

**FOUNDATION INVESTIGATION AND DESIGN REPORT
ALDER CREEK CULVERT REPLACEMENT
HIGHWAY 17, EAST OF MARATHON, ONTARIO
SITE 48E-82/C
G.W.P. 6026-07-00**

Geocres Number: 42C-24

Report to

GENIVAR

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at the location of a proposed culvert replacement at Alder Creek east of Marathon, Ontario. The existing culvert carries Alder Creek under Highway 17 in the Wabikoba Lake Area, Ontario.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile and, laboratory test results and written descriptions of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained in the course of the investigation.

Thurber carried out the investigation as a sub-consultant to Genivar, under the Ministry of Transportation Ontario (MTO) Agreement Number 6010-E-0012.

2 SITE DESCRIPTION

The Alder Creek culvert is located on Highway 17, approximately 46.5 km east of the Town of Marathon, Ontario. The site is approximately 6.5 km east of the intersection of Highway 17 and Highway 614.

The existing highway is a two-lane paved road and crosses the creek on approach embankments about 3.0 m to 4.0 m high.

Currently a CSP elliptical arch culvert carries Alder Creek under Highway 17. The culvert is approximately 4.0 m wide, 2.5 m high and 29.2 m long. Alder Creek flows to the south.

At the time of the investigation, the north and south ends of the culvert were flooded and the culvert was almost submerged. Water was observed at the toe of the highway embankment.

Lands surrounding the culvert site consist of forested areas with open swamps.

Photographs in Appendix C show the general nature of the surrounding land.

The site lies within the Michipicoten greenstone belt part of the Canadian Shield, characterized by low, rounded hills of Pre-Cambrian bedrock mantled by varying thicknesses of overburden. At this site, the overburden primarily consists of glaciolacustrine silts and clays.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out between May 1 and 3, 2011 and consisted of drilling and sampling a total of three boreholes (identified as AL11-01 to AL11-03) in the area of the existing culvert. One borehole was drilled at each end of the culvert and one borehole was drilled from the south shoulder of the Highway 17 embankment. Borehole advancement within the overburden soils extended to 15.8 m depth (elevations 83.9 to 86.2).

A dynamic cone penetration test (DCPT) was conducted adjacent to Borehole AL11-03 from ground surface to 22.3 m depth (elevation 79.7). In Borehole AL11-02, a DCPT was conducted from the base of the borehole to 30.5 m depth (elevation 71.5).

The approximate borehole locations are shown on the attached Borehole Locations and Soil Strata Drawing in Appendix F.

The borehole locations were marked in the field and utility clearances were obtained prior to drilling.

Drilling was carried out using a track mounted CME 55 drill rig and hollow-stem augers were used to advance the boreholes. Overburden samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). In situ vane shear testing was carried out to assess the undrained shear strength of soft to firm cohesive deposits.

The drilling and sampling operations were supervised on a full time basis by a member of Thurber's technical staff. The supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing.

Groundwater conditions were observed in the open boreholes upon completion of the drilling operations. One standpipe piezometer consisting of 19 mm PVC pipe with a slotted screen was installed in Borehole AL11-01 and enclosed in filter sand to permit longer term groundwater level monitoring. The boreholes were backfilled in accordance with O.Reg. 903 upon completion. The locations and decommissioning details of the boreholes are shown in Table 3.1.

Table 3.1 – Borehole Decommissioning Details

Borehole	Piezometer Tip Depth/ Elevation (m)	Decommissioning Details
AL11-01	15.2 / 84.5	Piezometer with 1.5 m slotted screen installed with sand filter to 13.4 m, bentonite from 13.4 m to surface.
AL11-02	None installed	Backfilled with bentonite holeplug from 15.8 m to 0.6 m, then sand and gravel to surface.
AL11-03	None installed	Backfilled with bentonite holeplug to surface.

4 LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to gradation analysis. The results of these tests are summarized on the Record of Borehole sheets included in Appendix A and are presented on the figures included in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets included in Appendix A. Details of the encountered soil stratigraphy are presented in these sheets and on the “Borehole Locations and Soil Strata” drawing included in Appendix F. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions.

In general terms, the site was found to be underlain by a native upper layer of silt overlying a deposit of varved clayey silt which in turn is underlain by a lower layer of silt. A thin layer of sandy silt was found at surface on the south side of the culvert. A layer of sand fill was encountered surficially at the borehole drilled through the highway embankment. More detailed descriptions of the individual strata are presented below.

5.1 Sand Fill

Brown sand fill containing some gravel and some silt and clay was encountered surficially in Borehole AL11-02, drilled at the south highway shoulder. The thickness of the sand fill was 4.0 m.

The depth to the base of the fill was 4.0 m (elevation 98.0).

Standard Penetration tests performed in the sand fill layer gave SPT N-values ranging from 9 to 23 blows per 0.3 m penetration, indicating a loose to compact relative density.

The moisture content in sand fill generally varies between 5% and 12%.

A sample of the sand fill underwent gradation analysis testing, the results of which are presented below. These results are also summarized on the Record of Borehole sheets in Appendix A and the grain size distribution curve for this sample is included in Figure B1 of Appendix B.

Soil Particles	Percentage (%)
Gravel	15
Sand	64
Silt and Clay	21

5.2 Sandy Silt

A thin layer of sandy silt mixed with organics was encountered surficially in Borehole AL11-01. This layer was 0.6 m thick.

A SPT N-value of 3 blows for 0.3 m penetration, indicating a very loose relative density, was recorded in this layer. The moisture content of a sample of the sandy silt was 35%.

5.3 Upper Silt Layer

An upper layer of brown to grey silt was encountered below the sandy silt in Borehole AL11-01, below the sand fill in Borehole AL11-02, and at surface in Borehole AL11-03.

The silt contains trace to some clay and trace sand. Occasional rootlets were observed in the upper silt layer near the surface.

The thickness of the upper silt layer varied from 2.1 m to 5.5 m. The depths to the base of the upper silt layer ranged from 4.6 m to 6.1 m (elevations 93.6 to 95.9).

