



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
KEKWANZIK LAKE CULVERT REPLACEMENT
HIGHWAY 599, SITE No. 48W-243/C
TOWNSHIP OF IGNACE
ONTARIO
G.W.P. No. 6836-14-00
GEOCRES Number: 52G-17**

Latitude 49.439045 ° , Longitude -91.625972 °

Report

to

HATCH Corporation

Date: February 8, 2018
File: 17077

TABLE OF CONTENTS

PART 1: FACTUAL INFORMATION

1.	INTRODUCTION	1
2.	SITE DESCRIPTION	1
3.	INVESTIGATION PROCEDURES.....	2
4.	LABORATORY TESTING.....	4
5.	DESCRIPTION OF SUBSURFACE CONDITIONS	5
5.1	Topsoil and Organics	5
5.2	Asphalt	5
5.3	Embankment Fill.....	6
5.4	Gravelly Sand.....	6
5.5	Sand	7
5.6	Silt to Sand and Silt.....	8
5.7	Gravel, Cobbles and Boulders	9
5.8	Bedrock	9
5.9	Groundwater Conditions.....	10
6.	CORROSIVITY AND SULPHATE TEST RESULTS.....	11
7.	MISCELLANEOUS	12

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8.	GENERAL.....	14
9.	CULVERT DESIGN	16
9.1	Culvert Replacement Options	16
9.2	Foundation Design for Culverts.....	17
9.2.1	Corrugated Steel Pipe Culvert	17
9.2.2	Precast Concrete Box Culvert	18
9.2.3	Steel Sheet Pile Walls	19
9.2.3.1	Sheet Pile Lateral Resistance.....	21
9.2.3.2	Construction Considerations for Sheet Piles	22
9.2.3.3	Downdrag	22
9.2.4	Culvert Headwall / Wingwalls	23
9.2.4.1	RSS Walls.....	23
9.2.4.2	Concrete Retaining Walls	24
9.3	Settlement.....	25
9.4	Frost Cover.....	25

10.	LATERAL EARTH PRESSURES	26
11.	CULVERT CONSTRUCTION CONSIDERATIONS.....	27
11.1	Subgrade Preparation	28
11.2	Culvert Bedding and Backfill	28
11.3	Excavation and Groundwater Control	29
12.	STREAM DIVERSION PIPE	30
13.	TEMPORARY PROTECTION SYSTEM.....	31
14.	EMBANKMENT WIDENING AND RESTORATION	32
15.	SEISMIC CONSIDERATIONS.....	32
16.	SCOUR AND EROSION PROTECTION	33
17.	CORROSION AND SULPHATE ATTACK POTENTIAL	34
18.	CONSTRUCTION CONCERNS	34
19.	CLOSURE	35

APPENDICES

Appendix A	Record of Borehole Sheets
Appendix B	Geotechnical and Analytical Laboratory Test Results and Rock Core Photos
Appendix C	Selected Site Photographs
Appendix D	Borehole Locations and Soil Strata Drawings
Appendix E	Foundation Comparison
Appendix F	List of Specifications and Suggested Wording for NSSP



**FOUNDATION INVESTIGATION AND DESIGN REPORT
KEKWANZIK LAKE CULVERT REPLACEMENT
HIGHWAY 599, SITE No. 48W-243/C
TOWNSHIP OF IGNACE
ONTARIO**

G.W.P. No. 6836-14-00

GEOCRES Number: 52G-17

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 Kekwanzik Lake Culvert on Highway 599, located in the Township of Ignace Ontario.

The purpose of this investigation was to explore the subsurface conditions at the culvert site 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 Corporation (Hatch) to carry out this foundation investigation under the Ministry of Transportation Ontario (MTO) Agreement Number 6016-E-0030.

2. SITE DESCRIPTION

The site is located on Highway 599, approximately 4.0 km north of the intersection of Highway 599 and Highway 17 in Ignace, Ontario. The key plan showing the general location of the culvert site is presented on the Borehole Location and soil Strata Drawings in Appendix D.

Highway 599 runs in a general southwest-northeast direction with the culvert perpendicular to the centreline of the highway. The culvert allows a tributary of the Kekwanzik Lake to flow in a northwest direction beneath the highway.

The Ontario Structural Inspection Manual (OSIM) prepared by MTO dated November 2, 2015 indicates that the existing structure is a 27-m long, three span open footing, timber structure culvert. Each span is 1.8 m wide, resulting in a total culvert width of 5.4 m. The culvert is 2.1 m

Client: Hatch Corporation

File No.: 17077

E file: H:\17000-17999\17077 MTO Detail Design of Six Structures on Hwy 599 6016-E-0030\Reports & Memos\Kekwanzik Lake Culvert\FINAL\Hwy 599 Kekwanzik- FIDR FINAL.docx

Date: February 8, 2018

Page: 1 of 35



in height. The grade level of Highway 599 at the existing culvert is at an approximate Elevation of 420.8 m. The height of the existing fill cover is approximately 2.0 m. The culvert invert is at approximately Elevation 416.8 m at the inlet and 416.7 m at the outlet. The upstream and downstream water levels at Kekwanzik Lave were measured at Elevations 417.7 and 416.8, respectively, in April 2016, as shown on drawings provided by Hatch.

The lands surrounding the Kekwanzik Lake Culvert site predominantly consist of heavily forested areas with occasional marsh lands and lakes. Local topography is generally of low relief and consists of organic terrain. Beaver dam activities were noted near the culvert inlet. Photographs of the culvert and surrounding area are presented in Appendix C.

Based on published geological information, the subsurface soils at the site generally consist of outwash plains of sand and gravel with organic deposits of peat located near by. Bedrock in the area has been identified as granodiorite to granite bedrock.

3. INVESTIGATION PROCEDURES

The borehole investigation and field testing program for this project was carried out between June 9 and August 1, 2017, and consisted of drilling and sampling ten (10) boreholes, designated as Boreholes KE17-01A, KE17-01B, KE17-01C, and KE17-02 to KE17-08. Three attempts were made to advance Borehole KE17-01 to an appropriate depth and are designated as KE17-01A to KE17-01C.

Boreholes KE17-01A to KE17-01C and KE17-02 to KE17-04 were drilled along the culvert alignment. Boreholes KE17-01A to KE17-01C were drilled at the outlet and terminated at depths ranging from 1.8 m to 7.3 m (Elevations 415.2 to 410.9). Boreholes KE17-02 and KE17-03 were drilled through the highway embankment. Borehole KE17-04 was drilled at the inlet. Borehole KE17-03 was terminated at 14.2 m (Elevation 406.4). Bedrock was proved by NQ size diamond in Boreholes KE17-02 and KE17-04, and advanced 3.0 m and 3.1 m into bedrock. Both boreholes were terminated at 16.8 m and 11.9 m depth (Elevations 404.0 and 406.6).

Boreholes KE17-05 to KE17-08 were drilled through the paved section of Highway 599, to the west and east of the existing culvert, at approximately 10.0 m intervals. These boreholes were advanced to assess the existence and extents of any frost taper near the culvert. Boreholes KE17-05 to KE17-08 were terminated at depths ranging from 1.2 m to 8.2 m (Elevations 419.7 to 412.6). Borehole KE17-06 was located 10.4 m west of the existing culvert centreline, near the alignment of the proposed diversion pipe.



The boreholes on the highway platform and at the inlet, were drilled using a rubber track mounted drill rig equipped with continuous flight hollow and solid stem augers. The boreholes drilled at the outlet were advanced using tripod equipment. NQ coring methods were used to advance Boreholes KE17-02 and KE17-04 into the bedrock. Samples of the overburden soils were obtained from the boreholes at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). A Dynamic Cone Penetration Test (DCPT) was carried out in proximity to Borehole KE17-02 to further assess the subsurface/soil conditions. This DCPT was conducted from 3.0 m (Elevation 417.8) depth to refusal reached at 13.4 m depth (Elevation 407.4).

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.

All rock cores were logged, and the Total Core Recovery (TCR), Rock Quality Designation (RQD) and the Fracture Indices (FI) were determined. Photos of the rock cores are included in Appendix B.

Groundwater conditions in the open boreholes were observed throughout the drilling operations and upon completion of drilling. A piezometer was installed in Borehole KE17-04 on June 11, 2017, and a piezometer reading was taken on June 13, 2017. The piezometer was decommissioned on June 13, 2017. The boreholes were backfilled in general accordance with Ontario Regulation 903. Completion details of the boreholes are summarized in Table 3.1.

Table 3.1 – Borehole Completion Details

Borehole Number	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
KE17-01A	1.8 / 415.7	None installed	Borehole backfilled with bentonite holeplug to surface.
KE17-01B	2.4 / 415.2	None installed	Borehole backfilled with bentonite holeplug to surface
KE17-01C	7.3 / 410.9	None installed	Borehole backfilled with bentonite holeplug to surface
KE17-02	16.8 / 404.0	None installed	Borehole backfilled with auger cuttings/slough to 5.5 m, bentonite holeplug to 0.2 m, then asphalt patch to surface.

Borehole Number	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
KE17-03	14.2 / 406.4	None installed	Borehole backfilled with auger cuttings/slough to 5.9 m, gravel to 0.2 m, then asphalt patch to surface.
KE17-04	11.9 / 406.6	8.8 / 409.7	Bentonite holeplug from 11.9 m to 8.8 m, screened depth from 8.8 m to 5.8 m, sand from 5.8 m to surface
KE17-05	1.2 / 419.7	None installed	Borehole backfilled with auger cuttings to 0.2 m, then asphalt to surface.
KE17-06	8.2 / 412.6	None installed	Borehole backfilled with auger cuttings to 0.9 m, concrete to 0.2 m, then asphalt to surface.
KE17-07	3.7 / 417.0	None installed	Borehole backfilled with auger cuttings to 0.9 m, concrete to 0.2 m, then asphalt to surface.
KE17-08	3.7 / 417.0	None installed	Borehole backfilled with auger cuttings to 0.9 m, concrete to 0.2 m, then asphalt to 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) 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.

