



**THURBER** ENGINEERING LTD.



**FOUNDATION INVESTIGATION AND DESIGN REPORT  
DILKE CREEK NO. 2 CULVERT REPLACEMENT  
HIGHWAY 11, TOWNSHIP OF DILKE  
DISTRICT OF RAINY RIVER, ONTARIO**

**G.W.P. No. 6813-14-00, W.P. No. 6342-14-00, SITE No. 45-149/C**

**GEOCRES Number: 52D-30**

**Report**

**to**

**HATCH**

Date: February 17, 2017  
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**PART 1: FACTUAL INFORMATION**

**1. INTRODUCTION**

This report presents the factual data obtained from a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) for the proposed replacement of the Dilke Creek Timber Culvert on Highway 11, located east of Rainy River, in the Township of Dilke, District of Rainy River, Ontario.

The purpose of this investigation was to explore the subsurface conditions at the culvert location and, based on the data obtained, to provide a borehole location plan, stratigraphic profile, records of boreholes, laboratory test results, and a written description of the subsurface conditions.

Thurber was retained by Hatch Ltd. (Hatch) to carry out this foundation investigation under the Ministry of Transportation Ontario (MTO) Agreement Number 6015-E-0018-005.

**2. SITE DESCRIPTION**

The site is located on Highway 11, approximately 8 km west of Highway 617, in the Township of Dilke, Ontario. The existing culvert allows Dilke Creek to flow in a southwesterly direction under Highway 11 towards Rainy River. Highway 11 generally runs in a northwest to southeast direction at the culvert site.

The Ontario Structure Inspection Manual (Inspection Form) prepared by MTO on Nov. 2, 2015 indicates that the existing structure is a double-cell timber box culvert, approximately 30.6 m long and 4.2 m wide with approximately 2.6 m fill above the culvert. The inspection report indicated that the structure is in an overall poor condition.

The lands surrounding the culvert site predominantly consist of agricultural lands dotted with

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forested areas. Dilke Creek discharges into Rainy River approximately 150 m southwest of the culvert. Rainy River runs generally parallel to the highway alignment in the area. Local topography is of low relief with no evident bedrock outcrops.

Photographs of the culvert and surrounding areas are presented in Appendix C.

Based on published geological information, the culvert lies within glaciolacustrine fine-grained deposits of silt and clay and silty clay to clayey silt till. Bedrock at the site is identified as felsic to intermediate metavolcanic rocks.

### **3. INVESTIGATION PROCEDURES**

The site investigation and field testing program for this project was carried out on August 27 and 28, 2016, and consisted of drilling and sampling four (4) boreholes (16-42 to 16-45). Boreholes 16-43 and 16-44 were drilled through the paved portion of Highway 11, north and south of the existing culvert. Boreholes 16-42 and 16-45 were drilled near the inlet/outlet of the existing culvert.

The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawing included in Appendix D.

Utility clearances were obtained prior to the start of drilling. The ground surface elevations for the boreholes were estimated from the cross sections and topographic drawings provided to Thurber by Hatch. The coordinate system MTM NAD 83, Zone 16 was used for these boreholes.

A rubber track mounted drill rig was used to advance the boreholes using hollow stem augers. Soil samples were obtained in the boreholes at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Field vane shear testing using a MTO “N” size shear vane was carried out in the cohesive soils.

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 throughout the drilling operations and in the open boreholes upon completion of drilling. The boreholes were backfilled in general accordance with Ontario Regulation 903. A piezometer was installed in BH 16-42 for monitoring of groundwater level.

Completion details of the boreholes and the piezometer are summarized in Table 3.1.

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**Table 3.1 – Borehole Completion Details**

Borehole Number	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
16-42	12.5 / 319.5	9.1 / 322.9	Bentonite holeplug from 12.5 m to 9.1 m, sand filter from 9.1 m to 5.8 m, then bentonite holeplug from 5.8 m to ground surface.
16-43	14.3 / 319.0	None installed	Borehole backfilled with bentonite holeplug and auger cuttings to 0.1 m, then asphalt to surface.
16-44	14.3 / 319.0	None installed	Borehole backfilled with bentonite holeplug and auger cuttings to 0.1 m, then asphalt to surface.
16-45	9.8 / 319.7	None installed	Borehole backfilled with bentonite holeplug and cuttings to ground surface.

#### **4. LABORATORY TESTING**

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

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the structure, a sample of the native soil, and a sample of the surface water from the creek upstream of the existing culvert were collected and submitted to SGS Canada Inc., a CALA accredited analytical laboratory in Lakefield, Ontario, for analytical testing of corrosivity parameters. The results of the analytical testing are summarized in this report and also presented 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 on the Record of Borehole sheets and on the Borehole Locations and Soil Strata drawing included in Appendix D. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes

precedence over this general description and must be used for interpretation of the site conditions. It must be recognized and expected that soil conditions may vary between and beyond the borehole locations.

In general, the subsurface conditions encountered below the existing embankment fill consisted of glaciolacustrine silty clay underlain by sandy silty clay till. Descriptions of the individual strata are presented below.

### **5.1 Asphalt**

Boreholes 16-43 and 16-44 were drilled through the paved portion of Highway 11. The asphalt was approximately 100 mm thick in both boreholes.

### **5.2 Topsoil**

Topsoil was encountered in Boreholes 16-42 and 16-45 drilled near the inlet and outlet of the existing culvert. The thickness of the topsoil ranged from 25 to 50 mm. The topsoil thickness may vary between and beyond the borehole locations and the data is not intended for the purpose of estimating quantities of topsoil removal.

### **5.3 Fill**

Embankment fill was encountered in Boreholes 16-43 and 16-44, and beneath the topsoil in Borehole 16-42. The fill was predominantly cohesionless consisting of gravelly sand to sand except in Borehole 16-44 where 0.8 m thick silty clay fill was encountered below the gravelly sand fill. The fill ranged from 2.1 to 2.9 m in thickness and extended to Elevation 330.4 to 329.9 m.

The SPT 'N' values of the fill ranged from 3 to 33 blows for 0.3 m penetration, indicating very loose to dense relative density. The measured moisture content ranged from 3% to 9% in the gravelly sand to sand fill and was 28% in the silty clay fill.

The results of grain size analyses conducted on samples of the cohesionless fill are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B1 of Appendix B. The results are summarized as follows:

Gravel %	1 to 21
Sand %	63 to 90
Silt and Clay %	9 to 16

## 5.4 Silty Clay

Grey silty clay was encountered beneath the embankment fill, at 2.1 to 3.0 m depth (Elevations 329.9 to 330.4), in Boreholes 16-42 to 16-44. The silty clay contained trace to some sand with trace organic staining. The silty clay layer was approximately 1.1 to 3.5 m thick and extended to 4.1 to 5.6 m depth (Elevations 326.4 to 329.2) in Boreholes 16-42 to 16-44.

SPT 'N' values recorded in the silty clay ranged between 2 to 6 blows for 0.3m penetration, indicating a soft to firm consistency. Measured moisture contents in the clay ranged from 35% to 47%. A field shear vane test carried out in the silty clay measured an undrained shear strength of 54 kPa, indicating a stiff consistency.

The results of grain size analyses conducted on samples of the silty clay are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B2 of Appendix B. The results are summarized as follows:

Gravel %	0
Sand %	10 to 15
Silt %	14 to 19
Clay %	71

## 5.5 Sandy Silty Clay Till

A layer of grey sandy silty clay till was encountered in all boreholes beneath the silty clay, with the exception of Borehole 16-45 where it was encountered immediately beneath the topsoil. The till generally contains trace gravel. Till formations are known to contain cobbles and boulders. All boreholes were terminated within the till deposit at depths ranging from 9.8 to 14.3 m (Elevation 319.0 to 319.7).

SPT 'N' values recorded in the silty clay till varied between 3 and 14 blows for 0.3 m penetration. The field vane shear test (VST) measured in-situ undrained shear strength ranging from 52 kPa to greater than 100 kPa. Based on the SPT and VST data, the consistency of the silty clay till is typically stiff to very stiff. Lower SPT 'N' values of 0 to 2 blows per 0.3 m of penetration were measured within the upper 2 m of the till in Borehole 16-45, indicating presence of streambed deposit. The sensitivity of the till, calculated as a ratio of undisturbed strength to remoulded strength, ranged from 2 to 4, indicative of low sensitivity.

Natural moisture contents in the silty clay till ranged from 16% to 21%.



The results of grain size analyses conducted on samples of the silty clay till are provided on the Record of Borehole sheets in Appendix A and illustrated in Figures B3 and B4 of Appendix B. The results are summarized as follows:

Gravel %	0 to 7
Sand %	25 to 31
Silt %	36 to 43
Clay %	25 to 33

The results of Atterberg Limits tests conducted on samples of the silty clay till are provided on the Record of Borehole sheets in Appendix A and illustrated in Figures B5 and B6 of Appendix B. The results are summarized as follows:

Liquid Limit	27 to 32
Plastic Limit	12 to 14
Plasticity Index	14 to 20

The results of the Atterberg Limits testing indicate that the sandy silty clay till has a low plasticity with group symbol CL.

## 5.6 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes upon completion of drilling. The groundwater levels measured in the open borehole is summarized in Table 5.1 below.

**Table 5.1 – Groundwater Measurements**

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
16-42	August 27, 2016	Dry	-	Open borehole
16-43	August 27, 2016	Dry	-	Open borehole
16-44	August 28, 2016	Dry	-	Open borehole
16-45	August 28, 2016	0.6	328.9	Open borehole

The groundwater level should be assumed to reflect the local creek water level. The above groundwater levels are short-term readings and seasonal fluctuations of the groundwater levels are to be expected. In particular, the groundwater levels may be at a higher elevation during spring and after periods of significant or prolonged precipitation.

## 6. CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the native silty clay till from Borehole 16-45, and a sample of the surface water from the creek were submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in Table 6.1. The laboratory certificates of analysis are presented in Appendix B.

**Table 6.1 – Analytical Test Results**

Parameter	Units (Soil)	Units (Water)	Test Results	
			16-45 SS#3 1.7 m	Dilke Creek
			(Silty Clay)	(Creek Water)
Corrosivity Index	-	-	4	4
Sulphide	%	mg/L	0.07	0.74
Chloride	µg/g	mg/L	23	180
Sulphate	µg/g	mg/L	260	9.4
pH	-	-	8.21 - 9.10	7.58
Conductivity	µS/cm	µS/cm	90	1360
Resistivity	Ohms.cm	MOhms.cm	11100	3630
Redox Potential	mV	mV	160	275

## 7. MISCELLANEOUS

Thurber obtained subsurface utility clearances prior to drilling. The northing and easting coordinates and ground surface elevations were estimated based on field measurements relative to the topographic plans provided by Hatch.

