the site conditions.

Boreholes 14-01 to 14-03 were drilled near the culvert alignment. In general, the subsurface conditions encountered in the borehole located at highway grade consists of embankment fill overlying a deposit of native silty clay till with sandy silt interlayers. Boreholes located near the culvert inlet and outlet encountered topsoil overlying silty clay till with a silt interlayer. More detailed descriptions of the individual stratum are presented below.

5.2 Topsoil

Topsoil 100 mm in thickness was encountered at the surface in Borehole 14-01.

The topsoil thickness may vary between and beyond the borehole locations and the limited data is not intended for the purpose of estimating quantities.

5.3 Pavement Asphalt and Granular

A 100 mm thick layer of asphalt was encountered at the surface in Borehole 14-02 drilled from the highway grade. Below the asphalt is a sand and gravel layer extending to 0.3 m depth.

5.4 Fill

Embankment fill was encountered below the pavement structure in Borehole 14-02. The fill consists of silt with trace sand and trace gravel underlain by silty clay with sand. The embankment fill extended to a depth of 3.0 m (Elev. 283.5 m).

An SPT N-value of 28 blows per 300 mm penetration was measured in the silt fill indicating a compact state. SPT N-values measured in the silty clay fill typically ranged from 14 to 16 blows per 300 mm of penetration indicating a stiff to very stiff consistency. The moisture contents of the recovered samples ranged from 8 to 18% for the silty clay fill and was 4% for the silt fill.

One laboratory grain size analysis was conducted on a sample of the silty clay fill. The results of this test are presented on the corresponding Record of Borehole sheets in Appendix A and the grain size distribution curve is plotted on Figure B1 of Appendix B. The results are summarized in the following table.

Soil Particles	%
Gravel	0
Sand	23
Silt	46
Clay	31

The results of an Atterberg Limit test performed on a sample of the silty clay fill are plotted on Figure B5 of Appendix B. A plasticity index of 12% and a liquid limit of 25% were measured indicating low plasticity (CL).

5.5 Silty Clay

A layer of 0.7 m thick (base Elev. 282.8 m) silty clay was encountered at ground surface in Borehole 14-03. A SPT 'N' value of 5 blows per 300 mm penetration indicate a firm consistency. A moisture content of 30% was measured for a sample this soil.

5.6 Silty Clay Till

A layer of silty clay till, trace to with sand, trace gravel was encountered below the soils noted above in all three boreholes. All three boreholes were terminated within the silty clay till at depths of 8.1 to 12.8 m (Elev. 270.9 to 275.4 m). Where encountered, the thickness of the silty clay ranged from 2.6 to 7.4 m with corresponding underside depths of 8.1 to 12.8 m (Elev. 270.9 to 275.4 m).

SPT N-values measured within the silty clay ranged from 8 to 90 blows per 300 mm of penetration, indicating stiff to hard consistency. The blow counts generally increased with

depth. The measured moisture contents of the recovered samples typically ranged from 10 to 25%.

Grain size analyses were performed on selected samples of the silty clay till. The results are presented on the corresponding Record of Borehole sheets in Appendix A and the grain size distribution curves are plotted on Figures B2 and B3 of Appendix B. These results are summarized in the following table.

Soil Particles	%
Gravel	0 to 5
Sand	5 to 37
Silt	43 to 56
Clay	17 to 46

The results of the Atterberg Limits tests performed on selected samples of the silty clay till are plotted on Figure B6 and B7 of Appendix B. The results of the tests are summarized above and indicate that the silty clay is of low plasticity.

Soil Property	%
Liquid Limit	21 to 31
Plasticity Index	9 to 15

5.7 Silt to Sandy Silt

A layer of silt some sand to sandy silt, some clay and trace gravel was encountered interlayering with the silty clay till in Boreholes 14-01 and 14-02. The thickness of this layer varied from 1.4 to 1.6 m with a corresponding underside depth of 7.0 to 7.2 m (Elev. 276.7 to 279.4 m).

SPT N-values measured in the silt to sandy silt were 18 to 77 blows per 300 mm of penetration, indicating a compact to very dense state. The moisture contents of the recovered soil samples ranged from 13 to 15%.

The gradation of the silt to sandy silt is shown on the record of borehole, summarized below and illustrated by the grain size distribution curves on Figure B4 of Appendix B.

Soil Particles	%
Gravel	2
Sand	15 to 21
Silt	58 to 68
Clay	15 to 19

5.8 Groundwater Conditions

Water levels were observed in the open boreholes during and upon completion of drilling. Standpipe piezometers were installed in Boreholes 14-01 and 14-03 to permit longer term monitoring. The water levels observed in the open boreholes and measured in the piezometers are as follows:

Table 6-1 Groundwater Elevations

Borehole	Date of Reading	Water Level Depth (m)	Water Level Elevation (m)	Comments
14-01	October 30, 2014	3.4	280.3	Open Hole
	October 31, 2014	4.6	279.1	Piezometer
	November 17, 2014	0.5	283.2	Piezometer
	December 12, 2014	2.1	281.6	Piezometer
14-02	October 30, 2014	6.6	280.0	Open Hole
14-03	November 17, 2014	1.1	282.4	Piezometer
	December 12, 2014	1.0	282.5	Piezometer

Where surface water is present, the groundwater level should be assumed to coincide with the local surface or creek water level. Local high water levels, spring snowmelt and periods of significant and/or prolonged precipitation events must also be taken into consideration.

6 DESCRIPTION OF SUBSURFACE CONDITIONS AT RETAINING WALL (SITE 2)

6.1 General

Reference is made to the Record of Borehole sheets in Appendix A and the Borehole Locations and Soil Strata Drawings in Appendix C for details of the soil stratigraphy encountered in the boreholes. An overall description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented in the record of boreholes governs any interpretation of the site conditions.

Boreholes 14-04 to 14-07 were drilled in the vicinity of the gabion wall distress. In general, the subsurface conditions encountered in the boreholes located at highway grade consists of embankment fill overlying interlayers of silty clay and silty sand overlying clayey silt till. Boreholes located north of the retaining wall encountered topsoil overlying layers of silty clay and silty sand. More detailed descriptions of the individual stratum are presented below.

6.2 Topsoil

Topsoil, ranging from 50 to 125 mm in thickness, was encountered at the surface in Boreholes 14-04, 14-06, HA-01, and HA-03.

The topsoil thickness may vary between and beyond the borehole locations and the limited data is not intended for the purpose of estimating quantities.

6.3 Pavement Asphalt and Granular

A 100 mm thick layer of asphalt was encountered at the surface in Boreholes 14-05 and 14-07 drilled from the highway grade. Below the asphalt is a dense (SPT 'N' values of 31 to 36 blows per 300 mm penetration) sand and gravel fill extending to 0.8 to 0.9 m depths. The measured moisture contents were in the order of 2 to 3%.

6.4 Fill

Embankment fill was encountered below the asphalt in Boreholes 14-05 and 14-07. The fill layer typically consists of brown sand, some silt, trace clay extending to depths of 2.2 to 2.3 m (Elev. 262.2 to 262.3 m).

SPT N-values measured in the embankment fill typically ranged from 17 to 24 blows per 300 mm of penetration indicating a compact state. The moisture contents of the recovered samples ranged from 7 to 11%.

Laboratory grain size analysis was performed on a sample of the fill. The results of this test is presented on the corresponding Record of Borehole sheets in Appendix A and the grain size distribution curve is plotted on Figure B8 of Appendix B. These results are summarized in the following table.

Soil Particles	%
Gravel	0
Sand	73
Silt	10
Clay	7

Silty clay fill was encountered below the sand fill between 2.3 and 4.6 m depths (base Elev. 260.0 m) in Borehole 14-07. SPT 'N' values between 6 and 12 blows per 300 mm penetration indicate firm to stiff consistency. Measured moisture contents ranged between 12% and 26%.

6.5 Silty Clay

A deposit of silty clay, trace to some sand to with sand, was encountered below the topsoil or fill in all Boreholes 14-04 to 14-07. Silty sand interlayers were also encountered. Where fully penetrated, the silty clay ranged from 1.7 to 5.6 m in thickness with corresponding underside depths of 5.6 to 8.7 m (Elev. 254.3 to 257.2 m).

SPT N-values measured within the silty clay typically ranged from 4 to 24 blows per 300 mm of penetration indicating firm to very stiff consistency. In Boreholes 14-06, a hard silty clay zone was encountered as indicated by SPT 'N' values of 51 blows per 300 mm penetration

and 75 blows for less than 300 mm penetration. A soft zone was encountered at ground surface as indicated by 'N' values of 2 to 3 blows per 300 mm penetration. The measured moisture contents of the recovered samples typically ranged from 20% to 41%.

Grain size analyses were performed on selected samples of the silty clay. The results are presented on the corresponding Record of Borehole sheets in Appendix A and the grain size distribution curves are plotted on Figures B9 and B10 of Appendix B. These results are summarized in the following table.

Soil Particles	%
Gravel	0
Sand	0 to 33
Silt	35 to 73
Clay	27 to 39

The results of the Atterberg Limits tests performed on selected samples of the silty clay are plotted on Figures B13 and B14 of Appendix B. The results of the tests are summarized above and indicate that the silty clay is classified as low plasticity.

Soil Property	%
Liquid Limit	23 - 33
Plasticity Index	9 - 15

6.6 Silty Sand to Sandy Silt

Layers of silty sand were found interlayering with the silty clay described in Section 6.5. The thickness of the cohesionless layers ranged from 0.6 to 2.2 m with varying underside depths and elevations.

SPT N-values measured in the silty sand ranged from 6 to 45 blows per 300 mm of penetration indicating loose to dense state. The moisture contents of the recovered soil samples ranged from 10% to 45%.

The gradation of the sand layer is shown on the records of boreholes summarized below and illustrated by the grain size distribution curves plotted on Figure B11 of Appendix B.

Soil Particles	%
Gravel	0
Sand	62
Silt	26
Clay	12

6.7 Clayey Silt Till

Clayey silt till, with sand, trace to some gravel was encountered below the soils noted above in Boreholes 14-05 to 14-07. All three boreholes were terminated within the till at depths of 7.8 to 12.5 m (Elev. 251.9 to 252.2 m).

SPT N-values measured within the clayey silt till ranged from 36 blows per 300 mm penetration to greater than 100 blows for less than 300 mm penetration, indicating a hard consistency throughout. The measured moisture contents of the recovered samples typically ranged from 8 to 15%.

Grain size analyses were performed on selected three samples of the clayey silt till. The results are presented on the corresponding Record of Borehole sheets in Appendix A and the grain size distribution curves are plotted on Figures B12 of Appendix B. These results are summarized in the following table.

Soil Particles	%
Gravel	7 to 11
Sand	35 to 48
Silt	29 to 42
Clay	10 to 16

6.8 Groundwater Conditions

Water levels were observed in the open boreholes during and upon completion of drilling. Standpipe piezometers were installed in Boreholes 14-04 and 14-05 to permit longer term monitoring. The water levels observed in the open boreholes and measured in the piezometer are as follows:

Table 6-1 Groundwater Elevations

Borehole	Date of Reading	Water Level Depth (m)	Water Level Elevation (m)	Comments
14-04	November 13, 2014	Above ground*	>261.5	Piezometer
	November 17, 2014	Above ground*	>261.5	Piezometer
	December 12, 2014	0.7 m above ground*	262.2	Piezometer
14-05	October 29, 2014	4.5	259.9	Open Borehole
	October 31, 2014	1.5	262.9	Piezometer
	November 17, 2014	0.5	263.9	Piezometer
	December 12, 2014	1.0	263.4	Piezometer

* Artesian condition

Water levels indicate that the silty sand layer below the silty clay at 7.1 m depth in Borehole 14-04 is under artesian conditions.

Where surface water is present, the groundwater level should be assumed to coincide with the local surface or creek water level. Local high water levels, spring snowmelt and periods of significant and/or prolonged precipitation events must also be taken into consideration.

7 MISCELLANEOUS

Tentative borehole locations were selected by Thurber. R. F. Dore Surveying provided northing and easting coordinates and ground surface elevations for the as-drilled borehole locations.

Altech Drilling & Investigation Services of Elmira, Ontario supplied and operated a truck-mounted drill rig, and Walker Drilling of Utopia, Ontario supplied a tri-pod drill to carry out the drilling, sampling, in-situ testing operations and standpipe installations.

The drilling and sampling operations in the field were supervised on a full time basis by Mr. George Azzopardi and Mr. Alistair Hall of Thurber. Routine laboratory testing was carried out by Thurber's geotechnical laboratory in Oakville, Ontario.

Overall project management and direction of the field program was provided by Mr. Lukasz Gilarski, P.Eng and Dr. Sydney Pang, P.Eng. Interpretation of the field data and preparation of this report was completed by Mr. Lukasz Gilarski, P.Eng., and Dr. Sydney Pang, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

THURBER ENGINEERING LTD.

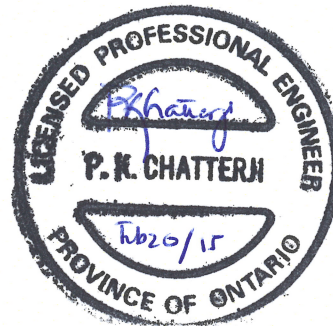
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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8 GENERAL

This report presents interpretation of the geotechnical data in the factual report and presents foundation recommendations for the remediation of the gabion retaining wall instability and for the replacement of the existing culverts on Highway 9 located east of Bervie, Ontario.

The existing culvert structure consists of one concrete box culvert with dimensions of 900 x 900 mm and one concrete open footing culvert with dimensions of 1500 x 1200 mm, both of which have approximately equal lengths and different invert elevations. The two culverts are adjacent to each other and are generally perpendicular to Highway 9. The grade of the highway in the vicinity of the culvert is at approximate Elevation 286.6 m resulting in an embankment height above the culverts in the order of 3 to 3.5 m.

The existing gabion retaining wall structure is approximately 55 m long and located at the north east quadrant of the Highway 9 bridge crossing of Penetangore River. Subsequent to the slumping and settling of a section of the wall, emergency repair work was conducted in August 2014 by placing rip rap at the base of the wall for temporary stabilization. The grade of the existing Highway 9 in the vicinity of the retaining wall is at approximate Elevation 264 m.

The discussion and recommendations presented in this report are based on our understanding of the project and on the factual data obtained during the course of this investigation. There is no archived foundation information available for the existing culverts. Archived foundation information for the Penetangore Bridge, located immediately to the west of the wall, is available. Select photographs showing the general conditions of the two site areas are included in Appendix E for reference.

9 CULVERT FOUNDATIONS

9.1 General

The current project requirements involve replacement of the existing concrete culverts with a new structural culvert along the same alignment. No highway grade raise is anticipated. Physical dimensions and associated details for the proposed culvert are unknown at this time.

9.2 Foundation Alternatives

This section presents discussions on alternate types of replacement culverts and foundation alternatives, and provides recommendations on feasible and/or preferred foundation option. Several common culvert and foundation types are listed below and a comparison of these alternatives, based on their respective advantages and disadvantages, is included in Appendix D.

Given the subsurface conditions and the anticipated construction sequencing, precast concrete box culvert is the preferred culvert replacement option from a foundation engineering standpoint. Precast sections, rather than cast-in-place construction, can be installed rapidly with less potential for disturbance of the founding soils during installation. Alternatively, concrete rigid frame, open footing, culverts may be used.

From a foundation engineering standpoint, concrete, steel and HDPE pipes are technically feasible alternatives, provided that other design issues including flow capacity, hydraulic properties and durability can be satisfied.

This report focuses on providing foundation recommendations on the design and construction of concrete box and open footing culverts.

9.3 Foundation Design

The founding elevation of the culverts depends on factors including hydrologic, hydraulic and environmental considerations to be addressed by others. It is assumed that the replacement culvert will be founded at approximately the same base level as those of the existing culverts.

9.3.1 Concrete Box Culverts

Since the replacement culvert is anticipated to be constructed along the same alignments as the existing culverts, it is anticipated that the subgrade soils within the new culvert footprint will not be subjected to any significant additional loading.

In order to provide a more uniform foundation subgrade condition, a minimum 300 mm thick layer of bedding material conforming to OPSS 1010 Granular A requirements must be provided under the base of the box culvert as per OPSD 803.010. The bedding material must be placed on the approved subgrade as soon as practical for protecting the subgrade from disturbance during construction following its inspection and approval. Preparation and inspection of the subgrade, and construction of the box must be carried out in the dry. Construction equipment must not be allowed to travel on the bedding or the prepared subgrade.

A plan and profile drawing dated September 2012 indicates that the invert of the existing box culvert is at approximate Elevation 282.3 m, whereas the invert of the existing open footing culvert is at approximate Elevation 281.8 m.

Based on the current borehole information, it is recommended that the underside of the Granular A pad be founded at or below Elevation 281.8 m on undisturbed, stiff to very stiff silty clay till. Any soft soils at the design subgrade level must be sub-excavated and replaced with engineered fill as outlined below. The recommended geotechnical resistances for the above founding elevation are as follows:

- Factored Geotechnical Resistance at ULS of 300 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 200 kPa.

Resistance to lateral forces / sliding resistance between the precast concrete and the underlying Granular A should be evaluated in accordance with the CHBDC (2010) assuming an ultimate coefficient of friction of 0.4.

It is recommended that the culverts be designed to resist external loadings including frost forces, lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loadings and surcharge due to construction equipment.

9.3.2 Settlements

It is assumed that there is no grade raise at this site. Given the similar weights between the replacement concrete box and the existing concrete culverts, the silty clay subgrade would be subjected to comparable loadings. Accordingly, no additional foundation settlement beneath the new culvert footprint should be expected.

9.3.3 Subgrade Preparation

After the excavation and removal of the existing concrete culverts and surrounding soils are completed to the design founding elevation, any remaining fill, topsoil, organics, creek bed deposits, disturbed or softened soils, and any deleterious materials within the culvert replacement footprint must be sub-excavated to undisturbed native stiff to very stiff silty clay at or below the desired founding elevations. The exposed surface must be inspected to confirm that the subgrade is suitable and uniformly competent. Any soft areas should be sub-excavated and replaced with well compacted granular fill consisting of compacted OPSS 1010 Granular A or Granular B Type II material.

This work must be carried out in accordance with OPSS 902 and construction must be carried out in the dry.

9.4 Concrete Open Footing Culverts

Alternatively, a concrete rigid frame, open footing, culvert supported by strip footings founded on the stiff to very stiff silty clay till may be considered. In order to avoid localized punching shear failure, it is recommended that the width of the strip footing be equal to, or greater than, 1.0 m which is a typical footing width for this type of culvert. Loading conditions will dictate the actual required footing width.

Founding depths, elevations, recommended geotechnical resistances, settlement considerations and subgrade preparation procedures discussed above for box culverts may be used.

Resistance to lateral forces / sliding resistance between the precast concrete and the underlying silty clay should be evaluated in accordance with the CHBDC (2010) assuming an ultimate coefficient of friction of 0.35.

9.5 Frost Depth

The frost penetration depth for this site is 1.4 m. The base of the footings should be protected by 1.4 m of earth or its thermal equivalent.

9.6 Construction Considerations

Staged open cutting will most likely be employed to construct the replacement culvert at Station 23+515. Temporary widening of the existing highway platform may be required in order to maintain traffic during culvert replacement. Further foundation recommendations will be provided as necessarily once more detailed design and construction information is available.

10 CULVERT BACKFILL AND LATERAL EARTH PRESSURES

It is recommended that backfill to the culvert and wingwalls (where required) consists of free-draining, non-frost susceptible granular materials such as Granular A or Granular B Type II conforming to the requirements of OPSS 1010. Reference should be made to the backfill arrangements stipulated in OPSD 803.01 as appropriate.

All fills must be placed in regular lifts and be compacted in accordance with OPSS 501. The backfill must be placed and compacted in simultaneous lifts on both sides of a culvert, and the top of backfill elevation should be the same on both sides of the culvert at all times. Heavy compaction equipment must not be used adjacent to the walls and roofs of the culverts. Care must be exercised when compacting the fill immediately above the crown of the box in order not to damage the box.

Earth pressures acting on the culvert walls and wingwalls may be assumed to impose a triangular distribution. For a fully drained backfill, the pressures should be computed in accordance with the CHBDC 2010 but are generally given by the expression:

	p_h	=	$K (\gamma h + q)$
where	p_h	=	horizontal pressure on the wall at depth h (kPa)
	K	=	earth pressure coefficient (see table below)
	γ	=	bulk unit weight of retained soil (see table below)
	h	=	depth below top of fill where pressure is computed (m)
	q	=	value of any surcharge (kPa)

If full drainage is not achievable, the culvert walls must be designed to withstand full hydrostatic pressure assuming a water level at least equal to the design creek water level.