Point load tests were carried out on selected samples of intact bedrock upon arrival at the laboratory to assist in evaluation of the compressive strength of the bedrock. Results of point load tests on the rock core samples are included in Appendix B and on the Record of Borehole sheets in Appendix A.

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 existing native soil, and a sample of the surface water from the upstream of the existing culvert were collected. The samples were submitted to SGS Canada Inc., a CALA accredited analytical laboratory in Lakefield,



Ontario, for analytical testing of corrosivity parameters and sulphate content. The results of the analytical testing are summarized in Section 6 and are presented in Appendix B.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets included in Appendix A. 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 should be used for interpretation of 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 in the boreholes below the existing embankment fill typically consist of gravelly sand to sand overlying layers of native sand, gravelly sand, silt and, sand and silt, which were further underlain by gravel, cobbles and boulders. The native soils are underlain by granite bedrock. Descriptions of the individual strata are presented below.

5.1 Topsoil and Organics

Topsoil was encountered at the surface in Boreholes KE17-01B and KE17-01C. The thickness of the topsoil was 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.

Organics were encountered beneath the fill in Boreholes KE17-04 and KE17-06 at 2.7 m and 4.6 m depth (Elevations 415.8 and 416.2), respectively. The thickness of organics ranged from 50 mm to 300 mm.

Measured moisture contents in the organics were 25 percent to 42 percent.

5.2 Asphalt

The boreholes drilled through the paved portion of Highway 599 encountered approximately 25 mm of asphalt at the ground surface. The ground surface elevations of the boreholes drilled on the highway platform ranged from 420.6 to 420.9.



5.3 Embankment Fill

Embankment fill was encountered below the asphalt in all boreholes drilled on Highway 599 platform. The embankment fill generally consisted of sand containing trace to some silt, trace to some gravel and trace clay. Where fully penetrated, the embankment fill typically extended to depths of approximately 3.3 m to 4.6 m (Elevations 416.2 m to 417.4 m) below the existing road surface. Fill was also encountered at the outlet and inlet, in Boreholes KE17-01A and KE17-04 and extended to depths of 0.6 m and 2.7 m (Elevations 415.8 m and 416.9 m), respectively.

Boreholes KE17-05 and KE17-08 were terminated within the fill at 1.2 m and 3.7 m depth (Elevations 419.7 and 417.0), respectively.

SPT 'N' values in the granular fill ranged from 2 to 21 blows for 0.3 m penetration, indicating a very loose to compact relative density. Measured moisture contents ranged from 4 percent to 13 percent.

The results of grain size distribution analyses conducted on samples of the fill are presented on the Record of Borehole sheets included in Appendix A and are summarized in the following table. The results are also presented on Figure B1 in Appendix B.

Soil Particle	Fill (percent)
Gravel	3 to 20
Sand	70 to 81
Silt	12 to 15
Clay	3 to 4
Silt & Clay	10 to 15

5.4 Gravelly Sand

Native, brown gravelly sand containing trace to some silt and clay, was contacted below the fill and topsoil in Boreholes KE17-01A and KE17-01B, near the culvert outlet.

Boreholes KE17-1A and KE17-01B were terminated at 1.8 m and 2.4 m depth (Elevations 415.7 and 415.2), upon refusal.



A lower unit of grey gravelly sand was encountered in Borehole KE17-04 at 7.6 m (Elevation 410.9), above the bedrock. The thickness of the lower gravelly sand layer was 1.2 m.

SPT 'N' values recorded in the gravelly sand ranged from 10 to 87 blows for 0.3 m penetration, indicating a compact to very dense state. Measured moisture contents in the gravelly sand ranged from 6 percent to 17 percent.

The results of grain size distribution analyses conducted on samples of the gravelly sand are presented on the Record of Borehole sheets included in Appendix A and are summarized in the following table. The results are also presented on Figure B2 in Appendix B.

Soil Particle	Gravelly Sand (percent)
Gravel	22 to 29
Sand	64 to 70
Silt & Clay	7 to 10

5.5 Sand

Brown to grey sand containing some gravel, some silt and trace to some clay, was contacted in Borehole KE17-01C below the topsoil and also below the silt at 4.9 m depth (Elevation 413.3), and in Boreholes KE17-02 to KE17-04 at depths ranging from 2.7 m to 9.7 m (Elevations 415.8 to 410.9). The thickness of the sand varied from 0.8 m to 2.6 m.

The depth to the base of the sand was 3.5 m (Elevation 415.0) in Borehole KE17-04, and 12.2 m and 11.9 m (Elevations 408.6 and 408.7), in Boreholes KE17-02 and KE17-03, respectively.

Borehole KE17-01C was terminated within the sand layer at 7.3 m depth (Elevation 410.9).

SPT 'N' values recorded in the sand ranged from 7 to 25 blows for 0.3 m penetration, indicating a loose to compact relative density. Measured moisture contents in the sand deposits ranged from 10 percent to 23 percent.

The results of grain size distribution analyses conducted on samples of the sand are presented on the Record of Borehole sheets included in Appendix A and are summarized in the following table. The results are also presented on Figure B3 in Appendix B.



Soil Particle	Sand (percent)
Gravel	0 to 16
Sand	59 to 81
Silt	17
Clay	2
Silt & Clay	25

5.6 Silt to Sand and Silt

Layers of brown to grey silt to sand and silt were encountered in Boreholes KE17-01C, KE17-02 to KE17-04, KE17-06 and KE17-07 beneath the fill or native sand, at depths ranging from 0.7 m to 4.9 m (Elevations 417.5 to 415.0). The silt to sand and silt generally contains trace to some sand, trace clay. The thickness of the silt and, silt and sand layers ranged from 4.1 m to 6.2 m.

The silt to sand and silt generally extended to depths ranging between 4.9 m and 9.7 m (Elevations 413.3 and 410.9).

Boreholes KE17-06 and KE17-07 were terminated within the silt/sand and silt at 8.2 m and 3.7 m depth (Elevations 412.6 and 417.0), respectively.

SPT 'N' values recorded in the silt to sand and silt ranged from 1 to 37 blows for 0.3 m penetration, indicating a very loose to dense relative density. The loose to very loose conditions were noted within approximate Elevations 415.0 to 411.5, and may have been the result of hydraulic ground disturbance during drilling operations. Measure moisture contents in the silt to sand and silt ranged from 6 percent to 28 percent.

The results of grain size analyses conducted on samples of the silt to sand and silt are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B4 of Appendix B. The results are summarized as follows:



Soil Particle	Silt, Sand and Silt (percent)
Gravel	0
Sand	7 to 65
Silt	32 to 85
Clay	2 to 8

5.7 Gravel, Cobbles and Boulders

Cobbles and boulders were encountered in Borehole KE17-02 at 12.2 m depth (Elevation 408.6). The cobbles and boulders generally contained some sand and gravel and trace silt. The cobbles and boulders were proved by coring. The layer of the cobbles and boulders was 1.6 m thick.

The depth to the base of the cobbles and boulders was 13.8 m (Elevation 407.0).

A layer of gravel containing some sand, was contacted at 13.7 m depth (Elevation 406.9) in Borehole KE17-03. Borehole KE17-03 was terminated within the gravel layer at 14.2 m (Elevation 406.4).

A SPT 'N' value recorded in the gravel layer was 107 blows for 0.3 m penetration, indicating a very dense state. Measured moisture contents in the gravel, cobbles and boulders layers were 5 percent and 10 percent.

5.8 Bedrock

The overburden soils described above are underlain by granite bedrock. The bedrock was grey with occasional pink bands. Occasional mechanical breaks were noted throughout the bedrock cores. The bedrock is generally described as highly to moderately weathered. Bedrock was proved by coring in Boreholes KE17-02 and KE17-04. Table 5.1 summarizes depths and elevations to the top of bedrock.



Table 5.1 – Depths and Elevations of Top of Bedrock

Borehole	Top of Bedrock	
	Depth (m)	Elevation (m)
KE17-02 ⁽¹⁾	13.8	407.0
KE17-04 ⁽¹⁾	8.8	409.7

⁽¹⁾ Proved by coring.

Total Core Recovery (TCR) in the bedrock ranged from 93% to 100% with Solid Core Recovery (SCR) ranging from 23% to 88%. The Rock Quality Designation (RQD) determined from the recovered cores generally ranged from 0% to 82%, indicating very poor to good rock quality.

The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m of core, ranged from 1 to greater than 10.

Average unconfined compressive strengths (UCS) of the rock ranged between 30 MPa and 224 MPa, indicating the rock is medium strong to very strong. These estimated rock strength values are interpreted from point load tests that were conducted on rock cores recovered from the boreholes. A summary of the Point Load Test Results and photographs of bedrock cores are presented in Appendix B.

5.9 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes upon completion of drilling. A piezometer was also installed in Borehole KE17-04. The groundwater levels measured in the open boreholes and the piezometer are summarized in Table 5.2 below.

Table 5.2 – Groundwater Measurements

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
KE17-01A	June 16, 2017	1.2	416.3	Open borehole
KE17-01B	June 16, 2017	1.2	416.4	Open borehole
KE17-01C	June 17, 2017	0.7	417.5	Open borehole
KE17-02	June 13, 2017	3.9	416.9	Open borehole
KE17-03	June 15, 2017	3.5	417.1	Open borehole
KE17-04	June 13, 2017	1.0	417.5	Piezometer
KE17-05	June 09, 2017	Dry	-	Open borehole
KE17-06	June 16, 2017	3.9	416.9	Open borehole
KE17-07	June 14, 2017	3.0	417.7	Open borehole
KE17-08	June 14, 2017	Dry	-	Open borehole

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. The groundwater level should be assumed to reflect the local lake level.

6. CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the native sandy silt from Borehole KE17-03, and a sample of the lake water, taken from the inlet area, 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	
			KE17-03 SS5	Kekwanzik Lake
			(Sandy Silt)	(Lake Water)
Sulphide	%	mg/L	<0.02	<0.006
Chloride	µg/g	mg/L	240	8.8
Sulphate	µg/g	mg/L	10	2.0
pH	No unit	No unit	6.40	7.38
Electrical Conductivity	µS/cm	µS/cm	269	67
Resistivity	Ohms.cm	Ohms.cm	3720	15000
Redox Potential	mV	mV	338	312

7. MISCELLANEOUS

Thurber obtained subsurface utility clearances prior to drilling. Thurber obtained the northing and easting coordinates and ground surface elevations from measurements taken in the field 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. Ryan McCourt, P. Geo of Thurber. Overall supervision of the field program was provided by Mr. Cory Zanatta, EIT of Thurber.

Geotechnical laboratory testing was carried out at 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, The report was reviewed by Mr. Jason Lee, P.Eng and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



Thurber Engineering Ltd.

Cory Zanatta, B.A.Sc.
Geotechnical EIT



Jason Lee, P.Eng.
Principal/Senior Geotechnical Engineer



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

Client: Hatch Corporation

File No.: 17077

E file: H:\17000-17999\17077 MTO Detail Design of Six Structures on Hwy 599 6016-E-0030\Reports & Memos\Kekwanzik Lake Culvert\FINAL\Hwy 599 Kekwanzik- FIDR FINAL.docx

Date: February 8, 2018

Page: 13 of 35



**FOUNDATION INVESTIGATION AND DESIGN REPORT
KEKWANZIK LAKE CULVERT REPLACEMENT
HIGHWAY 599, SITE No. 48W-243/C
TOWNSHIP OF IGNACE
ONTARIO**

G.W.P. No. 6836-14-00

GEOCRES Number: 52G-17

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 Kekwanzik Lake culvert replacement located on Highway 599, approximately 4.0 km north of the intersection of Highway 599 and Highway 17 in Ignace, 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 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 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 dated November 2, 2015. The existing structure is a three-span open footing timber culvert. Each span is 1.8 m wide, resulting in a 5.4-m wide culvert. The length of the culvert is 27.0 m long. The estimated culvert invert level is at approximately Elevations 416.8 m at the inlet and 416.7 m at the outlet. The existing road grade at the culvert location is at about Elevation 420.7 m, which indicates approximately 1.8 m of fill above the culvert.

Client: Hatch Corporation

File No.: 17077

E file: H:\17000-17999\17077 MTO Detail Design of Six Structures on Hwy 599 6016-E-0030\Reports & Memos\Kekwanzik Lake Culvert\FINAL\Hwy 599 Kekwanzik- FIDR FINAL.docx

Date: February 8, 2018

Page: 14 of 35



General Arrangement (GA) Drawings and discussions with Hatch/MTO, indicate that three replacement options are being considered:

1. Multiple CSP Pipe Culvert

Two circular CSP pipes are being considered to provide increased hydraulic opening. The CSPs are likely to be approximately 4.0-m diameter each. The proposed founding level (base of culvert bedding) of the CSP pipes is near Elevations 415.1 to 415.3. The length of the pipes is 33.8 m.

2. Single Span Precast Concrete Box Culvert

A single cell precast concrete box culvert is an option for this site. Information provided by Hatch indicates that a 7.6 m x 2.7 m box culvert is being considered. The length of the box culvert is 33.1 m. The proposed founding level (base of culvert bedding) of the box culvert is near Elevations 415.1 to 415.2.

3. Sheet Pile Culvert

A culvert consisting of two parallel sheet pile walls supporting a slab consisting of precast concrete panels might be an option at this site. The proposed structure will have a span of 8.0 m, an unsupported height of about 2.7 m, and a sheet pile wall length of approximately 25.8 m of which 21.7 m will be capped by precast panels.

The alignment of the replacement culvert will remain largely the same as for the existing culvert. Grade raise of about 280 mm is proposed at the culvert location.

The culvert replacement is proposed to be constructed utilizing a traffic staging, which would require installation of a temporary roadway protection system and a temporary stream diversion pipe (CSP). A temporary water/lake diversion pipe, approximately 10.0 m west of the existing culvert centreline, with an invert elevation of approximately 416.8 (according to GA drawing), would be installed during construction.

The discussions and recommendations presented in this report are based on information provided by Hatch and on the factual data obtained during the course of the current investigation.



9. CULVERT DESIGN

9.1 Culvert Replacement Options

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, Structural Plate Corrugated Steel Pipe (SPCSP), or Helical Corrugated Structural Pipe (CSP)
- Concrete box (closed) culvert composed of pre-cast segments
- Concrete open frame culvert on spread footings
- Precast Concrete Slabs Supported on Sheet Pile Abutments (Sheet pile culvert)

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 SPCSP, CSP, precast box culvert or sheet pile culvert are all feasible options, based on the following considerations:

- Precast box culvert or pipe culverts 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;
- The sheet pile culvert minimizes any disturbance or environmental impact on the channel bed. The design also minimizes use of cast-in-place concrete which increases the cost of construction significantly;

An open footing culvert is not recommended at this site since it would involve deeper excavation and more dewatering effort. In addition, the soils at this site have very low geotechnical resistance and are prone to settlement. Hence, recommendations for this option have not been developed.



Recommendations for the design and installation of concrete pipe or SPCSP, concrete box and sheet pile culverts are presented below.

9.2 Foundation Design for Culverts

In general, the subsurface conditions encountered in the boreholes drilled through the highway platform consists of embankment fill, typically sand to sand and gravel, underlain by layers of native sand, silt and, sand and gravel. A layer of organics was encountered below the fill in one borehole drilled on the roadway. The thickness of the fill encountered at the boreholes drilled along the existing culvert alignment (Boreholes KE17-01A to KE17-01C and KE17-02 to KE17-04) varied from 0.6 m to 4.0 m. Layers of gravelly sand and cobbles/boulders were also encountered at this site. The native soils are underlain by bedrock. The water levels in the lake, indicated in available data, is at Elevations 416.87 and 417.77, in the outlet and inlet, respectively. The groundwater level measured in the installed piezometer was at approximately Elevation 417.5.

The founding soils encountered at the proposed founding elevations 415.1 to 415.3 (base of bedding) generally consist of native loose to compact silt, silt and sand, and sand.

Foundation design aspects for the replacement culvert include 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 Corrugated Steel Pipe Culvert

Replacement of the culvert with multiple SPCSPs or CSPs on the same alignment as the existing culvert may be considered for this site. Since there is a proposed grade raise of 280 mm, it is anticipated that the subgrade soils within the culvert footprint will be subjected to additional loading due to the culvert replacement and new fill. Settlement due to the new load is anticipated at the site, however the settlement is not expected to be more than 25 mm. The culvert must be designed to accommodate the estimated settlement.

If this alternative is selected, the SPCSPs or CSPs 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. The underside of the bedding layer should be placed at or below Elevations 415.2 to 415.3, which corresponds to native loose to compact silt, silt and sand, and sand. Geotextile should be placed between the founding soils and the granular layer of bedding material.



Any remaining organics, loose/soft or deleterious material should be removed from final subgrade level and replaced with compacted granular material. Culvert subgrade preparation and placement and compaction of the granular fill replacing the organics and existing fill must be carried out in the dry. Adequate preparation of the subgrade will be essential for performance of the culvert.

9.2.2 Precast Concrete Box Culvert

Replacement of the culvert with precast concrete box culvert on the same alignment is considered a viable alternative for this site. Since there is grade raise proposed, it is anticipated that the subgrade soils within the culvert footprint will be subjected to additional loading due to the culvert replacement. Therefore, settlement of the underlying soils is expected to be in the order of 20 mm to 30 mm.

Based on available information, it is anticipated that the proposed inlet and outlet founding levels (bottom of bedding) of the culvert are at Elevations 415.1 and 415.2, respectively.

The founding elevations will expose loose to compact silt, silt and sand, and sand.

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. 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 75 mm minimum thickness top levelling course consisting of uncompacted Granular A. Geotextile should be placed between the founding soils and the granular layer of bedding material. Subgrade preparation should also be conducted as indicated in Section 11.1.

The following geotechnical capacities could be used for design of a box culvert founded at or below Elevations 415.0 and 415.2 m on the native loose to compact silt, silt and sand, or sand:

- Factored Geotechnical Resistance at ULS of 175 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 125 kPa.

The above values of the geotechnical resistance and reaction were based on a box culvert width of about 7.6 m.



The consequence factor of 1 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 Canadian Highway and Bridge Design Code (CHBDC) 2014, Sec. 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 are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance used in design should be reduced in accordance with the CHBDC 2014, Clause 6.10.3 and Clause 6.10.4.

Resistance to lateral forces / sliding resistance between the concrete and the underlying Granular A or B Type II bedding material should be calculated assuming an ultimate coefficient of friction of 0.35.

Immediate settlement, 20 mm to 30 mm, is anticipated due to placement of new fill at the site. The culvert must be designed to accommodate the estimated settlement.

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 Steel Sheet Pile Walls

Consideration was given to supporting the culvert on steel sheet piles driven to bedrock or to refusal. As indicated in the factual part of the report, a layer of cobbles and boulders was contacted at 12.2 m depth (Elevation 408.6), above the bedrock surface, and it is possible that some of the sheet piles may encounter refusal on this layer.

The current design proposes steel sheet pile walls installed adjacent to the culvert in lieu of conventional wingwalls or headwalls. The sheet piles will provide containment and resistance to lateral earth pressures from the approach fill. The design and installation of all sheet piles should be conducted as described below.

The depths and elevations where bedrock and/or refusal were contacted, are presented in Table 9.1.



