

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
KENEL CREEK CULVERT REPLACEMENT**

**Highway 17, Site 48E-66/C**

**G.W.P. 6026-07-00**

**Township of Bomby**

**East of Marathon, Ontario**

**Geocres Number: 42C-25**

**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 Kenel Creek in the Township of Bomby, Ontario. The existing culvert carries Kenel Creek under Highway 17.

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, laboratory test results and a written description 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 Kenel Creek culvert is located approximately 40 m east of the intersection of Highway 17 and Highway 614 in the Township of Bomby, Ontario. The site is approximately 40 km east of the Town of Marathon, Ontario.

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

Currently a CSP elliptical arch culvert carries Kenel Creek under Highway 17. The culvert is approximately 4.0 m wide, 2.4 m high and 31.2 m long. Kenel Creek flows to the south.

Lands surrounding the culvert site are generally flat and undeveloped forested areas.

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 on April 30 and May 1, 2011 and consisted of drilling and sampling a total of three boreholes (identified as KN11-01 to KN11-03) in the area of the existing culvert. One borehole was drilled near each end of the culvert and one borehole was drilled on the eastbound lane of Highway 17. Boreholes were extended to depths ranging from 6.1 m to 10.4 m (elevations 91.1 to 92.9).

Dynamic cone penetration tests (DCPT) were conducted adjacent to Boreholes KN11-01 and KN11-03 from ground surface to 7.6 m and 6.8 m depth (elevations 91.7 and 92.2), respectively.

The approximate borehole locations are shown on the attached Borehole Locations and Soil Strata Drawing included 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).

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 KN11-03 and enclosed in filter sand to permit longer term groundwater level monitoring. The boreholes were backfilled in accordance with O.Reg. 903 upon completion and the details are shown in Table 3.1.

**Table 3.1 –Borehole Decommissioning Details**

<b>Borehole</b>	<b>Piezometer Tip Depth/ Elevation (m)</b>	<b>Borehole Decommissioning Details</b>
KN11-01	None installed	Backfilled with bentonite holeplug to surface.
KN11-02	None installed	Backfilled with bentonite holeplug from 10.4 m to 0.15 m, then asphalt patch to surface.
KN11-03	6.1 / 92.9	Piezometer with 1.5 m slotted screen installed with sand filter to 4.3 m, bentonite from 4.3 m 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 native silt overlying deposits of sandy silt and sand. A thin layer of organics mixed with sand and clay was encountered at surface near the culvert inlet and outlet areas. Pavement structure overlying sand fill was encountered surficially in the borehole advanced through the highway embankment. Boreholes were terminated upon auger refusal on probable bedrock or boulders. More detailed descriptions of the individual strata are presented below.

##### **5.1 Pavement structure**

Pavement structure consisting of approximately 40 mm of asphalt overlying granular (sand fill) road base was encountered in Boreholes KN11-02 drilled through the existing Highway 17 eastbound lane.

##### **5.2 Organics**

A thin layer of dark brown organics mixed with sand and clay and trace of silt was contacted surficially in Boreholes KN11-01 and KN11-03 drilled at the south and north ends of the culvert, respectively. The thickness of the organic layer was 0.3 m and 0.4 m in KN11-01 and KN11-03, respectively.

The moisture contents of samples collected from the organics layer were 32% and 41%.

##### **5.3 Sand Fill**

Sand fill containing some gravel and trace to some silt and clay was encountered below the asphalt in Borehole KN11-02. Occasional cobbles and boulders were encountered within the sand fill between 1.8 m and 2.9 m depth. The thickness of the sand fill was 3.7 m.

The depth to the base of the fill was 3.7 m (elevation 97.8).

Standard Penetration tests performed in the sand fill layer gave SPT N-values of 18 blows per 0.3 m penetration to 50 blows for less than 0.1 m penetration. These N-values indicate a compact to very dense relative density. N-values of 50 blows for less than 0.1 m penetration appear to correspond to the presence of cobbles and boulders in the fill.

The moisture content of samples of the sand fill generally varies between 5% and 12%.

A sample of the sand fill underwent gradation analysis testing. These results are 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. The results of the laboratory test are summarized as follows:

<b>Soil Particles</b>	<b>Percentage (%)</b>
Gravel	19
Sand	64
Silt and Clay	17

#### **5.4 Silt**

Native silt containing trace to some clay was encountered below the layer of organics in Boreholes KN11-01 and KN11-03 and below the sand fill in Borehole KN11-02. The thickness of the silt layer varied from 3.8 m to 5.7 m.

The depth to the base of the silt was 4.6 m and 7.5 m (elevations 94.7 and 94.0) in Boreholes KN11-01 and KN11-02, respectively.

Borehole KN11-03 was terminated within the silt layer at 6.1 m depth (elevation 92.9) upon refusal on probable bedrock or boulders.

Standard Penetration tests recorded in the silt layer gave SPT N-values of 5 to 22 blows per 0.3 m of penetration, indicating a loose to compact relative density.

The moisture content of samples from the silt layer generally varies between 18% and 24%.

Selected samples of the silt underwent gradation analysis testing, the results of which are summarized below. These results are also summarized on the Record of Borehole sheets in Appendix A and the grain size distribution curves for the tested samples are included in Figure B2 of Appendix B.

Soil Particles	Percentage (%)
Gravel	0
Sand	0
Silt	88 to 91
Clay	9 to 12

### 5.5 Sandy Silt

Grey sandy silt containing trace clay was encountered in Borehole KN11-01 below the silt layer at 4.6 m depth (elevation 94.7). The thickness of the sandy silt layer was 3.0 m.