Standard Penetration Tests recorded in the upper silt layers gave SPT N-values of 5 to 15 blows per 0.3 m of penetration, indicating a loose to compact relative density.

The moisture content of samples from the upper silt layer generally varies between 19% and 38%. A moisture content of 53% was measured in Borehole AL11-03.

Grain size distribution curves for samples of silt tested are presented on the Record of Borehole sheets and on Figure B2 of Appendix B. The results of the laboratory test are summarized as follows:

Soil Particles	Percentage (%)
Gravel	0
Sand	0 to 6
Silt	87 to 91
Clay	7 to 13

5.4 Clayey Silt

A layer of grey clayey silt was encountered between the upper and lower silt layers. This clayey silt deposit is varved. The thickness of the clayey silt layer varied from 4.6 m to 7.6 m.

The depths to the base of the clayey silt ranged from 10.7 m to 13.7 m (elevations 88.3 to 89.8).

Standard Penetration Tests recorded in the clayey silt layer gave SPT N-values of 4 to 15 blows per 0.3 m of penetration, indicating a soft to stiff consistency. Shear Vane Tests were also performed where low N-values were recorded. The shear strength of the clayey silt ranges from 20 to 40 kPa.

The moisture content of samples from the clayey silt layer generally varies between 22% and 40%.

Grain size distribution curves for samples of the clayey silt tested are presented on the Record of Borehole sheets and on Figure B3 of Appendix B. The results of the laboratory test are summarized as follows:

Soil Particles	Percentage (%)
Gravel	0
Sand	0
Silt	75 to 78
Clay	22 to 25

The DCPT conducted from the base of Borehole AL11-02 and adjacent to Borehole AL11-03 recorded 100 blows at about 30.5 m and 22.3 m depth (elevations 71.5 and 79.7), respectively.

5.5 Lower Silt Layer

A lower silt layer was encountered below the clayey silt at depths ranging from 10.7 m to 13.7 m (elevations 88.3 to 89.8) in all the boreholes. The silt contains trace to some clay and trace sand.

All the boreholes were terminated within the lower silt layer at 15.8 m depth (elevations 83.9 to 86.2).

Standard Penetration Tests recorded in the lower silt layer gave SPT N-values of 6 to 20 blows per 0.3 m of penetration, indicating a loose to compact relative density.

The moisture content of samples from the lower silt layer generally varies between 19% and 22%.

Grain size distribution curves for samples of silt tested are presented on the Record of Borehole sheets and on Figure B2 of Appendix B. The results of the laboratory test are summarized as follows:

Soil Particles	Percentage (%)
Gravel	0
Sand	0 to 1
Silt	86 to 93
Clay	7 to 13

5.6 Water Levels

Water levels were observed in the open boreholes upon completion of the drilling operations. One standpipe piezometer was installed in Borehole AL11-01 to monitor water levels after completion of drilling. The water levels measured in the open boreholes and piezometer are summarized in Table 5.1.

Table 5.1 – Water Level Measurements

Borehole	Date	Water Level (m)		Comment
		Depth	Elevation	
AL11-01	May 1, 2011	2.7	97.0	Open borehole
	May 3, 2011	1.0	98.7	Piezometer
	May 4, 2011	1.0	98.7	Piezometer
	May 5, 2011	1.0	98.7	Piezometer
AL11-02	May 2, 2011	3.9	98.1	Open borehole
AL11-03	May 3, 2011	1.3	99.2	Open borehole

The piezometric readings indicate that the groundwater level is near elevation 98.7.

The GA indicates that the water level of Alder Creek at this site on July 20, 2011 was at elevation 99.1.

The above values are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

6 MISCELLANEOUS

Borehole locations were selected and marked in the field by Thurber Engineering Ltd. Upon completion of drilling, the borehole elevations were established from a contour plan provided by Genivar.

Thurber obtained utility clearances for the borehole locations prior to drilling.

Eastern Ontario Diamond Drilling Ltd. from Hawkesbury, Ontario supplied a track mounted CME 55 drill rig and conducted the drilling, sampling and in-situ testing operations.

The field program was supervised on a full time basis by Mr. George Azzopardi of Thurber.

Routine laboratory testing was carried out by Thurber Engineering Ltd.

Overall supervision of the field program was conducted by Ms. Lindsey Blaine, E.I.T. Interpretation of the data and preparation of this report were carried out by Ms. Lindsey Blaine, E.I.T. and Ms. R. Palomeque Reyna, P.Eng.

The report was reviewed by Dr. P.K. Chatterji, P.Eng. a Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

This report presents interpretation of the geotechnical data in the factual report and presents geotechnical recommendations for design of a new culvert to replace the existing culvert at Alder Creek.

The existing culvert is a CSP elliptical arch with a length of 29.2 m, width of 4.0 m and height of approximately 2.5 m. Information provided by Genivar, indicates that the inlet and outlet elevations of the existing culvert are 97.5 and 97.4, respectively.

The proposed culvert (as shown on the Preliminary General Arrangement dated April 2011) consists of two parallel sheet pile walls supporting a slab consisting of precast concrete panels. The new structure will have a span of 7.4 m and a length of 23.3 m of which 19.5 m will be capped by precast panels.

The embankment heights are in the order of 2.0 m to 4.0 m.

The proposed culvert design was selected to avoid or minimize any disturbance or environmental impact on the stream bed. The design also minimizes use of cast-in-place concrete which increases the cost of construction significantly.

The discussions and recommendations presented in this report are based on the factual data obtained during the course of the investigation. The plans and profiles used for preparation of this report were provided by Genivar.

8 STRUCTURE FOUNDATIONS

In general terms, the site is underlain by native upper and lower layers of loose to compact silt. A 4.6-m to 7.6-m thick layer of soft to stiff clayey silt was encountered between the upper and lower silt layers. A thin layer of sandy silt was found at surface on the south side of the culvert. The existing embankment consists of 4.0 m of sand fill overlying native silt and clayey silt.