Table 9.1 – Depths and Elevations to Bedrock or Refusal

Borehole location relative to culvert	Borehole	Refusal/ Bedrock Depth (m)	Refusal/ Depth Elevation (m)	Comment
Outlet	KE17-01C	7.3	410.9	Refusal depth encountered by tripod drill equipment. The sheet pile may be able to advance deeper.
Roadway	KE17-02	12.2	408.6	Refusal on cobbles and boulders, above the bedrock.
		13.8	407.0	Bedrock.
Roadway	KE17-03	13.7	406.9	Layer of very dense sand/gravel.
Inlet	KE17-04	8.8	409.7	Bedrock.

Vertical, factored geotechnical resistance at Ultimate Limit States (ULSf) and geotechnical resistance at Serviceability Limit States (SLS) for two sheet pile sections driven to refusal or to bedrock are presented in Table 9.2. The geotechnical resistance values have been reduced to account for the possibility that some or all of the sheet piles may encounter refusal in the cobbles and boulders above the bedrock. Sheet piles should be driven to refusal at or below the specified elevations noted in Table 9.1. An additional note should be included to indicate that installation of permanent sheet pile walls by vibratory equipment is not permitted.

Table 9.2– Recommended Axial Resistances of Steel Sheet Piles

Sheet Pile Section	Factored ULS Resistance per meter width (kN/m)	SLS Resistance (kN/m)
EZ-88	650	515
SKZ-22	600	475

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

Sheet piles should be provided with sheet pile tip protector to minimize any tip damage.



Vertical design loads on the sheet pile walls were provided by Hatch, and are as follows:

- 378 kN/m (ULS)
- 285 kN/m (SLS)

Steel sheet pile installation should be in accordance with OPSS 903.

9.2.3.1 Sheet Pile Lateral Resistance

Design for lateral resistance of the sheet piles may be carried out using the earth pressure coefficients (K_a = active, K_o = at rest, K_p = passive) and soil unit weights provided in Table 9.3 below and Table 10.1 in Section 10.

The interaction between the sheet pile wall and the adjacent soil may be analysed using a soil-spring model and a coefficient of horizontal subgrade reaction, k_s . The value of k_s may be assumed to be constant with depth. In cohesionless soils, the horizontal subgrade reaction per linear meter varies with depth and can be calculated as follows:

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

where z = depth of embedment of pile in metres

n_h = coefficient related to soil density, see table below (kN/m^3)

For soil-spring analysis, the spring constant, K_s , may be obtained by the expression $K_s = k_s L$ (kN/m), where k_s is the coefficient of horizontal subgrade reaction (kN/m^3) and L is the length (m) of the pile segment or element used in the analysis.

Table 9.3 – Soil Parameters for Lateral Pile Resistance

Soil Unit	Elevation (m)		γ' (kN/m^3)	n_h (kN/m^3)	K_a	K_o	K_p
	Top	Bottom					
Sand Fill	420.8	417.0	21	1,500*	0.33	0.50	1.3*
Silt/Sand and Silt	417.0	411.0	9	1,500	0.35	0.52	2.9
Sand	411.0	406.9	10	2,000	0.33	0.50	3.0

Note: * Top of fill at the existing culvert; top of sheet pile may vary. K_p accounts for 2H:1V fill slope.

** Sheet pile tip elevations may vary at sheet pile locations.



9.2.3.2 Construction Considerations for Sheet Piles

In general, backfill to the sheet pile walls should be in accordance with OPSS 902 and should consist of Granular A, Granular B Type II or Granular B Type III material. All granular material should meet the specifications of OPSS.PROV 1010. Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS 501.

Even though cobbles and boulders were not encountered within the embankment fill during the investigation, they may be encountered during driving the sheet piles through the existing embankment fill. Any rock fill/erosion protection materials if present at the culvert site, as well as any visible obstructions along the sides of the culvert should be removed prior to driving the sheet piles.

The sheet pile alignment should be strategically located to avoid encountering existing ancillary structures.

Use of tip protection is recommended for the sheet piles at this site.

In light of the loose foundation sands and silts, vibratory methods should not be used at this site to install the sheet piles.

Design of the permanent sheet pile culvert should consider environmental factors such as road salts, presence of organic deposits or fluctuating lake water level that may cause corrosion and reduce the service life of the structure.

The native soils in front of the sheet piles must be protected from lake erosion so that the sheet piles do not lose lateral support.

Consideration should be given to placement of biaxial geogrid above the sheet pile structure to mitigate potential settlement that may develop in the approach fills. The biaxial geogrid should extend a minimum of 10.0 m beyond the sheet pile abutment and should be placed longitudinally as a single uninterrupted run of geogrid with no transverse joints/overlaps.

9.2.3.3 Downdrag

Downdrag on the piles is not considered to be an issue at this site.



9.2.4 Culvert Headwall / Wingwalls

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

The borehole information indicates that the founding soils at the inlet and outlet generally consist of very loose sand fill, over very loose to loose sand and, sand and silt and compact gravelly sand. Bedrock was encountered below the native soils. A layer of organics was contacted in the outlet area, below the fill.

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.

If topsoil/organics are encountered along the alignment of the RSS wall, they must be removed down to native sand/silt. The RSS mass should then be founded on a 0.5 m thick engineered fill pad resting on the native sand/silt at or below approximate Elevation 415.0. 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). The 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 0.35.

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.

Anticipated settlement of 25 mm is anticipated for the RSS. The RSS wall supplier must be consulted if the proprietary system can accommodate the settlement.

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. Since the RSS wall will be constructed adjacent to a lake/water course, the wall may be subjected to flooding. The RSS supplier should be made aware that for submerged conditions the RSS strips may need to be longer than the usual 70% of fill height and the strips must be corrosion resistant.

Adequate scour and erosion protection must be provided for the bases of the RSS walls so that they are not undermined by lake/water course flow.

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 10. 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 loose to compact subgrade. All topsoil, organics or soft soils



encountered along the alignment of the walls must be removed. The walls should be provided with a sufficient frost cover (minimum 2.5 m at this site) and founded at Elevations 415.0 to 415.5. 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 underlying sand, and sand and gravel should be evaluated in accordance with the CHBDC (2014) assuming an ultimate coefficient of friction of 0.35.

Lateral earth pressures acting on the wingwalls should be computed as described in Section 10. If the wall is retaining sloping backfill, appropriate earth pressure parameters for sloping backfill should be used.

Adequate erosion protection must be provided for the bases of the retaining walls so that they are not undermined by lake/water course flow.

9.3 Settlement

Embankment grade raise, approximately 280 mm, is anticipated as part of the culvert replacement. It is recommended that the underlying layer organics, encountered below the fill, be excavated. The estimated settlements after culvert construction and embankment reconstruction at this site is estimated to be 20 mm to 30 mm.

The culvert must be designed to accommodate the estimated settlement.

It must be noted that any additional load imposed on the culvert replacement, including fill placed adjacent to the extended culvert barrels, will induce immediate settlement of the loose cohesionless soils at this site.

9.4 Frost Cover

The depth of frost penetration at this site is approximately 2.5 m, as per OPSD 3090.100. The base of retaining wall footings, if employed, should be provided with a minimum of 2.5 m of earth cover as protection against frost action. The pipe and box culvert options do not require frost cover/protection.



The frost taper investigation indicated the presence of 3.3 m to 4.6 m of sand fill overlying native silt, silty sand and, sand and silt layers, to approximately 20 m north and south of the centreline of the existing culvert. The majority of the granular fill and the native cohesionless soils are not frost susceptible. It is not known whether the granular fill material was intentionally placed as a frost taper, or as road embankment fill and base material.

As the frost penetration line is below the top of culvert, frost treatment/taper for the culvert would normally be provided as per OPSD 803.031. Since the existing embankment material beyond the excavations for the existing culvert does not contain frost susceptible soils within the frost penetration depth (2.5 m), a new frost taper does not appear to be warranted.

10. LATERAL EARTH PRESSURES

A triangular distribution of lateral earth pressures acting on the culvert walls may be assumed for design. 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)
	γ	=	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 unfactored values are shown in Table 10.1 below.

Table 10.1 – 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 $\phi = 32^\circ$; $\gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48
At-rest (Restrained Wall)	0.43	0.62	0.47	0.70
Passive	3.7	-	3.3	-

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

11. CULVERT CONSTRUCTION CONSIDERATIONS

It is understood that construction staging will be required to maintain one lane of traffic.

Staged construction sequencing will likely require the following:

- Diversion of the lake/creek will be required 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 and headwall subgrade preparation and foundation preparation must be carried out in the dry.



11.1 Subgrade Preparation

Performance of the replacement culvert and any headwalls 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. The organics observed below the embankment fill must be removed to expose the underlying competent sand and silt subgrade. Any remaining fill, topsoil, lake bed deposits, disturbed soils and any deleterious materials within the replacement culvert and headwall footprint at the subgrade level must be removed and replaced with well compacted granular materials.

In the event that subexcavation is required, the width of the subexcavation 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 subexcavated 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 and all subgrade preparation and placement and compaction of granular material must be carried out in the dry.

Construction equipment should not be allowed to travel on the prepared subgrade, which has to be protected from disturbance during construction.

11.2 Culvert Bedding and Backfill

A minimum 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 CSP or box culvert and compacted in accordance with OPSS 501 in the dry. The culvert subgrade preparation, placement and compaction of granular bedding should be carried out in the dry. However, if the dewatering efforts are not fully effective and if the culvert is to be constructed in the remaining wet condition, coarse 53 mm clear stone wrapped in geotextile should be used as backfill in the wet below the culvert. Once the clear stone backfill is above the water level, granular bedding for the culvert may then be placed and compacted in the dry. The clear stone backfill may be fully enclosed in geotextile. Geotextile should be placed between the founding soils and the granular layer of bedding material for separation purpose.



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 802.014, and as per the requirements of the CHBDC.

Backfilling for the culvert should be in accordance with OPSS 501, OPSS 902, and as per the CHBDC requirements. 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.