Earth pressure coefficients for backfill to the retaining walls are dependent on the material used as backfill. Recommended unfactored values are shown in the following Table 10.1. Active pressures should be used for any wing wall or unrestrained wall.

For rigid structures such as concrete box or rigid frame structures, it is recommended that at-rest horizontal earth pressures be used for design.

Table 10.1
Earth Pressure Coefficients (K)

Wall Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ; \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I (modified) $\phi = 32^\circ; \gamma = 21.2 \text{ kN/m}^3$		Embankment Fill $\phi = 28^\circ; \gamma = 20.0 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48	0.36	-
At rest (Restrained Wall)	0.43	0.62	0.47	0.70	0.53	-
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-	2.8	-

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I, or at a depth of 1.7 m for Granular A or Granular B Type II.

11 EMBANKMENT DESIGN AND CONSTRUCTION

The existing highway embankment is in the order of 3 m in height at the culverts. It is understood that that there is no planned grade raise at this site.

Embankment reconstruction after culvert replacement should be carried out in accordance with OPSS 206. The embankment material should consist of either Granular A or Granular B Type II material.

Provided that the granular material is placed as recommended, it is anticipated that a slope inclination of 2H : 1V or flatter should remain stable. Where applicable, benching of the existing earth slope surface should be carried out as per OPSD 208.010 in order to enhance the keying in of the new fill.

In general, surface vegetation, peat, topsoil, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from the areas around the culvert inlet and outlet, and within the culvert subgrade and embankment footprints. Inspection and approval of the foundation surfaces by qualified geotechnical personnel is recommended.

12 EROSION CONTROL

Erosion protection should be provided at the culvert inlet and/or outlet areas. Design of the erosion protection measures must consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field.

Typically, rip-rap should be provided over all surfaces with which creek water is likely to be in contact. Treatment at the outlets should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS 804.

It is recommended that a clay seal or a concrete cut-off wall be used to minimize the potential for erosion or piping around the culvert. The clay seal must extend to the order of 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5m. The material requirements should be in accordance with OPSS 1205. A geo-synthetic clay liner may be used as a clay seal.

13 EXCAVATION AND GROUNDWATER CONTROL

All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill and native silty clay till at the culvert site are classified as Type 3 soils above the water level and Type 4 soils below the water level. Surficial alluvial deposits that are anticipated in the inlet and outlet areas are classified as Type 4 soils. Excavation and backfilling for culvert construction must be carried out in accordance with OPSS 902. Excavations for culvert replacement will typically be carried out through the existing embankment fill and extended into the native silty clay till deposits. The work should be carried out within a protection system.

Any protection system should be designed by licensed Professional Engineers experienced in such designs. OPSS 539 “Construction Specification for Protection Systems” will have to be included in the contract documents. It is recommended that Performance Level 2 as per Clause 539.04.02.01 (maximum horizontal displacement of 25 mm) be specified for this culvert replacement site.

Groundwater perched within the embankment fill will seep into the excavations during culvert replacement. Surface runoff will also tend to accumulate in these excavations. The groundwater level

is expected to be largely governed by the water level in the creek. Creek water diversion, protection systems such as sheet piled cofferdams and pumping from filtered sumps, or some combination, will be required to maintain dry excavations during the course of staged construction.

14 ROADWAY PROTECTION DESIGN

Roadway protection and/or sheetpiled cofferdams will be required during various stages of construction. The design of roadway protection is the responsibility of the Contractor. However, one option that is considered to be suitable for use at the culvert site is steel interlocking sheet pile enclosures which are also anticipated to provide an effective groundwater cutoff. It is anticipated that the sheet piles will need to be extended into the stiff to very stiff silty clay till to develop the required toe resistance.

An interlocking sheet piled wall may be designed using the parameters given below:

γ	=	20 kN/m ³
γ_w	=	10 kN/m ³
K_a	=	0.33 (road embankment fill)
	=	0.33 (silty clay till)
K_p	=	3.0 (silty clay till)

Full hydrostatic pressure should be considered assuming a water level at least equal to the design creek water level.

The actual 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. Typically, a triangular earth pressure distribution similar to the one used for culvert lateral pressure design should be used for a cantilevered sheet piled wall.

The designer of the roadway protection system should check whether the penetration depth is sufficiently deep to provide base fixity.

All shoring systems should be designed by a Professional Engineer experienced in such designs.

15 CONSTRUCTION CONCERNS

During construction, the Contract Administrator should employ experienced geotechnical staff to observe construction activities related to foundation construction, and to inspect and approve the culvert subgrade.

Potential construction concerns include, but are not necessarily limited to, the following:

- Impact of excavation on the existing pavement surface

Daily visual inspection of the pavement surface must be carried out in the vicinity of the culvert replacement. If cracks form in the pavement or settlement is observed to occur, these matters

must immediately be brought to the attention of the C.A. for determining as to whether remedial action is required.

- Effective dewatering of the temporary excavation for installation of culvert
- Removal of peat, organics, soft soils and alluvial deposits near creek and stream channels,
- Disturbance of the soil subgrade within the culvert foundation footprints,
- Confirmation that the culvert backfills and approach fills are adequately placed and compacted to specifications.

It is recommended that provision(s) be included in the contract requiring the QVE to confirm that the above issues are adequately addressed. Should there be any doubts about issues such as depth of sub-excavation, these provisions should require the QVE to alert the CA.

16 GABION WALL REMEDIATION

16.1 General

Based on a historic design drawing titled “Gabion Details” prepared by Paragon Engineering Limited for MTO Contract 92-17, the gabion wall is in the order of 55 m in length and up to 4m in height. It consists of between 1 and 4 layers of gabion baskets depending on the topography. No construction or as-built records were available to date to confirm that the wall had been constructed as designed.

Results of our site inspection indicate that the distressed section has bulged and that some cracks has developed behind the wall at highway grade. A drawing summarizing the slope survey also appears to depict backward tilting of some gabions (Section B-B).

The gabions are between 2 to 4 m in length with two sets of cross-sectional dimensions. The first set is 1 m in width and 1 m in depth (type 1), while the second set is 0.5 m in width and 1m in depth (type 2). The second type is only used within the deepest section of the wall of approximately 20 m in length (from about 10 m to 30 m distances from the westerly limit of the wall. The gabions are typically arranged in two columns with type 1 dimensions except for the deepest section discussed above where a third row of type 2 dimensions are used for the two bottom stacks. The exterior of the wall typically measures 2 m in plan (2 gabion columns) except for a short section at the easterly limit where it is 1 m in plan (1 gabion). A trapezoidal wedge of Granular A backfill immediately behind the wall was also a part of the design.

As part of the current investigation, a survey firm (Dore) was retained to provide three slope cross-sections within the section of the gabion wall under distress. The survey indicates that the plan width of the wall is only 1.8 m as opposed to the design width of 2 m. There is no information to determine if smaller gabions were used or if the gabions were stacked

differently from the design configuration. According to the historic design drawing, this distressed wall section is supposed to have 4 tiers of gabions for a retained height of 4 m and a base width of 2.5 m. Based on results of this survey and Thurber's site observations, it is noted that the gabion wall consists of at least three tiers of gabions each of about 1 m in height. It was unclear whether there is a buried fourth tier with a widened base in accordance with the design.

Subsurface conditions depicted by the borehole investigation indicate that a 3-tier gabion wall is likely founded on the upper, soft to firm, portion of the silty clay deposits. Should this be a 4-tier section, the gabion wall would be founded on loose to compact silty sand.

16.2 Possible Causes of Instability

Based on the borehole information and the slope survey, slope stability analyses have been carried out for representative sections through the gabion wall. Cases for a 3-tier (3 m high) wall and a 4-tier (4 m high) wall have been included in the analysis. The limit equilibrium analysis was carried out using a commercially available computer program SLOPE/W. Results of the analysis are summarized in the following table.

Table 15.1
Factors of Safety from Stability Analysis

	Total Stress (short term)	Effective Stress (long term)
3 tiers of gabions	1.3	1.1
4 tiers of gabions	1.4	1.25

The above results indicate that the short term conditions generally satisfy the minimum Factor of Safety (F.S.) of 1.3 for short term conditions typically acceptable to MTO. Both long term conditions do not satisfy the minimum F.S. of 1.5 for long term conditions. Figures F1 to F4 in Appendix F are graphical presentation of the results summarized above.

Based on the above results and the site conditions, it is considered that the observed gabion wall distress and adjacent slope movement can be attributed to one or some combination of the following:

- Undercutting of the toe of the gabion wall by the outside bend of the meandering Penetangore River, resulting in potential undermining of the gabion wall founding subgrade and continual reduction in the passive resistance to the wall
- Full or partial hydrostatic build-up and the resulting increased lateral force behind the gabions may not have been accounted for during the original design. A layer of non-woven geotextile is designed to be placed immediately behind the wall. Potential plugging of the geotextile openings could have contributed to this scenario.

- For a 3-tier wall, progressive softening of the silty clay at subgrade level would reduce lateral sliding resistance to the wall. A preliminary calculation using assumed soil parameters indicates that the F.S. against sliding could be reduced from about 1.4 to 1.2. For a 4-tier wall, continual toe erosion and washing out of fines could result in loosening of the silty sand subgrade. The corresponding F.S. could be reduced from about 1.2 to less than 1.0.

16.3 Alternatives for Remediation

This section presents discussions on alternatives for remediation of the gabion wall and the highway embankment immediately adjacent to it. Discussions on available alternatives are included.

It is noted that access from the river side to the distressed wall location is difficult. In addition, the presence of the river and associated environmental issues would likely prohibit the use of heavy equipment for the remediation work. It is assumed that realignment of the river will not be permitted.

MTO has confirmed that there is no available construction or as-built records of the gabions. Based on Table 15.1, the 3-tier case is considered to be more critical due to its lower F.S. and has been selected for modelling the remediation alternatives.

Consideration was given to the following alternatives:

- Mechanical anchors as tie-backs to the gabions
- Sheetpiles in front of the gabion wall toe
- Toe berm
- Redesign and reconstruction of the gabions.

The following presents discussions and recommendations of the above alternatives.

Mechanical Anchors

This is a cost effective alternative given the site restrictions and lack of construction information. The gabions should be tied back to soils beyond the potential slip surface.

Limit equilibrium analysis was carried out by using a mechanical soil anchor model SR-3 with the trade name Stingray. The effects of the tie-backs were modelled by one row of anchors with a minimum anchor length of 5.5 m behind the face of the gabion wall, an anchor spacing of 1 m along the wall alignment and an allowable tie-back load of 76 kN. The model of the described anchor configuration satisfies a minimum Factor of Safety (F.S.) of 1.3 for short term conditions. A F.S. of 1.4 was obtained for long term conditions. Although less than 1.5, the long term global stability of the tied back gabions is considered acceptable given the nature of the project and conditions of the site. Figures F5 and F6 in Appendix F are

graphical representations of these results. Tie-backs do not address the issue of toe erosion and should be used in conjunction with measures such as sheetpiles to minimize toe erosion.

Sheetpiles

This is a feasible alternative as the sheetpiles would serve the dual purpose of minimizing further toe erosion by the river and assisting in stabilization the wall movement. It is recommended that this be used in conjunction with the tie-backs. Sheetpile installation will have to be carried out from the highway grade. Sheetpiles should be driven, and not vibrated, in place in order to minimize the risk of adverse impacts on the gabions.

Toe berm

Preliminary analyses show that a fairly large toe berm would be required to achieve adequate F.S. for the wall. Due to the presence of the river adjacent to the wall, this alternative is not recommended for use at this site.

Gabion Redesign and Reconstruction

An alternative to the tie-back and sheetpile options is to completely redesign and reconstruct the distressed section of the wall. The cost-effectiveness of this option needs to be evaluated by the designer.

16.4 Design of Mechanical Anchors

These anchors may be located within the embankment fill and the underlying silty clay. As a guide, mechanical soil anchors such as the Stingray marketed by Williams, helical tiebacks marketed by Chance, or equivalent mechanical anchors may be considered. Taking into consideration the physical constraints at this site, the anchors should be limited to a single level at the uppermost tier of the wall. The axial design capacities may be selected from the available products. If the Stingray SR-3 is used, they should be installed at the uppermost level of gabion baskets at 1 m intervals along the wall alignment with a rod length of 5.5 m and at a nominal sub-horizontal angle of 10°. Proprietary suppliers/installers of this type of anchors should be consulted prior to finalizing the design. Proof testing of each anchor and installation requirements must be in accordance with the applicable guidelines.

14 CLOSURE

Preparation of this foundation design report was carried out by Mr. Lukasz Gilarski, P.Eng. and Dr. Sydney Pang, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng.

THURBER ENGINEERING LTD.

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Geotechnical Engineer



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Associate, Senior Foundations Engineer



P.K. Chatterji, P.Eng.
Principal, Designated MTO Contact



METRIC

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

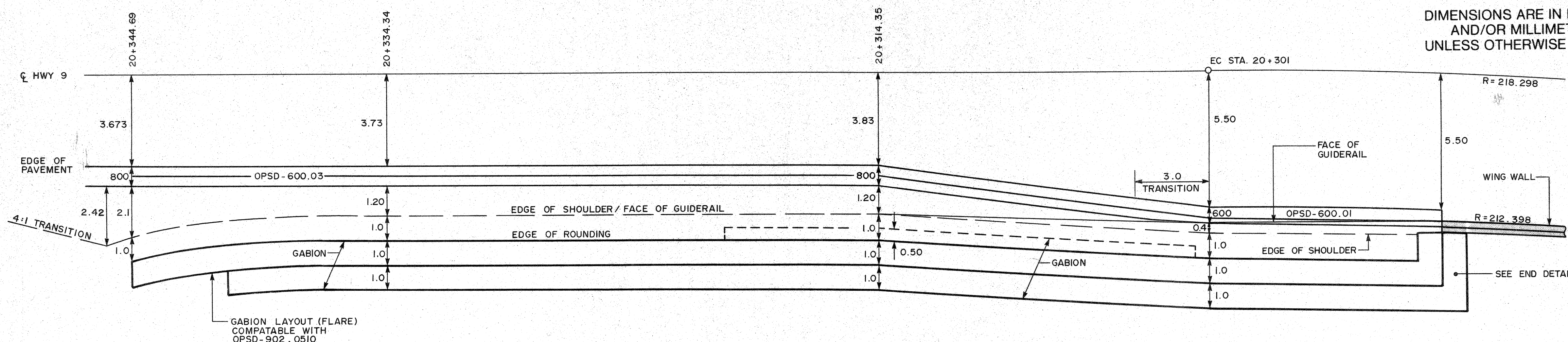
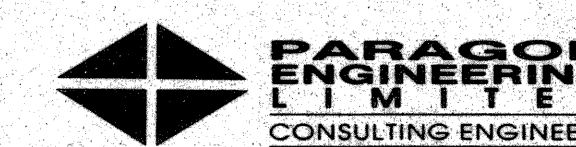
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WP No 158-88-00

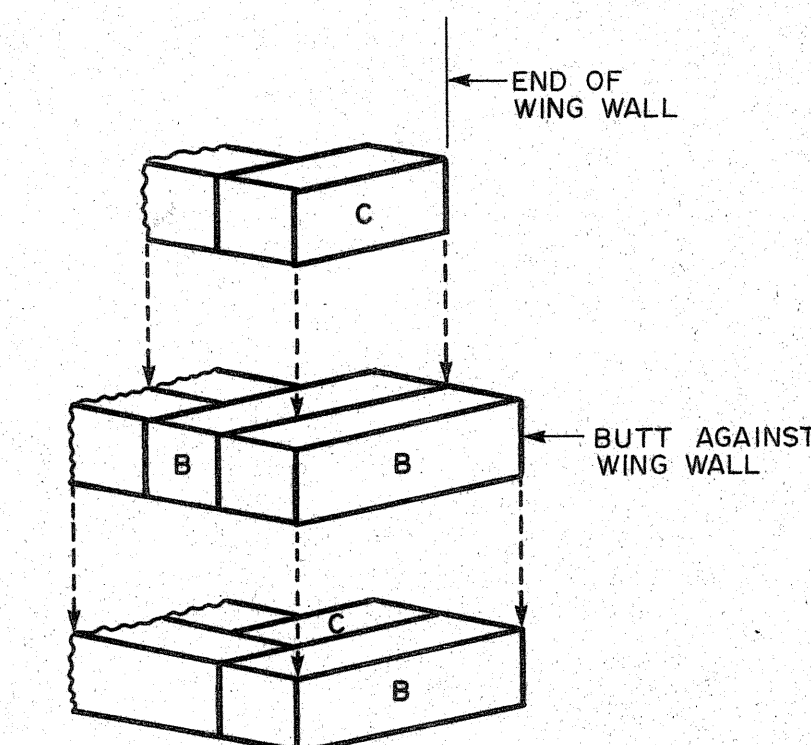
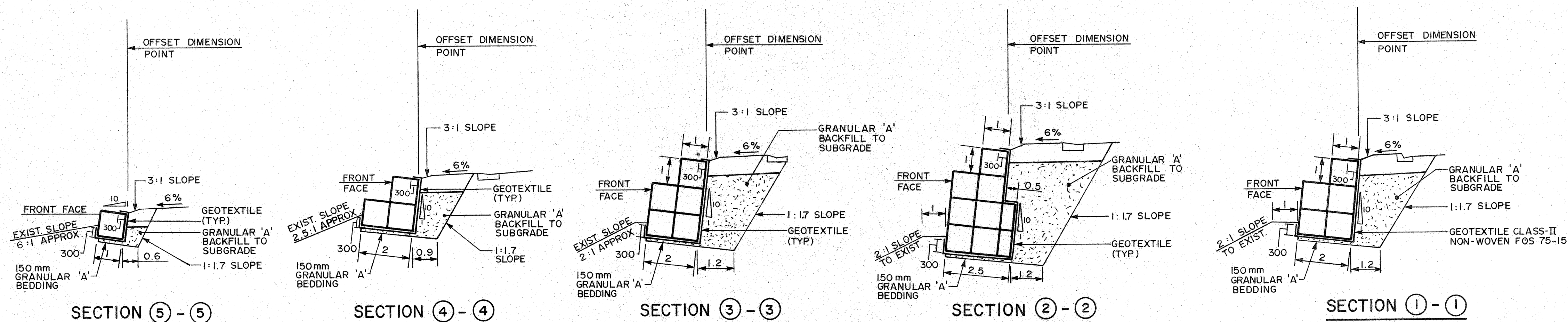
GABION DETAILS

SHEET
18



PLAN VIEW - GABION LAYOUT

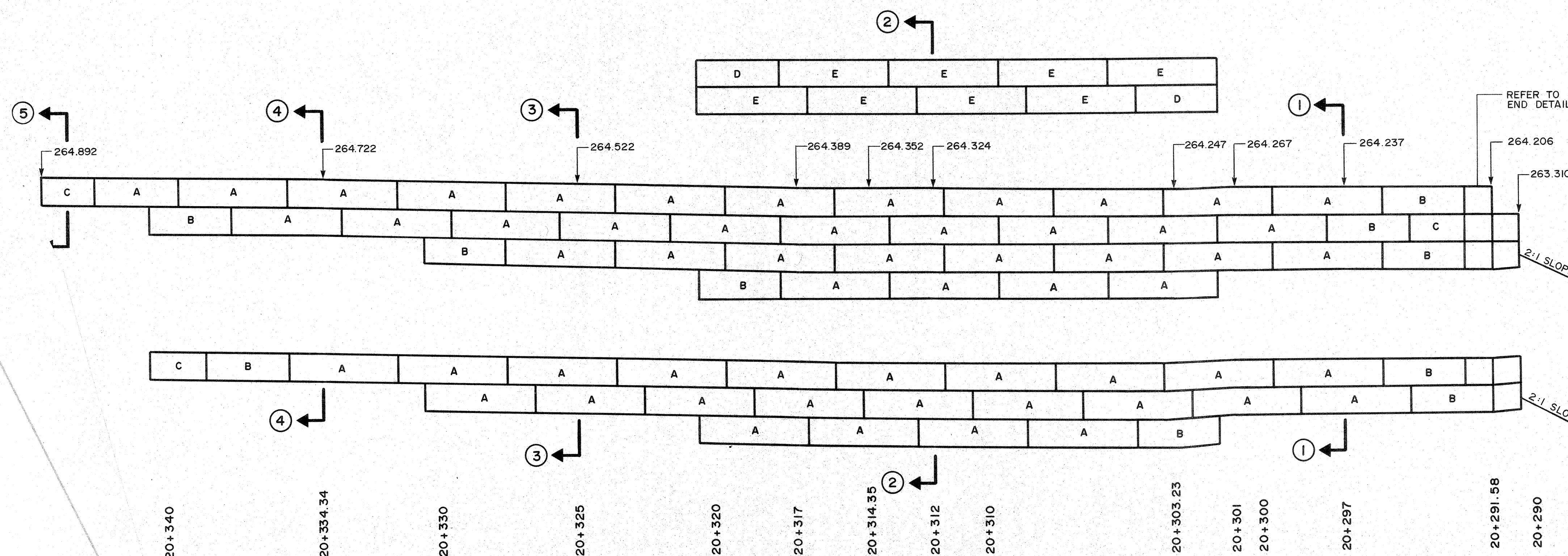
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END DETAIL