RPM Drilling Inc. of Thunder Bay, Ontario supplied and operated the drilling, sampling and in-situ testing equipment for the field investigation. The field investigation was supervised on a full time basis by Mr. Tim Sivak of Thurber. Overall supervision of the field program was provided by Mr. Mark Farrant, P.Eng. of Thurber.

Geotechnical laboratory testing was carried out in Thurber's geotechnical laboratory. Analytical laboratory testing was carried out by SGS Canada Inc.

Interpretation of the field data and preparation of this report was carried out by Mr. Cory Zanatta, EIT 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**

**8. GENERAL**

This report provides an interpretation of the geotechnical data in the factual report, and presents foundation design recommendations for design of the proposed Dilke Creek Culvert replacement on Highway 11, located in the Township of Dilke, District of Rainy River, Ontario.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The design-build contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

Information on the existing culvert site was obtained from the MTO Terms of Reference and the Ontario Structure Inspection Manual (Inspection Form) prepared by MTO on November 2, 2015. Based on the MTO Terms of Reference and a highway profile drawing provided by Hatch, the existing structure is a double-cell timber box culvert. Each cell measures 2.1 m wide and 1.75 m high. The culvert is approximately 30.6 m long. The estimated culvert invert is at approximate Elevation 329.2 m at the inlet (east) and 328.8 m at the outlet (west). The existing road grade at the culvert location is at approximate Elev. 333.3 m, which indicates approximately 2.6 m of fill above the culvert.

Detailed information for the culvert design has not been provided. However, it is understood that the invert level and alignment of the replacement culvert will remain the same as those of the

existing culvert and no grade raise will be required for the approach embankment at this site.

## **9. CULVERT DESIGN**

### **9.1 Culvert Alternatives**

This section presents discussions on available types of replacement culverts and foundation alternatives, and provides recommendations on preferred foundation options.

Several common culvert types that may be considered for the culvert replacement at this site are listed below:

- Concrete pipe or Corrugated steel pipe (CSP)
- Concrete box (closed) culvert composed of pre-cast segments
- Concrete open frame culvert on spread footings

A comparison of the culvert types and foundation alternatives based on their respective advantages and disadvantages is included in Appendix E. From a foundations and constructability perspective, use of the CSP or precast box culverts are both feasible options, based on the following considerations:

- Precast box culvert or pipe culvert would require shallower depth of excavation compared with the open footing culvert;
- Pre-cast concrete box or pipe segments can often be installed more expeditiously than cast-in-place open footing culvert, resulting in shorter durations for dewatering and construction;
- A segmental box or pipe structure can accommodate some potential differential settlement along the culvert axis.

Recommendations for the design and installation of concrete pipe or CSP, concrete box and open footing concrete culverts are presented below.

### **9.2 Foundation Design for Culverts**

It is anticipated that the invert level of the replacement culvert will be similar to the invert of the existing culvert and no grade raise or embankment widening is proposed. There is approximately

2.6 m of fill above the existing culvert. Foundation design aspects for the replacement culvert includes subgrade conditions and preparation, geotechnical capacities, settlement of founding soils, lateral earth pressures, roadway protection system design, groundwater control, staged construction, and restoration of the roadway embankment.

### **9.2.1 Concrete Pipe or Corrugated Steel Pipe Culvert**

Replacement of the culvert with a concrete pipe or CSP on the same alignment may be considered for this site. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading due to the culvert replacement.

If this alternative is selected, the concrete pipe or CSP should be placed on a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements as per OPSD 802.034 or 802.010. The bedding material should be placed on the prepared subgrade as soon as practical, following its inspection and approval. The subgrade preparation and placement and compaction of bedding must be carried out in the dry. Construction equipment must not be allowed to travel on the bedding or the prepared subgrade, which must be protected from disturbance during construction.

The underside of the bedding layer should be placed at or below Elevation 329 m, which corresponds to firm to stiff silty clay/silty clay till subgrade. Very soft to soft silty clay till deposit was encountered to a depth of 1.5 m in Borehole 16-45 drilled approximately 8 m west of the existing culvert outlet. If similar soil conditions are encountered at the outlet of the replacement culvert, the very soft to soft deposit should be sub-excavated and replaced with compacted granular material to provide a uniformly competent subgrade condition.

### **9.2.2 Concrete Box Culvert**

Replacement of the culvert with a concrete box culvert on the same alignment is considered a viable alternative for this site. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading due to the culvert replacement.

In order to provide a uniform foundation subgrade, a 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements should be provided under the base of the box culvert, as shown on OPSD 803.010. The bedding material must be placed on the prepared subgrade as soon as practicable following its

inspection and approval. The subgrade preparation and placement and compaction of the bedding material must be carried out in the dry. The surface prepared to support the box units should have a minimum 75 mm thick top levelling course consisting of uncompacted Granular A as per OPSS 422. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which must be protected from disturbance during construction.

The underside of the bedding layer should be placed at or below Elevation 329. The native soils at that level consist of predominantly firm to stiff silty clay and silty clay till. Very soft to soft silty clay till deposit was encountered to a depth of 1.5 m in Borehole 16-45 drilled approximately 8 m west of the existing culvert outlet. If similar soil conditions are encountered at the outlet of the replacement culvert, the very soft to soft deposit should be sub-excavated and replaced with compacted granular material to provide a uniformly competent subgrade condition.

The following geotechnical capacities could be used for design of a box culvert of 4 to 5 m in width founded at or below Elevation 329 m on the firm to stiff silty clay and silty clay till subgrade:

- Factored Geotechnical Resistance at ULS of 190 kPa
- Geotechnical Resistance at SLS (for up to 25 mm of settlement) of 110 kPa

The consequence factor of 1.0 was utilized in this design adopting the typical consequence level. The geotechnical resistance factor of 0.5 for bearing and 0.8 for settlement, both adopted for typical degree of understanding, were used to obtain the above values, as per CHBDC 2014, Section 6.9.

The ULS resistance and settlement are dependent on the footing/culvert size, configuration and applied loads; the geotechnical resistances should therefore be reviewed if the culvert width or founding/invert elevation differs significantly from that given above.

The geotechnical resistances provided above are for vertical, concentric loading conditions. Where eccentric or inclined loads are applied, the resistance values used in design must be reduced in accordance with the CHBDC 2014, Clause 6.10.3 and Clause 6.10.4.

Resistance to sliding between the concrete slabs and the underlying Granular A or B Type II should be calculated assuming an ultimate coefficient of friction of 0.45.

The culvert should be designed to resist external loadings including frost forces, lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loadings and surcharge due to construction equipment.

### 9.2.3 Open Footing Concrete Culvert

Spread footings supporting an open frame concrete culvert should be founded on the stiff silty clay/silty clay till below the frost depth at or below Elevation 326.5 m. The footings should extend below any existing embankment fill and surficial organic materials, where encountered.

The recommended geotechnical resistances at the factored Ultimate Limit State (ULS) and the geotechnical reaction at Serviceability Limit State (SLS) for a 2 m wide footing founded at the above subgrade material:

- Factored Geotechnical Resistance at ULS of 175 kPa
- Geotechnical Resistance at SLS (for up to 25 mm of settlement) of 110 kPa

The above assumes that there is no grade raise. The consequence factor of 1.0 was utilized in this design adopting the typical consequence level. The geotechnical resistance factor of 0.5 for bearing and 0.8 for settlement, both adopted for typical degree of understanding, were used to obtain the above values, as per CHBDC 2014, Section 6.9.

The resistance values provided above are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance used in design must be reduced in accordance with the CHBDC Clause 6.10.3 and Clause 6.10.4.

Resistance to sliding between precast concrete and the underlying silty clay and silty clay till should be evaluated in accordance with the CHBDC (2014) assuming an ultimate coefficient of friction of 0.35.

All organic soil and excessively loose/soft material should be removed from the footing subgrade and granular material meeting OPSS.PROV 1010 Granular A or Granular B Type II requirements and compacted as per OPSS.PROV 501. The founding surface should be protected from softening during construction by placement of a 75 mm mud slab on the prepared bearing surface as soon as practical following inspection and approval. Subgrade preparation and construction of footings must be carried out in the dry.



## **9.2.4 Culvert Headwall / Wingwalls**

If headwalls or wingwalls are required, consideration may be given to the use of Retained Soil Systems (RSS) wall or cantilevered concrete wall. RSS walls are relatively more tolerant to some differential settlement.

The borehole information indicates that the founding soils at the inlet/outlet generally consist of the firm to stiff silty clay and silty clay till deposit. Very soft to soft silty clay till deposit was encountered to a depth of 1.5 m in Borehole 16-45 drilled approximately 8 m west of the existing culvert outlet. If similar soil conditions are encountered at the outlet of the replacement culvert, the very soft to soft deposit should be sub-excavated and replaced with compacted granular material to provide a competent subgrade condition.

### **9.2.4.1 RSS Walls**

For RSS walls, the contract drawings should include information on the longitudinal alignment of the wall in plan, the top and base elevations of the wall in profile, cross-sectional space constraints and an NSSP for the RSS wall.

The performance of a RSS is dependent on, among other factors, the characteristics of its foundation. Failure to provide an adequate foundation may lead to settlement and distortion of the RSS mass and, in severe cases, to possible failure of the system. The foundation under the entire RSS mass must be considered, i.e. from the face of the wall to the furthest extent of the reinforcement.

The RSS mass should be founded on a 0.5 m thick engineered fill pad resting on the native firm to stiff silty clay/silty clay till subgrade at or below approximate Elevation 328 m. An RSS wall founded on this subgrade material may be designed using a factored geotechnical resistance at ULS of 150 kPa and a geotechnical reaction at SLS of 100 kPa (up to 25 mm of settlement). Engineered fill pad placed under the RSS mass must consist of OPSS.PROV 1010 Granular A or Granular B Type II compacted to 100% of its SPMDD at a moisture content within 2% of optimum. The engineered pad must be at least 300 mm beyond the limits of the RSS mass and levelling strip.

The geotechnical resistances provided above are for concentric, vertical loading. The effects of load inclination and eccentricity need to be taken into account according to the CHBDC (2014) Clauses 6.10.3 and 6.10.4.

The entire block of reinforced earth must be designed against various modes of failure including sliding and overturning. Sliding resistance along the base of the wall may be estimated using an ultimate friction coefficient of 0.45 for an engineered granular fill subgrade.

Topsoil, organics, loose fill, and any soft/wet material must be stripped from the footprint of the RSS. The subgrade under the RSS foundation should be inspected and any soft spots sub-excavated and replaced with compacted granular materials prior to placing fill. The subgrade preparation for the RSS wall and placement and compaction of the granular fill must be carried out in the dry.