11.3 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 and native silts and sands at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level. Surficial alluvial deposits, should be classified as Type 4 soils.

Excavation for culvert construction should be carried out in accordance with OPSS 902. Excavations for culvert replacement will be carried out through the existing embankment fill and native silt, sand and gravelly sand layers.

Excavation for culvert replacement will be carried out below the lake/creek water level indicated at Elevation 416.87 in the GA drawing. Groundwater level was measured at Elevation 417.5 in the piezometer installed in Borehole KE17-04. In order to construct a pipe or a box culvert in the dry, diversion of the lake/creek flow will be required. Given the relatively high permeability of the embankment fill materials, water inflow/seepage into the excavation should be anticipated from the embankment fill. A combination of cofferdam enclosures and lake/creek/water course diversion along with the use of sumps/pumps within an enclosure will be required to maintain dry excavations during the course of staged construction. The use of interlocking and watertight, steel sheet pile cofferdam is a feasible option for this site. The dewatering scheme must be effective to lower the groundwater level to at least 0.5 m below the final subgrade level to avoid base boiling in the native soils.



Installation of a temporary cofferdam is planned at the inlet and outlet of the culvert. Boreholes were not drilled at the proposed cofferdam location; the closest boreholes to the cofferdam locations are Boreholes KE17-01 and KE17-04. Record of Boreholes Sheets of these boreholes are included in Appendix B.

Dewatering of all excavations should be carried out in accordance with OPSS. PROV 517, SP 517F01 Amendment to OPSS 517, November 216 (issued July 2017), and OPSS. PROV 902.

The design of an effective 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. 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.

12. STREAM DIVERSION PIPE

A stream diversion pipe consisting of a CSP may be used to facilitate construction of the CSP culvert and box culvert replacement options, as indicated on the Preliminary General Arrangement drawings provided by Hatch. The diversion pipe is shown to be located approximately 10.0 m to the west of the centreline of the existing culvert with the invert at approximate Elevation 416.8 as per GA drawing. Below the invert level, the subgrade will consist of loose sand fill, as documented in Borehole KE17-06.

A 300-mm thick layer of organics was encountered at Elevation 416.2 in Borehole KE17-06. The layer of organics should be sub-excavated where encountered. The organics should then be replaced with a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II, or clear stone if wet. 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 should be protected from disturbance during construction.

The stream diversion pipe could be installed within the temporary open cut excavations, or alternatively within a shored trench. The installation of the diversion pipe in open cut should follow OPSD 802.014 (Flexible Pipe Embedment in Embankment) and as per the requirements of the CHBDC.



13. TEMPORARY PROTECTION SYSTEM

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

Interlocking sheet piles or a soldier pile and lagging wall could be considered at this site. The soil parameters in Table 13.1 may be used for design of the temporary roadway protection system with horizontal backfill.

Full hydrostatic pressure should be considered assuming a water level equal to the design high water level in the lake.

Table 13.1 –Soil Parameters for Temporary Protection System Design

Soil Parameter	Existing Fill	Native Silt to Sand
Angle of Internal Friction (ϕ)	30°	30°
Bulk Unit Weight (γ)	20 kN/m ³	20 kN/m ³
Submerged Unit Weight (γ_w)	10 kN/m ³	10 kN/m ³
Coefficient of Active Earth Pressure (K_a)	0.33	0.33
Coefficient of Passive Earth Pressure (K_p)	3.0	3.0

Given the presence of the sensitive sand/silt deposits vibratory methods must not be used at this site to install or extract the sheet piles and H-piles (if used). A NSSP to this effect is provided in Appendix F.

The design of the temporary protection system is the responsibility of the Contractor. The actual pressure distribution acting on the protection/shoring system is a function of the construction sequence and the relative flexibility of the wall, and these factors have to be considered when designing the shoring system. All protection systems should be designed by a Professional Engineer experienced in such designs, who will determine an appropriate support system.



14. EMBANKMENT WIDENING AND RESTORATION

It is anticipated that there will be a grade raise of 280 mm at this site for the culvert replacement. Also, widening of the embankment, approximately 1.0 m on each side, is planned at this site, as per cross sections provided by Hatch.

Based on the GA drawings, the sides of the embankment fill will be contained by sheet pile walls installed along the edges of the road.

Provided that the embankment is reconstructed with side slopes inclined at not steeper than 2H:1V, the restored embankment slopes should remain stable.

Settlement of the embankment in the order of 20 mm to 30 mm should be expected under the existing culvert footprint of the culvert/embankment. The settlement will be immediate in nature and is anticipated to be completed by the end of construction. Inspection of the roadway surface and padding of the asphalt at the approaches to re-establish grades as necessary should be implemented during and after construction.

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. Where new embankment fill is placed against existing embankment slopes or on sloping ground surface steeper than 3H : 1V, the existing fill slope must be benched in accordance with OPSD 208.010.

In general, surface vegetation, alluvium/muskeg/organics, topsoil, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from the areas around the culvert inlets and outlets, and within the embankment footprints. Inspection and approval of the foundation surfaces by qualified geotechnical personnel must be conducted at this site.

15. SEISMIC CONSIDERATIONS

In accordance with the CHBDC 2014, the selection of the seismic site classification is based on the average soil conditions encountered in the upper 30 m of the stratigraphy. The stratigraphy of the site include loose to compact granular fill underlain by layers of native cohesionless soils consisting compact to loose sand, sandy silt and, sand and gravel. This would correspond to a Seismic 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% in 50 year probability of exceedance at this site is 0.054 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 15.1 may be used:

Table 15.1 – 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 $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	Existing Fill $\phi = 30^\circ, \gamma = 20 \text{ kN/m}^3$
Active (K_{AE})*	0.29	0.33	0.36
At Rest (K_{OE})**	0.50	0.54	0.57

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

** After Woods

The site is underlain by layers of loose to compact sand, silt, and, gravelly sand. Layers of cobbles, boulders were encountered over bedrock at this site. In view of the low potential for seismic activity in the area, liquefaction is not considered to be a concern at this site.

Localized liquefaction during a seismic event may result in local toe failure or minor embankment settlement, but this is expected to be readily repairable.

16. SCOUR AND EROSION PROTECTION

Erosion protection should be provided at the culvert inlet and outlet. Design of the erosion protection measures considering hydrologic and hydraulic factors should be carried out by specialists experienced in this field and in accordance with OPSD 810.010, OPSS 511 and OPSS PROV 1004.

Typically, rock protection will be required over all surfaces with which lake 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 a clay seal should be used to minimize the potential for erosion or piping around the culvert. The clay seal should be provided at the inlet and should extend 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 geosynthetic clay liner may be used in place of a compacted clay seal.



The ground in front of the sheet pile should be properly compacted and re-graded following removal of the existing timber culvert, and protected from river erosion so that the sheet piles do not lose lateral support.

If RSS or concrete retaining walls are selected for the culvert replacement design, adequate scour and erosion protection must be provided for the bases of the RSS walls so that they are not undermined by creek flow.

17. CORROSION AND SULPHATE ATTACK POTENTIAL

The results of the corrosivity and sulphate analytical tests conducted on the native soil and lake water from the current investigation indicates the following conditions at the locations tested:

- The potential for sulphate attack on concrete foundations from the surrounding native soil or surface water is considered to be negligible due to the low concentration of sulphate and chloride in the samples tested. The selection of class of concrete should consider the effects of the road de-icing salts.
- The potential for soil or surface water corrosion on metal is considered to be mild to moderate.
- Appropriate protection measures commensurate with the above are recommended if metal structural elements are used. The effects of road de-icing salts should be also considered.

18. CONSTRUCTION CONCERNS

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

- An effective dewatering / unwatering system must be employed to enable culvert construction in the dry and prevent base boiling, sloughing and instability of the excavation walls.
- The water level in the lake may fluctuate and be at higher elevation at the time of construction than indicated in the report.
- 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 (e.g., 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. Jason Lee, 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



Jason Lee, P.Eng.
Principal/Senior Geotechnical Engineer



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



Client: Hatch Corporation

File No.: 17077

E file: H:\17000-17999\17077 MTO Detail Design of Six Structures on Hwy 599 6016-E-0030\Reports & Memos\Kekwanzik Lake Culvert\FINAL\Hwy 599 Kekwanzik- FIDR FINAL.docx

Date: February 8, 2018

Page: 35 of 35



Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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



4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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

 Water Level
 Shear Strength Determination by Pocket Penetrometer

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

EXPLANATION OF ROCK LOGGING TERMS


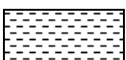

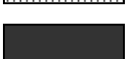

ROCK WEATHERING CLASSIFICATION

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

DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
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

Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
	(MPa)	(psi)	
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 KE17-01A 1 OF 1 METRIC

GWP# 6836-14-00 LOCATION Kekwanzik Lake Culvert, MTM NAD 83 Zone 16 N 5 478 833.0 E 404 445.2 ORIGINATED BY BRM
 HWY 599 BOREHOLE TYPE Tripod - Wash Boring COMPILED BY AN
 DATUM Geodetic DATE 2017.06.16 - 2017.06.16 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)	
417.5	GROUND SURFACE							20	40	60	80	100							
0.0	SAND , trace gravel, occasional organics Compact Brown Moist (FILL) Gravelly SAND , trace to some silt and clay Dense to Very Dense Brown Wet		1	SS	21		417												
416.9			2	SS	30														
0.6			3	SS	87														
415.7							416										22 68 10 (SI+CL)		
1.8	END OF BOREHOLE AT 1.8m UPON CASING REFUSAL. WATER LEVEL MEASURED AT 1.2m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.																		