SCALE: 1:100

NOTATION	GABION SIZES			No. of DIAPHRAGMS	QTY
	LENGTH	WIDTH	DEPTH		
A	4	1	1	3	57
B	3	1	1	2	13
C	2	1	1	1	5
D	3	0.5	1	2	2
E	4	0.5	1	3	8



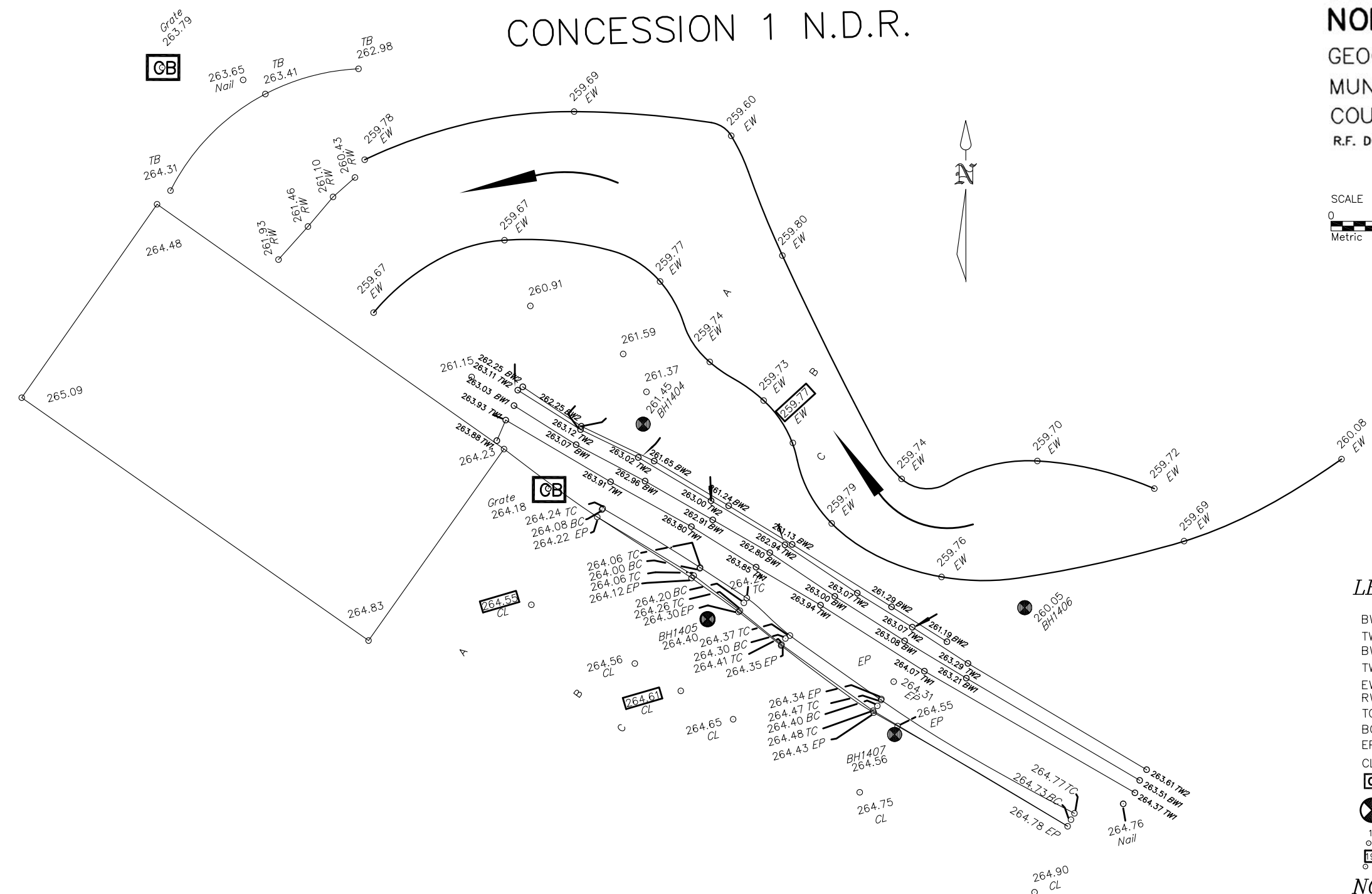
NORTH ELEVATION - GABION LAYOUT

SCALE: 1:100 HORIZ.
1:100 VERT.

DRAWING NOT TO BE SCALED.
100 mm ON ORIGINAL DRAWING

LOT 51
CONCESSION 1 N.D.R.

PLAN SHOWING SPOT ELEVATIONS AND PROFILES
ON
**PART OF LOT 51
CONCESSION 1
NORTH OF THE DURHAM ROAD**
GEOGRAPHIC TOWNSHIP OF KINCARDINE
MUNICIPALITY OF KINCARDINE
COUNTY OF BRUCE
R.F. DORE SURVEYING LTD.



LEGEND

- BW1 BOTTOM OF RETAINING WALL 1 (GABION BASKETS)
- TW1 TOP OF RETAINING WALL 1 (GABION BASKETS)
- BW2 BOTTOM OF RETAINING WALL 2 (GABION BASKETS)
- TW2 TOP OF RETAINING WALL 2 (GABION BASKETS)
- EW EDGE OF WATER
- RW RETAINING WALL (GABION BASKETS)
- TC TOP OF CURB
- BC BOTTOM OF CURB
- EP EDGE OF PAVEMENT
- CL CENTRELINE
- CB CATCHBASIN
- BH BOREHOLE
- SPOT ELEVATIONS
- INTERPOLATED ELEVATIONS

NOTES

- (1) ORIGINAL DATA COLLECTED NOVEMBER 11, 2014.
- (2) ELEVATIONS ARE GEODETIC OBTAINED FROM GPS OBSERVATIONS.

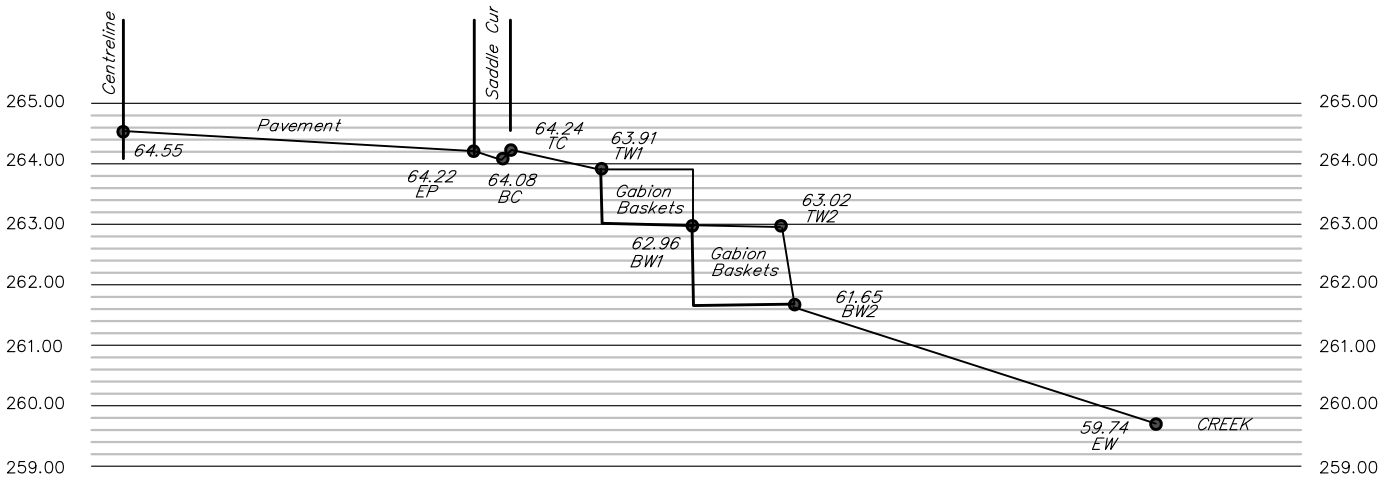
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CONVERTED TO FEET BY DIVIDING BY 0.3048.

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ONTARIO LAND SURVEYOR
BOX 571, 932 QUEEN STREET, KINCARDINE
ONTARIO N2Z 2Y2
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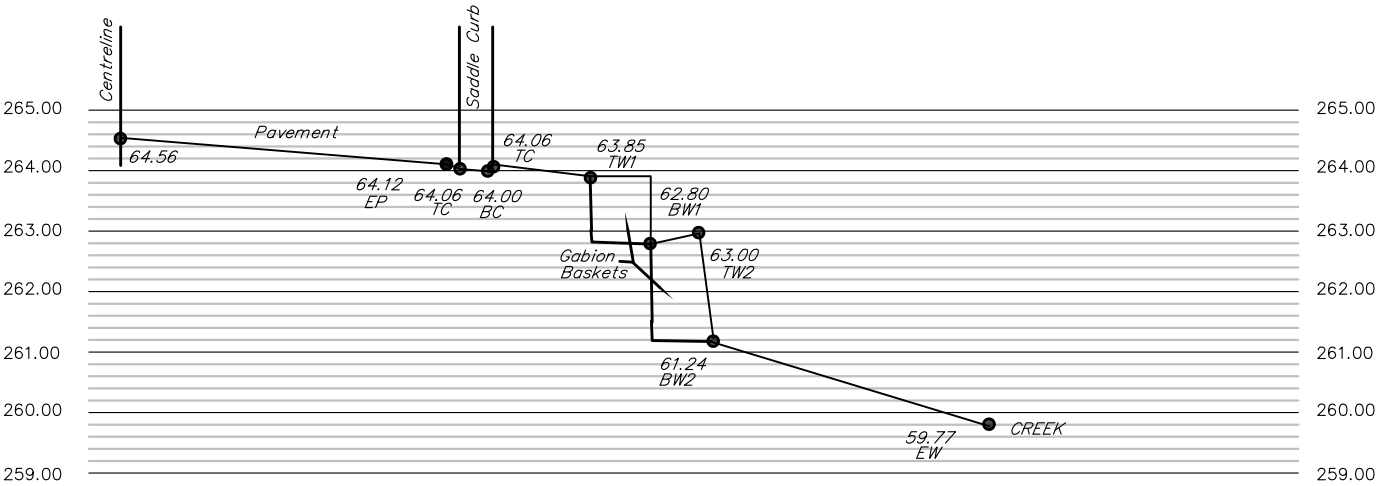
RD
O.L.S.

SCALE 1:250 METRIC

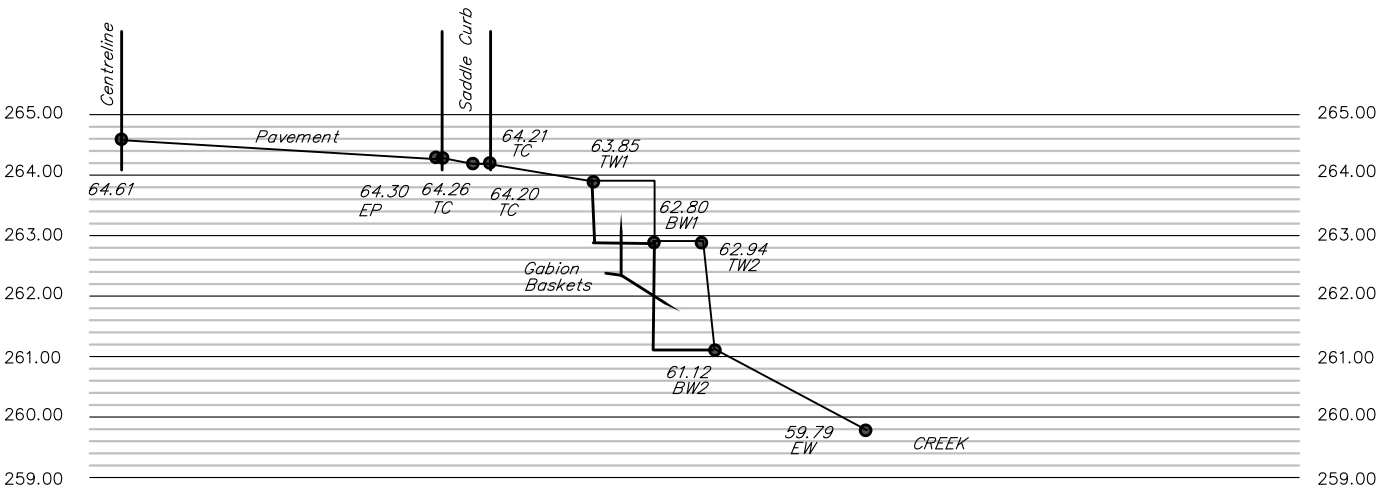
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SECTION A-A
HORZ: VERT SCALE 1:125m

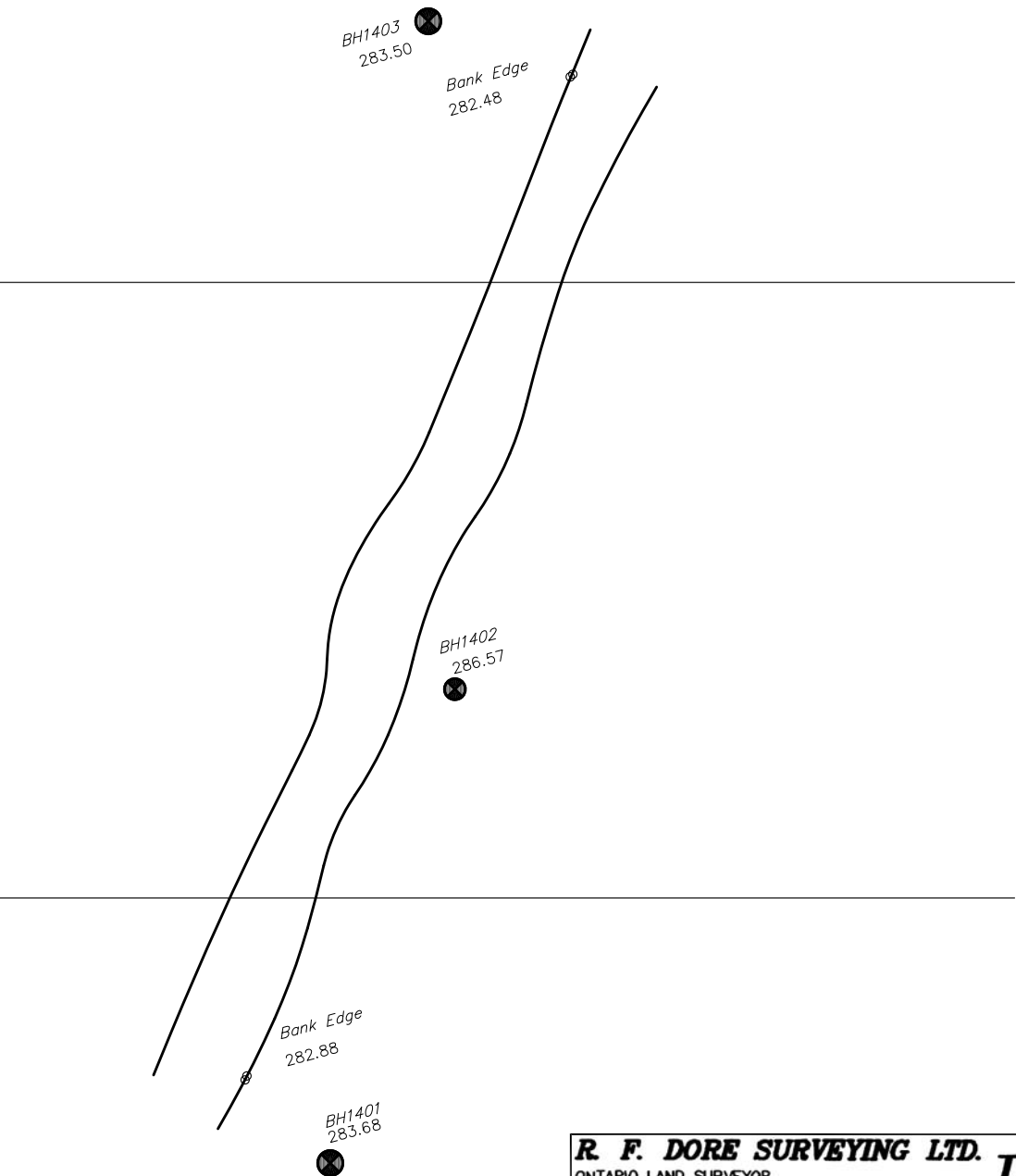
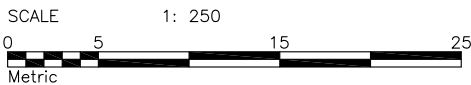


SECTION B-B
HORZ: VERT SCALE 1:125m



SECTION C-C
HORZ: VERT SCALE 1:125m

PLAN SHOWING SPOT ELEVATIONS AND PROFILES
ON
**PART OF LOT 51
CONCESSION 1
NORTH OF THE DURHAM ROAD**
GEOGRAPHIC TOWNSHIP OF KINCARDINE
MUNICIPALITY OF KINCARDINE
COUNTY OF BRUCE
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O.L.S.

SCALE 1:250 METRIC	FILE No. 148244
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Appendix A

Record of Borehole Sheets

15-64-30

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT ⁽¹⁾ 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer


4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$

 Water Level


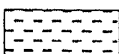



C_{pen} Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS W _L < 50%	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. (W _L < 30%).
		CI	Inorganic clays of medium plasticity, silty clays. (30% < W _L < 50%).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS W _L > 50%	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION		SYMBOLS	
Fresh (FR)	No visible signs of weathering.		CLAYSTONE
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.		SILTSTONE
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SANDSTONE
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.		COAL
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.		Bedrock (general)
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.		

DISCONTINUITY SPACING		STRENGTH CLASSIFICATION			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m				
Very thinly bedded	20 to 60mm	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Laminated	6 to 20mm				
Thinly Laminated	Less than 6mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
		Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
		Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
		Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

TERMS	
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index: (FI)	Frequency of natural fractures per 0.3 m of core run.

RECORD OF BOREHOLE No 14-01

1 OF 2

METRIC

W.P. 3126-10-00 LOCATION Culvert Replacement N 4 884 924.5 E 462 593.5 ORIGINATED BY GA
 HWY 9 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.10.30 - 2014.10.30 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W _P W W _L				GR SA SI CL				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%)								
283.7	GROUND SURFACE							20	40	60	80	100									
0.0	TOPSOIL: (100mm) Silty CLAY , with sand, trace gravel, occasional rootlets Stiff to Very Stiff Brown Moist (TILL)		1	SS	17									○							
0.1			2	SS	22										○						
			3	SS	14										○						
			4	SS	22										○						
			5	SS	14										○						
			6	SS	18										○						
			7	SS	22										○						
278.0	SILT , some sand, some clay, trace gravel Very Dense Grey Moist		8	SS	77									○							
5.6																					
276.7	Silty CLAY , trace sand, trace gravel Hard Grey Moist (TILL)		9	SS	86									○							
7.0																					
				10	SS	84									○						

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 14-01

2 OF 2

METRIC

W.P. 3126-10-00 LOCATION Culvert Replacement N 4 884 924.5 E 462 593.5 ORIGINATED BY GA
 HWY 9 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.10.30 - 2014.10.30 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
							20	40	60	80	100	W _p	W	W _L			
	Continued From Previous Page																
	Silty CLAY , trace sand, trace gravel Hard Grey Moist (TILL)		11	SS	38												
			12	SS	54												
270.9																	
12.8	END OF BOREHOLE AT 12.8m. BOREHOLE OPEN TO 12.8m AND WATER LEVEL AT 3.4m. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2014.10.31 4.6 279.1 2014.11.17 0.5 283.2 2014.12.12 2.1 281.6																

ONTMT4S 6430.GPJ 2012TEMPLATE(MTO).GDT 12/17/14

RECORD OF BOREHOLE No 14-02

1 OF 2

METRIC

W.P. 3126-10-00 LOCATION Culvert Replacement N 4 884 941.4 E 462 597.9 ORIGINATED BY GA
 HWY 9 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.10.30 - 2014.10.30 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
286.6	GROUND SURFACE							20 40 60 80 100					
0.0	ASPHALT: (100mm)												
286.3	SAND and GRAVEL: (FILL)		1	SS	28		286						
0.3	SILT, trace sand, trace gravel Compact Brown Moist (FILL)		2	SS	16								
285.7	Silty CLAY, with sand Very Stiff to Stiff Brown Moist (FILL)		3	SS	15		285						
0.8			4	SS	14		284						
283.5			5	SS	8		283						
3.0	Silty CLAY, occasional rootlets Stiff Brown to Black Moist (TILL)		6	SS	9								
282.0			7	SS	19		282						
4.6	with sand, trace gravel Very Stiff Brown Moist (TILL)		8	SS	18		281						
280.9	Sandy SILT, some clay, trace gravel Compact Grey Moist		9	SS	13		280						
5.6			10	SS	75		279						
279.4	Silty CLAY, some sand, trace gravel Stiff Grey Wet (TILL)						278						
7.2							277						
277.9	Hard												
8.7													

Continued Next Page

+³, ×³: Numbers refer to Sensitivity
 20
 15
 10
 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 14-02

2 OF 2

METRIC

W.P. 3126-10-00 LOCATION Culvert Replacement N 4 884 941.4 E 462 597.9 ORIGINATED BY GA
 HWY 9 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.10.30 - 2014.10.30 CHECKED BY LPG

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	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
							20	40	60	80	100						
	Continued From Previous Page																
	Silty CLAY , some sand Hard Grey Wet (TILL)		11	SS	81		276									0 14 56 30	
							275										
273.9			12	SS	90		274										
12.6	END OF BOREHOLE AT 12.6m. BOREHOLE OPEN TO 12.6m AND WATER LEVEL AT 6.6m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.6m, CONCRETE TO 0.2m, THEN ASPHALT COLD PATCH TO SURFACE.																