Borehole KN11-01 was terminated within the sandy silt layer at 7.6 m depth (elevation 91.7) upon refusal on probable bedrock or boulder.

Standard Penetration tests recorded in the sandy silt layer gave SPT N-values of 3 and 5 blows per 0.3 m of penetration, indicating a very loose to loose relative density.

The moisture contents of samples from the sandy silt were 19% and 21%.

One sample of the sandy silt was selected for laboratory gradation analysis testing, the results of which are summarized 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 presented in Figure B3 of Appendix B.

Soil Particles	Percentage (%)
Gravel	0
Sand	29
Silt	67
Clay	4

### 5.6 Sand

Grey sand containing trace silt was encountered in Borehole KN11-02 below the silt at 7.5 m depth (elevation 94.0). The thickness of the sand layer was 2.9 m.

Borehole KN11-02 was terminated within the sand layer at 10.4 m depth (elevation 91.1) upon refusal on probable bedrock or boulders.

Standard Penetration tests recorded in the sand gave SPT N-values of 4 blows per 0.3 m of penetration, indicating a loose relative density.

The moisture content of a sample from the sand layer was 21%.



## 5.7 Water Levels

Water levels were observed in the open boreholes upon completion of the drilling operations. One standpipe piezometer was installed in Borehole KN11-03 to monitor water levels after completion of drilling. The water levels measured in the open boreholes and piezometers are summarized in Table 5.1.

**Table 5.1 – Water Level Measurements**

Borehole	Date	Water Level (m)		Comment
		Depth	Elevation	
KN11-01	April 30, 2011	4.5	94.8	Open borehole
KN11-02	May 1, 2011	4.0	97.5	Open borehole
KN11-03	April 30, 2011	0.3	98.7	Open borehole
	May 3, 2011	0.3*	99.3	Piezometer
	May 4, 2011	0.3*	99.3	Piezometer
	May 5, 2011	0.3*	99.3	Piezometer

\*Indicates artesian conditions (water level above ground surface)

The piezometric readings reveal that the groundwater level is 0.3 m above ground surface, indicating artesian conditions at this site.

The GA indicates that water level of Kennel Creek at this site on July 20, 2011 was at elevation 98.38.

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.

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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 Kenel Creek.

The existing culvert is a CSP elliptical arch with a length of 31.2 m, width of 4.0 m and height of approximately 2.4 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 May 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, a height of about 2.8 m, and a sheet pile wall length of 33.3 m of which 24.0 m will be capped by precast panels.

The original ground is near Elevation 99.2 m. The finished road grades over the culvert will be near Elevation 101.7 m, resulting in a maximum embankment height of about 2.5 m.

The proposed culvert design was selected to minimize any disturbance or environmental impact on the creek 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 was found to be underlain by loose to compact native silt overlying deposits of very loose to loose sandy silt and sand. Pavement structure overlying a layer of

compact to very dense sand fill was encountered surficially in one borehole advanced through the highway embankment. The fill was 3.7 m thick and contains occasional cobbles and boulders. A 300-mm to 400-mm thick layer of organics mixed with sand and clay was encountered at surface near the culvert inlet and outlet areas. Boreholes were terminated upon auger refusal on probable bedrock or boulders at depths and elevations given in Table 8.1.

**Table 8.1 – Depths and Elevations of probable bedrock or boulders**

Location	Borehole/DCPT	Top of Probable Bedrock or boulder	
		Depth (m)	Elevation (m)
North end of culvert	KN11-01	7.6	91.7
	DCPT- KN11-01	7.6	91.7
Middle of the culvert	KN11-02	10.4	91.1
South end of the culvert	KN11-03	6.1	92.9
	DCPT- KN11-03	6.8	92.2

The groundwater level at the site was measured at 0.3 m (elevation 99.3) above the ground surface in the piezometer, indicating artesian conditions at the site. The water level of Kenel Creek at the site (inside the existing culvert) is indicated in the GA at elevation 98.38.

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 relatively low geotechnical resistance available in the overburden, dewatering difficulties that may be encountered during temporary excavation for footings, presence of artesian water pressures and the potential disturbance to the creek that may be caused by footing excavation.

Caissons are not recommended at this site since construction of caissons in loose saturated silts and sands below water table will be difficult and require specialized construction techniques. Due to high water table noted at this site including artesian conditions, the base of the caissons would be about 6 m to 10 m below the groundwater level, resulting in high hydrostatic heads at the base. The permeable nature of the overburden soil would make it difficult to seal the bottom of the caisson liner into the founding stratum to exclude groundwater.

These foundation options (spread footings and augered caissons) 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 sand.

The factored Geotechnical Resistances at ULS (per metre width) and Geotechnical Resistances at SLS recommended for three sheet pile sections driven to depths of 6.0 m and 7.5 m into the native silt are as follows:

**Table 8.2 – Recommended Axial Resistances of Steel Sheet Piles**

Sheet Pile Section	Sheet pile Length (m)	Approximate Pile Toe Elevation (m)	Factored ULS Resistance per meter width (kN)	SLS Resistance (kN)
EZ-88	6.0	93.3	150	120
	7.5	91.8	195	155
XZ-100	6.0	93.3	160	115
	7.5	91.8	210	150
JZ-127	6.0	93.3	165	120
	7.5	91.8	220	160

The SLS values are based on a vertical pile settlement of 25 mm.