The groundwater level at the site was measured at 1.0 m depth (elevation 98.7) in the piezometer. The water level of Alder Creek at the site (inside the existing culvert) on July 20, 2011 is indicated in the GA at elevation 99.1.

Recommendations are provided for a sheet pile foundation supporting the precast cap panels.

Consideration was also given to the option of open footing culvert supported on:

- Spread footings on native soils or bedrock
- Augered Caissons (drilled shafts)
- Driven piles

A comparison of the foundation alternatives based on advantages and disadvantages of each one is included in Appendix D.

Spread footings are not recommended at this site due to the low geotechnical resistance and potential settlement in the near surface soils.

Caissons are not recommended at this site since suitable end bearing materials were not encountered within the depth explored. In addition construction of caissons in loose saturated silts below water table will be difficult and require specialized construction techniques.

These foundation options were therefore not developed further.

8.1 Steel Sheet Pile Walls

Driven steel sheet piles will develop resistance to vertical loads primarily through frictional resistance along the sides of the piles within the native loose to compact silt and soft to stiff clayey silt.

The factored Geotechnical Resistances at ULS (per metre width of sheet pile) and Geotechnical Resistances at SLS recommended for EZ-88 sheet pile sections driven to depths of 5, 10 and 15 m into the native silt are as follows:

Table 8.1 – Recommended Axial Resistances of Steel Sheet Piles

Sheet Pile Section	Embedment Length in Native Silt (m)	Approximate Pile Toe Elevation (m)	Factored ULS Resistance per meter width (kN)	SLS Resistance (kN)
EZ-88	5	93.0	160	120
	10	88.0	420	300
	15	83.0	800	520

The SLS values are based on a vertical pile settlement of 25 mm at the base of the embankment fill.

Pile installation should be in accordance with OPSS 903, November 2009.

Sheet piles should be driven to the specified elevation noted in Table 8.1. The appropriate pile driving note is “Sheet piles to be driven to El. ____”. An additional note should be included to indicate that installation of permanent sheet pile walls by vibratory equipment is not permitted.

The lateral resistance of sheet piles may be computed using the lateral earth pressure distribution and parameters presented in Section 9.

For open footing culverts, the following foundation option was considered:

8.2 Driven Steel H-Pile Foundations

Driven steel H-piles will develop resistance to vertical loads primarily through frictional resistance along the shafts of the piles within the native loose to compact silt and soft to stiff clayey silt.

The factored Geotechnical Resistances at ULS (per pile) and Geotechnical Resistance at SLS (25 mm settlement) recommended for an HP 310x110 H-pile section driven to various depths into the native silt are as follows:

Table 8.2 – Recommended Axial Resistances for Steel H-Piles

Embedment Length in Native Silt and Clayey Silt (m)	Approximate Pile Tip Elevation (m)	Factored ULS Resistance per pile (kN)	SLS Resistance (kN)
10	90	250	200
15	85	400	325

The structural resistance of the pile must be checked by the structural designer.

Downdrag on the piles is not considered to be an issue at this site, since no highway grade raise is proposed.

Pile installation should be in accordance with OPSS 903, November 2009.

8.2.1 Pile Lateral Resistance

The geotechnical lateral resistance acting on an H-pile in silt may be calculated using a value for the coefficient of horizontal subgrade reaction (k_s) and ultimate lateral resistance (p_{ult}) as follows:

	k_s	=	$n_h z / D$	(kN/m ³)
	p_{ult}	=	$3 \gamma z K_p$	(kPa)
where	z	=	depth of embedment of pile in metres	
	D	=	pile width in metres	
	n_h	=	coefficient of horizontal subgrade reaction	
		=	4,000 kN/m ³ in loose to compact silt below groundwater level	
	γ	=	unit weight	
		=	11 kN/m ³ (buoyant unit weight below water table)	
	K_p	=	passive earth pressure coefficient	
		=	3.0 for loose to compact silt	

The ultimate lateral resistance of piles may be computed using the lateral earth pressure parameters presented in Section 9 with $p_{ult} = K_p \gamma z$. The coefficient of horizontal subgrade reaction may be computed using the equation above and a pile width D of unity.

The above equations and recommended parameters may be used to analyze the interaction between a pile and the surrounding soil. The lateral pressures obtained from the analysis must not exceed the ultimate lateral resistance.

The spring constant, K_s , for analysis may be obtained by the expression, $K_s = k_s \times L \times D$ (kN/m), where k_s is the coefficient of horizontal subgrade reaction (kN/m³), D is the pile width (m) and L is the length (m) of the pile segment or element used in the analysis. The ultimate lateral resistance, P_{ult} , may be obtained from the expression, $P_{ult} = p_{ult} \times L \times D$. This represents the ultimate load at which the pile fails and will not support any additional load at greater displacements. It is recommended, however, that the total lateral resistance assumed in one pile be limited to no more than 120 kN at ULS and 50 kN at SLS.

The modulus of subgrade reaction may have to be reduced, based on the pile spacing. The reduction factors to be used for a pile group oriented perpendicular or parallel to the direction of loading are provided in Table 8.3. Intermediate values may be obtained by linear interpolation.

Table 8.3 – Subgrade Reaction Reduction Factors for Pile Spacing

Condition	Pile Spacing, Centre to Centre*	Reduction Factor
Pile group oriented <i>perpendicular</i> to direction of loading	4D	1.0
	1D	0.5
Pile group oriented <i>parallel</i> to direction of loading	8D	1.0
	6D	0.7
	4D	0.4
	3D	0.25

* where D is the width of pile

Alternatively, horizontal loads may be resisted by means of battered piles.

8.3 Proposed Foundation

We understand that based on environmental issues and cost of cast-in-place concrete, the preferred solution for culvert replacement at this site is precast cap panels founded on sheet piles. This is a feasible foundation alternative.

For an open footing culvert, H-pile foundations are also a feasible alternative.

8.4 Frost Cover

The depth of frost penetration at this site is 2.3 m. The base of all footings and pile caps, if employed, must be provided with a minimum of 2.3 m of earth cover as protection against frost action.