RECORD OF BOREHOLE No 14-03

1 OF 1

METRIC

W.P. 3126-10-00 LOCATION Culvert Replacement N 4 884 965.3 E 462 597.0 ORIGINATED BY ADH
 HWY 9 BOREHOLE TYPE Tripod Portable 70lb Hammer - Wash Boring with Casing COMPILED BY AN
 DATUM Geodetic DATE 2014.11.14 - 2014.11.17 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								20 40 60 80 100				W _P W W _L				
283.5	GROUND SURFACE															
0.0	Silty CLAY , trace sand, trace organics Stiff Brown Moist		1	SS	5*								○			
282.8																
0.7	Silty CLAY , with sand, trace gravel Stiff to Hard Brown to Grey Moist (TILL)		2	SS	9*								○			
			3	SS	12*								○		2 25 43 30	
			4	SS	20*								○			
			5	SS	21*								○			
			6	SS	17*								○			
			7	SS	52*								○		5 32 43 20	
			8	SS	49*								○			
275.4																
8.1	END OF BOREHOLE AT 8.1m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. *Converted to an equivalent value for a standard 140lb hammer. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2014.11.17 1.1 282.4 2014.12.12 1.0 282.5															

+³, ×³: Numbers refer to
Sensitivity 20
15 10 5 0
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 14-04

1 OF 1

METRIC

W.P. 3126-10-00 LOCATION Bervie Retaining Wall N 4 886 525.4 E 459 793.4 ORIGINATED BY ADH
 HWY 9 BOREHOLE TYPE Tripod Portable 70lb Hammer - Wash Boring with Casing COMPILED BY AN
 DATUM Geodetic DATE 2014.11.12 - 2014.11.13 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
261.5	GROUND SURFACE							20	40	60	80	100		
0.0	TOPSOIL: (50mm)							20	40	60	80	100		
	Silty CLAY , with sand Firm to Very Stiff Brown Moist		1	SS	4*		261							
			2	SS	10*		260							
			3	SS	8*									
259.3														
2.1	Silty SAND Compact Brown Wet		4	SS	15*		259							
258.7														
2.7	Silty CLAY , trace to some sand Stiff to Very Stiff Grey Wet		5	SS	11*		258							
			6	SS	13*		257							
							256							
			7	SS	17*		255							
254.3														
7.1	Silty SAND , some clay, trace gravel Very Dense Grey Moist						254							
253.5			8	SS	45*									
7.9	END OF BOREHOLE AT 7.9m. BOREHOLE OPEN TO 7.6m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. *Converted to an equivalent value for a standard 140lb hammer. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2014.11.13 +1.0 262.5 2014.11.17 +1.0 262.5 2014.12.12 +0.7 262.2													

ONTMT4S 6430.GPJ 2012TEMPLATE(MTO).GDT 12/17/14

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 14-05

1 OF 2

METRIC

W.P. 3126-10-00 LOCATION Bervie Retaining Wall N 4 886 515.1 E 459 796.8 ORIGINATED BY GA
 HWY 9 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.10.29 - 2014.10.29 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)					
264.4	GROUND SURFACE							20	40	60	80	100					
0.0	ASPHALT: (100mm)																
0.1	SAND and GRAVEL Dense Brown (FILL)		1	SS	36		264										
263.6																	
0.8	SAND, some silt, trace clay Compact Brown Moist (FILL)		2	SS	20		263										0 73 20 7
			3	SS	17												
262.2																	
2.2	Silty CLAY, with sand Firm Brown Moist		4	SS	4		262										
			5	SS	5		261										0 33 35 32
260.5																	
3.9	Silty SAND, some clay Loose to Compact Brown to Grey Wet		6	SS	6		260										
			7	SS	11												0 62 26 12
			8	SS	13		259										
258.3																	
6.1	Silty CLAY Very Stiff Grey Moist		9	SS	24		258										0 0 73 27
							257										
			10	SS	23												
255.7							256										
8.7	Clayey SILT, with sand, some gravel Dense to Very Dense Grey Wet																
			11	SS	36		255										

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity 20
15 10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 14-05

2 OF 2

METRIC

W.P. 3126-10-00 LOCATION Bervie Retaining Wall N 4 886 515.1 E 459 796.8 ORIGINATED BY GA
 HWY 9 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.10.29 - 2014.10.29 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	W P	W	W L			
	Continued From Previous Page													
	Clayey SILT , with sand, some gravel Dense to Very Dense Grey Wet		12	SS	100/	0.075							11 44 35 10	
251.9			13	SS	92									
12.5	END OF BOREHOLE AT 12.5m. BOREHOLE OPEN TO 12.2m AND WATER LEVEL AT 4.5m. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2014.10.31 1.5 262.9 2014.11.17 0.5 263.9 2014.12.12 1.0 263.4													

RECORD OF BOREHOLE No 14-06

1 OF 1

METRIC

W.P. 3126-10-00 LOCATION Bervie Retaining Wall N 4 886 515.7 E 459 813.6 ORIGINATED BY ADH
 HWY 9 BOREHOLE TYPE Tripod Portable 70lb Hammer - Wash Boring with Casing COMPILED BY AN
 DATUM Geodetic DATE 2014.11.13 - 2014.11.13 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT							UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa													
								20 40 60 80 100									PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									W P W W L				
							WATER CONTENT (%) 20 40 60														
260.1	GROUND SURFACE						260														
0.0	TOPSOIL: (50mm)		1	SS	2*																
	Silty CLAY , some sand, trace gravel, trace organics Soft Brown Moist		2	SS	3*		259														
258.5																					
1.5	Silty CLAY , trace gravel Stiff Grey Moist		3	SS	11*		258										0	0	61	39	
			4	SS	8*																
			5	SS	14*		257														
							256														
255.5			6	SS	51*		255														
4.6	Hard																				
254.5																					
5.6	Clayey SILT , with sand, trace gravel Hard Grey Moist to Wet (TILL)		7	SS	55*		254											9	48	29	14
							253														
252.2			8	SS	75/ 0.075*																
7.8	END OF BOREHOLE AT 7.8m. BOREHOLE OPEN TO 7.6m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE. *Converted to an equivalent value for a standard 140lb hammer.																				

ONTMT4S 6430.GPJ 2012TEMPLATE(MTO).GDT 12/17/14

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 14-07

1 OF 2

METRIC

W.P. 3126-10-00 LOCATION Bervie Retaining Wall N 4 886 509.1 E 459 806.7 ORIGINATED BY GA
HWY 9 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
DATUM Geodetic DATE 2014.10.29 - 2014.10.29 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								20 40 60 80 100					
264.6	GROUND SURFACE												
0.0	ASPHALT: (100mm)												
0.1	SAND and GRAVEL Dense Brown (FILL)		1	SS	31		264						
263.6													
0.9	SAND, some silt, trace clay Compact Brown Moist (FILL)		2	SS	24		263						
			3	SS	18								
262.3													
2.3	Silty CLAY, with sand Firm Grey Moist		4	SS	6		262						
261.5													
3.0	Stiff Brown		5	SS	9		261						
			6	SS	12								0 33 35 32
260.0							260						
4.6	Silty SAND, some clay, occasional rootlets Compact Brown Wet		7	SS	10								
259.2													
5.3	Silty CLAY, with sand, occasional rootlets Stiff to Very Stiff Brown/Grey Wet		8	SS	13		259						0 20 47 33
			9	SS	19		258						
257.2													
7.3	Clayey SILT, with sand, trace gravel Compact Grey Moist		10	SS	24		257						7 35 42 16
							256						
255.9													
8.7	Very Dense		11	SS	86		255						

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity


20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 14-07

2 OF 2

METRIC

W.P. 3126-10-00 LOCATION Bervie Retaining Wall N 4 886 509.1 E 459 806.7 ORIGINATED BY GA
 HWY 9 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.10.29 - 2014.10.29 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
	Continued From Previous Page							20 40 60 80 100							
	Clayey SILT , with sand, trace gravel Very Dense Grey Moist		12	SS	50/ 0.150		254								
							253								
252.2			13	SS	100/ 0.150										
12.3	END OF BOREHOLE AT 12.3m. BOREHOLE OPEN TO 12.3m AND WATER LEVEL AT 4.6m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.6m, CONCRETE TO 0.2m, THEN ASPHALT COLD PATCH TO SURFACE.				0.150										

RECORD OF BOREHOLE No HA-01

1 OF 1

METRIC

W.P. 3126-10-00 LOCATION Bervie Retaining Wall N 4 886 524.2 E 459 793.4 ORIGINATED BY GA
 HWY 9 BOREHOLE TYPE Hand Auger COMPILED BY AN
 DATUM Geodetic DATE 2014.10.28 - 2014.10.28 CHECKED BY LPG

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	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
261.6	GROUND SURFACE																
0.0	TOPSOIL: (125mm)																
0.1	SAND, occasional silt Brown Moist (FILL)																
260.7																	
0.9	Silty CLAY, some sand Brown/Grey Moist																
260.1																	
1.5	END OF BOREHOLE AT 1.5m UPON AUGER REFUSAL. AUGER HOLE DRY UPON COMPLETION.																

RECORD OF BOREHOLE No HA-02

1 OF 1

METRIC

W.P. 3126-10-00 LOCATION Bervie Retaining Wall N 4 886 525.5 E 459 790.6 ORIGINATED BY GA
 HWY 9 BOREHOLE TYPE Hand Auger COMPILED BY AN
 DATUM Geodetic DATE 2014.10.28 - 2014.10.28 CHECKED BY LPG

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	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
262.2	GROUND SURFACE																
0.0	Silty CLAY , occasional rootlets Brown Moist (FILL)						262										
261.6																	
0.6	END OF BOREHOLE AT 0.6m UPON AUGER REFUSAL.																

RECORD OF BOREHOLE No HA-03

1 OF 1

METRIC

W.P. 3126-10-00 LOCATION Bervie Retaining Wall N 4 886 517.7 E 459 804.2 ORIGINATED BY GA
HWY 9 BOREHOLE TYPE Hand Auger COMPILED BY AN
DATUM Geodetic DATE 2014.10.28 - 2014.10.28 CHECKED BY LPG

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	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
261.1	GROUND SURFACE																
0.0	TOPSOIL: (100mm)						261										
0.1	Silty CLAY, occasional rootlets Brown Moist																
							260										
259.6	END OF BOREHOLE AT 1.5m UPON AUGER REFUSAL. AUGER HOLE DRY UPON COMPLETION.																
1.5																	

Appendix B

Laboratory Test Results

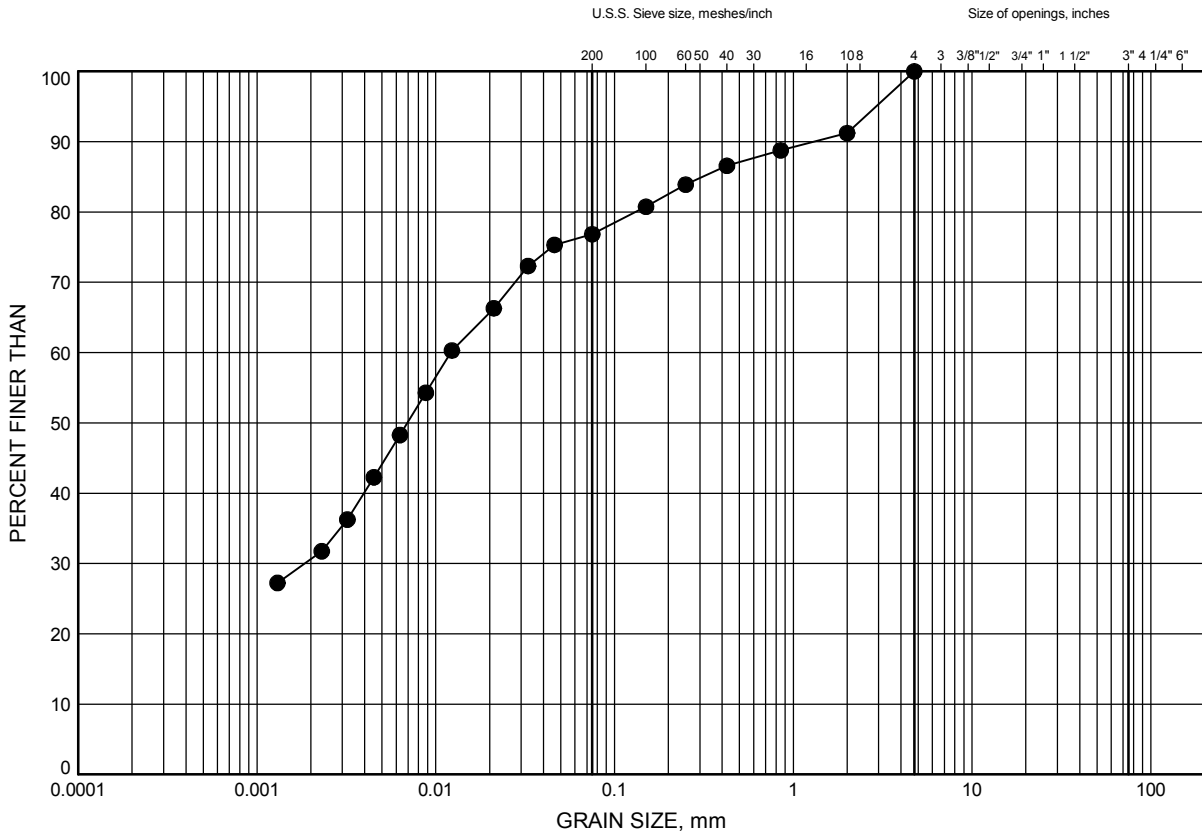
15-64-30

Fill Slope Stabilization & Culvert Installation

GRAIN SIZE DISTRIBUTION

FIGURE B1

Silty CLAY FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-02	1.83	284.74

Date December 2014
W.P. 3126-10-00



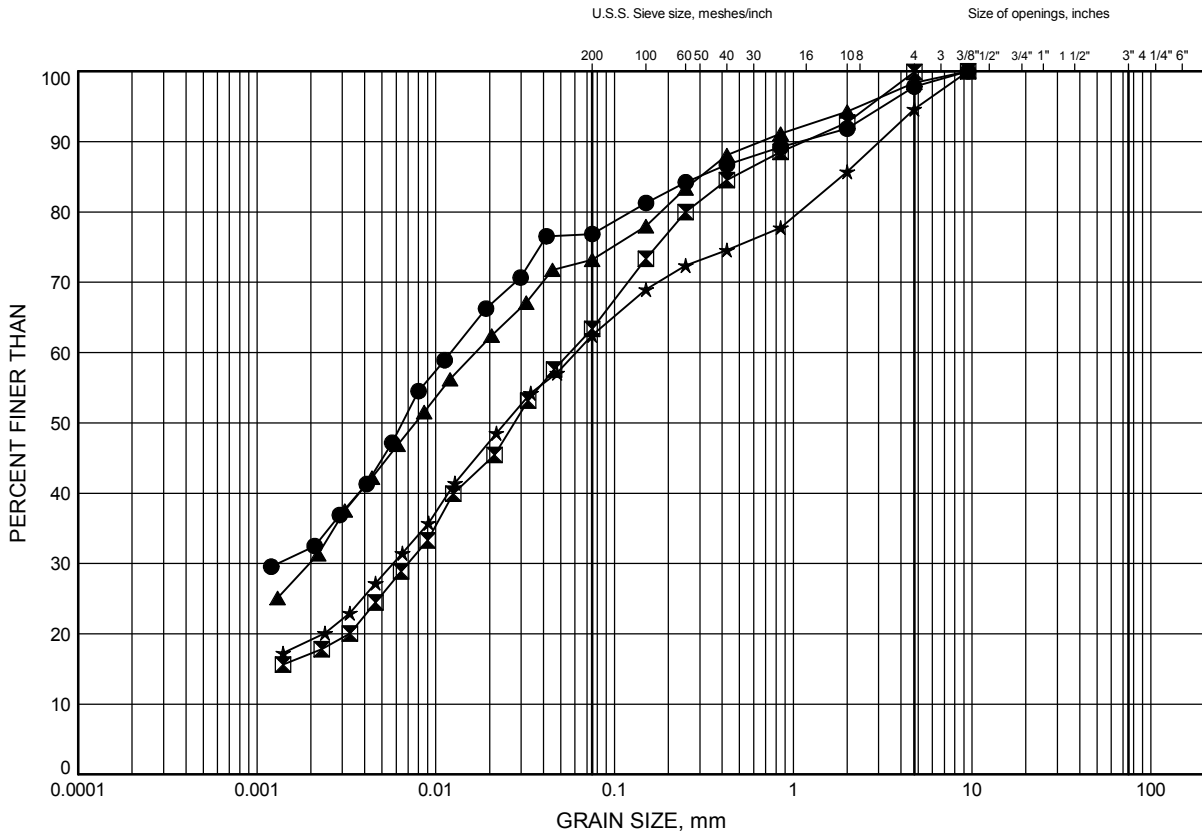
Prep'd MFA
Chkd. SKP

Fill Slope Stabilization & Culvert Installation

GRAIN SIZE DISTRIBUTION

FIGURE B2

Silty CLAY TILL, with sand



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-01	1.83	281.85
⊠	14-01	4.88	278.80
▲	14-03	1.83	281.67
★	14-03	6.32	277.18