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

Sheet piles should be driven to the specified elevation noted in Table 8.2. 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.

It must be noted that cobbles and boulders were encountered in the existing fill. Sheet piles should be provided with sheet pile tip protector to minimize any tip damage. It is understood the all exposed sheet piles will be coated with Hycote 151 to 300 mm below the finished grade.

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 Steel H-Pile Foundations

Steel H-piles (HP 310x110) driven to refusal at or below elevations 91.0 to 93.0 may be designed for the geotechnical resistances presented in Table 8.3.

**Table 8.3 – Recommended Axial Resistances for Steel H-Piles**

<b>Approximate Pile Tip Elevation (m)</b>	<b>Factored ULS Resistance per pile (kN)</b>	<b>SLS Resistance (kN)</b>
91.0 to 93.0	1,000	800

H-piles should be driven to the specified elevation noted in Table 8.3.

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

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

### 8.2.1 Pile Tips

The tips of all piles should be fitted with cast steel, H-section rock points from an approved manufacturer such as Titus Steel (Standard H-point) or approved equivalent.

### 8.2.2 Pile Driving

As boreholes encountered refusal upon probable bedrock or boulders at elevations ranging from 91.0 to 93.0, an NSSP should require the QVE to terminate driving before the pile is damaged by overdriving. Suggested texts for NSSP's are included in Appendix E.

### 8.2.3 Artesian Water Pressure

Piezometer indicated groundwater at 0.3 m (elevation 99.3) above ground surface. Artesian pressure has the potential to cause flow up the pile shaft, with accompanying loss of fines.

It is expected that any artesian flow that will travel up a pile shaft will drain into the sand and gravel fill near the surface.

If any artesian flow is noted up the pile shafts during construction, this issue should be referred to the design team by the CA. Measures such as provision of a sand filter at the surface to minimize any loss of fines may be required.

### 8.2.4 Downdrag

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

### 8.2.5 Pile Lateral Resistance

The geotechnical lateral resistance of an H-pile embedded 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:

$$k_s = n_h z / D \quad (\text{kN/m}^3)$$

$$p_{ult} = 3 \gamma z K_p \quad (\text{kPa})$$

where  $z$  = depth of embedment of pile in metres

$D$  = pile width in metres

$n_h$  = coefficient of horizontal subgrade reaction  
= 3,000 kN/m<sup>3</sup> in loose to compact silt

$\gamma$  = unit weight  
= 11 kN/m<sup>3</sup> (buoyant unit weight below water table)

$K_p$  = passive earth pressure coefficient  
= 3.0 for loose to compact silt

The ultimate lateral resistance of sheet 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/m<sup>3</sup>),  $D$  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 40 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 8.4. Intermediate values may be obtained by linear interpolation.

**Table 8.4 – 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 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 walls and roof of the culvert. Compaction should be carried out in accordance with OPSS 501 dated November 2010. Backfill for a conventional 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)  
 $\gamma$  = bulk unit weight of retained soil (see Tables 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 $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	Native silt and sand $\phi = 29^\circ$ $\gamma = 20 \text{ kN/m}^3$
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 earth pressure calculation, 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.

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 creek 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 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 piezometer installed in Borehole KN11-03 revealed artesian conditions at the site, with groundwater level measured 0.3 m (elevation 99.3) above ground surface. The water level of Kenel Creek at the site (inside the existing culvert) is indicated in the GA at elevation 98.38.

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 culvert 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 III. Therefore, according to Table 4.4 of the CHBDC, a Site Coefficient “S” (ground motion amplification factor) of 1.5 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 $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	Native Silt or sand $\phi = 30^\circ$ $\gamma = 21.2 \text{ kN/m}^3$
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 potential for liquefaction of the foundations soils was assessed using the Seed and Idriss (1971) method<sup>1</sup>. Using this method, it is estimated that under the existing conditions the foundation soils are not prone to liquefaction.

The existing embankments are above the groundwater level and are not considered to be in danger of undergoing liquefaction. Some toe failure may occur but it is expected to be of limited nature and readily repairable.

<sup>1</sup> Seed, H.B. and Idriss, I.M. 1971, “Simplified Procedure for Evaluating Soil Liquefaction Potential” *Journal of Soil Mechanics and Foundations Division*, ASCE, Vol. 101, No. SM9, September, pp. 1249-1273.

### 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 have to be implemented to facilitate staging of removals and support the existing Highway 17 adjacent to the excavation.

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

Conventional steel soldier pile and timber lagging walls is one option 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.

$\gamma$	=	20 kN/m <sup>3</sup>	(bulk unit weight)
$\gamma_w$	=	10 kN/m <sup>3</sup>	(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)
$h_w$	=	98.38	(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:

- Potential for encountering cobbles/boulders exists in the embankment fill. Sheet piles should be protected with sheet pile tip protector.
- Groundwater levels were encountered above the existing ground level. If artesian groundwater flow is observed during pile driving, or any other construction activities, the contractor or QVE must immediately advise the CA. The CA should refer this issue to the design team.
- Potential variability of pile lengths due to probable bedrock or boulders contacted at depths ranging from 6.1 m to 10.4 m (elevations 91.1 to 92.9). It is possible that piles will achieve refusal at variable depths.
- Excavation below the water level, if required, will involve lowering of the groundwater level below the excavation base to maintain a reasonably dry excavation.
- 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.
- The side embankment slopes should be inspected after construction for surficial disturbance. Where necessary, erosion control measures must be implemented.