A geotextile filter fabric must be incorporated in the RSS design to prevent loss of fines from granular material behind the wall subject to fluctuating water level.

The proprietary RSS system must meet MTO's specifications for performance and appearance. The RSS supplier/designer may specify more stringent criteria or other requirements related to the particular design. The internal stability of the RSS wall must be analyzed by the supplier/designer of the proprietary product selected for this site.

Lateral earth pressures acting on the wingwalls should be computed as described in Section 12. If the wall is retaining sloping backfill, appropriate earth pressure parameters for sloping backfill should be used.

Global stability of the RSS walls should be assessed once the detailed configurations of the walls are known.

#### **9.2.4.2 Concrete Retaining Walls**

From a foundation standpoint, concrete retaining walls may be supported on spread footings founded on the firm to stiff silty clay/silty clay till subgrade. The walls should be provided with a sufficient frost cover (minimum 2.3 m at this site) and founded at Elevation 326.5 m or lower. A factored geotechnical resistance at ULS of 150 kPa and a geotechnical reaction at SLS of 100 kPa (up to 25 mm of settlement) may be used for design. A minimum 300 mm thick granular levelling pad should be provided below the wall footing. Load inclination and eccentricity should also be taken into account as outlined above.

Resistance to sliding between precast concrete and the granular levelling pad should be evaluated in accordance with the CHBDC (2014) assuming an ultimate coefficient of friction of 0.40.

Lateral earth pressures acting on the wingwalls should be computed as described in Section 12. If the wall is retaining sloping backfill, appropriate earth pressure parameters for sloping backfill should be used.

### **9.2.5 Frost Cover**

The depth of frost penetration at this site is approximately 2.3 m. The base of open footing concrete culvert or retaining wall footings, if employed, should be provided with a minimum of 2.3 m of earth cover as protection against frost action. The frost cover requirement does not apply to the concrete pipe, CSP or box culvert.

As the top of the culvert will have an approximately 2.6 m soil cover which exceeds the depth of frost penetration, a frost taper will not be required provided the backfill material above the top of the culvert consists of non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS.PROV 1010.

### **9.2.6 Subgrade Preparation**

Performance of the replacement culvert will depend on the preparation of the subgrade. After the excavation reaches the design subgrade elevation, the exposed surface should be inspected to confirm that the subgrade is suitable and uniformly competent. Any remaining fill, topsoil, peat, streambed deposits, disturbed soils and any deleterious materials within the replacement culvert footprint must be removed and replaced with bedding materials compacted as per OPSS.PROV 501.

In the event that sub-excavation is required, the width of the sub-excavation should be defined by a line extending from 0.3 m beyond the outside edge of the proposed culvert, outward and downward at 1H:1V. The sub-excavated area should then be backfilled with granular material meeting OPSS.PROV 1010 Granular A or Granular B Type II requirements and compacted as per OPSS.PROV 501.

The work should be carried out in accordance with OPSS 902 and culvert construction, subgrade preparation and placement and compaction of granular material must be carried out in the dry.

### **9.2.7 Settlement**

It is anticipated that the replacement culvert will be constructed approximately on the same alignment and with similar opening size as the existing culvert with no grade raise on the overlying embankment. Therefore, post construction settlement is expected to be negligible at this site and will be essentially complete at the end of construction. It must be noted that any additional load imposed on the foundation soils, including fill to widen the embankment or additional fill placed behind wingwalls will induce immediate settlement and consolidation settlement of the compressible cohesive deposits (silty clay and silty clay till) at this site.

### **9.3 Construction Considerations**

Detailed construction sequencing was not available at the time of preparation of this report. However, it is anticipated that one lane of traffic must be maintained, which will require staged construction.

Staged construction sequencing will likely require the following:

- Diversion of the creek is anticipated for construction. In addition, a suitable dewatering plan will be required to construct the culvert in the dry.
- Temporary roadway protection may be required during all stages of construction, including excavation and removal of the existing culvert, installation of the new culvert and backfilling.
- All culvert subgrade preparation and foundation preparation must be carried out in the dry.

## **10. EXCAVATION AND GROUNDWATER CONTROL**

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill, native silty clay and silt clay till at this site are classified as Type 3 soils. Surficial alluvial deposits and any cohesionless soils that are anticipated in the inlet and outlet areas should be classified as Type 4 soils.

Excavation and backfilling for culvert construction should be carried out in accordance with OPSS 902. Excavation for culvert replacement will be carried out through the existing embankment fill and extended into the native silty clay and silty clay till deposit. It must be noted that obstructions may be encountered within the fill, and cobbles and boulders within the till deposit.

Installation of the culvert should be carried out in the dry. It is anticipated that excavation for culvert replacement will be carried out at or below the creek water level, and diversion of the creek flow will be required. Seepage should be anticipated from the embankment fill. Depending on the

time of construction, a combination of cofferdam enclosure and creek diversion along with pumping from filtered sumps within an enclosure will be required to maintain dry excavation during the course of staged construction. Dewatering operations should be carried out in accordance with OPSS 517 and OPSS 518.

The design of an effective dewatering system is the responsibility of the Contractor and the Contract Documents must alert him to this responsibility and the need to engage a dewatering specialist. Dewatering must remain operational and effective until the culvert is installed and backfilled. Suggesting wording for an NSSP in this regard is included in Appendix F.

## **11. STREAM DIVERSION PIPE**

It is understood that a CSP stream diversion pipe is planned at this site for diversion of the creek during construction. Details of the diversion pipe were not provided at the time of preparation of this report. Temporary shoring might be required to install the diversion pipe.

The CSP should be placed on a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements as per OPSD 802.010. The bedding material should be placed on the prepared subgrade as soon as practical, following its inspection and approval. The subgrade preparation should be carried out in the dry. The prepared subgrade must be protected from disturbance during construction.

## **12. CULVERT BACKFILL AND LATERAL EARTH PRESSURES**

Backfill to the culvert should consist of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS.PROV 1010. Reference should be made to the backfill arrangements stipulated in OPSD 802.010, 803.010 or 802.034, as appropriate. Backfilling for the culvert should be in accordance with OPSS.PROV 401 for a CSP or OPSS 902 for a box culvert. All fills should be placed in regular lifts and be compacted in accordance with OPSS.PROV 501. The backfill should be placed and compacted in simultaneous lifts on both sides of the culvert, and the top of backfill elevation should not differ more than 500 mm on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and on the roof of the culvert. Compaction equipment to be used adjacent to the culvert should be restricted in accordance with OPSS.PROV 501.

Lateral earth pressures acting on the culvert walls may be assumed a triangular distribution. For a fully drained backfill, the pressures should be computed in accordance with the CHBDC 2014, but are generally given by the expression:

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

where

$p_h$  = horizontal pressure on the wall at depth  $h$  (kPa)

$K$  = earth pressure coefficient (see table below)

$\gamma$  = bulk unit weight of retained soil (see table below)

$h$  = depth below top of fill where pressure is computed (m)

$q$  = value of any surcharge (kPa)

Earth pressure coefficients for backfill to the culvert walls are dependent on the material used as backfill. Recommended coefficient values are shown in Table 12.1 below.

**Table 12.1 – Lateral Earth Pressure Coefficients (K)**

Loading Condition	OPSS Granular A or Granular B Type II $\phi = 35^\circ; \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I (modified) $\phi = 32^\circ; \gamma = 21.2 \text{ kN/m}^3$		Existing Fill $\phi = 30^\circ; \gamma = 20 \text{ kN/m}^3$	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48	0.33	0.54
At-rest (Restrained Wall)	0.43	0.62	0.47	0.70	0.50	0.76
Passive	3.7	-	3.3	-	3.0	-

Note: Submerged unit weight should be used below the groundwater level/high creek level.

For rigid structures such as concrete box culverts, at-rest horizontal earth pressures should be used for design. Active pressures should be used for any unrestrained wall.

The use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) is preferred as it results in lower earth pressures acting on the culvert.

In accordance with Clause 6.12.3 of the CHBDC 2014, a compaction surcharge should be added. The magnitude of the surcharge should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 1.7 m for Granular B Type I, or at a depth of 2.0 m for Granular A or B Type II.

### 13. SEISMIC CONSIDERATIONS

In accordance with the CHBDC 2014, the selection of the seismic site class is based on the soil conditions encountered in the upper 30 m of the stratigraphy. In view of the presence of

predominantly stiff silty clay/silty clay till, this site is classified as Site Class D in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC. The peak ground acceleration, PGA, for a 2,475-year return period seismic event at this site is 0.037 g as per the National Building Code of Canada (NBCC).

In accordance with Clause 4.6.5 of the CHBDC 2014, 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 13.1 may be used:

**Table 13.1 – Earth Pressure Coefficients for Earthquake Loading**

Condition	Earth Pressure Coefficient (K)		
	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	OPSS Granular B Type I (modified) $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	Existing Fill $\phi = 30^\circ; \gamma = 20 \text{ kN/m}^3$
Active ( $K_{AE}$ )*	0.29	0.33	0.35
Passive ( $K_{PE}$ )	3.6	3.2	2.9
At Rest ( $K_{OE}$ )**	0.51	0.55	0.56

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

\*\* After Woods

The site is underlain by firm to stiff silty clay and stiff to very stiff silty clay till. In view of the low potential for seismic activity in the area, liquefaction is not considered to be a concern at this site.

## 14. TEMPORARY PROTECTION SYSTEM

Temporary roadway protection system should be implemented in accordance with OPSS PROV 539 and designed for Performance Level 2.

Options for roadway protection are a soldier pile-lagging system or sheet piles, although the sheet piles may be difficult to drive in the native till which might contain cobbles and boulders.

The soil parameters in Table 14.1 may apply for design of the temporary roadway protection system with horizontal backfill.

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

**Table 14.1 –Soil Parameters for Temporary Protection System Design**

Soil Parameter	Existing Fill	Silty Clay	Silty Clay Till
$\gamma$ (total unit weight)	20 kN/m <sup>3</sup>	18 kN/m <sup>3</sup>	20 kN/m <sup>3</sup>
$\gamma'$ (submerged unit weight)	10 kN/m <sup>3</sup>	8 kN/m <sup>3</sup>	10 kN/m <sup>3</sup>
$K_a$	0.33	0.4	0.36
$K_p$	3.0	2.5	2.8

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

## 15. EMBANKMENT RESTORATION

The existing Highway 11 embankment is approximately 3.0 m in height at the culvert location and the existing embankment slopes appear to be stable. Provided that the embankment is reconstructed at the same slope inclination as the existing embankment, but not steeper than 2H:1V, the restored embankment slope should remain stable.