Date December 2014
W.P. 3126-10-00



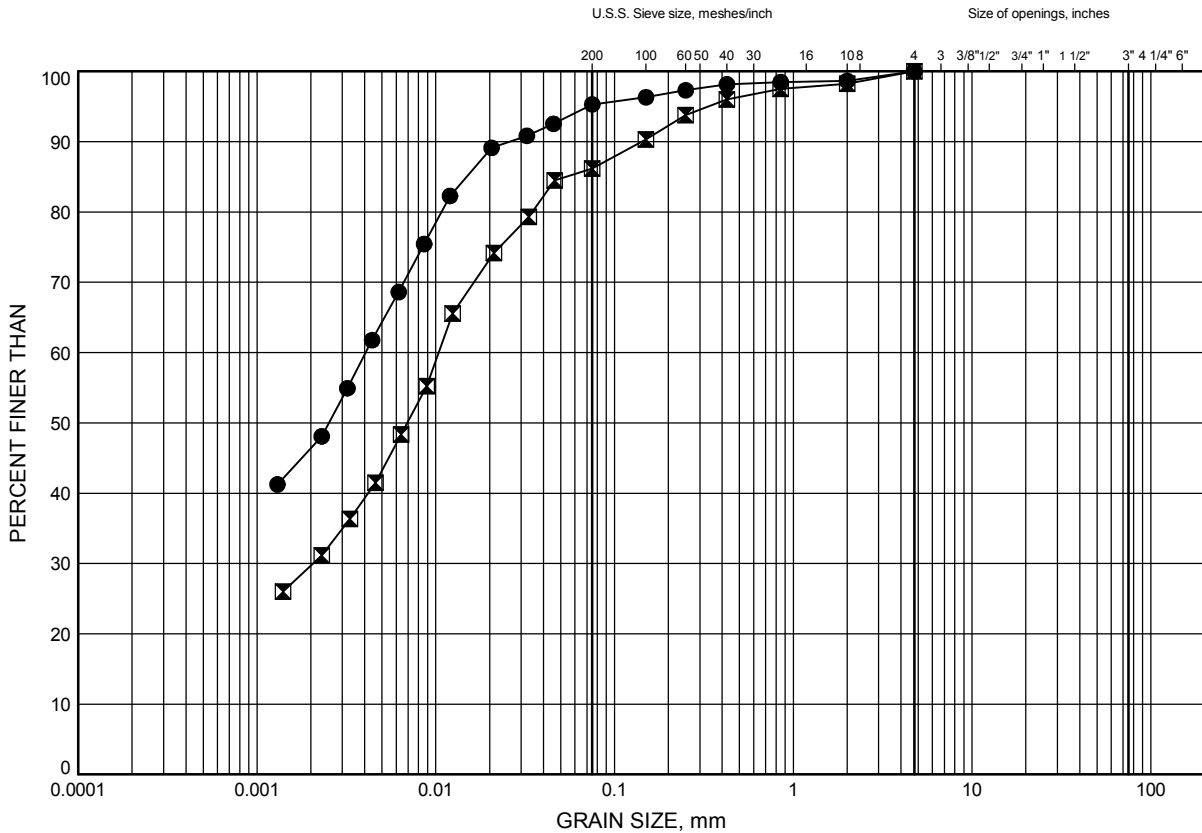
Prep'd MFA
Chkd. SKP

Fill Slope Stabilization & Culvert Installation

GRAIN SIZE DISTRIBUTION

FIGURE B3

Silty CLAY TILL, trace to some sand



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-01	12.50	271.18
⊠	14-02	10.82	275.75

Date December 2014
W.P. 3126-10-00



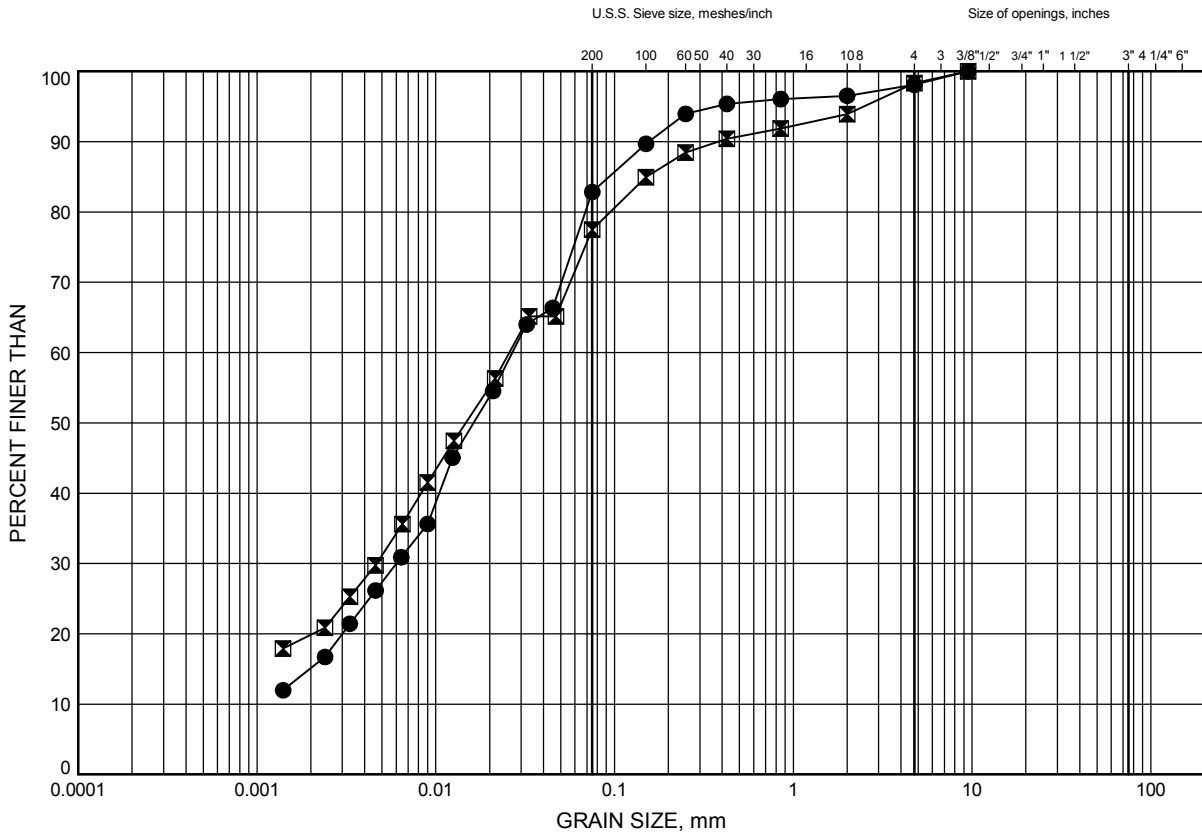
Prep'd MFA
Chkd. SKP

Fill Slope Stabilization & Culvert Installation

GRAIN SIZE DISTRIBUTION

FIGURE B4

SILT to Sandy SILT



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-01	6.40	277.28
⊠	14-02	6.40	280.17

Date December 2014
W.P. 3126-10-00

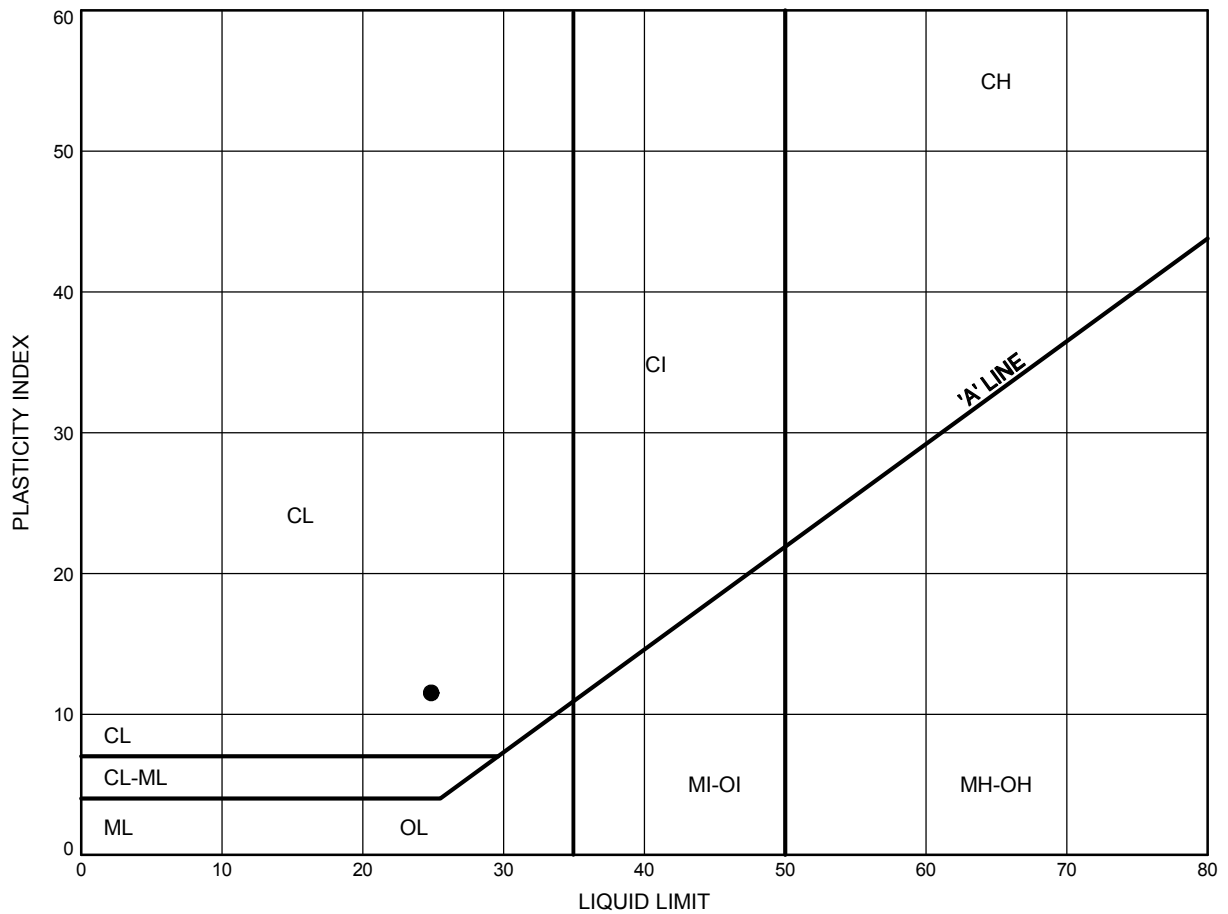


Prep'd MFA
Chkd. SKP

Fill Slope Stabilization & Culvert Installation
ATTERBERG LIMITS TEST RESULTS

FIGURE B5

Silty CLAY FILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-02	1.83	284.74

Date December 2014
 W.P. 3126-10-00

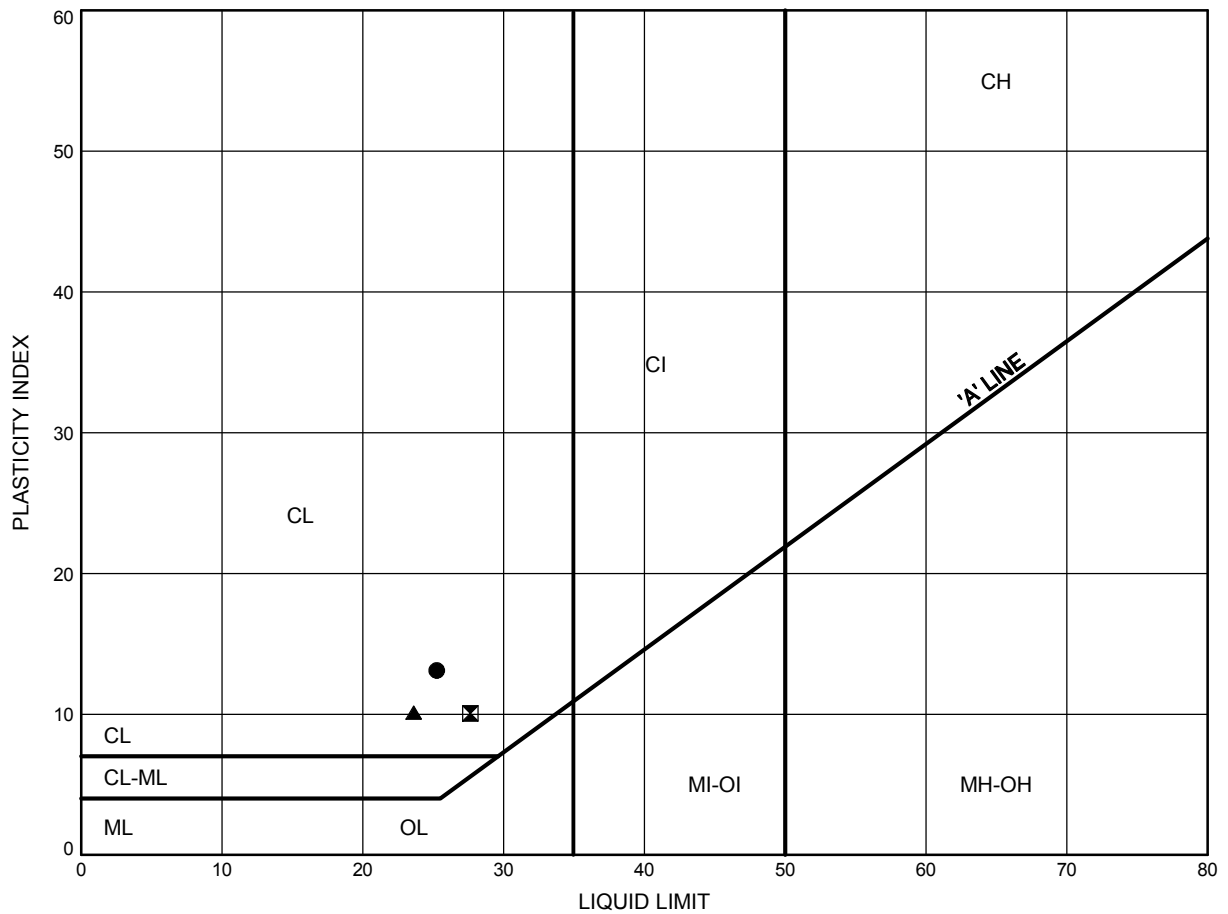


Prep'd MFA
 Chkd. SKP

Fill Slope Stabilization & Culvert Installation
ATTERBERG LIMITS TEST RESULTS

FIGURE B6

Silty CLAY TILL, with sand



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-01	1.83	281.85
⊠	14-01	4.88	278.80
▲	14-03	1.83	281.67

Date December 2014
W.P. 3126-10-00



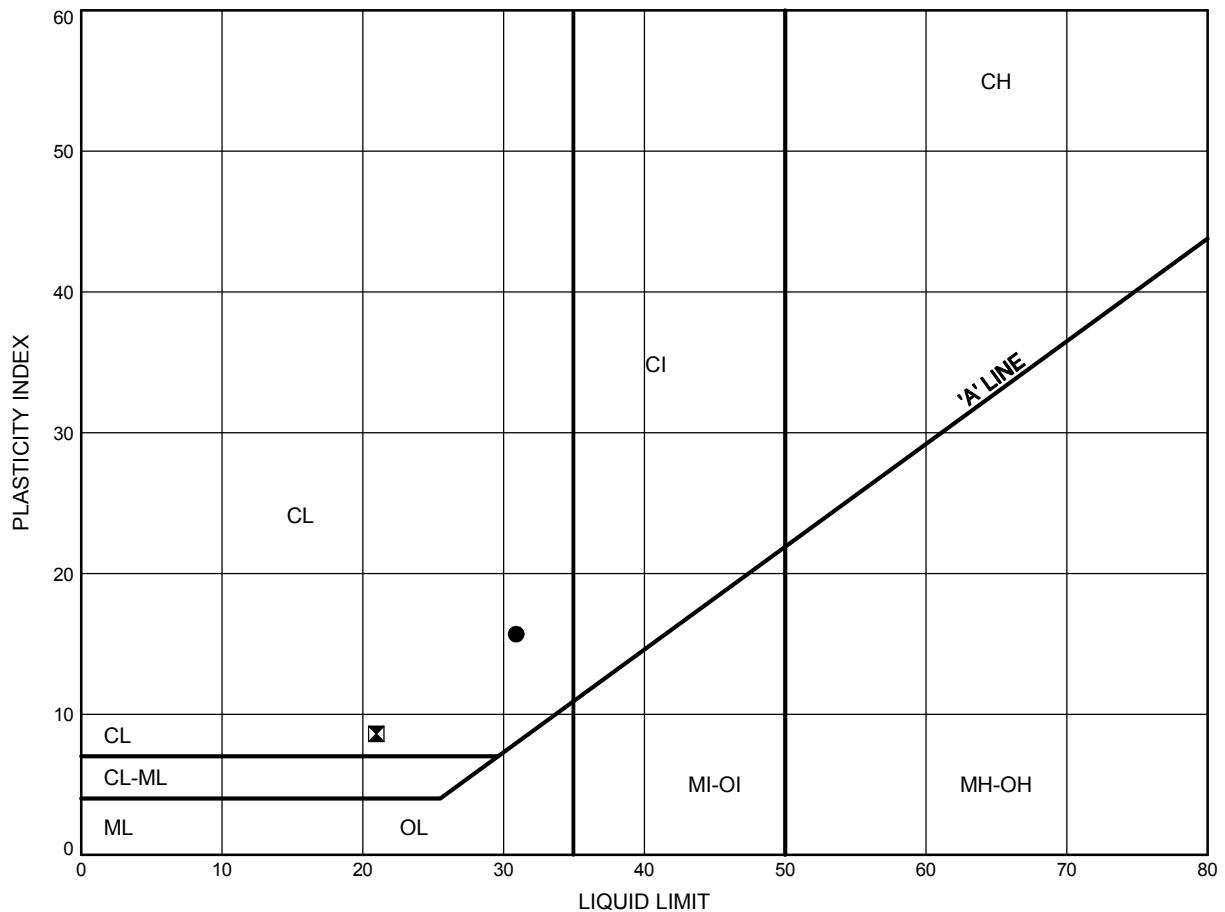
Prep'd MFA
Chkd. SKP

Fill Slope Stabilization & Culvert Installation

ATTERBERG LIMITS TEST RESULTS

FIGURE B7

Silty CLAY TILL, trace to some sand



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-01	12.50	271.18
⊠	14-02	10.82	275.75

Date December 2014
W.P. 3126-10-00



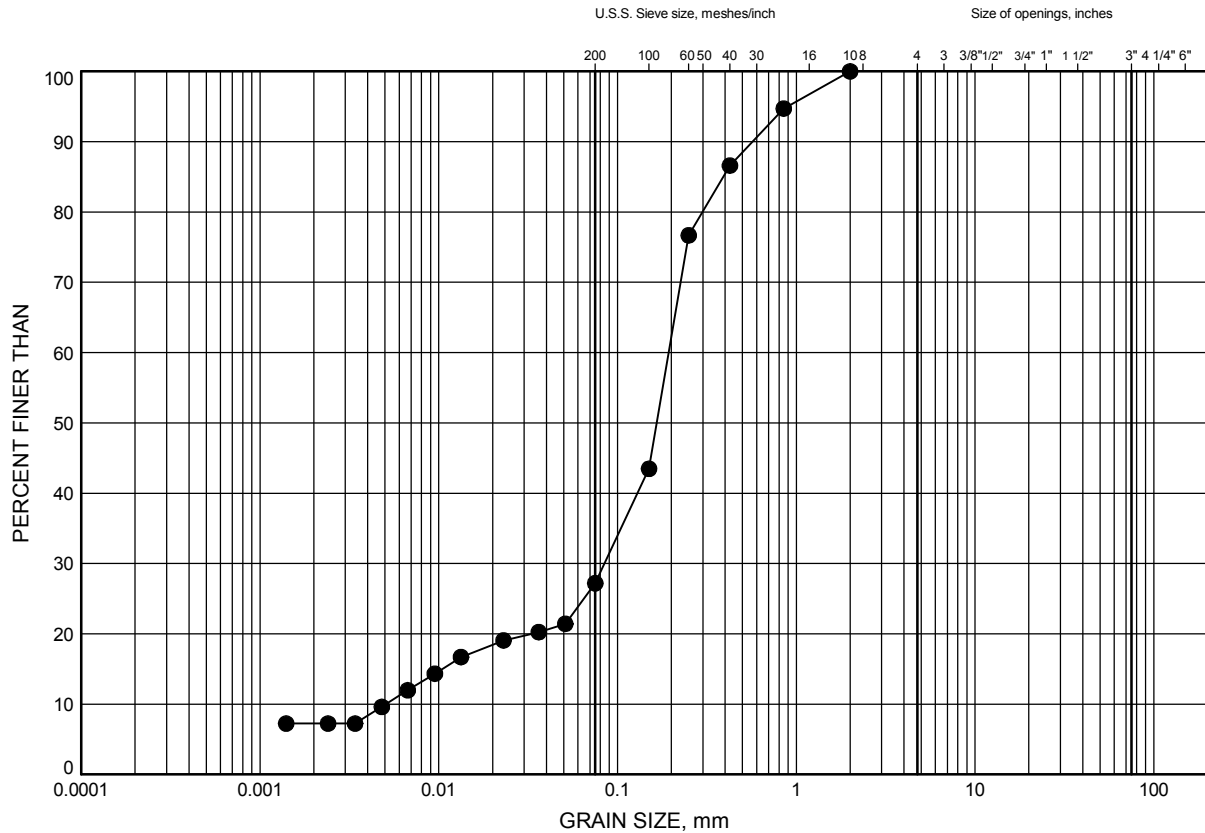
Prep'd MFA
Chkd. SKP

Fill Slope Stabilization & Culvert Installation

GRAIN SIZE DISTRIBUTION

FIGURE B8

SAND, some Silt FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-05	1.07	263.33