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 <sup>(1)</sup> '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<sub>pen</sub>

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 KN11-01

1 OF 1

METRIC

W.P. 6026-07-00 LOCATION N 4 990.1 E 1 021.3 Kenel Creek Culvert ORIGINATED BY GA  
 HWY 617 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2011.04.30 - 2011.04.30 CHECKED BY LRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
99.3														
0.0	ORGANICS, mixed with silty clay Dark Brown		1	SS	12		99							
99.0														
0.3	SILT, some clay Compact Grey Damp to Moist		2	SS	18		98							
			3	SS	20		97							
			4	SS	20		96							0 0 89 11
			5	SS	18		95							
94.7														
4.6	Sandy SILT, trace clay Loose to Very Loose Grey Wet		6	SS	5		94							
			7	SS	3		93							0 29 67 4
							92							
91.7														
7.6	END OF BOREHOLE AT 7.6m UPON AUGER REFUSAL ON PROBABLE BEDROCK OR BOULDERS. BOREHOLE OPEN TO 7.6m AND WATER LEVEL AT 4.5m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.													

ONTMT4S 0840.GPJ 12/12/11

+ <sup>3</sup> . X <sup>3</sup> : Numbers refer to Sensitivity 20 15 10 5 (%) STRAIN AT FAILURE

## 1 OF 1

METRIC

W.P.	6026-07-00	LOCATION	N 4 990.2 E 1 019.1 Kenel Creek Culvert	ORIGINATED BY	GA
HWY	617	BOREHOLE TYPE	Dynamic Cone Penetration Test	COMPILED BY	AN
DATUM	Geodetic	DATE	2011.04.30 - 2011.04.30	CHECKED BY	LRB

[illegible]

ONTMT4S 0840.GPJ 12/12/11

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No KN11-02

1 OF 2

METRIC

W.P. 6026-07-00 LOCATION N 4 997.4 E 1 024.4 Kenel 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			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
101.5	ASPHALT: (40mm)		1	SS	18		101					
97.8	SAND, some gravel, trace to some silt and clay Compact to Dense Brown Damp (FILL)		2	SS	40		100					
	Very Dense Occasional cobbles and boulders from 1.8m to 2.9m		3	SS	50/ 0.150		99					
			4	SS	50/ 0.100		98					
	Compact		5	SS	21		97					
97.8	SILT, some clay Compact Light Grey Wet		6	SS	18		96					
			7	SS	13		95					
94.0	SAND, trace silt Loose Grey Wet		8	SS	4		94					
			9	SS	4		93					
							92					

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No KN11-02

2 OF 2

METRIC

W.P. 6026-07-00 LOCATION N 4 897.4 E 1 024.4 Kenel 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 <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W <sub>P</sub>	W	W <sub>L</sub>		
91.1	SAND, trace silt Loose Grey Wet																
10.4	Continued From Previous Page  END OF BOREHOLE AT 10.4m UPON AUGER REFUSAL ON PROBABLE BEDROCK OR BOULDERS. BOREHOLE OPEN TO 10.4m AND WATER LEVEL AT 4.0m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG FROM 10.4m TO 0.15m, THEN ASPHALT PATCH TO SURFACE.																

ONTMT4S 0840.GPJ 12/12/11

# RECORD OF BOREHOLE No KN11-03

1 OF 1

METRIC

W.P. 6026-07-00 LOCATION N 5 020.9 E 1 029.1 Kenel Creek Culvert ORIGINATED BY GA  
 HWY 617 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2011.04.30 - 2011.04.30 CHECKED BY LRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  γ  kN/m <sup>3</sup>	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		
99.0							20 40 60 80 100										
0.0	ORGANICS, mixed with sand Grey		1	SS	5		99										
98.6																	
0.4	SILT, trace to some clay Loose to Compact Light Grey Wet		2	SS	13		98										
			3	SS	17		97										
			4	SS	16		96								0 0 91 9		
			5	SS	22		95										
							94								0 0 89 11		
	Loose		6	SS	5												
92.9							93										
6.1	END OF BOREHOLE AT 6.1m UPON AUGER REFUSAL ON PROBABLE BEDROCK OR BOULDERS. WATER LEVEL OBSERVED AT 0.3m 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 0.3* 99.3 May04/ 11 0.3* 99.3 May05/ 11 0.3* 99.3  * Artesian condition (Above ground surface)																

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No DCPT-KN11-03

1 OF 1

METRIC

W.P. 6026-07-00 LOCATION N 5 021.1 E 1 026.5 Kenel Creek Culvert ORIGINATED BY GA  
HWY 617 BOREHOLE TYPE Dynamic Cone Penetration Test COMPILED BY AN  
DATUM Geodetic DATE 2011.04.30 - 2011.04.30 CHECKED BY LRB

SOIL PROFILE		SAMPLES				GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>		
99.0 0.0	Start DCPT from surface.						99							
							98							
							97							
							96							
							95							
							94							
							93							
92.2 6.8	END OF DCPT AT 6.7m.													