It is anticipated that there will be no grade raise or embankment widening at this site for the culvert replacement, and therefore settlement of the embankment is not a concern. Any settlement due to changes in the culvert configuration is expected to be less than 25 mm. Additional settlement would be induced if the final configuration includes additional fill to raise or widen the embankment, including placement of fill behind wingwalls.

Embankment restoration after completion of the culvert replacement should be carried out in accordance with OPSS.PROV 206 and OPSS.PROV 209. The embankment material may consist of imported Granular A, Granular B Type II, or Granular B Type III material. Alternatively, the existing granular fill may be used above the culvert cover and below the roadbase granular fill, provided it is free of organics, unfrozen, and at a moisture content that is suitable for compaction.

In general, surface vegetation, peat, topsoil, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from the areas around the culvert inlet and outlet, and within



the embankment footprint. Inspection and approval of the foundation subgrade by qualified geotechnical personnel should be conducted.

## **16. SCOUR AND EROSION PROTECTION**

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

Typically, rock protection should be provided over all surfaces with which creek water is likely to be in contact. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804.

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

## **17. CORROSION AND SULPHATE ATTACK POTENTIAL**

The results of the corrosivity and sulphate analytical tests conducted on the silty clay till and creek water indicates the following conditions at the locations tested:

- The potential for corrosion or sulphate attack on concrete foundations from the surrounding soil is considered to be negligible. The sulphate attack from the surface water is considered to be negligible due to the low concentrations of sulphate and chloride in the water sample tested.
- The potential for soil or surface water corrosion on metal is considered to be very mild.
- Appropriate protection measures are recommended if metal structural elements are used.

## **18. CONSTRUCTION CONCERNS**

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

- A suitable dewatering / unwatering system must be employed to enable culvert construction in the dry and prevent sloughing and instability of the excavation walls.
- The water level in the creek may fluctuate and be at higher elevation at the time of construction than indicated in the report.
- Buried obstructions may be encountered during excavation in the native till and may interfere with installation of the temporary roadway protection system. Suggested wording for an NSSP on obstructions is included in Appendix F.
- The Contractor's selection of construction equipment and methodology should include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structures or fill (i.e., as a pad for crane support). Site conditions may limit the type of equipment suitable for use during construction. The design and safety of any temporary works is the responsibility of the Contractor.

## 19. CLOSURE

Engineering analysis and preparation of this report was carried out by Ms. R. Palomeque Reyna, P.Eng and Mr. Keli Shi, 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



Keli Shi, P.Eng.  
Foundations Engineer



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



## **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  
 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.

## EXPLANATION OF ROCK LOGGING TERMS


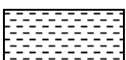

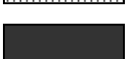

### ROCK WEATHERING CLASSIFICATION

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

### DISCONTINUITY SPACING

<b>Bedding</b>	<b>Bedding Plane Spacing</b>
Very thickly bedded	Greater than 2m
Thickly bedded	0.6 to 2m
Medium bedded	0.2 to 0.6m
Thinly bedded	60mm to 0.2m
Very thinly bedded	20 to 60mm
Laminated	6 to 20mm
Thinly Laminated	Less than 6mm

### SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

### STRENGTH CLASSIFICATION

<b>Rock Strength</b>	<b>Approximate Uniaxial Compressive Strength</b>		<b>Field Estimation of Hardness*</b>
	<b>(MPa)</b>	<b>(psi)</b>	
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
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 % 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.

# 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			

# RECORD OF BOREHOLE No 16-42

1 OF 2

METRIC

W.P. 6813-14-00 LOCATION Dilke Creek N 5 396 512.9 E 212 005.0 ORIGINATED BY TS  
HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2016.08.27 - 2016.08.27 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)				
332.0	GROUND SURFACE							20	40	60	80	100					GR	SA	SI	CL	
0.0	TOPSOIL: (25mm)																				
	Gravelly SAND, some silt Very Loose to Loose Brown Moist (FILL)		1	SS	4																
			2	SS	3		331														
			3	SS	3		330														
329.9																					
2.1	Silty CLAY, some sand, organic staining Firm to Stiff Grey Moist		4	SS	4		329											0	15	14	71
			5	SS	4		328														
			6	SS	2		327														
326.4																					
5.6	Silty CLAY, sandy, trace gravel Stiff Grey Moist (TILL)		7	SS	5		326														
			8	SS	7		324											0	30	42	28
			9	SS	7		323														

Continued Next Page

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

20  
15  
10  
(%) STRAIN AT FAILURE



# RECORD OF BOREHOLE No 16-42

2 OF 2

METRIC

W.P. 6813-14-00 LOCATION Dilke Creek N 5 396 512.9 E 212 005.0 ORIGINATED BY TS  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2016.08.27 - 2016.08.27 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
	Continued From Previous Page																
	Silty <b>CLAY</b> , sandy, trace gravel Stiff Grey Moist (TILL)		10	SS	6		321									0 29 41 30	
			11	SS	9		320										
319.5																	
12.5	END OF BOREHOLE AT 12.5m. BOREHOLE OPEN AND DRY UPON COMPLETION. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.  WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m)																


ONTMT4S 13983-MTO.GPJ 2015TEMPLATE(MTO).GDT 10/27/16

# RECORD OF BOREHOLE No 16-43

1 OF 2

METRIC

W.P. 6813-14-00 LOCATION Dilke Creek N 5 396 493.7 E 212 007.2 ORIGINATED BY TS  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2016.08.27 - 2016.08.27 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL LIMIT      MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE				WATER CONTENT (%) W <sub>P</sub> W      W <sub>L</sub>					
333.3	GROUND SURFACE							20	40	60	80	100					
0.0	ASPHALT: (100mm)  Gravelly <b>SAND</b> , some silt Dense to Loose Brown Moist (FILL)																
0.1																	
			1	GS			333										
			2	SS	28		332										

Continued Next Page

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

# RECORD OF BOREHOLE No 16-43

2 OF 2

METRIC

W.P. 6813-14-00 LOCATION Dilke Creek N 5 396 493.7 E 212 007.2 ORIGINATED BY TS  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2016.08.27 - 2016.08.27 CHECKED BY RPR

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					
○ UNCONFINED    + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE													
	Continued From Previous Page						20 40 60 80 100	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT			
								W <sub>P</sub>	W	W <sub>L</sub>			
								WATER CONTENT (%)					
							20 40 60 80 100						

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

# RECORD OF BOREHOLE No 16-44

1 OF 2

METRIC

W.P. 6813-14-00 LOCATION Dilke Creek N 5 396 505.3 E 211 993.8 ORIGINATED BY TS  
HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2016.08.28 - 2016.08.28 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				
333.3	GROUND SURFACE							20 40 60 80 100		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		
0.0	ASPHALT: (100mm)							20 40 60 80 100		W <sub>P</sub> W W <sub>L</sub>		
0.1	Gravelly <b>SAND</b> , some silt, trace clay Loose Brown Moist (FILL)		1	GS			333					
			2	SS	8							
331.9							332					
1.4	Silty <b>CLAY</b> , trace sand and gravel Firm Brown Moist (FILL)		3	SS	6							
331.1												
2.2	<b>SAND</b> , trace silt, organic staining Compact Brown Moist (FILL)		4	SS	10		331					
330.3												
3.0	Silty <b>CLAY</b> , some sand Firm to Stiff Grey Moist		5	SS	6		330					
329.2												
4.1	Silty <b>CLAY</b> , sandy, trace gravel Stiff to Very Stiff Grey Moist (TILL)		6	SS	3		329					
							328		4.0			
			7	SS	5		327					
							326					
			8	SS	7		325					
							324					
			9	SS	11							

Continued Next Page

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

# RECORD OF BOREHOLE No 16-44

2 OF 2

METRIC

W.P. 6813-14-00 LOCATION Dilke Creek N 5 396 505.3 E 211 993.8 ORIGINATED BY TS  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2016.08.28 - 2016.08.28 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  <b>γ</b> 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					
								20 40 60 80 100					
	Continued From Previous Page							20 40 60 80 100					
	Silty <b>CLAY</b> , sandy, trace gravel Stiff to Very Stiff Grey Moist (TILL)		10	SS	14		323						2 29 36 33
							322						
			11	SS	10		321						
							320						
319.0			12	SS	10		319						
14.3	END OF BOREHOLE AT 14.3m. BOREHOLE DRY UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO 0.1m, THEN ASPHALT COLD PATCH TO SURFACE.												

# RECORD OF BOREHOLE No 16-45

1 OF 2

METRIC

W.P. 6813-14-00 LOCATION Dilke Creek N 5 396 486.5 E 211 982.4 ORIGINATED BY TS  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2016.08.28 - 2016.08.28 CHECKED BY RPR

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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20    40    60    80    100	W <sub>P</sub> W      W <sub>L</sub>	20    40    60				
SHEAR STRENGTH kPa								WATER CONTENT (%)						
○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE														
329.5	GROUND SURFACE													
0.0	TOPSOIL: (50mm)													
	Silty <b>CLAY</b> , sandy, trace gravel Very Soft to Stiff Grey Moist (TILL)		1	SS	0		329							
			2	SS	0		328							3    25    40    32
			3	SS	2									
			4	SS	5		327							
							326							
							325							
			5	SS	8		324							
							323							
			6	SS	9		322							
							321							0    31    39    30
			7	SS	10									
							320							
319.7			8	SS	10									
9.8	END OF BOREHOLE AT 9.8m.													

Continued Next Page

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

# RECORD OF BOREHOLE No 16-45

2 OF 2

METRIC

W.P. 6813-14-00 LOCATION Dilke Creek N 5 396 486.5 E 211 982.4 ORIGINATED BY TS  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2016.08.28 - 2016.08.28 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ 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					
	Continued From Previous Page WATER LEVEL AT 0.6m DURING DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO SURFACE.																