Date December 2014
W.P. 3126-10-00



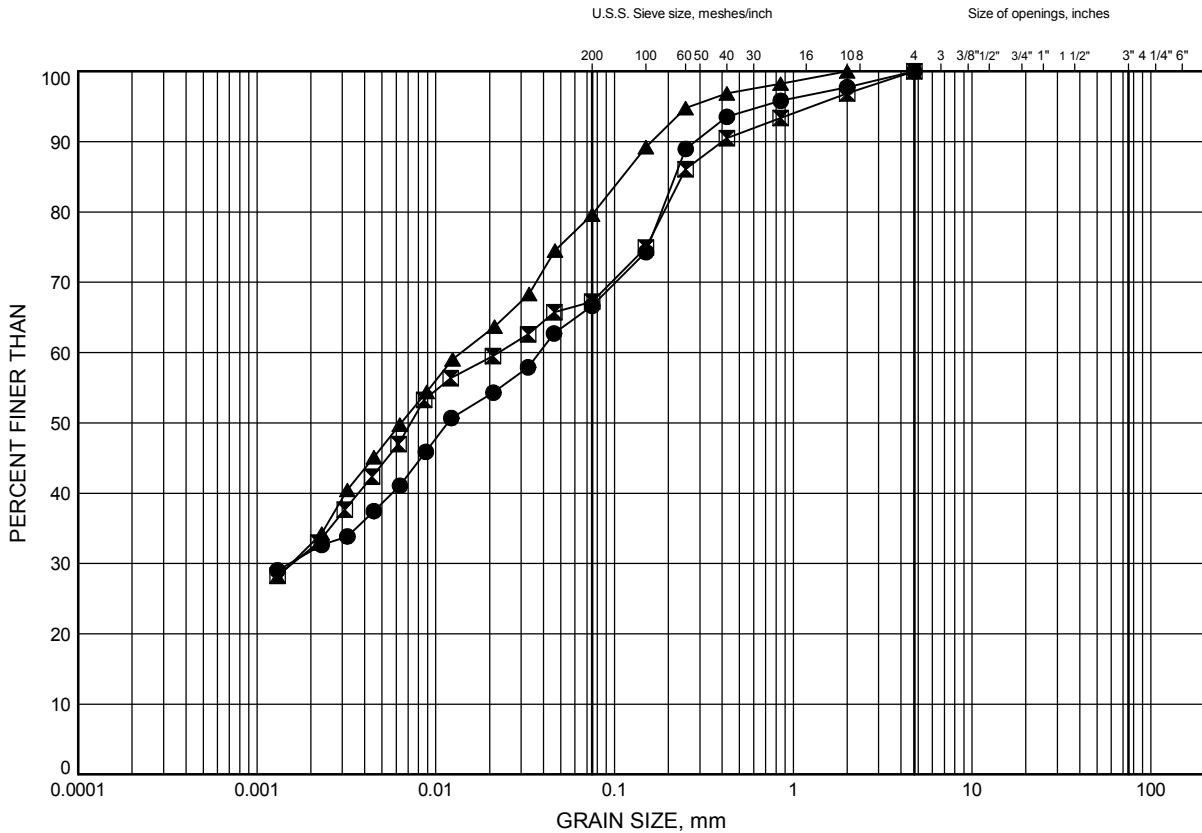
Prep'd MFA
Chkd. SKP

Fill Slope Stabilization & Culvert Installation

GRAIN SIZE DISTRIBUTION

FIGURE B9

Silty CLAY, with sand



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-05	3.35	261.05
◻	14-07	4.11	260.45
▲	14-07	5.64	258.92

Date December 2014
W.P. 3126-10-00



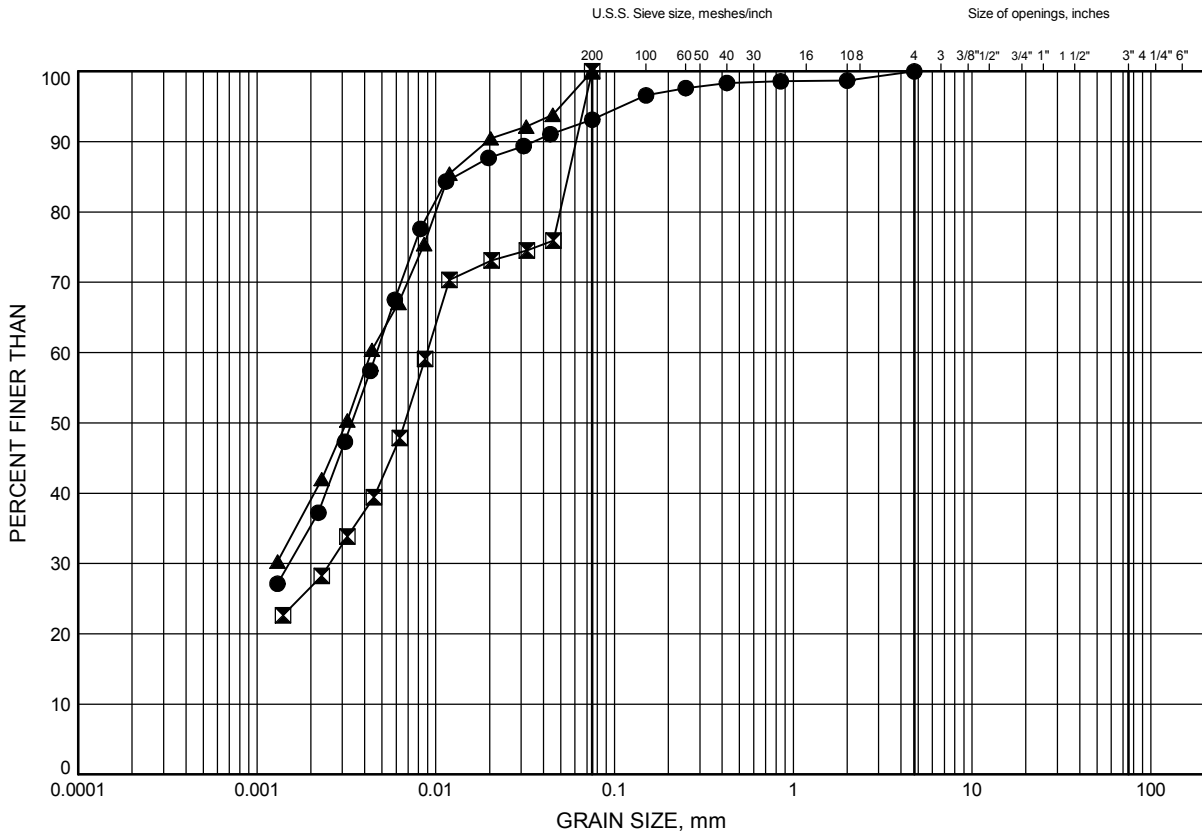
Prep'd MFA
Chkd. SKP

Fill Slope Stabilization & Culvert Installation

GRAIN SIZE DISTRIBUTION

FIGURE B10

Silty CLAY, trace to some sand



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-04	3.28	258.17
⊠	14-05	6.40	258.00
▲	14-06	1.83	258.22

Date December 2014
W.P. 3126-10-00



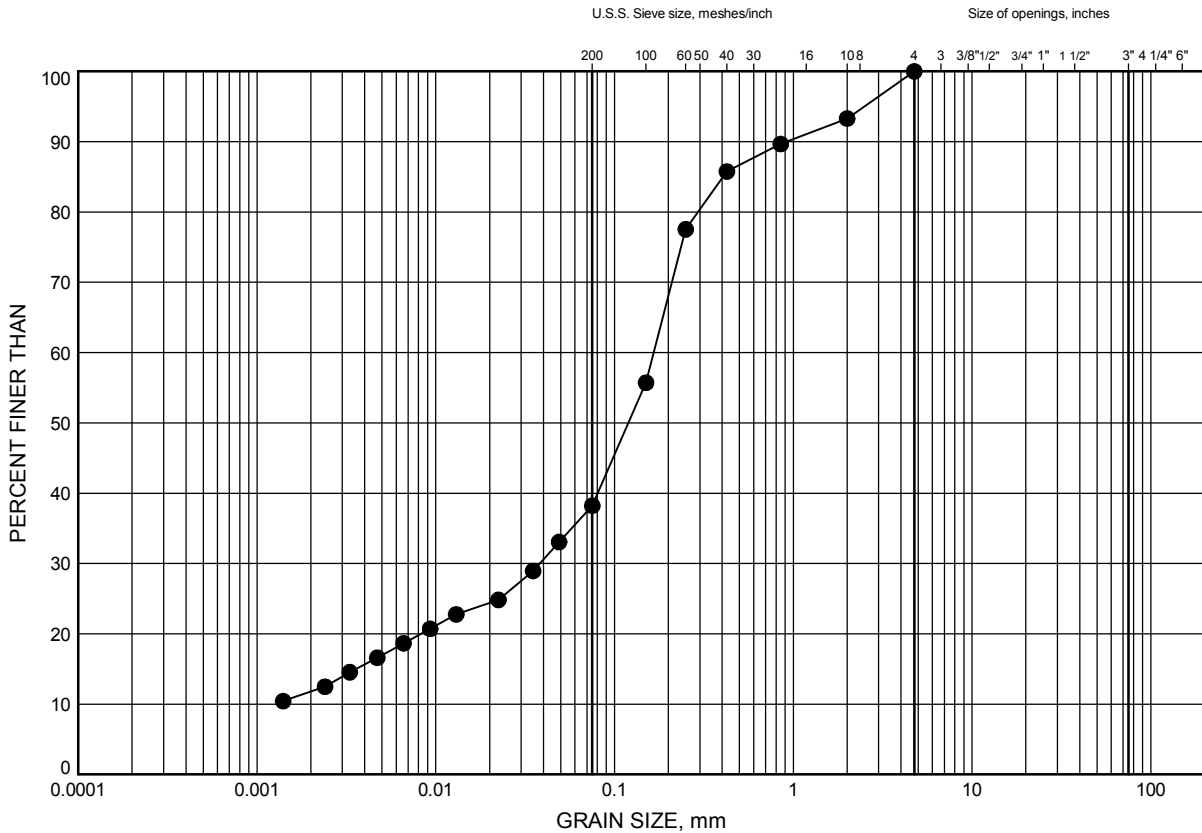
Prep'd MFA
Chkd. SKP

Fill Slope Stabilization & Culvert Installation

GRAIN SIZE DISTRIBUTION

FIGURE B11

Silty SAND



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-05	4.88	259.52

Date December 2014
W.P. 3126-10-00



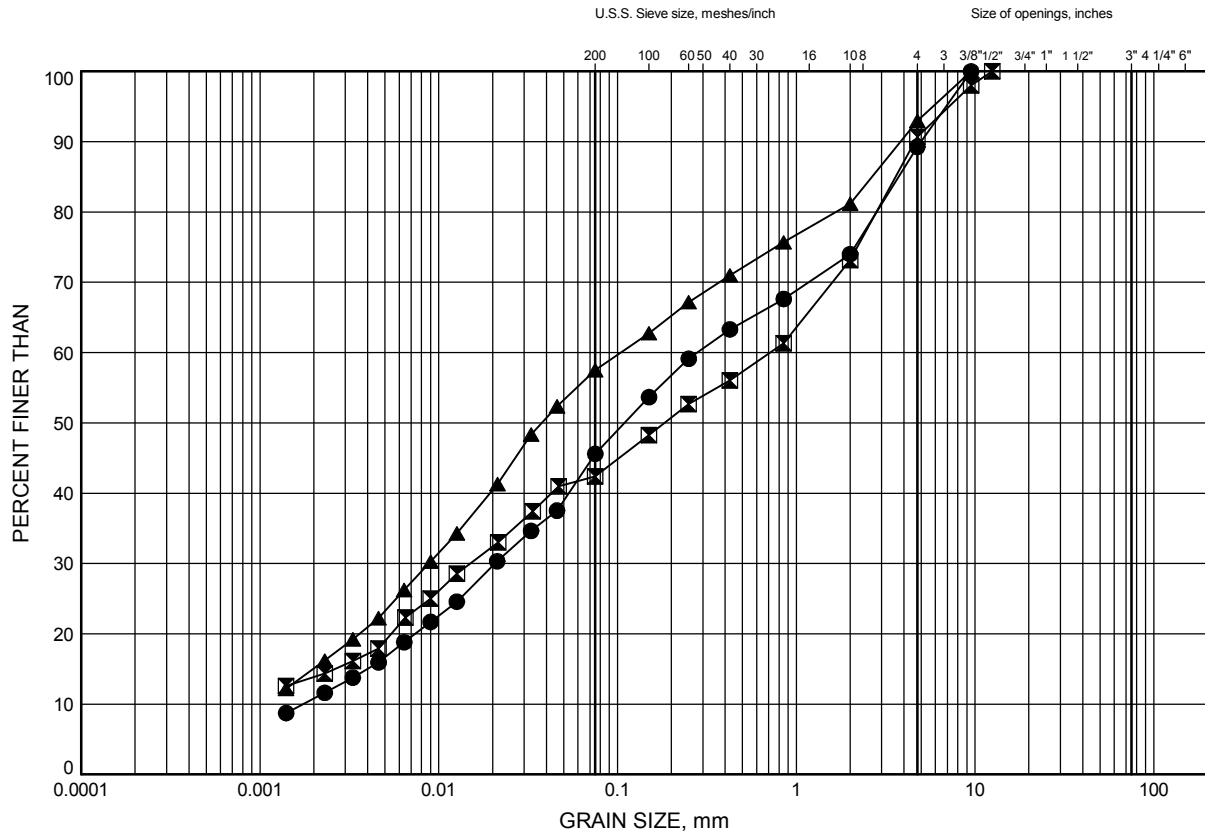
Prep'd MFA
Chkd. SKP

Fill Slope Stabilization & Culvert Installation

GRAIN SIZE DISTRIBUTION

FIGURE B12

Clayey SILT TILL, with sand



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-05	10.70	253.70
⊠	14-06	6.25	253.80
▲	14-07	7.92	256.64

Date December 2014
W.P. 3126-10-00

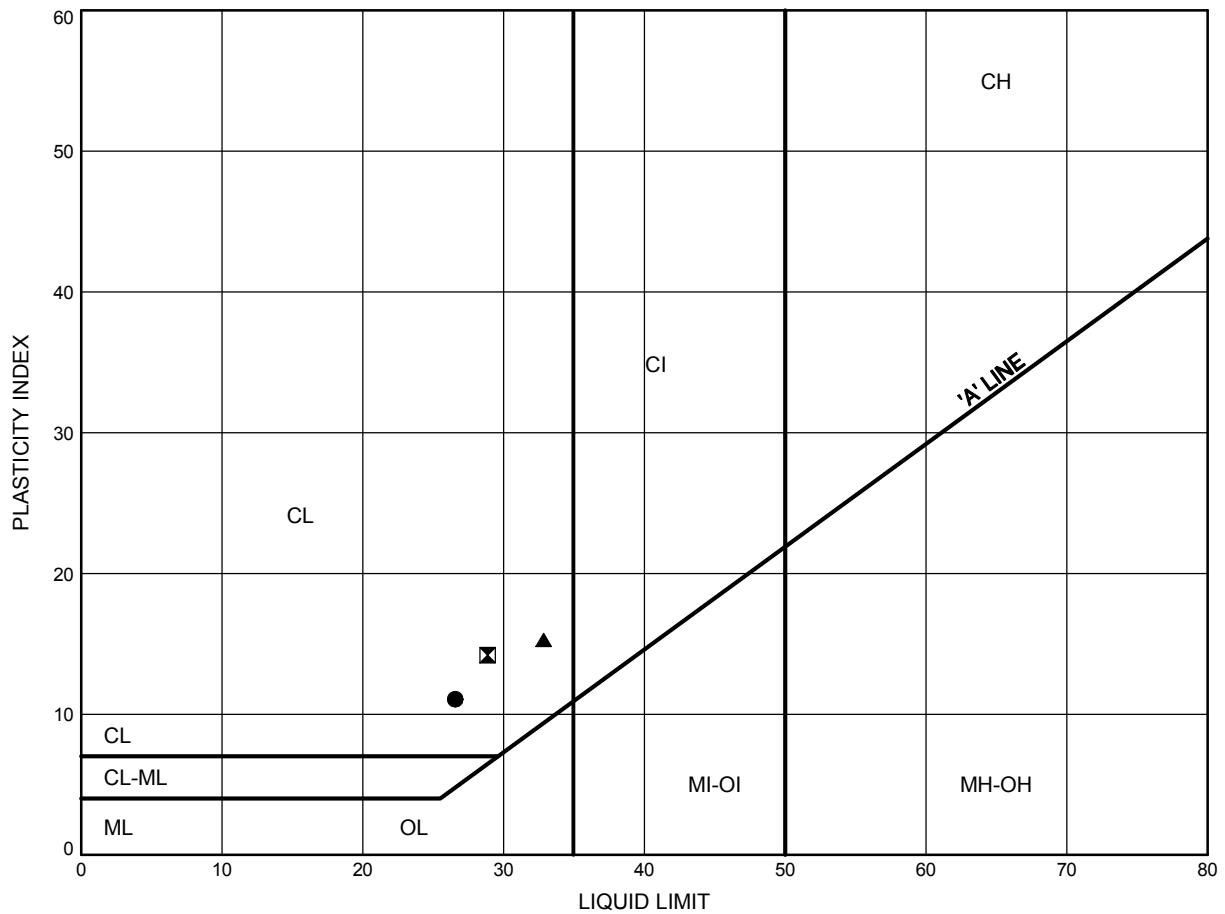


Prep'd MFA
Chkd. SKP

Fill Slope Stabilization & Culvert Installation
ATTERBERG LIMITS TEST RESULTS

FIGURE B13

Silty CLAY, with sand



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-05	3.35	261.05
⊠	14-07	4.11	260.45
▲	14-07	5.64	258.92

Date December 2014
W.P. 3126-10-00

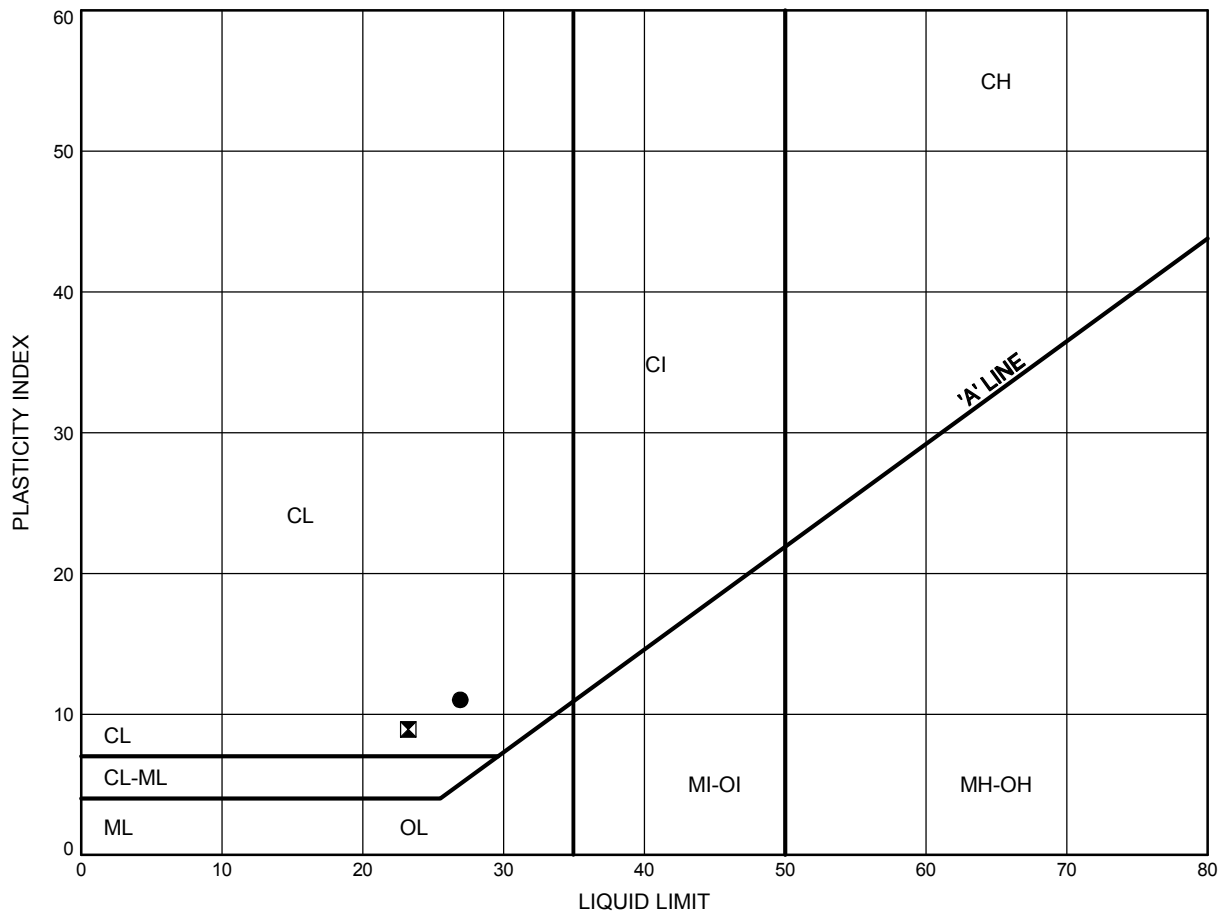


Prep'd MFA
Chkd. SKP

Fill Slope Stabilization & Culvert Installation
ATTERBERG LIMITS TEST RESULTS

FIGURE B14

Silty CLAY, trace to some sand



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-04	3.28	258.17
⊠	14-06	1.83	258.22