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

RECORD OF BOREHOLE No KE17-01B

1 OF 1

METRIC

GWP# 6836-14-00 LOCATION Kekwanzik Lake Culvert, MTM NAD 83 Zone 16 N 5 478 834.2 E 404 446.0 ORIGINATED BY BRM
 HWY 599 BOREHOLE TYPE Tripod - Wash Boring COMPILED BY AN
 DATUM Geodetic DATE 2017.06.16 - 2017.06.16 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT							UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa													
								20 40 60 80 100													
417.6	GROUND SURFACE							20 40 60 80 100													
0.0	TOPSOIL: (50mm)							20 40 60 80 100													
	Gravelly SAND , trace silt and clay Compact to Very Dense Brown Moist to Wet		1	SS	10	▽	417														
			2	SS	24																
			3	SS	55				416												
			4	SS	16																
415.2																					
2.4	END OF BOREHOLE AT 2.4m UPON CASING REFUSAL. WATER LEVEL MEASURED AT 1.2m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.																				

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

RECORD OF BOREHOLE No KE17-01C

1 OF 1

METRIC

GWP# 6836-14-00 LOCATION Kekwanzik Lake Culvert, MTM NAD 83 Zone 16 N 5 478 820.2 E 404 435.8 ORIGINATED BY BRM
 HWY 599 BOREHOLE TYPE Tripod - Wash Boring COMPILED BY AN
 DATUM Geodetic DATE 2017.06.17 - 2017.06.17 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)					
								○ UNCONFINED + FIELD VANE				w _P w w _L					
								● QUICK TRIAXIAL × LAB VANE									
418.2	GROUND SURFACE					▽	20	40	60	80	100	20	40	60			
0.0	TOPSOIL: (50mm)		1	SS	16												
417.5	SAND, trace gravel Compact Brown		2	SS	10												
0.7	Moist SILT, trace to some sand, trace clay Dense to Compact Brown to Grey Moist to Wet		3	SS	33												
			4	SS	23												
			5	SS	12												
			6	SS	11												
			7	SS	14												
			8	SS	16												
413.3	SAND, some silt, trace clay Compact to Loose Grey Moist		9	SS	19		413										0 7 85 8
		10	SS	25													0 81 17 2
		11	SS	7	412												
		12	SS	10													
410.9	END OF BOREHOLE AT 7.3m UPON CASING REFUSAL. WATER LEVEL MEASURED AT 0.7m UPON COMPLETION OF BOREHOLE. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.																
7.3																	

ONTMT4S MTO-17077.GPJ 2017TEMPLATE(MTO).GDT 1/29/18

RECORD OF BOREHOLE No KE17-02

1 OF 2

METRIC

GWP# 6836-14-00 LOCATION Kekwanzik Lake Culvert, MTM NAD 83 Zone 16 N 5 478 815.9 E 404 445.7 ORIGINATED BY BRM
 HWY 599 BOREHOLE TYPE Hollow Stem Augers/Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.06.13 - 2017.06.13 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 ³	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 _P W W _L					
420.8	GROUND SURFACE							20	40	60	80	100	20	40	60		
0.8	ASPHALT: (25mm)																
	SAND, some silt, trace clay, trace gravel Very Loose to Loose Brown Moist (FILL)		1	GS			420						○				
			2	GS									○				
			1	SS	3		419						○			3	81 12 4
			2	SS	9		418						○				
417.4			3	SS	6		417						○				
3.4	SAND and SILT, trace clay Loose to Very Loose Grey Moist																
			4	SS	7		416						○				
			5	SS	2		415						○				
	Low SPT "N" values due to hydraulic ground disturbance from approx. elevation 415.0m to 411.0m		6	SS	1		413						○			0	47 49 4
			7	SS	1		412						○				
411.2							411										
9.6	SAND, trace to some gravel, some silt and clay																

Continued Next Page

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

METRIC

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

Continued from previous page					
	SAND, some gravel, some silt and clay Compact Grey Wet		8	SS	15
408.6					
12.2	COBBLES and BOULDERS some sand, some gravel		1	RUN	
407.0					
13.8	BEDROCK GRANITE highly weathered, pink and grey, mechanical breaks		2	RUN	
			3	RUN	
404.0	Slightly weathered				
16.8	END OF BOREHOLE AT 16.8m. WATER LEVEL AT 3.9m UPON COMPLETION. BOREHOLE BACKFILLED WITH SLOUGH TO 5.5m, BENTONITE HOLEPLUG TO 0.2m, THEN ASPHALT TO SURFACE.				

CONTMT4S MTO-17077.GPJ 2017TEMPLATE(MTO).GDT 1/29/18

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No KE17-03

1 OF 2

METRIC

GWP# 6836-14-00 LOCATION Kekwanzik Lake Culvert, MTM NAD 83 Zone 16 N 5 478 821.6 E 404 454.6 ORIGINATED BY BRM
 HWY 599 BOREHOLE TYPE Hollow Stem Augers/Dynamic Cone Penetration Test COMPILED BY AN
 DATUM Geodetic DATE 2017.06.15 - 2017.06.15 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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	20	40	60	80	100	W _P		W	W _L		
420.6	GROUND SURFACE																		
0.0	ASPHALT: (25mm)																		
	SAND, some silt, trace gravel, trace clay Very Loose to Loose Brown Moist (FILL)		1	GS									○						
			1	SS	5								○						
			2	SS	3								○						
			3	SS	7								○						
			4	SS	8								○						
416.6																			
4.0	SILT, some sand, trace clay Compact to Very Loose Brown Moist		5	SS	10								○						
	Brown to Grey Wet		6	SS	7								○						
			7	SS	3								○						
	Dense		8	SS	37								○						
410.9																			
9.7	SAND, trace gravel Compact																		

Continued Next Page

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

RECORD OF BOREHOLE No KE17-03

2 OF 2

METRIC

GWP# 6836-14-00 LOCATION Kekwanzik Lake Culvert, MTM NAD 83 Zone 16 N 5 478 821.6 E 404 454.6 ORIGINATED BY BRM
 HWY 599 BOREHOLE TYPE Hollow Stem Augers/Dynamic Cone Penetration Test COMPILED BY AN
 DATUM Geodetic DATE 2017.06.15 - 2017.06.15 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
	Continued From Previous Page																
408.7	SAND , trace gravel Compact Grey Wet		9	SS	17		410										
11.9	End of sampling at 11.9m and start DCPT						409										
406.9							408										
13.7	GRAVEL some sand Very Dense Brown Moist		10	SS	107		407										
406.4																	
14.2	END OF BOREHOLE AT 14.2m. WATER LEVEL MEASURED AT 3.5m UPON COMPLETION. BOREHOLE WAS WASH BORED FROM 11.9m TO 13.7m. BOREHOLE BACKFILLED WITH SLOUGH TO 5.9m, GRAVEL TO 0.2m, THEN ASPHALT TO SURFACE.																

RECORD OF BOREHOLE No KE17-04

1 OF 2

METRIC

GWP# 6836-14-00 LOCATION Kekwanzik Lake Culvert, MTM NAD 83 Zone 16 N 5 478 802.5 E 404 453.6 ORIGINATED BY BRM
 HWY 599 BOREHOLE TYPE Hollow Stem Augers/Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.06.11 - 2017.06.11 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w _P	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
418.5	GROUND SURFACE							20	40	60	80	100				
0.0	SAND , some silt, trace gravel, trace clay Very Loose Brown Moist (FILL)		1	GS												
			1	SS	3											
			2	SS	2											
415.8			3	SS	2											
415.8	ORGANICS Dark Brown Wet (50mm)															
415.0	SAND , trace gravel Very Loose to Loose Grey Wet		4	SS	7											
3.5	SAND and SILT , trace clay Very Loose Brown to Grey Moist to Wet															
	Low SPT "N" values due to hydraulic ground disturbance from approx. elevation 414.5m to 412.5m		5	SS	1											
	Grey Wet		6	SS	4											
410.9																
7.6	Gravelly SAND , trace silt and clay Compact Grey Wet		7	SS	11											
409.7			8	SS	50/ 0.150											
8.8	BEDROCK GRANITE moderately weathered, pink, blue and grey, mechanical breaks															
			1	RUN												

Continued Next Page

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

ONTMT4S MTO-17077.GPJ 2017TEMPLATE(MTO).GDT 1/29/18

RECORD OF BOREHOLE No KE17-04 2 OF 2 METRIC

GWP# 6836-14-00 LOCATION Kekwanzik Lake Culvert, MTM NAD 83 Zone 16 N 5 478 802.5 E 404 453.6 ORIGINATED BY BRM
 HWY 599 BOREHOLE TYPE Hollow Stem Augers/Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.06.11 - 2017.06.11 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20 40 60 80 100									
	Continued From Previous Page																
	BEDROCK GRANITE moderately weathered, pink, blue and grey, mechanical and sub-vertical breaks															7	RUN #2 TCR=100% SCR=23% RQD=0% UCS=30MPa (Average)
																8	
																>10	
																4	
																5	
406.6																5	
11.9	END OF BOREHOLE AT 11.9m. Well installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.05m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.06.13 1.0 417.5																

RECORD OF BOREHOLE No KE17-05 1 OF 1 METRIC

GWP# 6836-14-00 LOCATION Kekwanzik Lake Culvert, MTM NAD 83 Zone 16 N 5 478 801.9 E 404 437.0 ORIGINATED BY BRM
 HWY 599 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.06.09 - 2017.06.09 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
420.9	GROUND SURFACE							20	40	60	80	100		
0.0	ASPHALT: (25mm)													
	SAND, some silt and clay, trace gravel Light Brown Moist (FILL)		1	GS									o	
			2	GS			420						o	8 77 15 (SI+CL)
419.7														
1.2	END OF BOREHOLE AT 1.2m UPON AUGER REFUSAL. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILED WITH AUGER CUTTINGS TO 0.2m, THEN ASPHALT TO SURFACE.													