## **Appendix B**

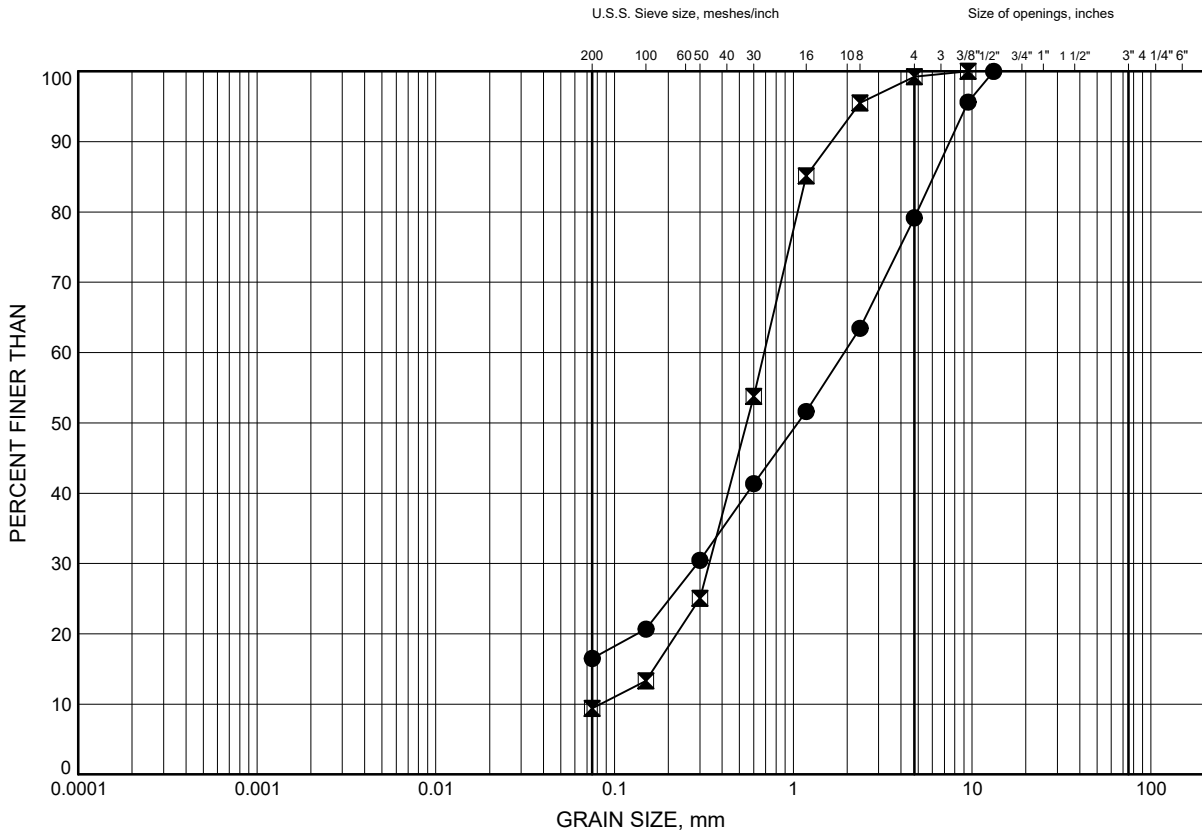
### **Geotechnical and Analytical Laboratory Test Results**



# Dilke Creek GRAIN SIZE DISTRIBUTION

FIGURE B1

## Gravelly SAND to SAND FILL



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-43	1.07	332.23
⊠	16-44	2.59	330.71

Date ..October 2016.....  
W.P. ..6813-14-00.....

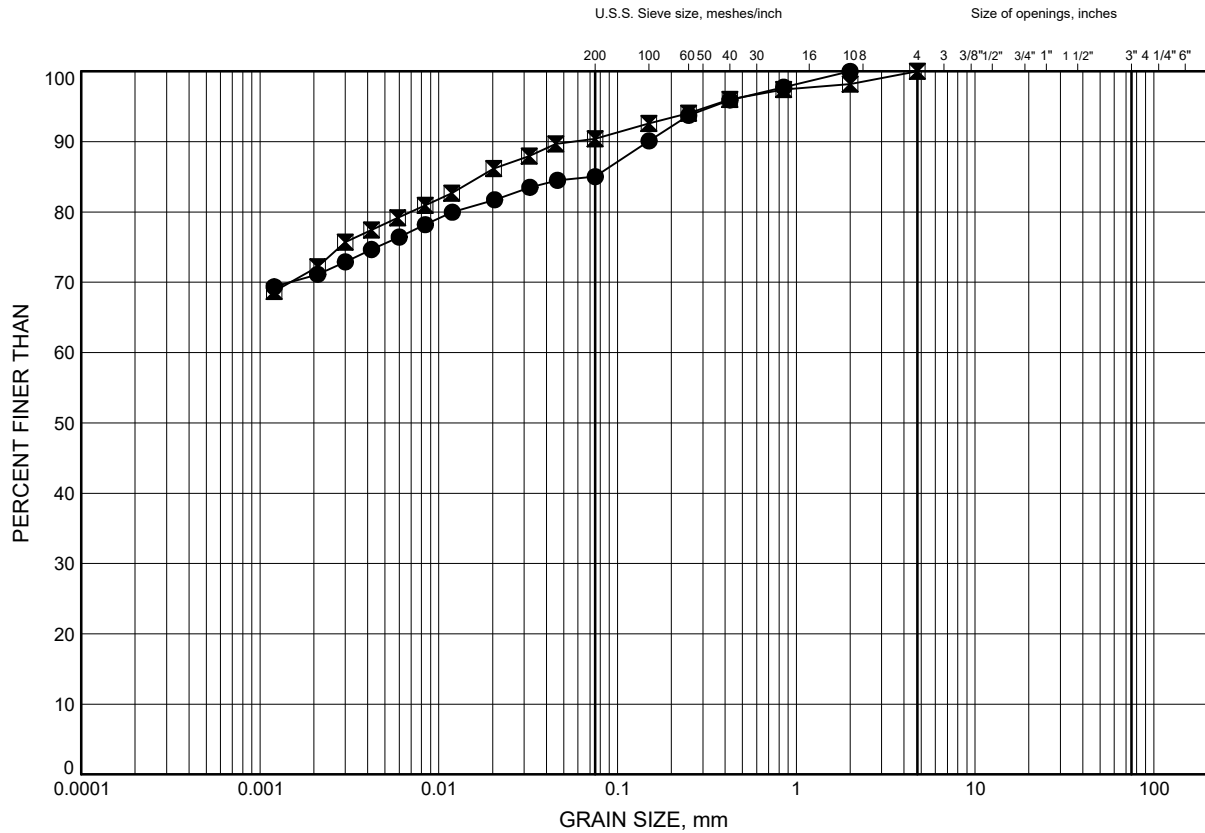


Prep'd .....AN.....  
Chkd. ....KS.....

# Dilke Creek GRAIN SIZE DISTRIBUTION

FIGURE B2

## Silty CLAY



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-42	2.59	329.41
⊠	16-43	3.35	329.95

Date ..October 2016.....  
W.P. ..6813-14-00.....

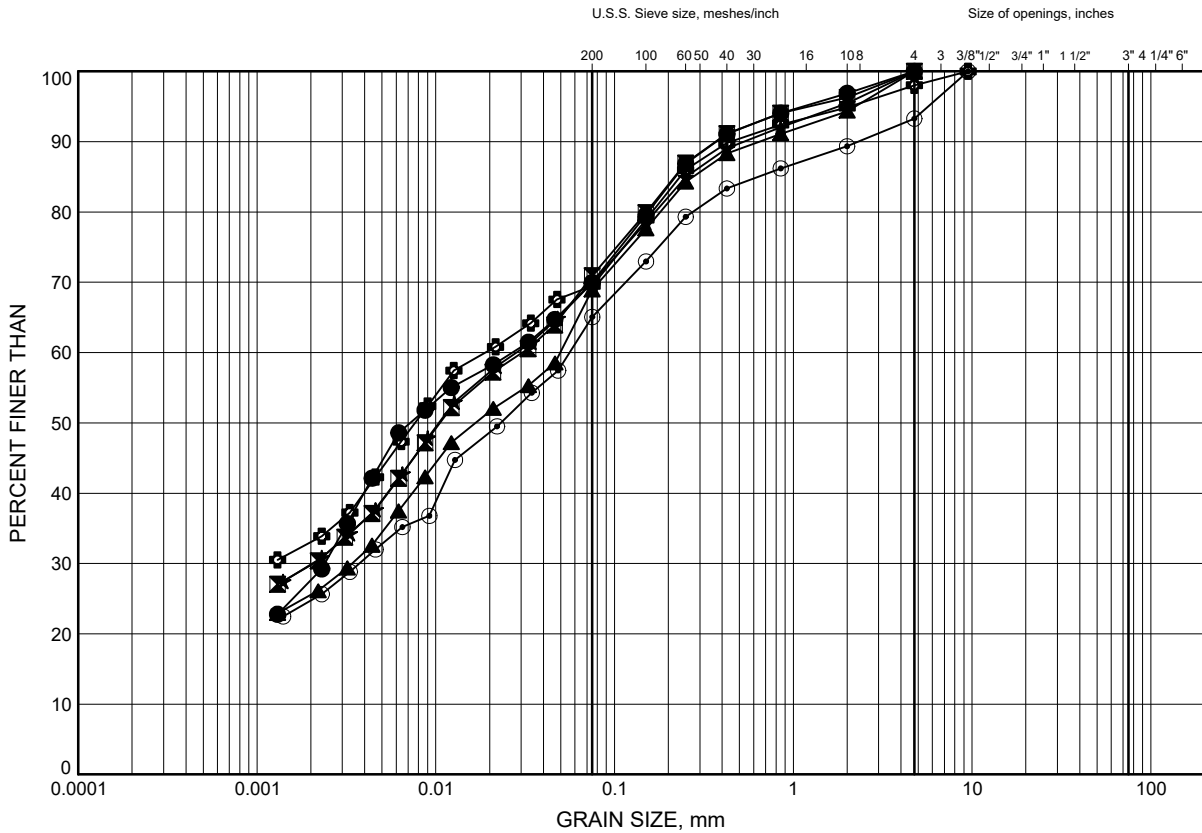


Prep'd .....AN.....  
Chkd. ....KS.....

# Dilke Creek GRAIN SIZE DISTRIBUTION

FIGURE B3

Sandy, Silty CLAY TILL



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-42	7.92	324.08
⊠	16-42	10.97	321.03
▲	16-43	9.45	323.85
★	16-43	14.02	319.28
⊙	16-44	6.40	326.90
⊕	16-44	10.97	322.33

Date ..October 2016.....  
W.P. ..6813-14-00.....