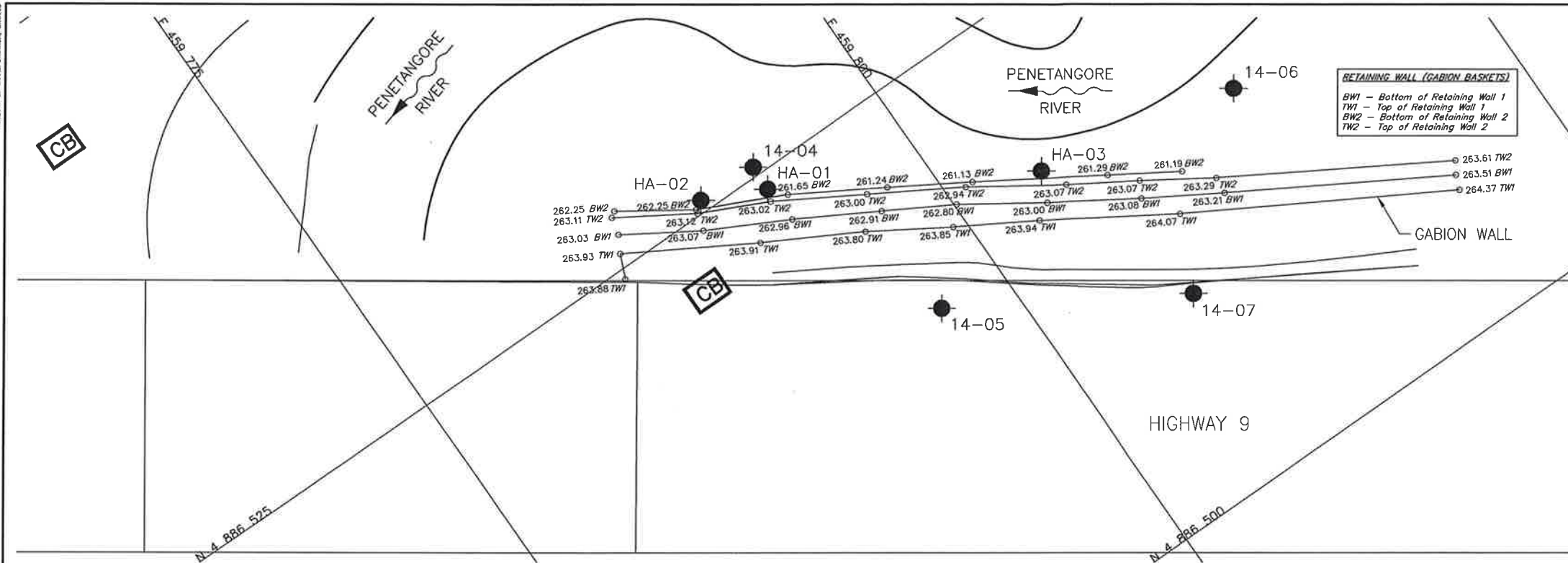
Date December 2014
W.P. 3126-10-00



Prep'd MFA
Chkd. SKP

Appendix C

Borehole Locations and Soil Strata Drawings



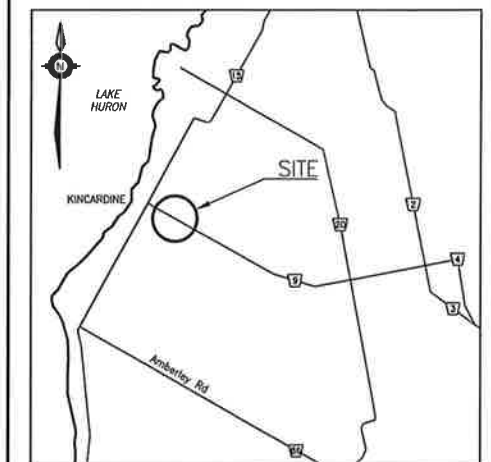
METRIC
 DIMENSIONS ARE IN METRES
 AND/OR MILLIMETRES
 UNLESS OTHERWISE SHOWN

CONT No
 GWP No 3033-14-00

HIGHWAY 9
 GABION RETAINING WALL
 REMEDIATION
 BOREHOLE LOCATIONS AND SOIL STRATA



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

- Borehole
- ⊕ Borehole and Cone
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60° Cone, 475J/blow)
- PH Pressure, Hydraulic
- W Water Level
- HA Head Artesian Water
- P Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
14-04	261.5	4 886 525.4	459 793.4
14-05	264.4	4 886 515.1	459 796.8
14-06	260.1	4 886 515.7	459 813.6
14-07	264.6	4 886 509.1	459 806.7
HA-01	261.6	4 886 524.2	459 793.4
HA-02	262.2	4 886 525.5	459 790.6
HA-03	261.1	4 886 517.7	459 804.2

-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

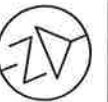
GEOCREs No. 41A-236



DATE	BY	DESCRIPTION
DESIGN	LPG	CHK PKC CODE
DRAWN	MFA	CHK LPG SITE
LOAD		DATE JAN 2015
STRUCT		DWG 1

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No	
GWP No 3033-14-00	

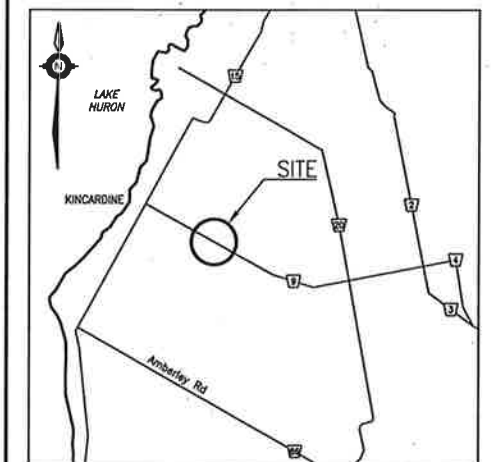


HIGHWAY 9
CULVERT REPLACEMENT
AT STATION 23+515
BOREHOLE LOCATIONS AND SOIL STRATA






SHEET



THURBER ENGINEERING LTD.



KEYPLAN
LEGEND

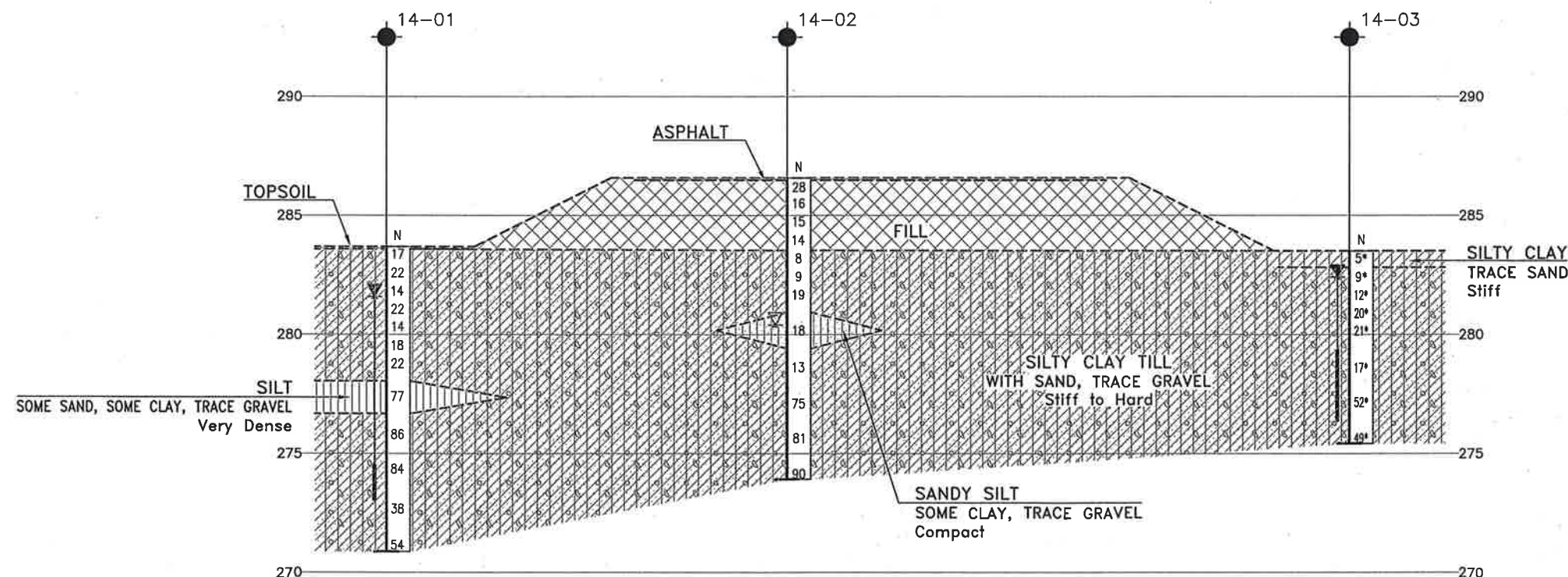
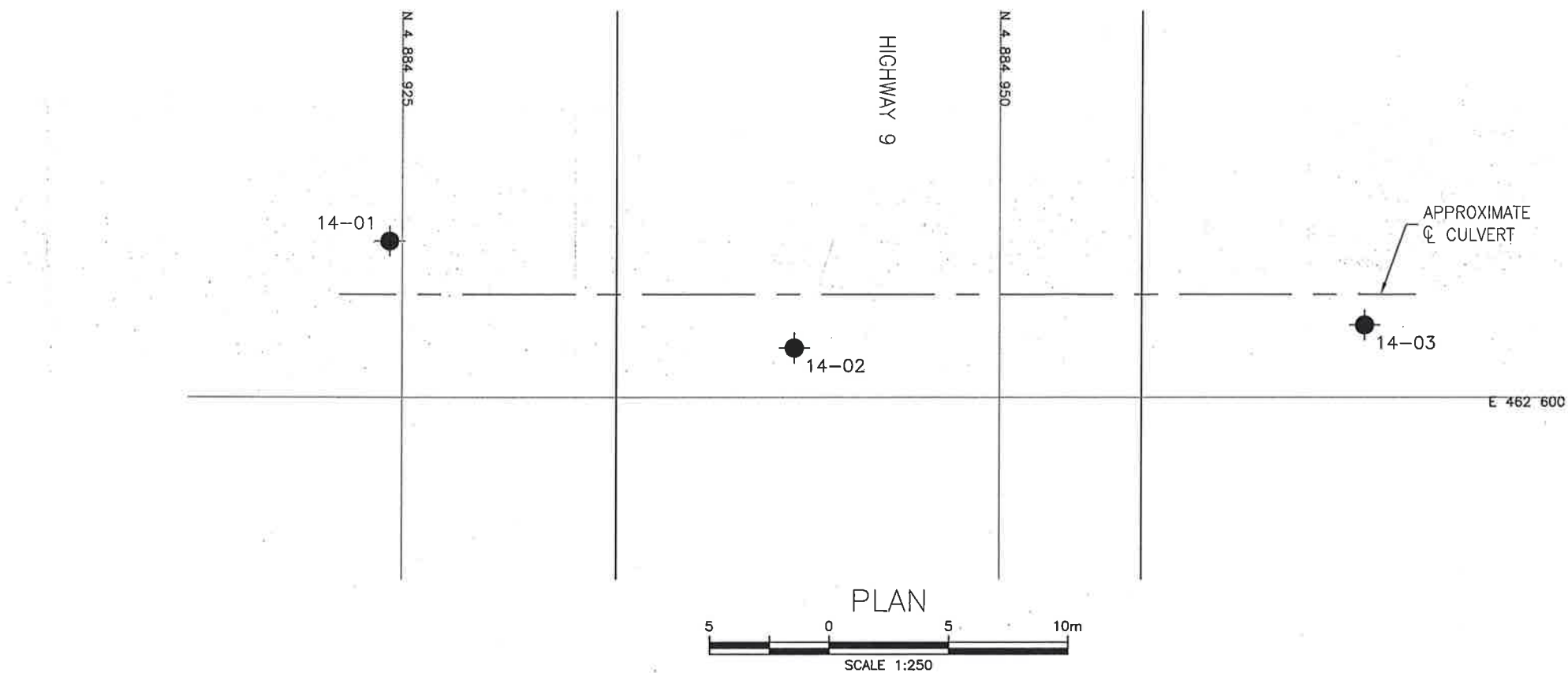
	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
14-01	283.7	4 884 924.5	462 593.5
14-02	286.6	4 884 941.4	462 597.9
14-03	283.5	4 884 965.3	462 597.0

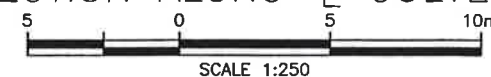
-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 41A-236



SECTION ALONG CULVERT

[illegible]

Appendix D

Foundation Alternatives Comparison

COMPARISON OF ALTERNATIVE CULVERT TYPES

Location	Concrete Open Footing Culvert	Concrete Rigid Box Culvert	Circular Pipe Culvert (concrete, CSP, HDPE)
Culvert Replacement	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Relatively expedient installation if precast units are used. <p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Narrower strip footings will result in larger settlement than box culverts. ii. Potential for post construction settlement. <p style="text-align: center;">FEASIBLE</p>	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade. ii. Relatively expedient installation if precast units are used. <p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Requires compacted granular pad on subgrade. <p style="text-align: center;">RECOMMENDED</p>	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Can tolerate larger magnitude of settlement than concrete (rigid frame) culverts. ii. Lower cost than concrete (rigid frame) culverts. <p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. CSP and HDPE pipes not as durable as concrete culverts. ii. Feasibility also depends on flow capacity and other hydraulic properties. <p style="text-align: center;">GENERALLY FEASIBLE</p>

Appendix E

Selected Photographs of Retaining Wall and Culvert Locations

Retaining Wall and Culvert Replacement
Highway 9



Photo 1: Retaining Wall in Bervie



Photo 2: Retaining Wall in Bervie

Retaining Wall and Culvert Replacement
Highway 9



Photo 3: Culvert Outlet

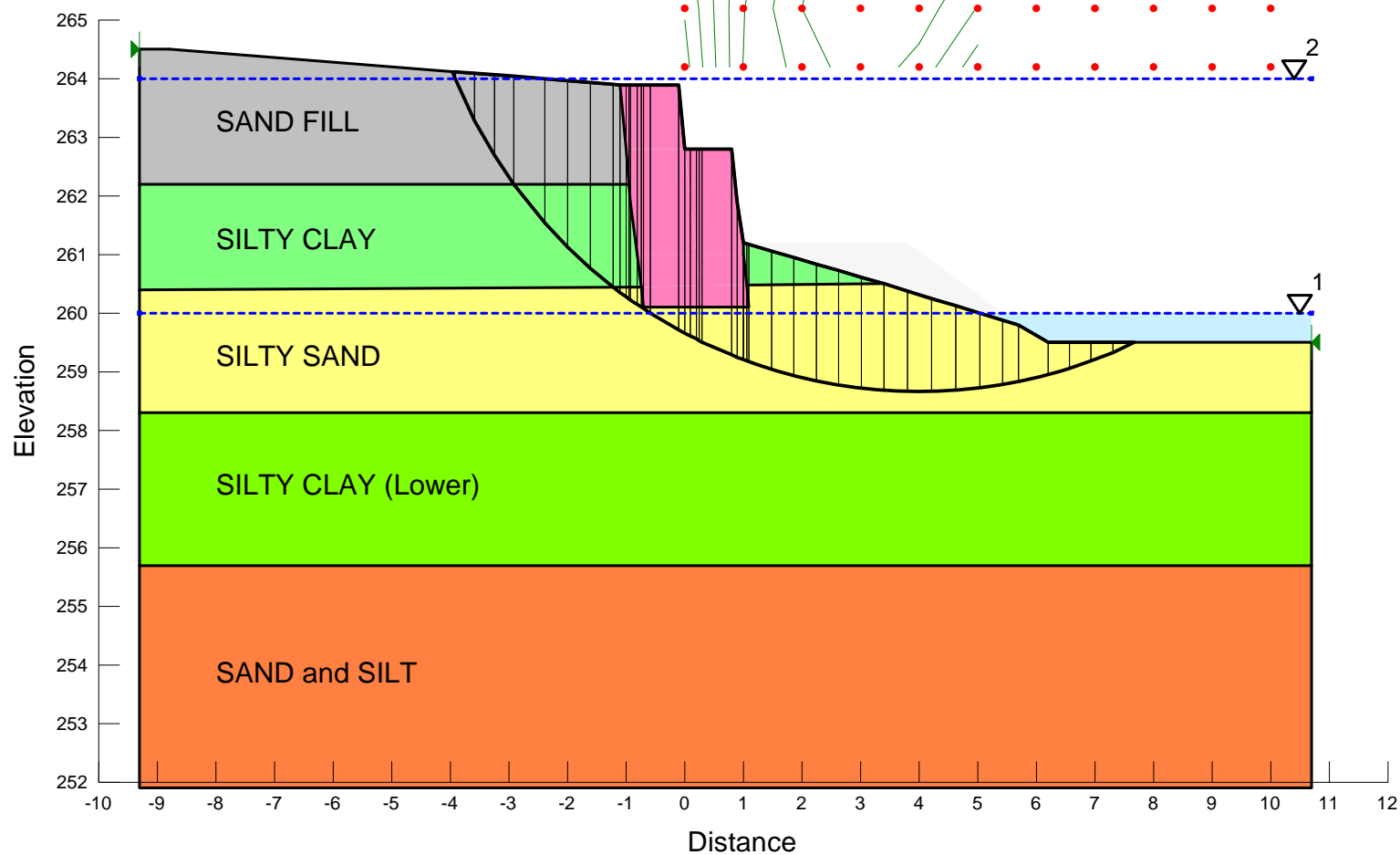


Photo 4: Culvert Inlet

Appendix F

Selected Stability Analysis Results

Title: 15-64-30
 Comments: Bervie Retaining Wall
 Name: Effective Stress w/ buried gabian