9 CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Culvert backfill should consist of free-draining granular material conforming to OPSS Granular A or Granular B Type II specifications. The existing highway embankment fill consists of sand with some gravel and is not considered susceptible to frost action.

Heavy compaction equipment should not be used adjacent to the sheet pile walls and roof of the culvert. Compaction should be carried out in accordance with OPSS 501 dated November 2010. Backfill for the culvert should be placed and compacted in simultaneous equal lifts on both sides of the culvert, and the top of backfill elevation should be within 400 mm on both sides of the culvert at all times.

In general, earth pressures acting on the culvert walls may be assumed to impose a triangular distribution governed by the characteristics of the backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are given by the expression:

$$p = K (\gamma h + q)$$

- where: p = horizontal pressure on the wall at depth h (kPa)
 K = earth pressure coefficient (see Tables 9.1)
 γ = bulk unit weight of retained soil (see Table 9.1)
 h = depth below top of fill where pressure is computed (m)
 q = value of any surcharge (kPa)

Earth pressure coefficients for backfill to the culvert are dependent on the material used as backfill and the inclination of the ground surface behind the wall. Recommended unfactored values for a level ground surface are shown in Table 9.1. The at-rest coefficients should be employed for restrained culvert walls. Active pressures shall be used for any wingwalls or unrestrained walls.

If the ground surface behind the sheet pile walls is sloping, the earth pressure parameters will increase. Thurber should be contacted to provide revised earth pressure parameters for this condition.

The parameters in the table correspond to full mobilization of active and passive earth pressures, and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design can be assessed from Figure C6.9.1 (a) of the Commentary to the CHBDC.

Table 9.1 – Earth Pressure Coefficients (K) for Horizontal Ground Surface

Condition	Earth Pressure Coefficient (K)		
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	Existing Sand Fill or OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	Clayey Silt and native silt $\phi = 29^\circ$ $\gamma = 20 \text{ kN/m}^3$
Active (Unrestrained Wall)	0.27	0.31	0.35
At rest (Restrained Wall)	0.43	0.47	0.51
Passive (Movement Towards Soil Mass)	3.7	3.3	2.9

For the at-rest condition, all soil above a horizontal surface behind the wall should be treated as a surcharge load.

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.

The design of the culvert must incorporate measures such as weepholes or subdrains to permit drainage of the culvert backfill, or alternatively the culvert walls should be designed to withstand the potential build-up of hydrostatic pressures behind the walls.

Since no grade change is proposed at this site, foundation settlement is not an issue.

10 EROSION CONTROL

Erosion protection should be provided for the culvert channel as well as the inlet and outlet areas. Design of the erosion protection measures must consider hydrologic and hydraulic concerns and should be carried out by specialists experienced in this field.

Typically, rip-rap should be provided over all surfaces with which stream flow 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, November 2010.

11 EXCAVATION AND GROUNDWATER CONTROL

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the sand fill and native silt forming the existing embankment may be classified as Type 3 soils. The native silt above the water table may also be classed as Type 3 soils. This classification is based on the lack of cohesion in the soils. The silt below the water table is a Type 4 soil.

The water level of Alder Creek at the site (inside the existing culvert) on July 20, 2011 is indicated in the GA at elevation 99.1. The groundwater level at the site is expected to be at or above the water level measured in the piezometer (elevation 98.7 m in May 2011). In addition, flooding was noted at the south and north ends of the culvert. We understand that measures such as creek diversions will not be permitted to avoid disturbance of the creek. The water level in the creek may be lower in the dry seasons and construction should be conducted during these periods.

Based on the preliminary culvert design, excavation below the groundwater level to construct the new sheet pile wall will not be required. However, if required, any excavation below the groundwater level without prior dewatering is not recommended since the inflow of groundwater will cause boiling and sloughing of the soil below the water table making it difficult to maintain a dry, sound base on which to work.

The design of the dewatering system that may be required is the responsibility of the Contractor and the Contract Documents must alert him to this responsibility and the need to engage a dewatering specialist. The Contractor should also be prepared to pump from sumps to remove any remaining seepage water or surface water collecting in an excavation. Placement of concrete (if required) must be done in the dry. Unwatering must remain operational and effective until the culvert is installed and backfilled.

The excavation and backfilling for foundations must be carried out in accordance with OPSS 902, November 2010.

12 SEISMIC CONSIDERATIONS

The following seismic parameters should be used for design:

- Velocity Related Seismic Zone 0
- Zonal Velocity Ratio 0.0
- Acceleration Related Seismic Zone 0
- Zonal Acceleration Ratio 0.0
- Peak Horizontal Acceleration 0.02

The soil profile type at this site has been classified as Type IV. Therefore, according to Table 4.4 of the CHBDC, a Site Coefficient “S” (ground motion amplification factor) of 2.0 should be used in seismic design.

In accordance with Clause 4.6.4 of the CHBDC, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 12.1 may be used:

Table 12.1 – Earth Pressure Coefficients for Earthquake Loading

Condition	Earth Pressure Coefficient (K)		
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	Existing Sand Fill or OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	Clayey Silt and Native Silt $\phi = 29^\circ$ $\gamma = 20 \text{ kN/m}^3$
Active (K_{AE})*	0.28	0.32	0.36
Passive (K_{PE})	3.7	3.2	0.54
At Rest (K_{OE})**	0.45	0.50	2.9

* After Mononobe and Okabe, passive case assumes a horizontal surface in front of the wall.

** After Woods

The site overlies loose to compact cohesionless deposits and a high water table is present at this site. A cursory review of the subsurface conditions indicates that a potential for liquefaction exists under current conditions at this site. Localized liquefaction during a seismic event may result in local toe failure or minor embankment settlement, but this is expected to be readily repairable.

13 ROADWAY PROTECTION

During the new culvert construction, temporary excavation of existing embankments will be required. The culvert construction will be done in stages in order to keep at least one highway lane operational. Roadway protection will be required to facilitate staging of removals and support the existing Highway 17 adjacent to the excavation.

Roadway protection should be provided in accordance with OPSS 539 and designed for Performance Level 2.