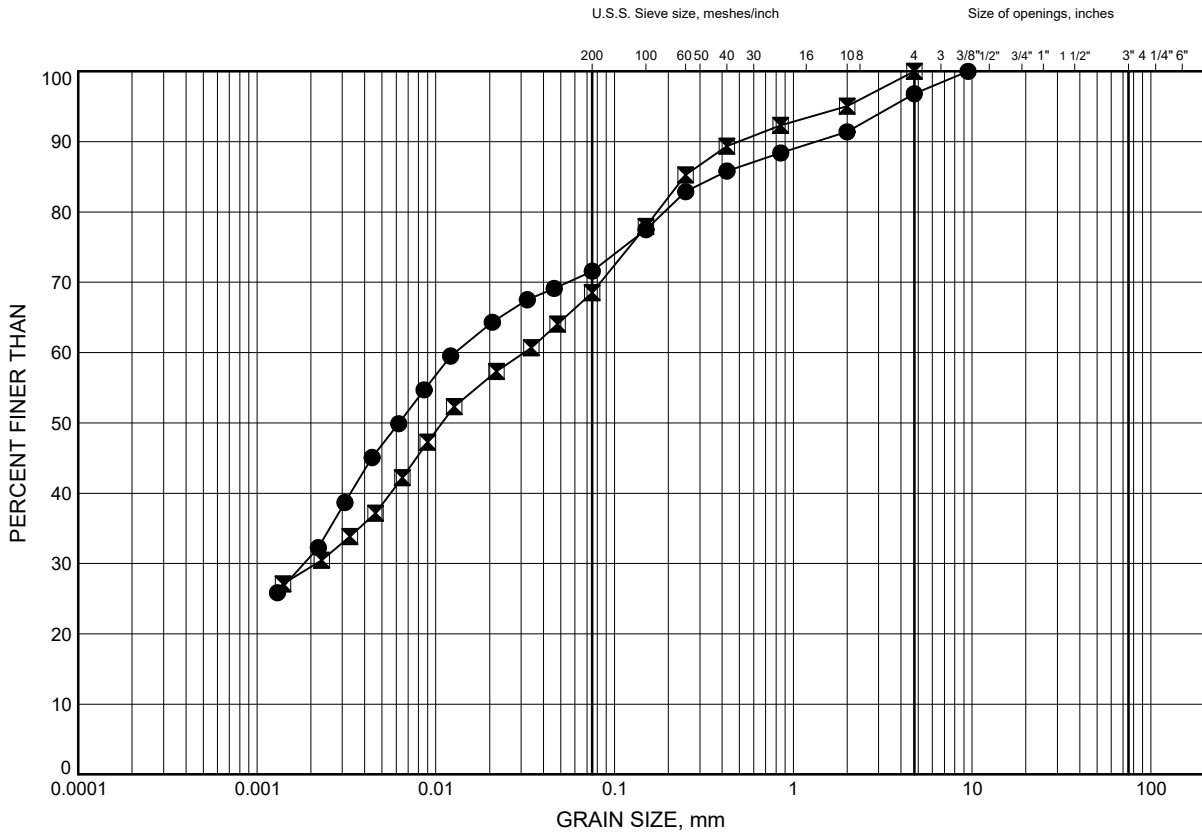


Prep'd .....AN.....  
Chkd. ....KS.....

# Dilke Creek GRAIN SIZE DISTRIBUTION

FIGURE B4

Sandy, Silty CLAY TILL



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-45	1.07	328.43
⊠	16-45	7.92	321.58

Date ..October 2016.....  
W.P. ..6813-14-00.....

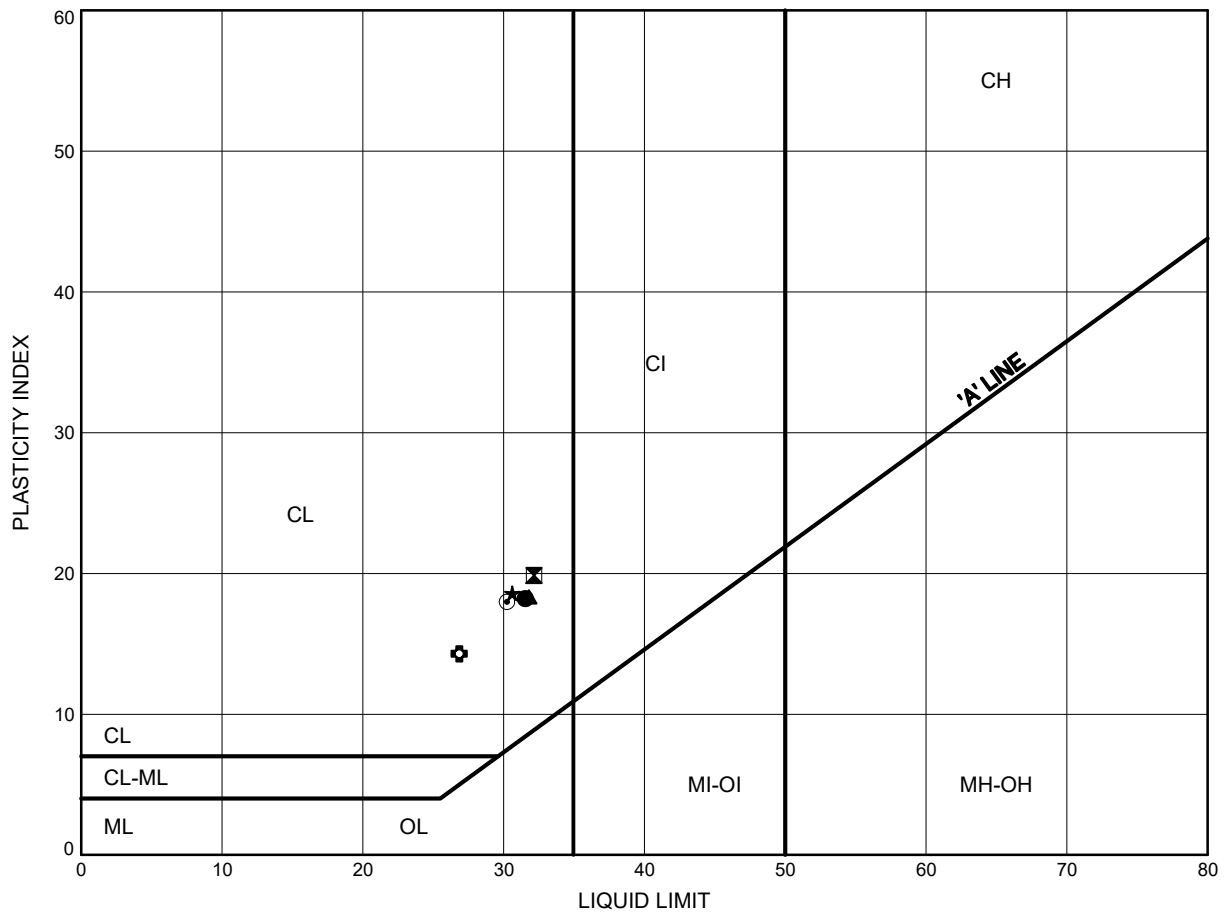


Prep'd .....AN.....  
Chkd. ....KS.....

# Dilke Creek ATTERBERG LIMITS TEST RESULTS

FIGURE B5

Sandy, Silty CLAY TILL



## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-42	10.97	321.03
⊠	16-43	9.45	323.85
▲	16-43	14.02	319.28
★	16-44	6.40	326.90
⊙	16-44	10.97	322.33
⊕	16-45	1.07	328.43

Date October 2016  
W.P. 6813-14-00

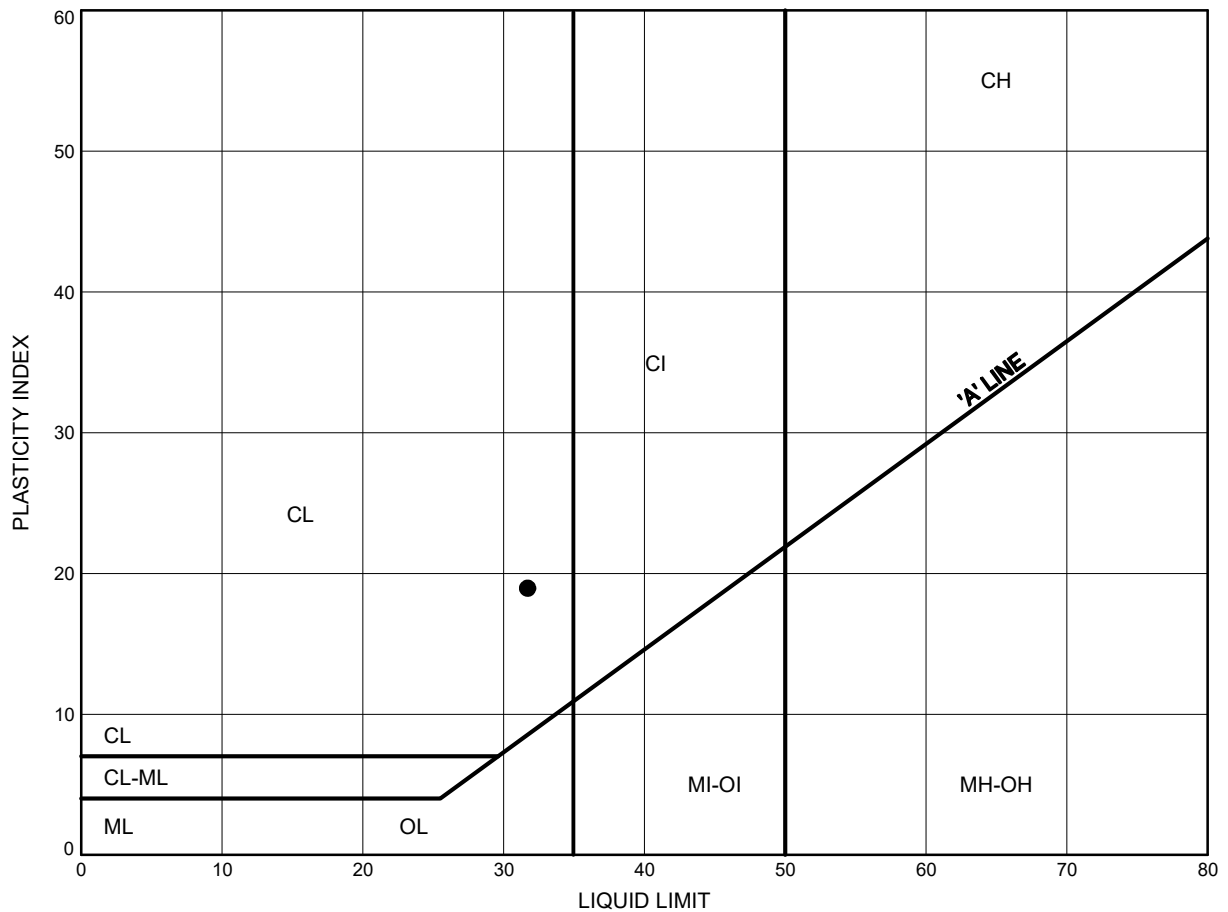


Prep'd AN  
Chkd. KS

Dilke Creek  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B6

Sandy, Silty CLAY TILL



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-45	7.92	321.58

Date ..October 2016.....  
W.P. ..6813-14-00.....



Prep'd .....AN.....  
Chkd. ....KS.....