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

RECORD OF BOREHOLE No KE17-06

1 OF 1

METRIC

GWP# 6836-14-00 LOCATION Kekwanzik Lake Culvert, MTM NAD 83 Zone 16 N 5 478 810.4 E 404 442.8 ORIGINATED BY BRM
 HWY 599 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.06.16 - 2017.06.16 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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)					
420.8	GROUND SURFACE							20	40	60	80	100					
0.0	ASPHALT: (25mm)																
	SAND , some silt, trace gravel, trace clay Compact to Very Loose Brown Moist (FILL)		1	GS			420										
			1	SS	13												
			2	SS	6		419										
			3	SS	3		418									4	78 15 3
			4	SS	6												
							417										
416.2																	
4.6	ORGANICS trace gravel						416										
415.9	Dark Brown		5	SS	10												
4.9	Wet (300mm)						415										
	SAND and SILT , trace clay Loose Grey Wet																
			6	SS	6		414										
			7	SS	5		413									0	65 32 3
412.6																	
8.2	END OF BOREHOLE AT 8.2m. WATER LEVEL MEASURED AT 3.9m UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 0.9m, CEMENT TO 0.2m, THEN ASPHALT TO SURFACE.																

ONTMT4S MTO-17077.GPJ 2017TEMPLATE(MTO).GDT 1/29/18

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

RECORD OF BOREHOLE No KE17-07 1 OF 1 METRIC

GWP# 6836-14-00 LOCATION Kekwanzik Lake Culvert, MTM NAD 83 Zone 16 N 5 478 827.4 E 404 458.6 ORIGINATED BY BRM
 HWY 599 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.06.14 - 2017.06.14 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							PLASTIC LIMIT W _P NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L		
420.7	GROUND SURFACE							20	40	60	80	100					
0.8	ASPHALT: (25mm)																
	SAND, some silt and clay, trace gravel Brown Moist (FILL)		1	GS			420							○			
			2	GS			419							○			
			3	GS			418							○			8 80 12 (SI+CL)
			4	GS										○			
417.4																	
3.3	SILT, some clay, occasional organics		1	SS	4									○			
417.0	Loose Dark Brown																
3.7	Wet																
	END OF BOREHOLE AT 3.7m. WATER LEVEL MEASURED AT 3.0m UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 0.9m, CONCRETE TO 0.2m, THEN ASPHALT TO SURFACE.																

ONTMT4S MTO-17077.GPJ 2017TEMPLATE(MTO).GDT 1/29/18

RECORD OF BOREHOLE No KE17-08

1 OF 1

METRIC

GWP# 6836-14-00 LOCATION Kekwanzik Lake Culvert, MTM NAD 83 Zone 16 N 5 478 835.7 E 404 464.5 ORIGINATED BY BRM
 HWY 599 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.06.14 - 2017.06.14 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
420.7	GROUND SURFACE							20 40 60 80 100						
0.8	ASPHALT: (25mm)													
	SAND, some gravel, trace to some silt and clay Loose Brown Moist (FILL)		1	GS			420							
			2	GS			419							
			3	GS			418							
			4	GS										
417.0			1	SS	7									20 70 10 (SI+CL)
3.7	END OF BOREHOLE AT 3.7m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 0.9m, CONCRETE TO 0.2m, THEN ASPHALT TO SURFACE.													

ONTMT4S MTO-17077.GPJ 2017TEMPLATE(MTO).GDT 1/29/18

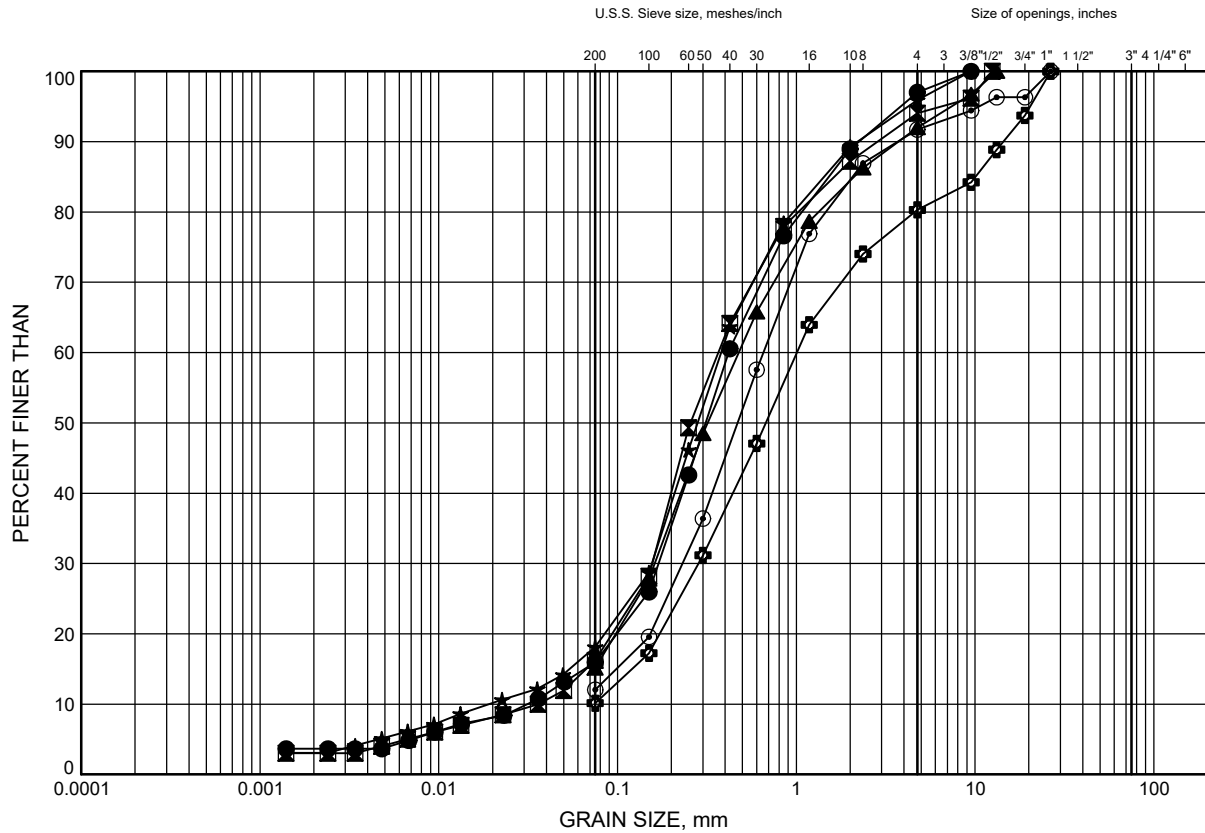
Appendix B

Geotechnical and Analytical Laboratory Test Results and Rock Core Photos

Kekwanzik Lake Culvert 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)
●	KE17-02	1.8	419.0
⊠	KE17-03	1.8	418.8
▲	KE17-05	0.9	416.9
★	KE17-06	2.6	418.2
⊙	KE17-07	1.8	418.9
⊕	KE17-08	3.4	417.3

Date September 2017

GWP# 6836-14-00



Prep'd AN

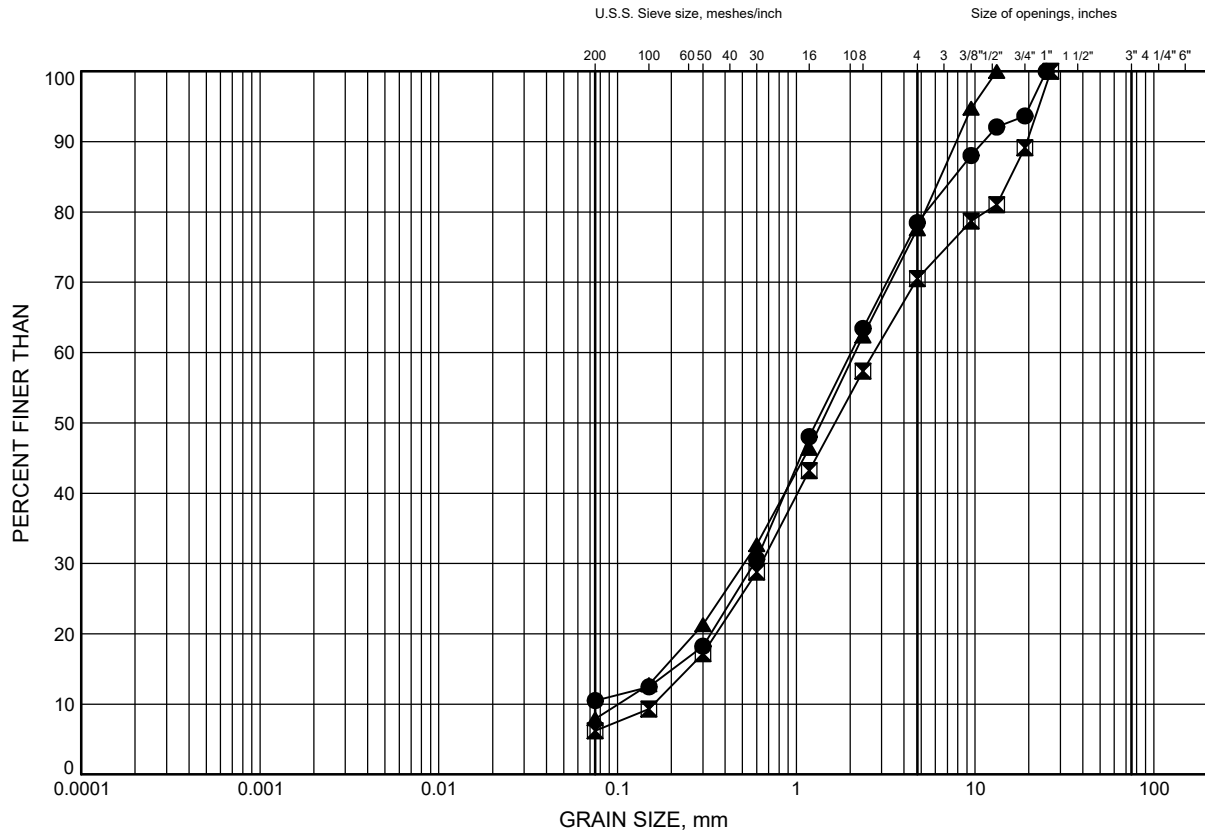
Chkd. RPR

Kekwanzik Lake Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B2

Gravelly SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KE17-01A	1.5	416.0
⊠	KE17-01B	2.1	415.5
▲	KE17-04	8.7	409.8