+<sup>3</sup>, X<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

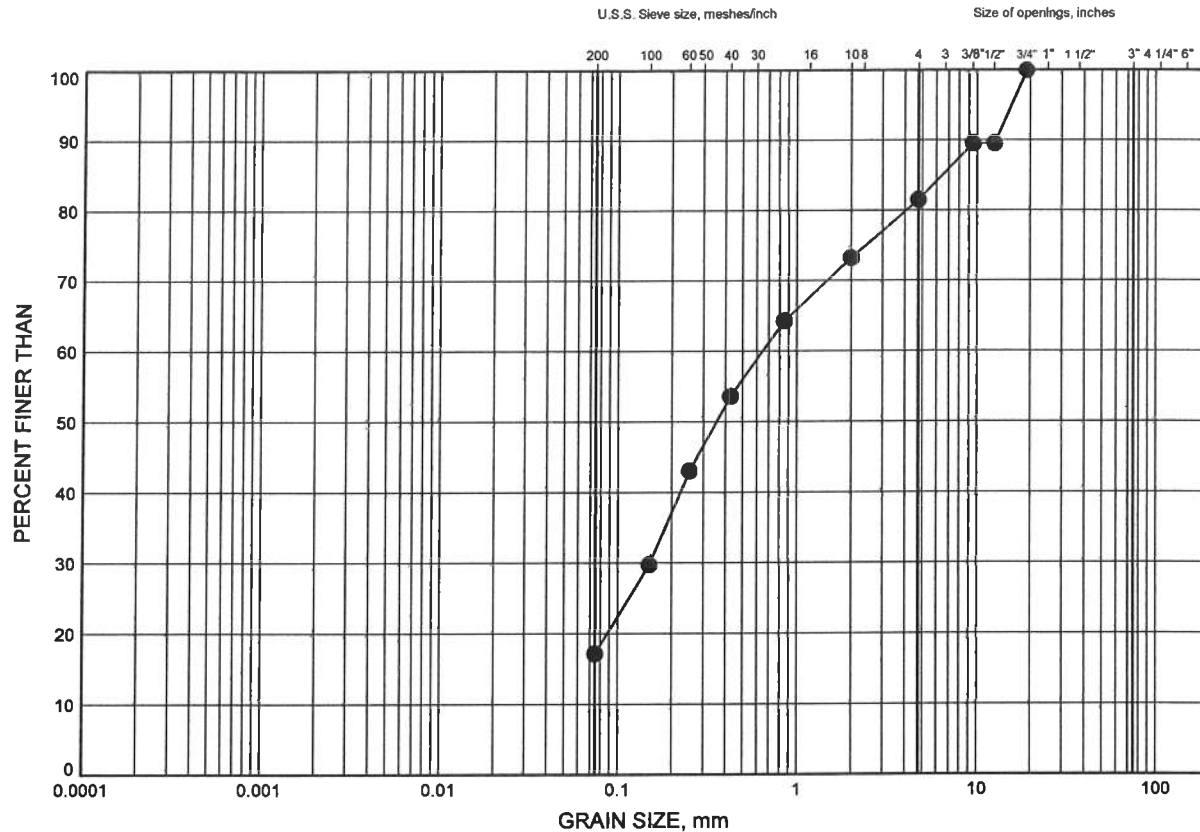


**Appendix B**  
**Laboratory Test Results**

# NWR HWY 11 Bridge GRAIN SIZE DISTRIBUTION

FIGURE B1

## SAND FILL



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

### LEGEND

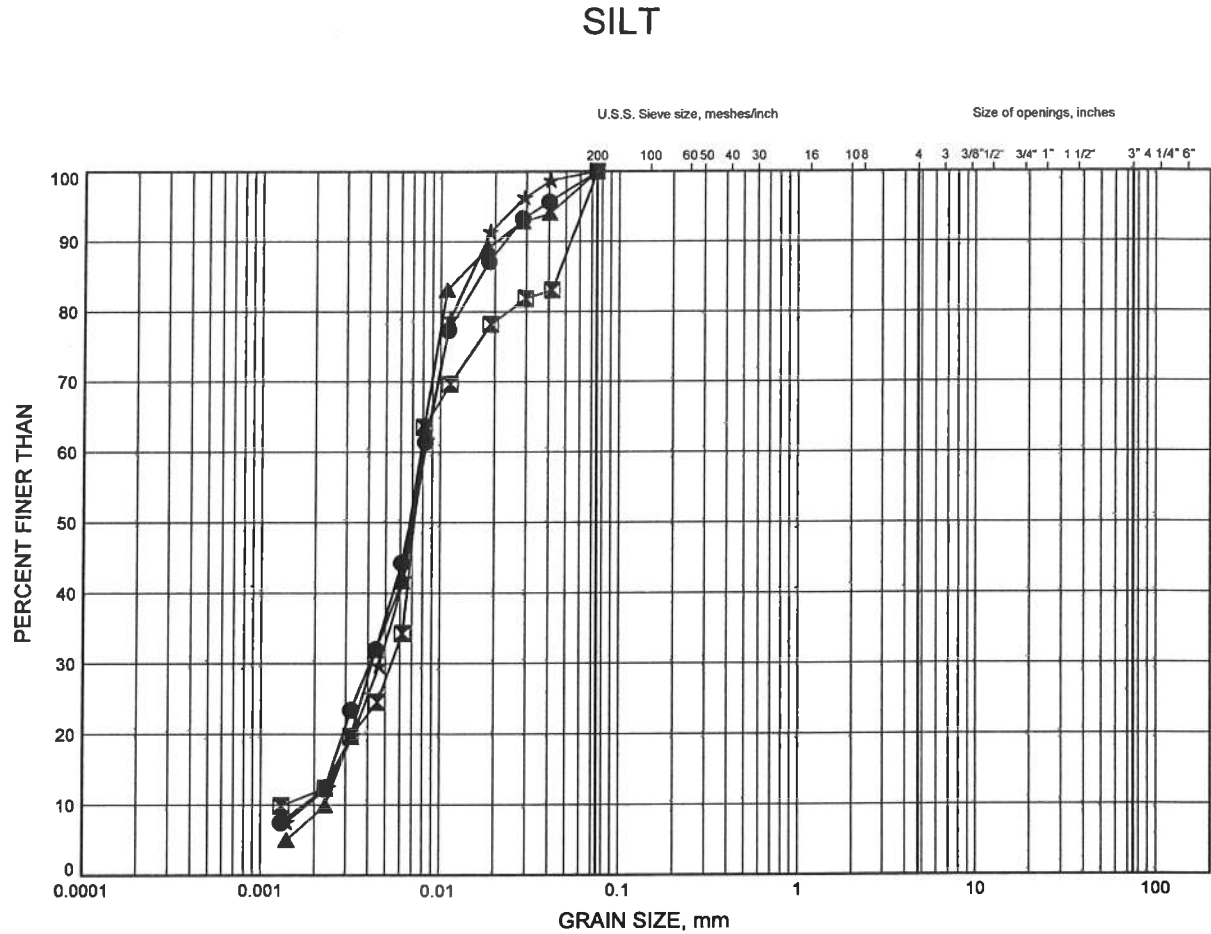
SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KN11-02	3.35	98.15