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.  
Lakefield - Ontario - K0L 2H0  
Phone: 705-652-2000 FAX: 705-652-6365

**Project : 13983****12-September-2016****Thurber Engineering Ltd.****Attn : Mark Farrant**

103, 2010 Winston Park Drive  
Oakville, ON  
L6H 5R7,

Phone: 905-829-8666 x 228  
Fax:

**Date Rec. :** 06 September 2016  
**LR Report:** CA15062-SEP16  
**Reference:** 13983 Mark Farrant

**Copy: #1**

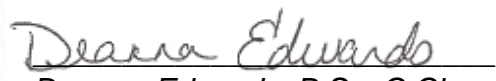
## CERTIFICATE OF ANALYSIS

### Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Approval Date	4: Analysis Approval Time	5: MDL	7: Dilke
Sample Date & Time						21-Aug-16
Temperature Upon Receipt [°C]	---	---	--	--	---	23.0
Corrosivity Index [none]	12-Sep-16	17:18	12-Sep-16	17:18		4
pH [no unit]	07-Sep-16	06:39	07-Sep-16	15:48	0.05	7.58
Conductivity [µS/cm]	07-Sep-16	06:39	07-Sep-16	15:48	2	1360
Resistivity (calculated) [MOhms.cm]	07-Sep-16	14:35	07-Sep-16	14:35	---	3630
Redox Potential [mV]	06-Sep-16	14:30	07-Sep-16	08:34	---	275
Chloride [mg/L]	08-Sep-16	09:42	12-Sep-16	13:27	0.04	180
Sulphate [mg/L]	08-Sep-16	09:42	12-Sep-16	13:27	0.04	9.4
Sulphide [mg/L]	07-Sep-16	12:00	08-Sep-16	10:41	0.006	0.74

Temperature of Samples upon receipt 23 degrees C  
Cooling Agent Present  
Custody Seal not Present

Corrosivity Index is based on the American Water Works Corrosivity Scale according to AWWA C-105. An index greater than 10 indicates the soil matrix may be corrosive to cast iron alloys.

  
**Deanna Edwards, B.Sc, C.Chem**  
**Project Specialist**  
**Environmental Services, Analytical**

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.  
Lakefield - Ontario - K0L 2H0  
Phone: 705-652-2000 FAX: 705-652-6365

**Project :** 13983**LR Report :** CA15062-SEP16

### Method Descriptions

Parameter	SGS Method Code	Reference Method Code
Anions by IC	ME-CA-[ENV]IC-LAK-AN-001	EPA300/MA300-Ions1.3
Conductivity	ME-CA-[ENV]EWL-LAK-AN-006	SM 2510
pH	ME-CA-[ENV]EWL-LAK-AN-006	SM 4500
Redox Potential		SM 2580
Sulphide by SFA	ME-CA-[ENV]SFA-LAK-AN-008	SM 4500





**SGS Canada Inc.**

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**Project :** 13983

**LR Report :** CA15062-SEP16

## Quality Control Report

Inorganic Analysis												
Parameter	Reporting Limit	Unit	Method Blank				LCS / Spike Blank			Matrix Spike / Reference Material		
					RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
						%		Low	High		Low	High
Anions by IC - QCBatchID: DIO0089-SEP16												
Anions by IC - QCBatchID: DIO0105-SEP16												
Chloride	0.04	mg/L	<0.04		2	20	94	80	120	105	75	125
Sulphate	0.04	mg/L	<0.04		0	20	101	80	120	100	75	125
Conductivity - QCBatchID: EWL0061-SEP16												
Conductivity	2	µS/cm	< 2		0	10	98	90	110	NA		
pH - QCBatchID: EWL0061-SEP16												
pH	0.05	no unit	NA		0		100			NA		
Redox Potential - QCBatchID: EWL0056-SEP16												
Redox Potential	no	mV	NA		2	20	100	80	120	NA		
Sulphide by SFA - QCBatchID: SKA0038-SEP16												
Sulphide	0.006	mg/L	<0.006		ND	20	84	80	120	nv	75	125

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.  
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Phone: 705-652-2000 FAX: 705-652-6365

**Project : 13983****22-September-2016****Thurber Engineering Ltd.****Attn : Mark Farrant**

103, 2010 Winston Park Drive  
Oakville, ON  
L6H 5R7,

Phone: 905-829-8666 x 228  
Fax:


**Date Rec. :** 16 September 2016  
**LR Report:** CA14401-SEP16  
**Reference:** 13983 Mark Farrant

**Copy: #1**

## CERTIFICATE OF ANALYSIS

### Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Approval Date	4: Analysis Approval Time	8: 16-45 SS#3 5'7'
Sample Date & Time					12-Sep-16
Temperature Upon Receipt [°C]	---	---	---	---	9.0
Corrosivity Index [none]	21-Sep-16	16:51	21-Sep-16	16:51	4
pH [no unit]	19-Sep-16	10:18	19-Sep-16	13:26	8.21
Soil Redox Potential [mV]	19-Sep-16	16:42	20-Sep-16	10:53	160
Sulphide [%]	21-Sep-16	11:12	21-Sep-16	11:40	0.07
% Moisture (wet wt) [%]	21-Sep-16	07:55	21-Sep-16	08:50	17.4
pH [no unit]	19-Sep-16	06:59	20-Sep-16	10:41	9.10
Chloride [µg/g]	20-Sep-16	20:39	21-Sep-16	16:30	23
Sulphate [µg/g]	20-Sep-16	20:39	21-Sep-16	16:30	260
Conductivity [uS/cm]	19-Sep-16	06:59	20-Sep-16	10:42	90
Resistivity (calculated) [Ohms.cm]	21-Sep-16	10:49	21-Sep-16	10:49	11100

  
**Deanna Edwards, B.Sc, C.Chem**  
**Project Specialist**  
**Environmental Services, Analytical**



**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.  
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Phone: 705-652-2000 FAX: 705-652-6365

**Project : 13983**

**LR Report : CA14401-SEP16**

Temperature of Samples upon receipt 15 degrees C  
No cooling agent present

Corrosivity Index is based on the American Water Works Corrosivity Scale according to AWWA C-105. An index greater than 10 indicates the soil matrix may be corrosive to cast iron alloys.

Temperature of Samples upon receipt 9 degrees C  
Cooling agent present  
Custody Seal not present

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.

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Phone: 705-652-2000 FAX: 705-652-6365

**Project :** 13983**LR Report :** CA14401-SEP16

## Method Descriptions

Parameter	SGS Method Code	Reference Method Code
Anions by IC	ME-CA-[ENV]IC-LAK-AN-001	EPA300/MA300-Ions1.3
Carbon/Sulphur	ME-CA-[ENV]ARD-LAK-AN-020	ASTM E1918
Conductivity	ME-CA-[ENV]EWL-LAK-AN-006	SM 2510
pH	ME-CA-[ENV]EWL-LAK-AN-001	SM 4500



**SGS Canada Inc.**

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Lakefield - Ontario - KOL 2HO

Phone: 705-652-2000 FAX: 705-652-6365

**Project :** 13983

**LR Report :** CA14401-SEP16

## Quality Control Report

Inorganic Analysis												
Parameter	Reporting Limit	Unit	Method Blank				LCS / Spike Blank			Matrix Spike / Reference Material		
							RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)
						%	Low	High		Low	High	
Anions by IC - QCBatchID: DIO0260-SEP16												
Chloride	0.4	µg/g	<0.4		1	20	107	80	120	105	75	125
Sulphate	0.4	µg/g	<0.4		0	20	101	80	120	100	75	125
Carbon/Sulphur - QCBatchID: ECS0026-SEP16												
Sulphide	0.02	%	<0.02		4	20	106	80	120			
Conductivity - QCBatchID: EWL0235-SEP16												
Conductivity	2	uS/cm	< 2		ND	10				NA		
pH - QCBatchID: ARD0047-SEP16												
pH	0.05	no unit			0	20	100	80	120			