Continuous sheet pile wall or conventional steel soldier pile with timber lagging walls are two options to provide temporary support to the soils during excavation. Timber lagging boards should be installed as soon as the soil face is exposed and properly prepared.

The following parameters apply for design of the temporary shoring system.

γ	=	20 kN/m ³	(bulk unit weight)
γ_w	=	10 kN/m ³	(submerged unit weight under groundwater table)
K_a	=	0.33	(Active pressure coefficient for road embankment fill)
	=	0.35	(Active pressure coefficient for silt)
K_p	=	3.0	(Passive pressure coefficient for road embankment fill)
	=	2.9	(Passive pressure coefficient for silt)
h_w	=	0	(assuming that the groundwater is maintained below the base of the excavation and that there is no hydrostatic pressure build-up behind a presumably permeable wall, soldier pile and lagging)
h_w	=	99.1	(elevation for hydrostatic pressure build-up behind sheet piles)

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.

Temporary groundwater and surface water control measures will be required during construction.

The design of roadway protection should be the responsibility of the Contractor. All shoring systems should be designed by a Professional Engineer experienced in such designs, who will determine an appropriate support system.

14 CONSTRUCTION CONCERNS

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

- Buried obstructions in the existing embankment fill that may be encountered during excavation or interfere with driving of piles.
- The culvert is flooded at the north and south ends and culvert construction should be carried out in dry low flow seasons.
- Roadway protection must be provided to maintain traffic during construction. Temporary shoring systems should be properly designed by a Professional Engineer experienced in such designs.
- Erosion protection should be provided to the embankment surfaces after construction.

The successful performance of the culvert will depend largely upon good workmanship and quality control during construction. Pile driving supervision, subgrade examination and field density testing should be carried out by qualified geotechnical personnel during construction to confirm that foundation recommendations are correctly implemented and material specifications are met.

15 CLOSURE

Engineering analysis and preparation of the report were carried out by Ms. R. Palomeque Reyna, P.Eng.

The report was reviewed by Dr. P.K. Chatterji, P.Eng. a Designated Principal Contact for MTO Foundations Projects.

THURBER ENGINEERING LTD.

Rocío Palomeque Reyna, P.Eng.
Geotechnical Engineer



P. K. Chatterji, P.Eng.
Review Principal



Appendix A

Record of Borehole Sheets

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








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.		
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.		CLAYSTONE
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SILTSTONE
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.		SANDSTONE
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.		COAL
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.		Bedrock (general)

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 0.3m of core run.

RECORD OF BOREHOLE No AL11-01

1 OF 2

METRIC

W.P. 6026-07-00 LOCATION N 539 553.1 E 590 118.4 Alder Creek Culvert ORIGINATED BY GA
HWY 617 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
DATUM Geodetic DATE 2011.05.01 - 2011.05.01 CHECKED BY LRB

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 (%)				
								○ UNCONFINED + FIELD VANE		● QUICK TRIAXIAL x LAB VANE							
						20	40	60	80	100	20	40	60				
99.9																	
0.0	Sandy SILT, with organics Very Loose Brown Moist		1	SS	3							○					
99.3																	
0.6	SILT, some clay, trace sand, occasional rootlets Loose to Compact Brown to Grey Damp		2	SS	7							○					
			3	SS	7							○					
			4	SS	13							○			0 0 89 11		
			5	SS	5							○					
			6	SS	6							○					

Continued Next Page

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

RECORD OF BOREHOLE No AL11-01

2 OF 2

METRIC

W.P. 6026-07-00 LOCATION N 539 553.1 E 590 118.4 Alder Creek Culvert ORIGINATED BY GA
 HWY 617 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2011.05.01 - 2011.05.01 CHECKED BY LRB

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 (%)						
								○ UNCONFINED		+ FIELD VANE			● QUICK TRIAXIAL			x LAB VANE			w _p w w _L
								20	40	60	80	100	20	40	60	GR	SA	SI	CL
	Continued From Previous Page																		
89.2	Clayey SILT, varved Firm to Stiff Grey																		
10.7	SILT, trace clay Loose to Compact Grey Wet		10	SS	6		89												
							88												
			11	SS	18														
							87												
			12	SS	16		86								0 0 93 7				
							85												
84.1			13	SS	17														
15.8	END OF BOREHOLE AT 15.8m. WATER LEVEL OBSERVED AT 2.7m UPON COMPLETION OF DRILLING. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) May03/ 11 1.0 98.9 May04/ 11 1.0 98.9 May05/ 11 1.0 98.9																		

+³, ×³: Numbers refer to
Sensitivity

20
15
10


(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No AL11-02

1 OF 4

METRIC

W.P. 6026-07-00 LOCATION N 539 564.7 E 590 117.0 Alder Creek Culvert ORIGINATED BY GA
HWY 617 BOREHOLE TYPE Hollow Stem Augers/DCPT COMPILED BY AN
DATUM Geodetic DATE 2011.05.02 - 2011.05.02 CHECKED BY LRB

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						WATER CONTENT (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
								○ UNCONFINED + FIELD VANE		● QUICK TRIAXIAL × LAB VANE				W _P	W	W _L																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
101.9						20	40	60	80	100	20	40	60																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
0.0	SAND, some gravel, some silt and clay Compact to Loose Brown Damp (FILL)		1	SS	19																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				

Continued Next Page

+³, X³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No AL11-02

2 OF 4

METRIC

W.P. 6026-07-00 LOCATION N 539 564.7 E 590 117.0 Alder Creek Culvert ORIGINATED BY GA
HWY 617 BOREHOLE TYPE Hollow Stem Augers/DCPT COMPILED BY AN
DATUM Geodetic DATE 2011.05.02 - 2011.05.02 CHECKED BY LRB

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	WATER CONTENT (%)					
	Continued From Previous Page													
88.2	Clayey SILT, varved Stiff to Firm Grey		10	SS	12		91							
							90							
			11	SS	6		89							
							88							
13.7	SILT, trace clay Compact Grey Wet		12	SS	20		87							
							86							
86.1			13	SS	18		85							
15.8	End of sampling and start DCPT at 15.8m						84							
							83							
							82							