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 SIZE
FINE GRAINED	SAND			GRAVEL		

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KN11-01	2.57	96.73
■	KN11-02	4.88	96.62
▲	KN11-03	2.57	96.43
★	KN11-03	4.88	94.12

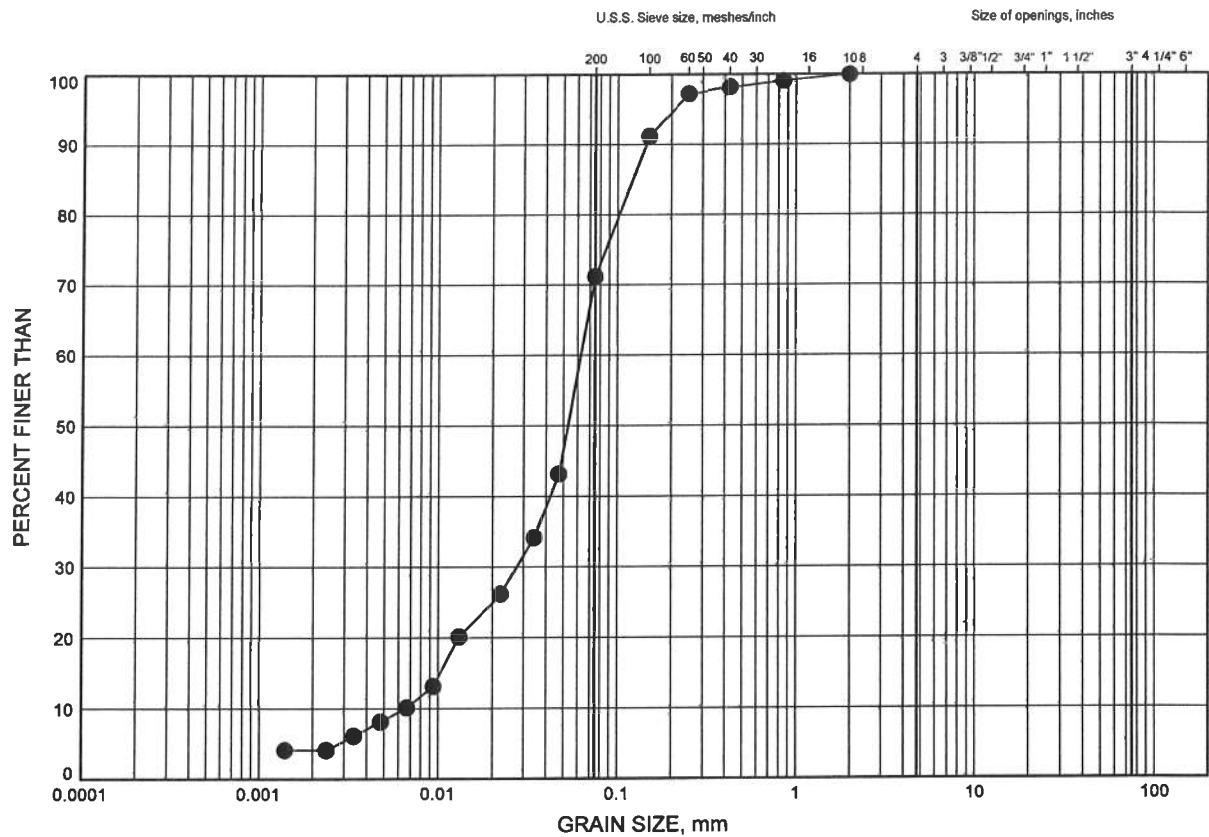


W.P.# 19-5308-40  
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Checked By LRB

# NWR HWY 11 Bridge GRAIN SIZE DISTRIBUTION

FIGURE B3

## SANDY SILT



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KN11-01	6.40	92.90



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

**Appendix C**  
**Site Photographs**

Kenel Creek Culvert Replacement  
Highway 17, Site 48E-66C

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**Photograph 1** – Kenel Creek Culvert, north end