## **Appendix C**

### **Site Photographs**



**Photo 1: Dilke Creek Culvert, looking West**





**Photo 2: Dilke Creek Culvert**





**Photo 3: Dilke Creek Culvert**





**Photo 4: Dilke Creek Culvert, embankment**





**Photo 5: Dilke Creek Culvert, embankment**

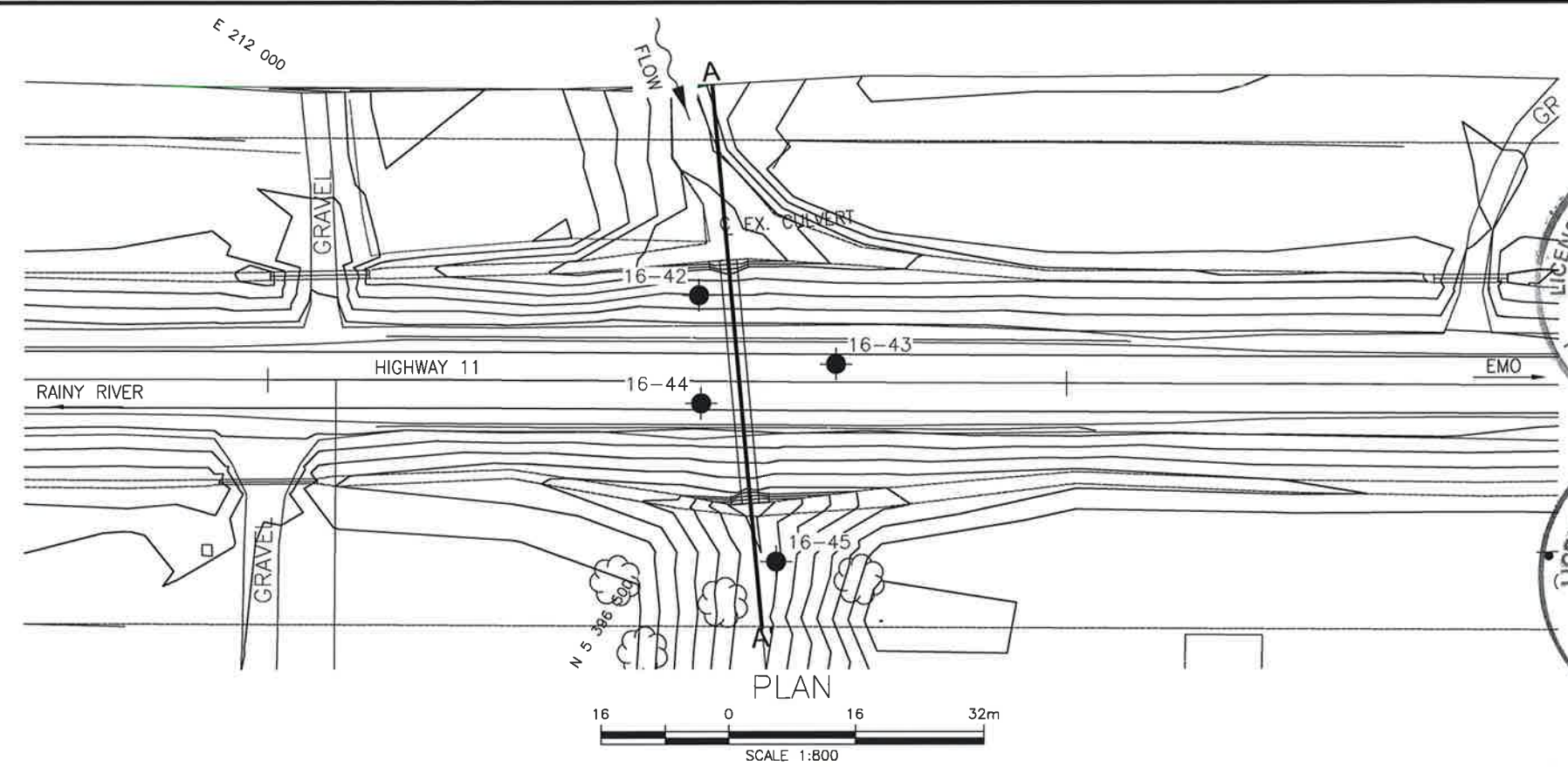


## **Appendix D**

### **Borehole Locations and Soil Strata Drawing**



MINISTRY OF TRANSPORTATION, ONTARIO

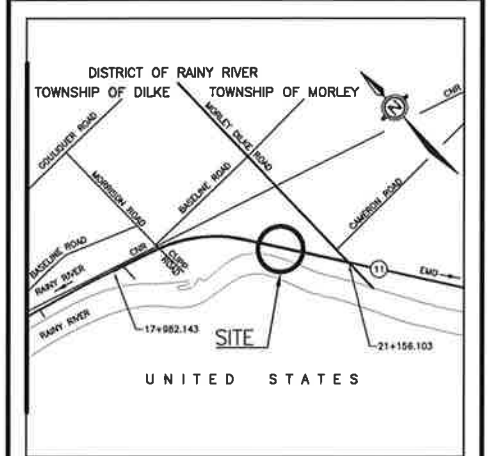


METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN



CONT No  
WP No 6813-14-00

HIGHWAY 11  
DILKE CREEK NO. 2  
CULVERT REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA



KEYPLAN

LEGEND

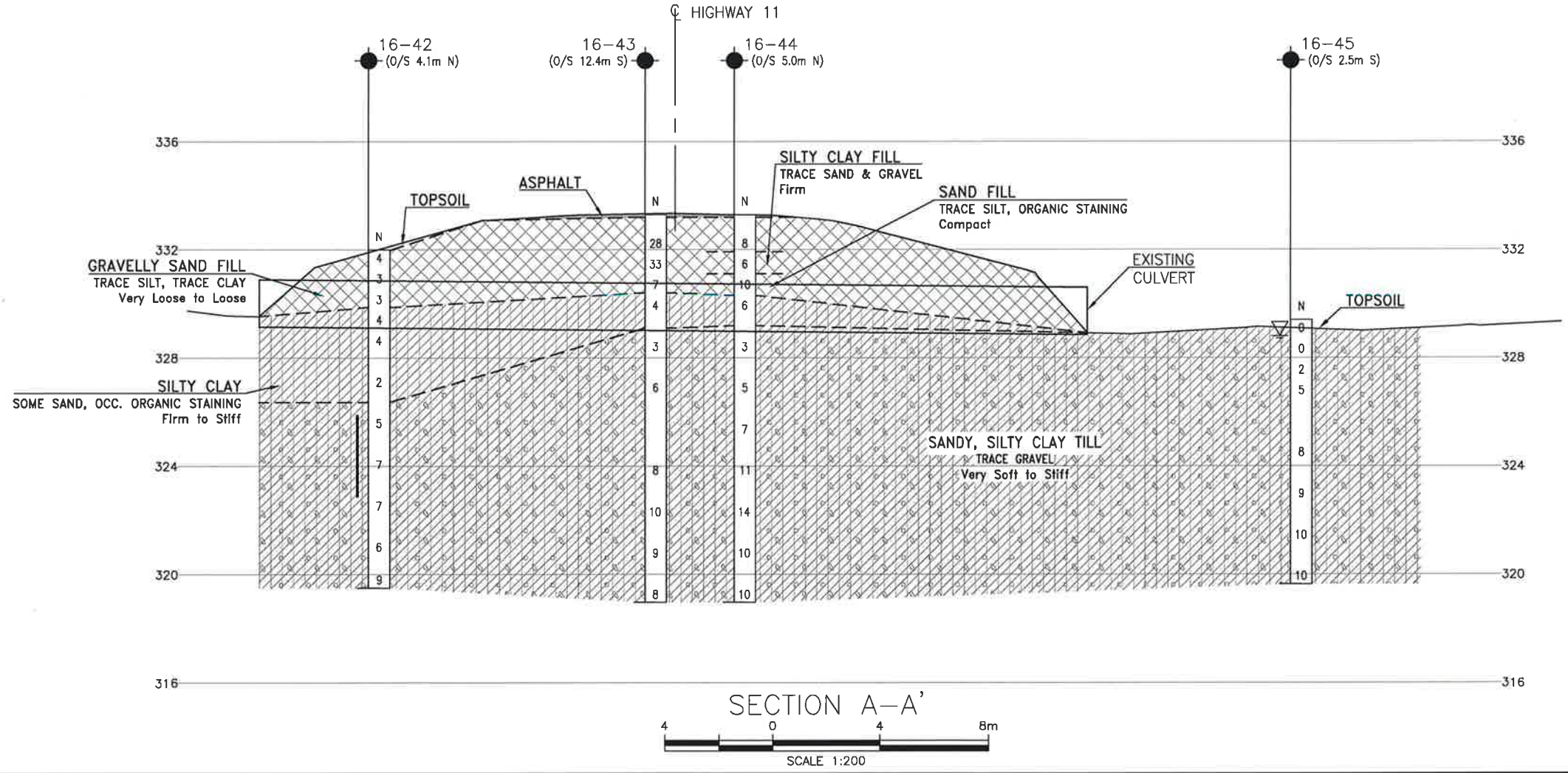
- Borehole
- Borehole and Cone
- N  
Blows /0.3m (Std Pen Test, 475J/blow)
- CONE  
Blows /0.3m (60' Cone, 475J/blow)
- PH  
Pressure, Hydraulic
- W  
Water Level
- HA  
Head Artesian Water
- P  
Piezometer
- 90%  
Rock Quality Designation (RQD)
- A/R  
Auger Refusal

NO	ELEVATION	NORTHING	EASTING
16-42	332.0	5 396 512.9	212 005.0
16-43	333.3	5 396 493.7	212 007.2
16-44	333.3	5 396 505.3	211 993.8
16-45	329.5	5 396 486.5	211 982.4

NOTES

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- MTM Zone 16 co-ordinate system used to obtain borehole Northings and Eastings.
- Preliminary general arrangement drawing provided by Hatch in digital format.

GEOCRES No. 52D-30



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	MEF	CHK	PKC
CODE	LOAD	DATE	FEB 2017
DRAWN	AN	CHK	MEF
SITE	STRUCT	DWG	1

FILENAME: H:\Drawing\13000\13983\13983-13983-BHP-DC.dwg  
PLOTDATE: 2/23/2017 10:44 AM



## **Appendix E**

### **Foundation Comparison**

### COMPARISON OF FOUNDATION ALTERNATIVES

Concrete Pipe or Corrugated Steel Pipe (CSP) Culvert	Concrete Box Culvert	Concrete Open Footing Culvert
<u>Advantages:</u> <ul style="list-style-type: none"> <li>i. Ease of construction.</li> <li>ii. Less stringent requirement for soil geotechnical resistances.</li> <li>iii. Segmental pipes can accommodate potential differential settlement along culvert axis</li> <li>iv. Concrete or steel pipes may be more cost effective than concrete box or open footing culverts.</li> </ul>	<u>Advantages:</u> <ul style="list-style-type: none"> <li>i. Relatively rapid installation and less disturbance to subgrade soils if precast segments are used.</li> <li>ii. Less stringent requirement for soil geotechnical resistances as loading is spread over a larger area.</li> <li>iii. Segmental option can accommodate potential differential settlement along culvert axis.</li> </ul>	<u>Advantages:</u> <ul style="list-style-type: none"> <li>i. Conventional construction.</li> <li>ii. Possibly less disturbance of creek channel / less environmental issues such as those involving spawning fish species.</li> </ul>
<u>Disadvantages:</u> <ul style="list-style-type: none"> <li>i. Steel pipes may have shorter design life than concrete culverts.</li> <li>ii. Multiple pipes needed to meet hydraulic requirements.</li> <li>iii. Roadway protection system required during open cut excavation.</li> </ul>	<u>Disadvantages:</u> <ul style="list-style-type: none"> <li>i. More expensive than a concrete pipe or CSP culvert.</li> <li>ii. Larger excavation required to install culvert.</li> <li>iv. Roadway protection system required during open cut excavation.</li> </ul>	<u>Disadvantages:</u> <ul style="list-style-type: none"> <li>i. Requires deeper excavation and potentially more robust dewatering requirements.</li> <li>ii. Less tolerant of differential settlements.</li> </ul>
<b>FEASIBLE</b>	<b>FEASIBLE</b>	<b>NOT RECOMMENDED</b>



## **Appendix F**

### **List of OPSSs and OPSDs and Suggested Wording for NSSP**



**1. List of OPSS and OPSD Documents Relevant to this Project**

- OPSS PROV 206
- OPSS PROV 209
- OPSS 422
- OPSS PROV 401
- OPSS PROV 501
- OPSS PROV 539
- OPSS PROV 804
- OPSS 902
- OPSS PROV 1010
- OPSS PROV 1205
- OPSS 1860
- OPSD 802.010
- OPSD 803.010
- OPSD 803.031

**2. Suggested Wording for NSSP on Dewatering**

Effective dewatering shall be designed and provided by the Contractor during structure excavation, bedding placement and backfilling to allow the work to proceed in the dry. Excavation below the creek and groundwater level will lead to subgrade softening. The dewatering system must be effective to maintain the water level at a minimum depth of 0.5 m below the final subgrade level throughout construction. The dewatering system must remain operational and effective until the culvert is installed and backfilled.

**3. Suggested Wording for NSSP on Obstructions**

Excavations and installation of cofferdams and roadway protection systems could encounter obstructions such as cobbles and boulders embedded in the native soils. Such obstructions may impede excavation progress and/or sheet pile installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions to achieve the design depths.