Continued Next Page

+³ × 3: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No AL11-02

3 OF 4

METRIC

W.P. 6026-07-00 LOCATION N 539 564.7 E 590 117.0 Alder Creek Culvert ORIGINATED BY GA
HWY 617 BOREHOLE TYPE Hollow Stem Augers/DCPT COMPILED BY AN
DATUM Geodetic DATE 2011.05.02 - 2011.05.02 CHECKED BY LRB

SOIL PROFILE		SAMPLES				GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT W _p NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
							81				
							80				
							79				
							78				
							77				
							76				
							75				
							74				
							73				
							72				

Continued Next Page

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

RECORD OF BOREHOLE No AL11-02

4 OF 4

METRIC

W.P. 6026-07-00 LOCATION N 539 564.7 E 590 117.0 Alder Creek Culvert ORIGINATED BY GA
 HWY 617 BOREHOLE TYPE Hollow Stem Augers/DCPT COMPILED BY AN
 DATUM Geodetic DATE 2011.05.02 - 2011.05.02 CHECKED BY LRB

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE							
	Continued From Previous Page							20 40 60 80 100							
71.4															
30.5	END OF BOREHOLE AT 30.5m. WATER LEVEL AT 3.9m UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG FROM 15.8m TO 0.6m, THEN SAND AND GRAVEL TO SURFACE.						71								

+ ³, X ³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No AL11-03

1 OF 2

METRIC

W.P. 6026-07-00 LOCATION N 539 584.6 E 590 125.2 Alder Creek Culvert ORIGINATED BY GA
HWY 617 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
DATUM Geodetic DATE 2011.05.02 - 2011.05.03 CHECKED BY LRB

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				
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL		
100.1 0.0	SILT, trace sand, trace clay, occasional rootlets Loose to Compact Brown Damp		1	SS	7		100				WATER CONTENT (%) Wp W WL	GR SA SI CL
			2	SS	12		99					
			3	SS	6		98					
			4	SS	15		97					
			5	SS	14		96					
95.5 4.6			Clayey SILT, varved Soft to Firm Grey		6		SS	5	95			
	7	SS			4	94						
	8	SS			5	93						
	9	SS			5	92						
						91						

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No AL11-03

2 OF 2

METRIC

W.P. 6026-07-00 LOCATION N 539 584.6 E 590 125.2 Alder Creek Culvert ORIGINATED BY GA
HWY 617 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
DATUM Geodetic DATE 2011.05.02 - 2011.05.03 CHECKED BY LRB

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				
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE	WATER CONTENT (%)		
	Continued From Previous Page					20 40 60 80 100	20 40 60	PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L		
89.4	Clayey SILT, varved Soft to Firm Grey						90					
10.7	SILT, some clay, trace sand Compact Grey Wet		10	SS	10		89					0 1 86 13
							88					
			11	SS	18							
							87					
			12	SS	19		86					
84.3			13	SS	17		85					
15.8	END OF BOREHOLE AT 15.8m. BOREHOLE OPEN TO 15.8m AND WATER LEVEL AT 1.3m UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.											

+³ ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No DCPT-AL11-03

1 OF 3

METRIC

W.P. 6026-07-00 LOCATION N 539 584.6 E 590 125.2 Alder Creek Culvert ORIGINATED BY GA
HWY 617 BOREHOLE TYPE Dynamic Cone Penetration Test COMPILED BY AN
DATUM Geodetic DATE 2011.05.03 - 2011.05.03 CHECKED BY LRB

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								
102.0													
0.0	Start DCPT from surface.						102						
							101						
							100						
							99						
							98						
							97						
							96						
							95						
							94						
							93						

Continued Next Page

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

RECORD OF BOREHOLE No DCPT-AL11-03

2 OF 3

METRIC

W.P. 6026-07-00 LOCATION N 539 584.6 E 590 125.2 Alder Creek Culvert ORIGINATED BY GA
HWY 617 BOREHOLE TYPE Dynamic Cone Penetration Test COMPILED BY AN
DATUM Geodetic DATE 2011.05.03 - 2011.05.03 CHECKED BY LRB

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					
	Continued From Previous Page						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	20 40 60					
						92							
						91							
						90							
						89							
						88							
						87							
						86							
						85							
						84							
						83							

Continued Next Page

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

RECORD OF BOREHOLE No DCPT-AL11-03

3 OF 3

METRIC

W.P. 6026-07-00 LOCATION N 539 584.6 E 590 125.2 Alder Creek Culvert ORIGINATED BY GA
HWY 617 BOREHOLE TYPE Dynamic Cone Penetration Test COMPILED BY AN
DATUM Geodetic DATE 2011.05.03 - 2011.05.03 CHECKED BY LRB

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	WATER CONTENT (%)					
	Continued From Previous Page						82	20 40 60 80 100	20 40 60					
							81							
							80							
79.7 22.3	END OF DCPT AT 22.3m.													