**Photograph 2** – Kenel Creek Culvert, south end

**Appendix D**  
**Foundation Comparison**

**COMPARISON OF FOUNDATION ALTERNATIVES FOR EACH FOUNDATION ELEMENT**

Driven Sheet Piles	Driven H-Piles	Footings on Native Soil	Caissons
<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Minimizes potential for disturbance of streambed.</li> <li>ii. Ease of construction.</li> <li>iii. Provides shoring and foundation elements in one operation.</li> <li>iv. Installation of piles could continue in freezing weather.</li> <li>v. Potentially minimizes volume of excavation.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Unconventional design.</li> <li>ii. Cost of sheet piles.</li> </ul> <p><b>RECOMMENDED</b></p>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Higher geotechnical resistances can be achieved if piles are driven to refusal.</li> <li>ii. Installation of piles could continue in freezing weather</li> <li>iii. Foundation construction may require less volume of excavation than footings.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Higher unit costs than footings.</li> <li>ii. Pile lengths required to achieve design resistance may vary.</li> </ul> <p><b>FEASIBLE</b></p>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Generally less costly construction than deep foundation elements.</li> <li>ii. Conventional culvert design is feasible.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Low available geotechnical resistance in native silt deposit.</li> <li>ii. Excavation to base of existing roadway embankment is required for footing construction.</li> <li>iii. Dewatering and stream diversion will be required.</li> <li>iv. Potential disturbance of creek during excavation.</li> </ul> <p><b>NOT RECOMMENDED</b></p>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Construction of caissons could continue in freezing weather.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Higher cost than spread footings</li> <li>ii. Specialized installation measures such as temporary liners and drilling mud will be required to install caissons in cohesionless soils under the water table.</li> <li>iii. Potential difficulty in cleaning and inspecting bases.</li> </ul> <p><b>NOT RECOMMENDED</b></p>