Sand Fill
 20 kN/m³
 0 kPa
 30 °
 1

Silty Clay (ESA)
 18 kN/m³
 0 kPa
 28 °
 1

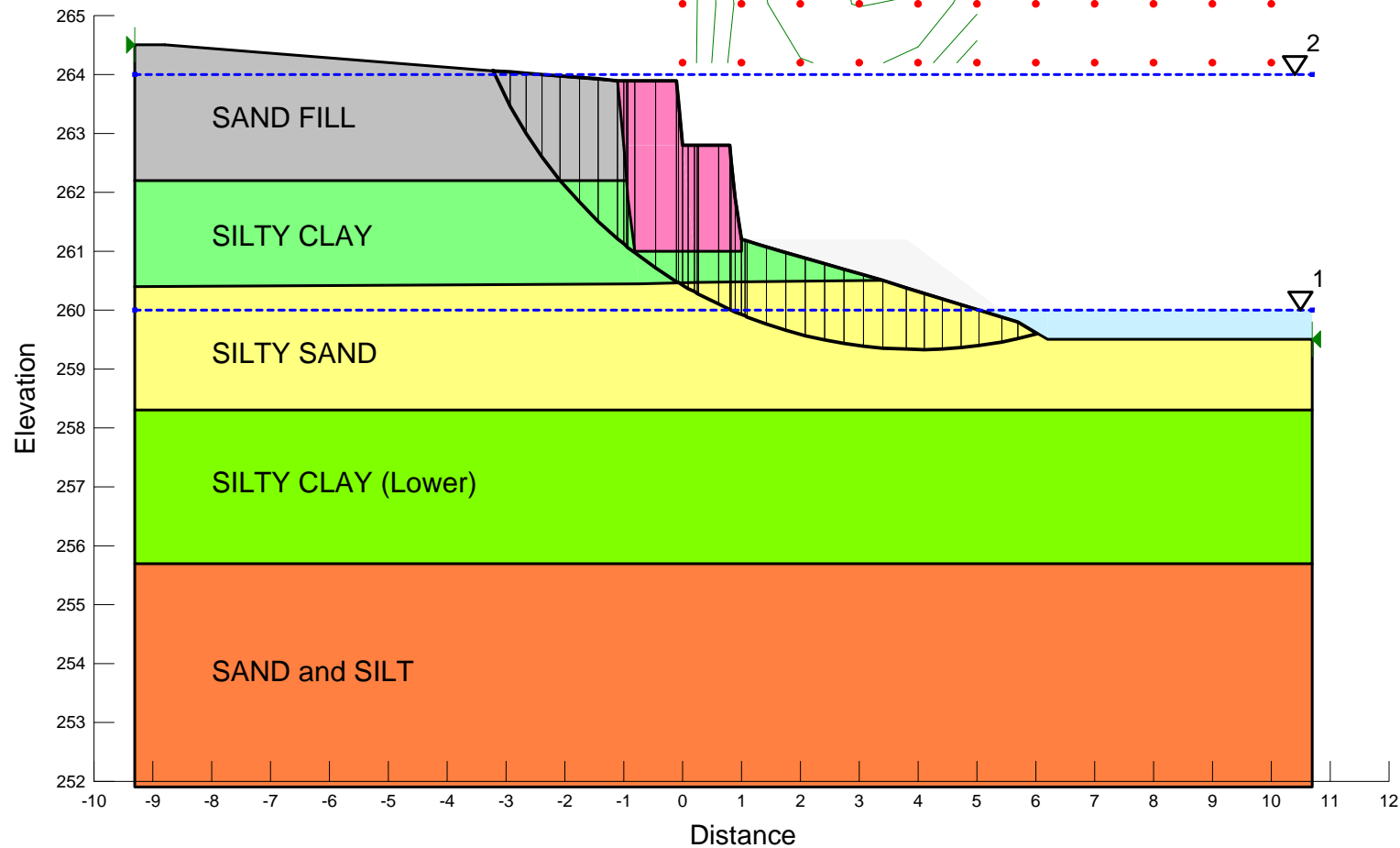
Silty Sand
 20 kN/m³
 0 kPa
 30 °
 1

Silty Clay Lower (ESA)
 19 kN/m³
 0 kPa
 28 °
 1

Sand and Silt
 20 kN/m³
 0 kPa
 35 °
 2

Gabion Baskets
 19 kN/m³
 200 kPa
 45 °
 1

Title: 15-64-30
 Comments: Bervie Retaining Wall
 Name: Effective Stress



Sand Fill
 20 kN/m³
 0 kPa
 30 °
 1

Silty Clay (ESA)
 18 kN/m³
 0 kPa
 28 °
 1

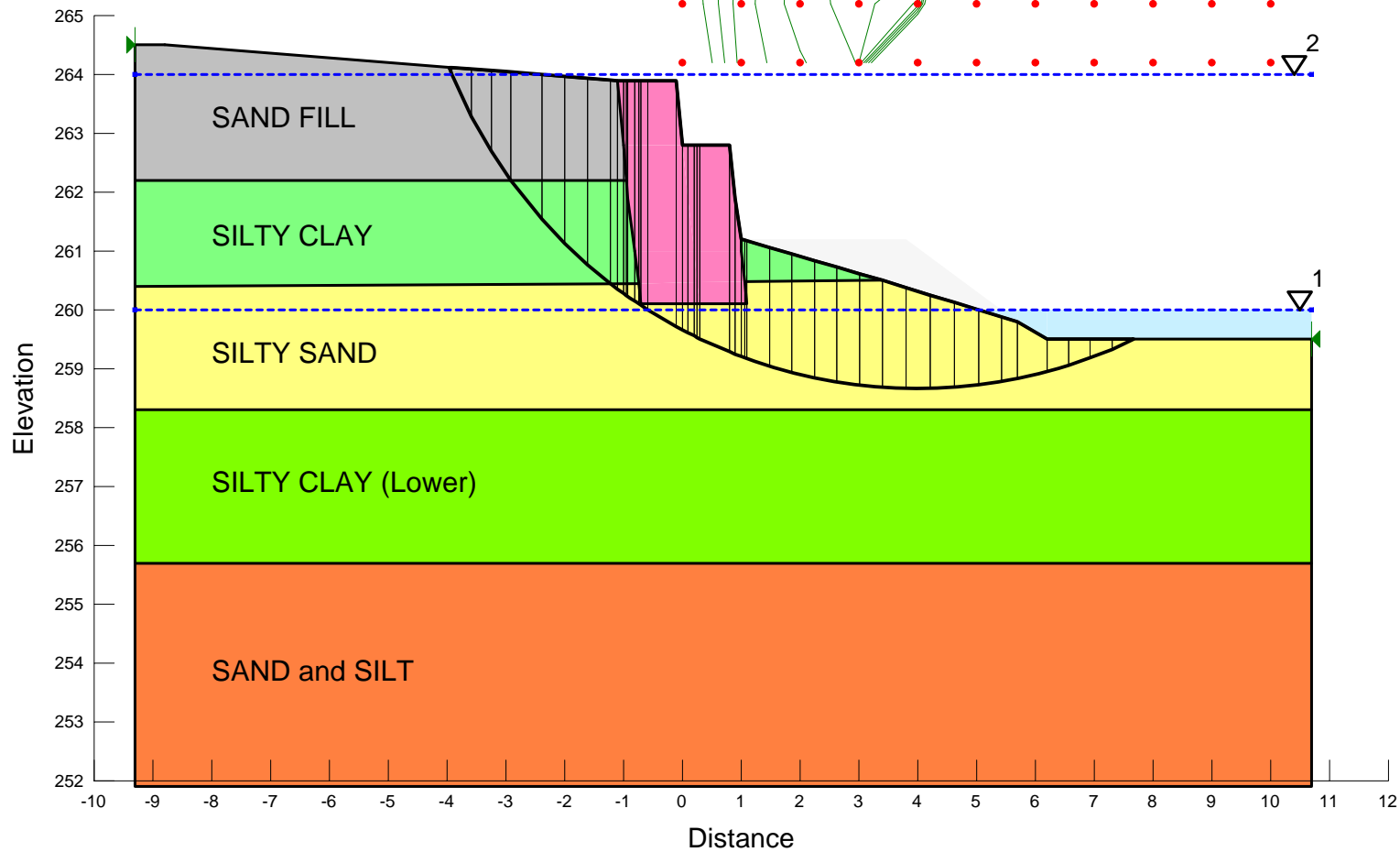
Silty Sand
 20 kN/m³
 0 kPa
 30 °
 1

Silty Clay Lower (ESA)
 19 kN/m³
 0 kPa
 28 °
 1

Sand and Silt
 20 kN/m³
 0 kPa
 35 °
 2

Gabion Baskets
 19 kN/m³
 200 kPa
 45 °
 1

Title: 15-64-30
 Comments: Bervie Retaining Wall
 Name: Total Stress w/ buried gabian



Sand Fill
 20 kN/m³
 0 kPa
 30 °
 1

Silty Clay (TSA)
 18 kN/m³
 25 kPa
 0 °
 1

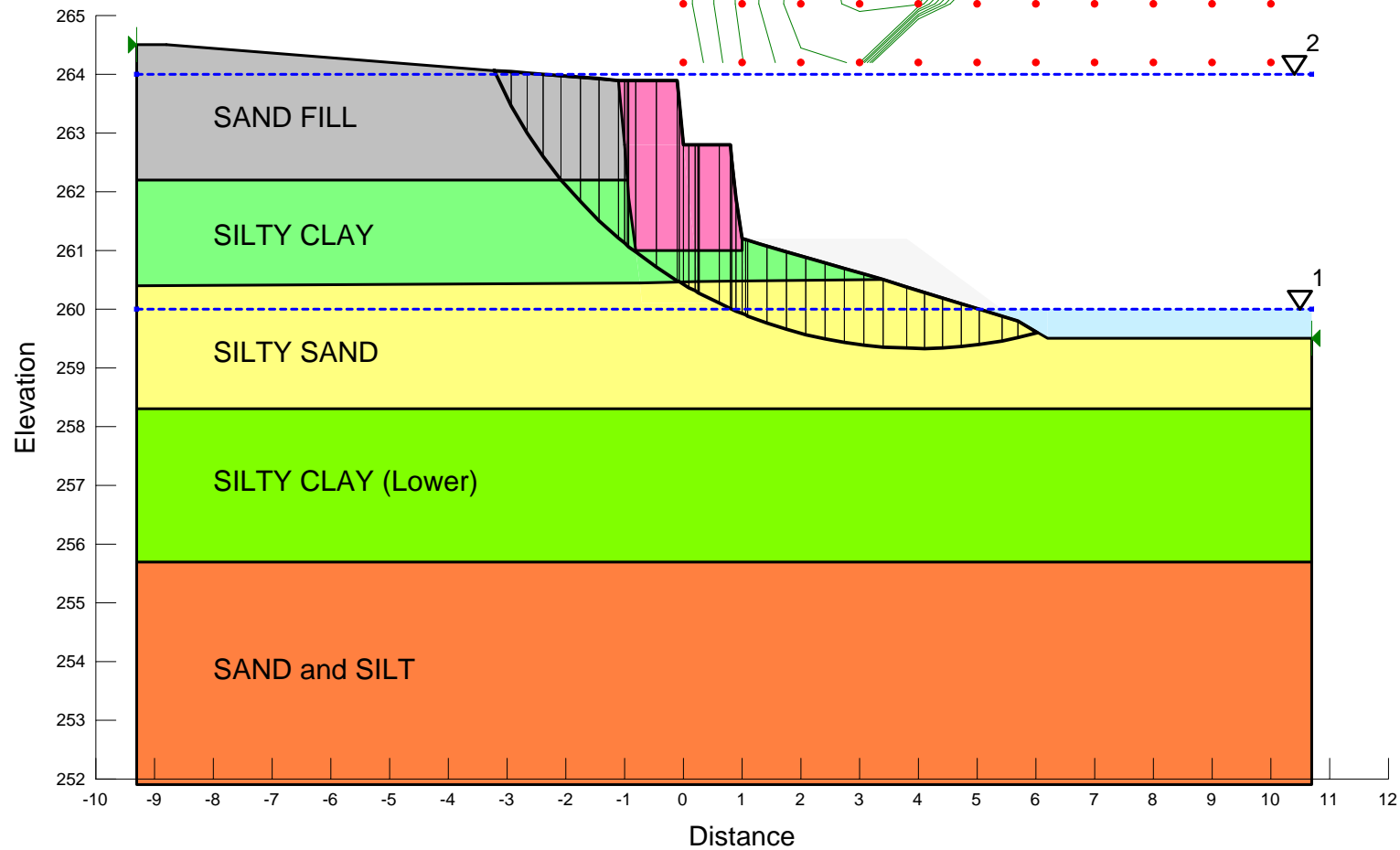
Silty Sand
 20 kN/m³
 0 kPa
 30 °
 1

Silty Clay Lower (TSA)
 19 kN/m³
 100 kPa
 0 °
 1

Sand and Silt
 20 kN/m³
 0 kPa
 35 °
 2

Gabion Baskets
 19 kN/m³
 200 kPa
 45 °
 1

Title: 15-64-30
 Comments: Bervie Retaining Wall
 Name: Total Stress



Sand Fill
 20 kN/m³
 0 kPa
 30 °
 1

Silty Clay (TSA)
 18 kN/m³
 25 kPa
 0 °
 1

Silty Sand
 20 kN/m³
 0 kPa
 30 °
 1

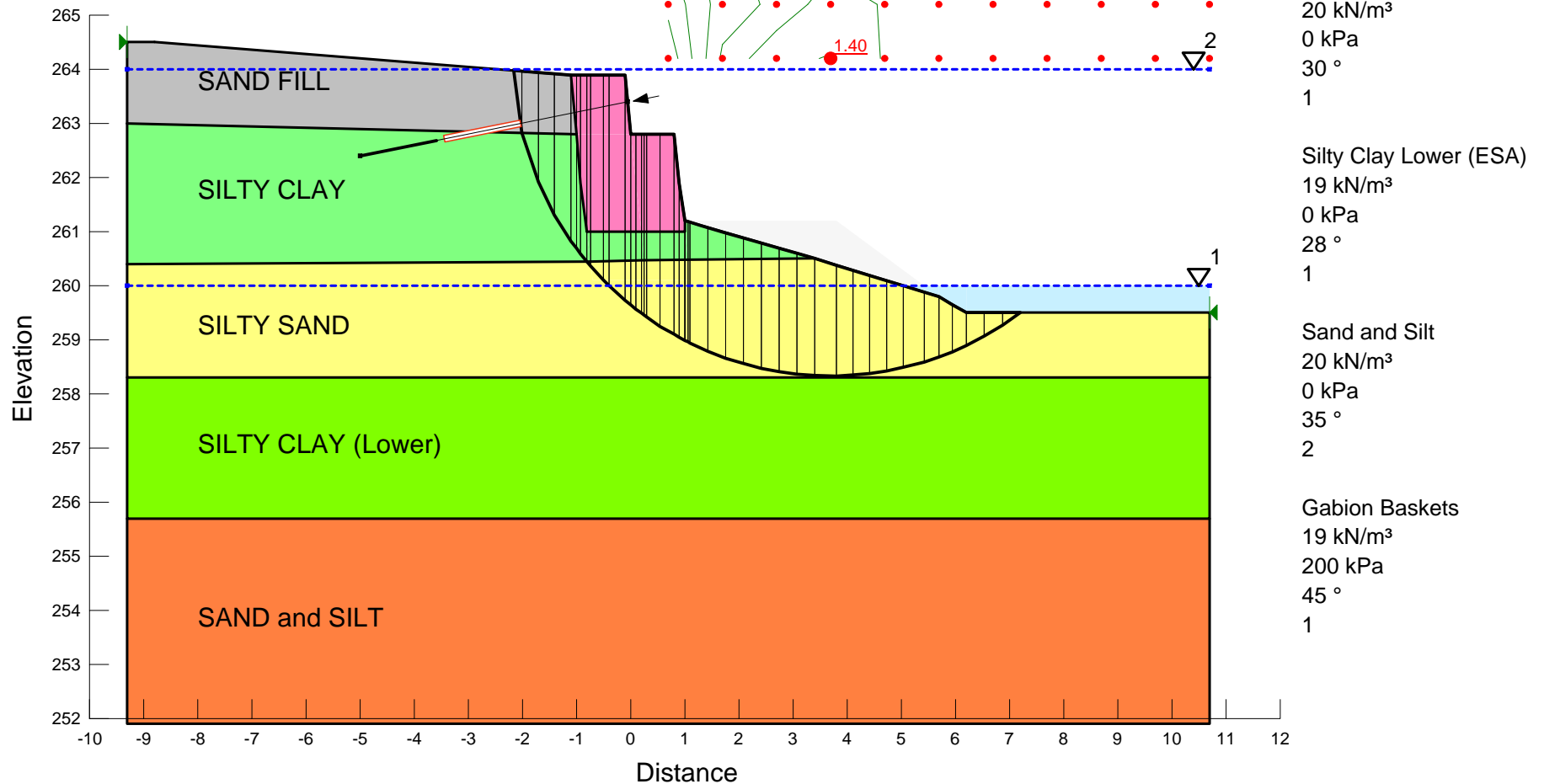
Silty Clay Lower (TSA)
 19 kN/m³
 100 kPa
 0 °
 1

Sand and Silt
 20 kN/m³
 0 kPa
 35 °
 2

Gabion Baskets
 19 kN/m³
 200 kPa
 45 °
 1

Title: 15-64-30
 Comments: Bervie Retaining Wall
 Name: Effective Stress w/ 1 anchor 1m spacing

Type: Anchor
 Total Length: 5.0464602 m
 Bond Length: 1.4478 m
 Bond Diameter: 0.4826 m
 Bond Safety Factor: 2
 Bond Skin Friction: 70 kPa
 Anchor Spacing: 1 m
 Applied Load: 76.826988 kN
 Bar Safety Factor: 2



Title: 15-64-30

Comments: Bervie Retaining Wall

Name: Total Stress w/ 1 anchor 1m spacing

Type: Anchor

Total Length: 5.0464602 m

Bond Length: 1.4478 m

Bond Diameter: 0.4826 m

Bond Safety Factor: 2

Bond Skin Friction: 70 kPa

Anchor Spacing: 1 m

Applied Load: 76.826988 kN

Bar Safety Factor: 2

Sand Fill

20 kN/m³

0 kPa

30 °

1

Silty Clay (TSA)

18 kN/m³

25 kPa

0 °

1

Silty Sand

20 kN/m³

0 kPa

30 °

1

Silty Clay Lower (TSA)

19 kN/m³

100 kPa

0 °

1

Sand and Silt

20 kN/m³

0 kPa

35 °

2

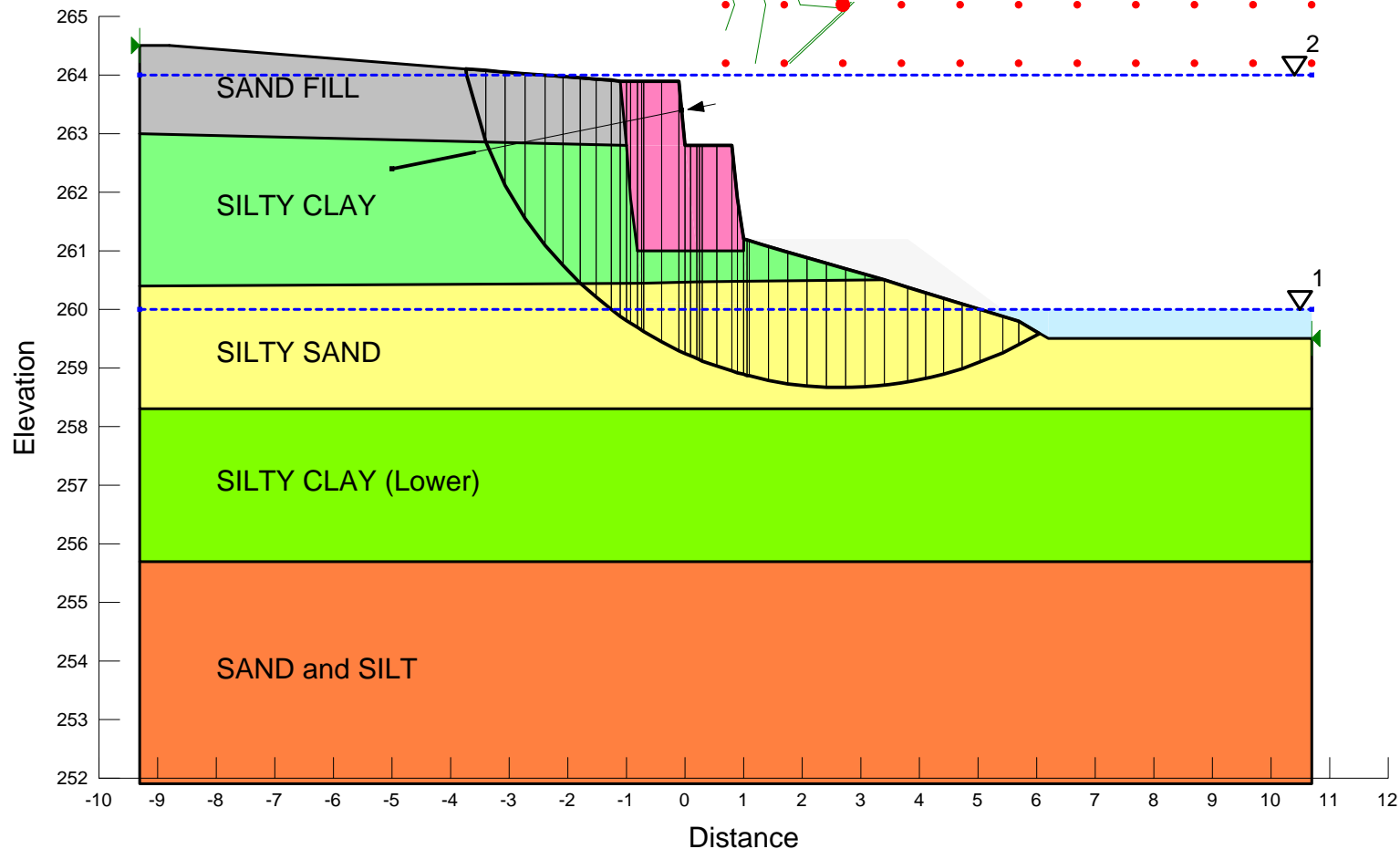
Gabion Baskets

19 kN/m³

200 kPa

45 °

1



Last Solved Date: 2/18/2015, 4:27:00 PM

Directory: H:\15\64\30 Fill Slope Stabilization and Culvert Installation, Hwy 9\Analysis\BervieRW Rev 04.gsz

Figure F6