ONTMT4S 0840.GPJ 12/12/11

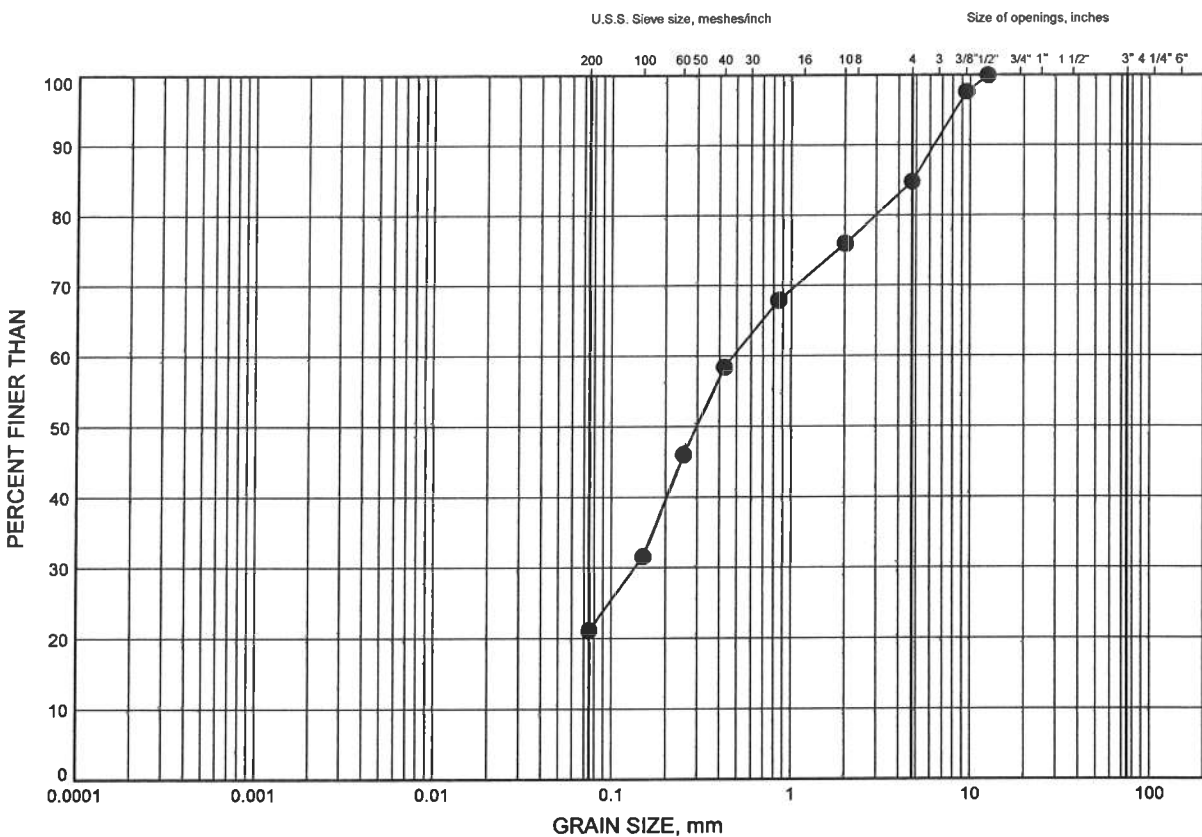
Appendix B
Laboratory Test Results

NWR HWY 11 Bridge

GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	AL11-02	1.83	100.17

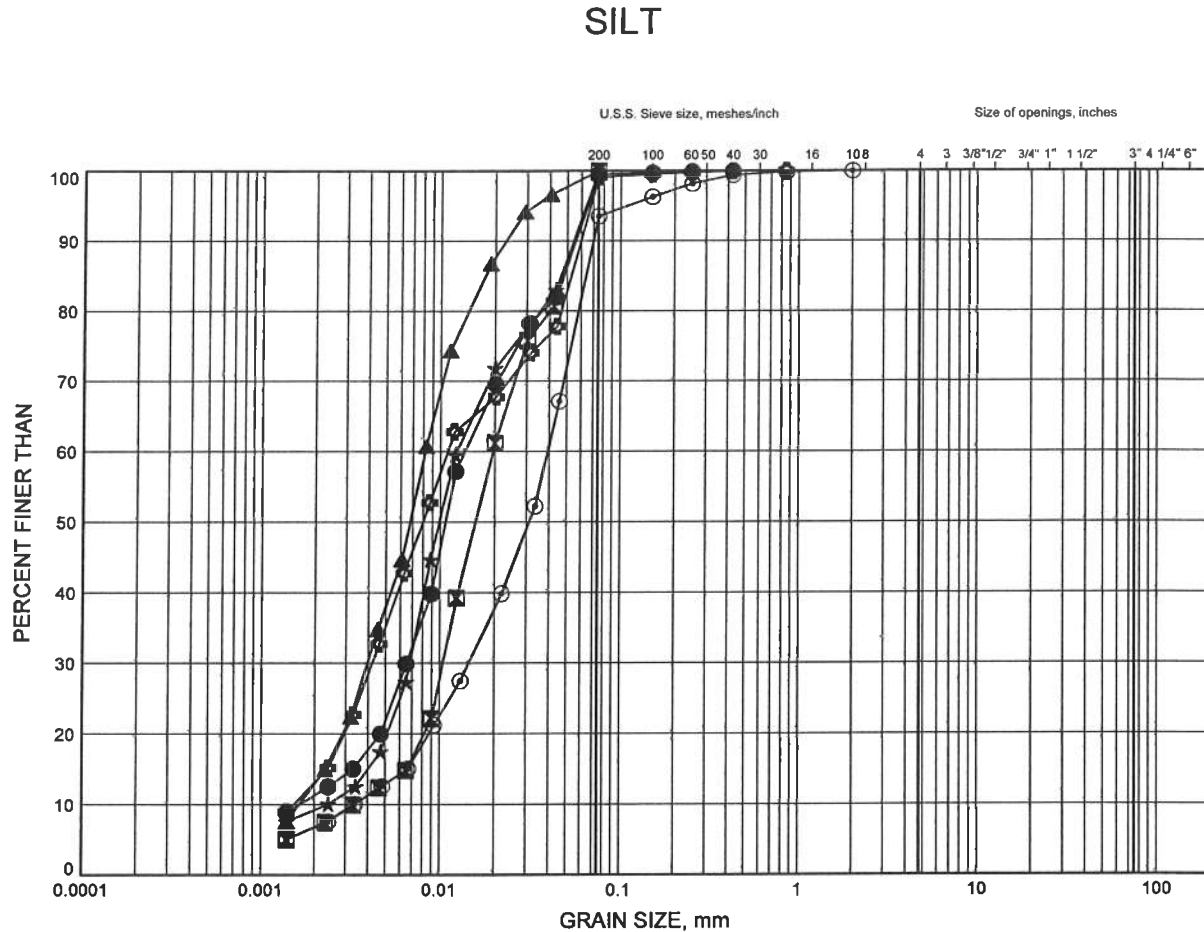
GRAIN SIZE DISTRIBUTION - THURBER 0840.GPJ 7/11/11