## **Appendix E**

### **List of SPs and OPSS, and Suggested Text for NSSP**

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

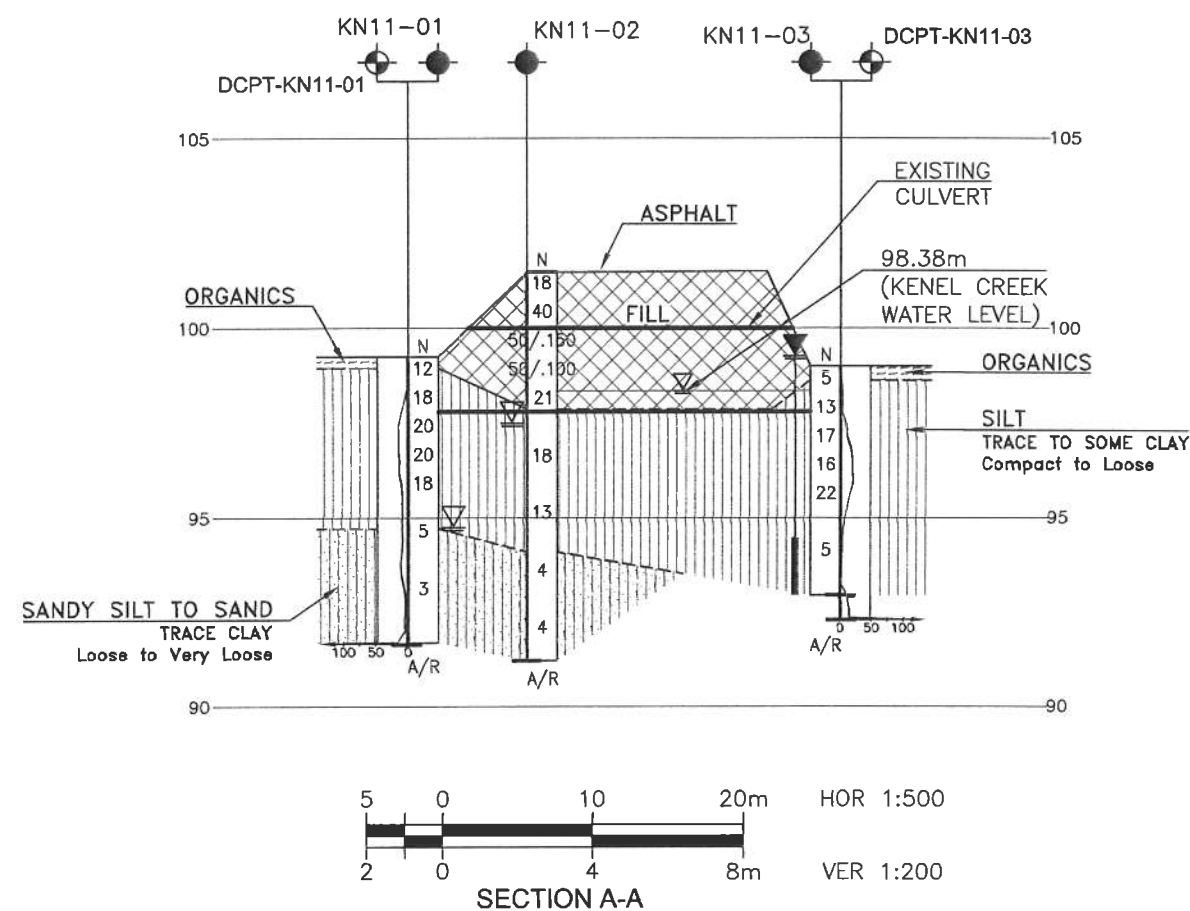
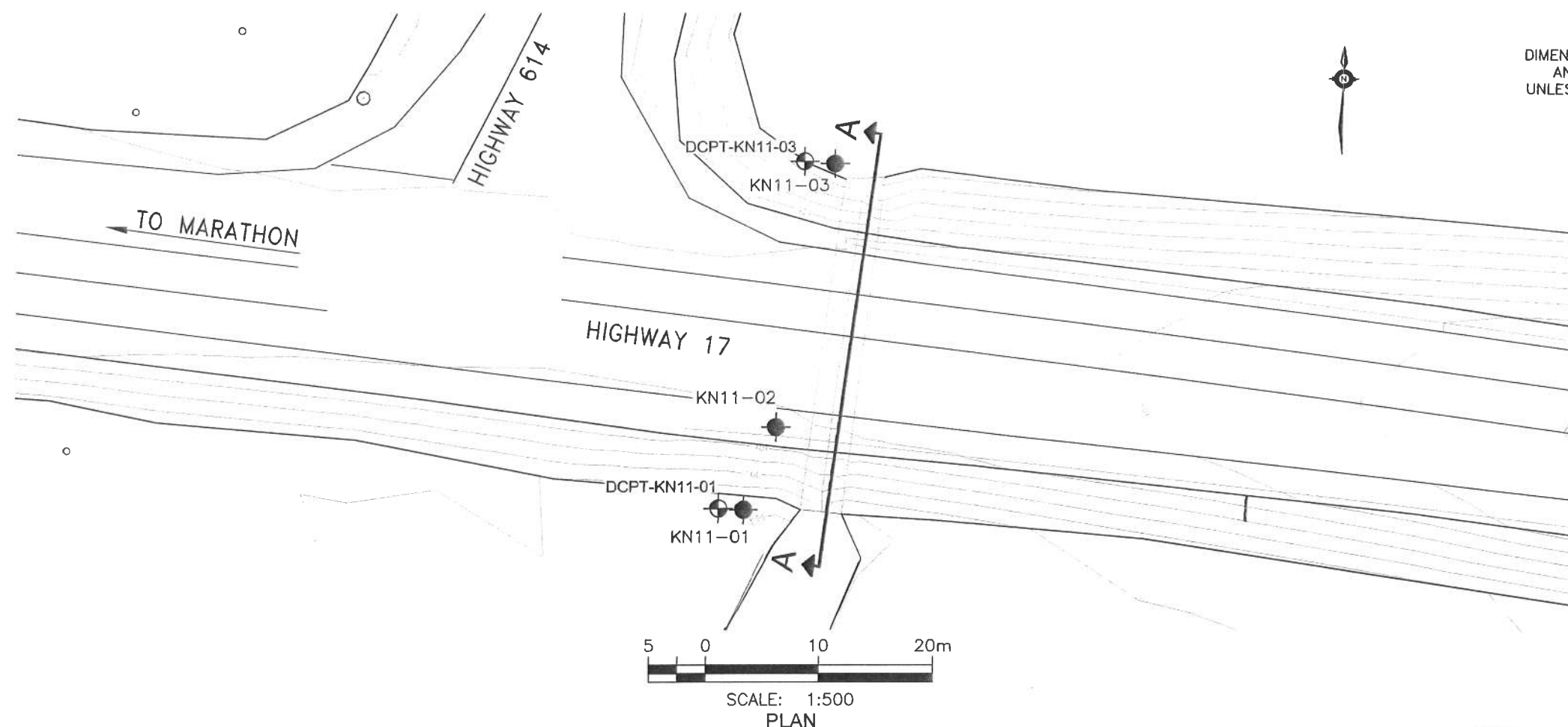
- OPSS 903, November 2009
- OPSS 501 dated November 2010
- OPSD 810.010
- OPSS 804, November 2010
- OPSS 902, November 2010
- OPSS 539

**2. Suggested text for a NSSP on Pile Installation**

If a pile meets refusal at a depth less than the anticipated depth, the QVE must terminate driving before the pile is damaged due to over-driving

## **Appendix F**

### **Borehole Locations and Soil Strata Drawings**



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

CONT No 2011-6025  
GWP No 6026-07-00  
WP No 6026-07-01



KENEL CREEK CULVERT  
REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA

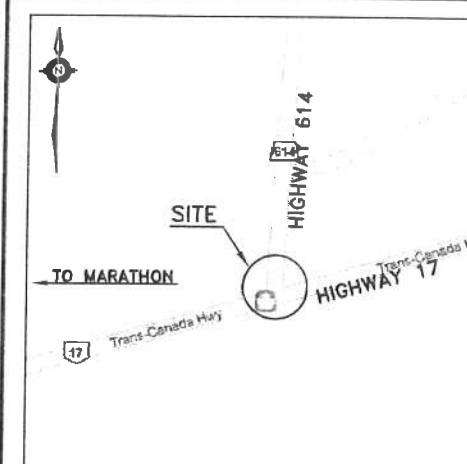
SHEET  
20








# GENIVAR



**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/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
KN11-01	99.3	4 990.1	1 021.3
KN11-02	101.5	4 997.4	1 024.4
KN11-03	99.0	5 020.9	1 029.1
DCPT-KN11-01	99.3	4 990.2	1 019.1
DCPT-KN11-03	99.0	5 021.1	1 026.5

-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. 42C-25**

REVISIONS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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