W.P.# 19-5308-40
 Prepared By AN
 Checked By LRB



NWR HWY 11 Bridge GRAIN SIZE DISTRIBUTION

FIGURE B2



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	AL11-01	2.57	97.13
⊠	AL11-01	14.02	85.68
▲	AL11-02	4.88	97.12
★	AL11-03	2.59	97.91
⊙	AL11-03	3.35	97.15
⊕	AL11-03	10.97	89.53

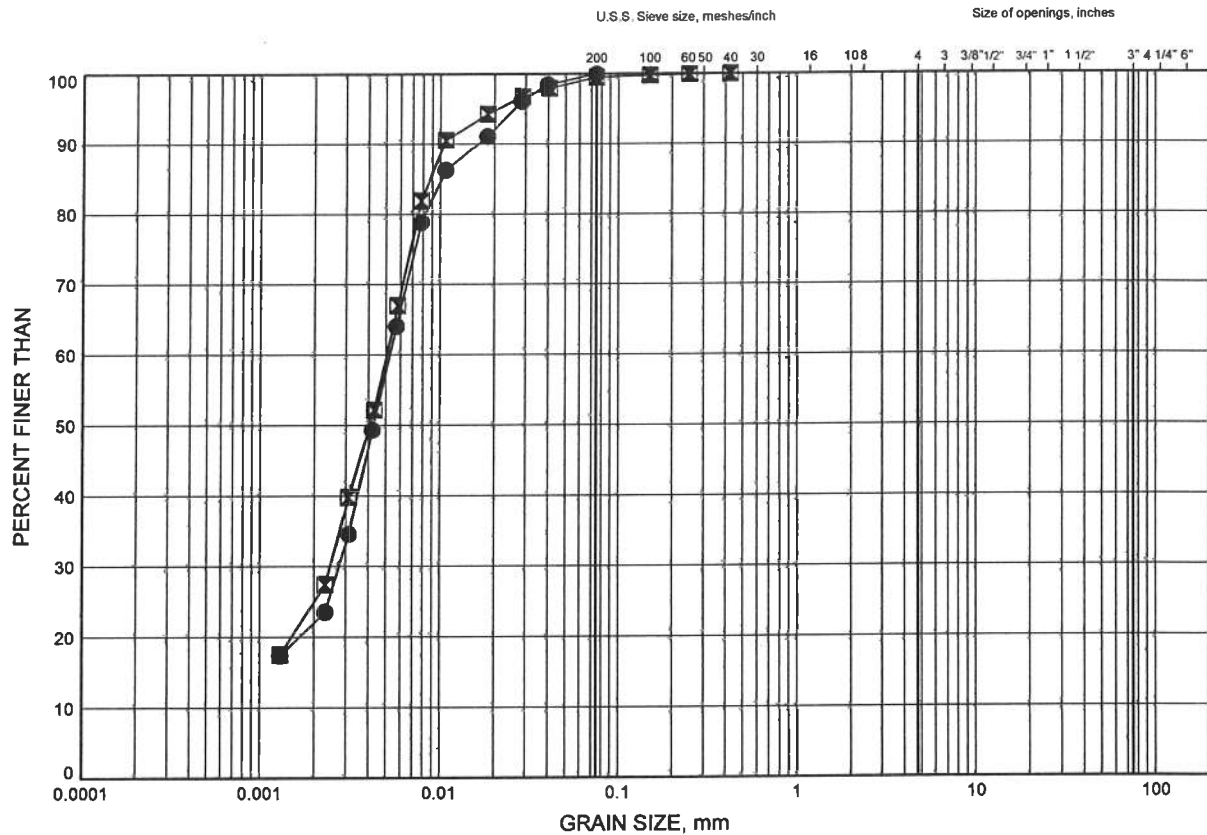


W.P.# .19-5308-40.....
Prepared By .AN.....
Checked By .LRB.....

NWR HWY 11 Bridge GRAIN SIZE DISTRIBUTION

FIGURE B3

CLAYEY SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	AL11-01	6.40	93.30
■	AL11-02	9.45	92.55



W.P.# .19-5308-40.....
Prepared By .AN.....
Checked By .LRB.....

Appendix C
Site Photographs



Photograph 1 – Alder Creek Culvert



Photograph 2 – Alder Creek Culvert

Appendix D
Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES FOR EACH FOUNDATION ELEMENT

Driven Sheet Piles	Driven H-Piles	Footings on Native Soil	Caissons
<p>Advantages:</p> <ul style="list-style-type: none"> i. Minimizes potential for disturbance of streambed. ii. Ease of construction. iii. Provides shoring and foundation elements in one operation. iv. Installation of piles could continue in freezing weather. v. Potentially minimizes volume of excavation. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Unconventional design. ii. Cost of sheet piles. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Piles will develop geotechnical resistance by shaft friction in loose to compact silt. ii. Installation of piles could continue in freezing weather iii. Foundation construction may require less volume of excavation than footings. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Higher unit costs than footings. ii. Relatively low axial and lateral resistance available. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Generally less costly construction than deep foundation elements. ii. Conventional culvert design is feasible. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Low available geotechnical resistance in native silt deposit. ii. Excavation to base of existing roadway embankment is required for footing construction. iii. Dewatering and stream diversion will be required. iv. Potential disturbance of creek during excavation. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Construction of caissons could continue in freezing weather. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. No suitable bearing stratum was encountered within the depth of borehole exploration. ii. Higher cost than spread footings iii. Specialized installation measures such as temporary liners and drilling mud will be required to install caissons in cohesionless soils under the water table. iv. Potential difficulty in cleaning and inspecting bases.
RECOMMENDED	FEASIBLE	NOT RECOMMENDED	NOT RECOMMENDED

Appendix E

List of SPs and OPSS, and Suggested Text for Selected NSSP

1. List of Special Provisions and OPSS Documents Referenced in this Report

- OPSS 903, November 2009
- OPSD 810.010
- OPSS 501 dated November 2010
- OPSS 804, November 2010
- OPSS 902, November 2010
- OPSS 539

Appendix F

Drawing

Borehole Locations and Soil Strata