Date September 2017

GWP# 6836-14-00

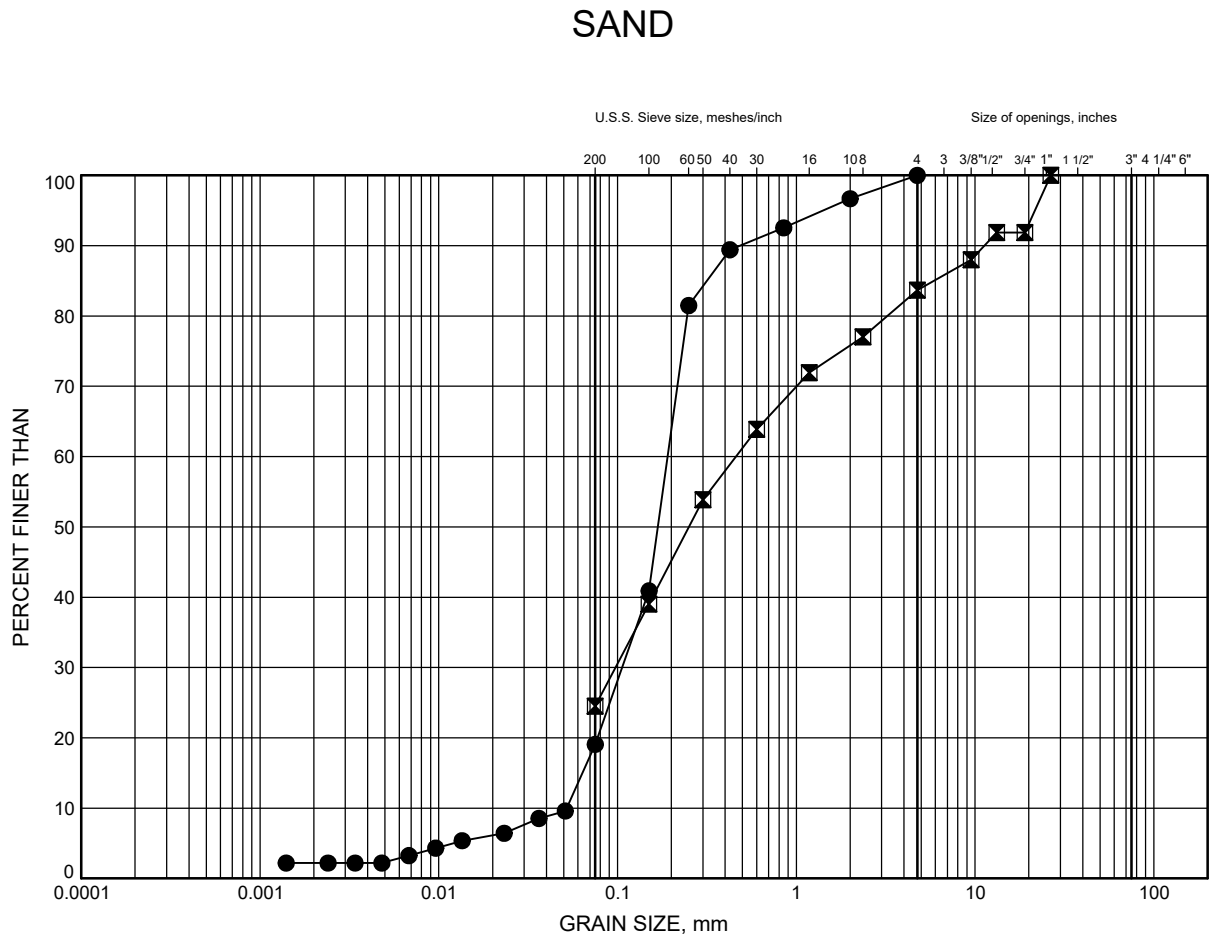


Prep'd AN

Chkd. RPR

Kekwanzik Lake Culvert GRAIN SIZE DISTRIBUTION

FIGURE B3



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KE17-01C	5.2	413.0
⊠	KE17-02	11.0	409.8

Date September 2017
GWP# 6836-14-00

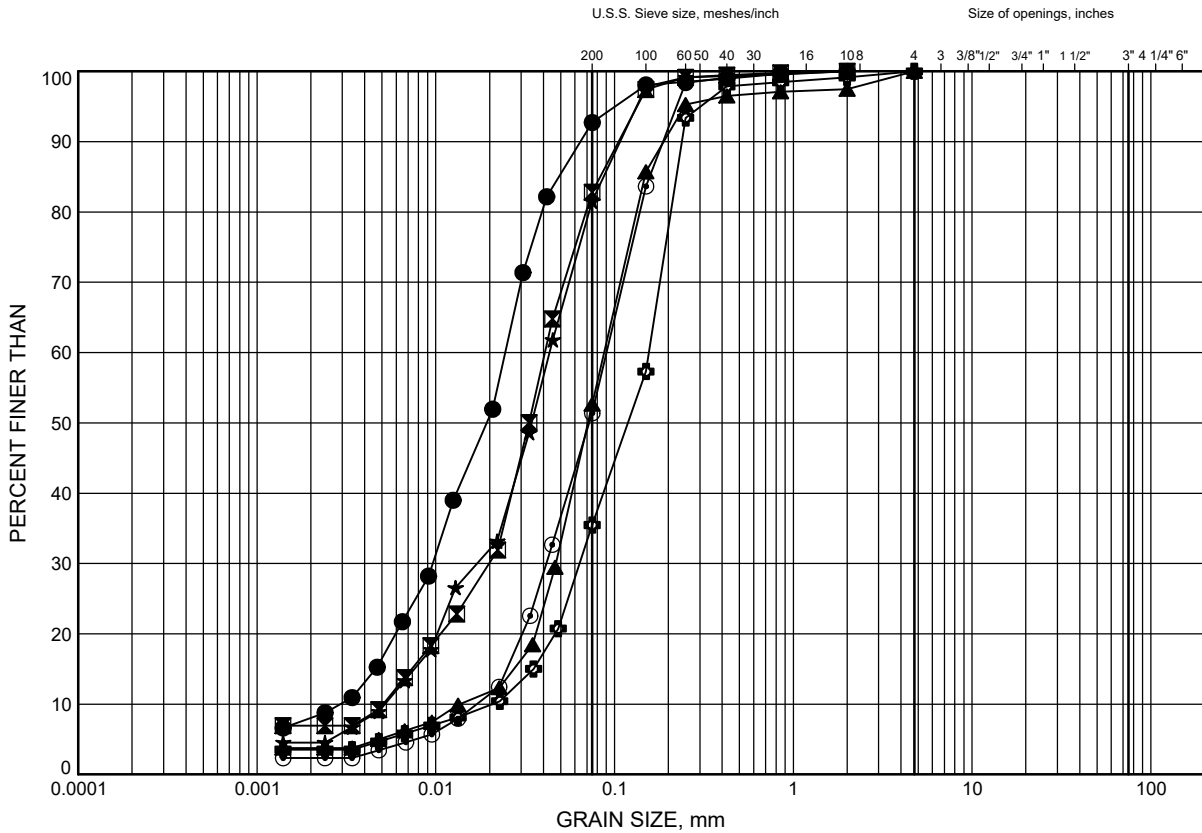


Prep'd AN
Chkd. RPR

Kekwanzik Lake Culvert GRAIN SIZE DISTRIBUTION

FIGURE B4

SILT to SAND and SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KE17-01C	2.1	416.1
⊠	KE17-01C	3.4	414.8
▲	KE17-02	7.9	412.9
★	KE17-03	6.4	414.2
⊙	KE17-04	4.9	413.6
⊕	KE17-06	7.9	412.9

Date September 2017

GWP# 6836-14-00



Prep'd AN

Chkd. RPR



THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 17077
Client: HATCH
Project Name: Kekwanzik Lake Culvert
Core Size: NQ BH No : 17-04

Date Drilled: 11-Jun-17
Date Tested: 26-Jun-17
Tester: ISP
Reviewed by: CZ

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	9.9	A	27.6	47.0	60.0	7.9	189.5	Granite	Very Strong
2	1	10.2	D	25.8	47.0	154.0	10.8	258.6	Granite	Extremely Strong
3	2	11.1	A	4.5	47.0	63.0	1.3	30.1	Granite	Medium Strong
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24.



THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 17077
Client: HATCH
Project Name: Kekwanzik Lake Culvert
Core Size: NQ BH No : 17-02

Date Drilled: 11-Jun-17
Date Tested: 26-Jun-17
Tester: ISP
Reviewed by: CZ

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	6.9	A	20.9	47.0	75.4	5.0	120.6	Granite	Very Strong
2	1	7.2	D	24.3	47.0	195.1	10.1	243.2	Granite	Very Strong
3	1	7.5	A	25.1	47.0	57.7	7.4	177.6	Granite	Very Strong
4	2	7.6	D	19.7	47.0	139.6	8.2	197.7	Granite	Very Strong
5	2	7.9	A	22.8	47.0	61.6	6.4	153.4	Granite	Very Strong
6	2	8.4	D	21.2	47.0	154.5	8.9	212.8	Granite	Very Strong
7	3	8.7	A	30.2	47.0	63.2	8.3	199.1	Granite	Very Strong
8	3	9.0	D	22.5	47.0	154.5	9.4	225.4	Granite	Very Strong
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										

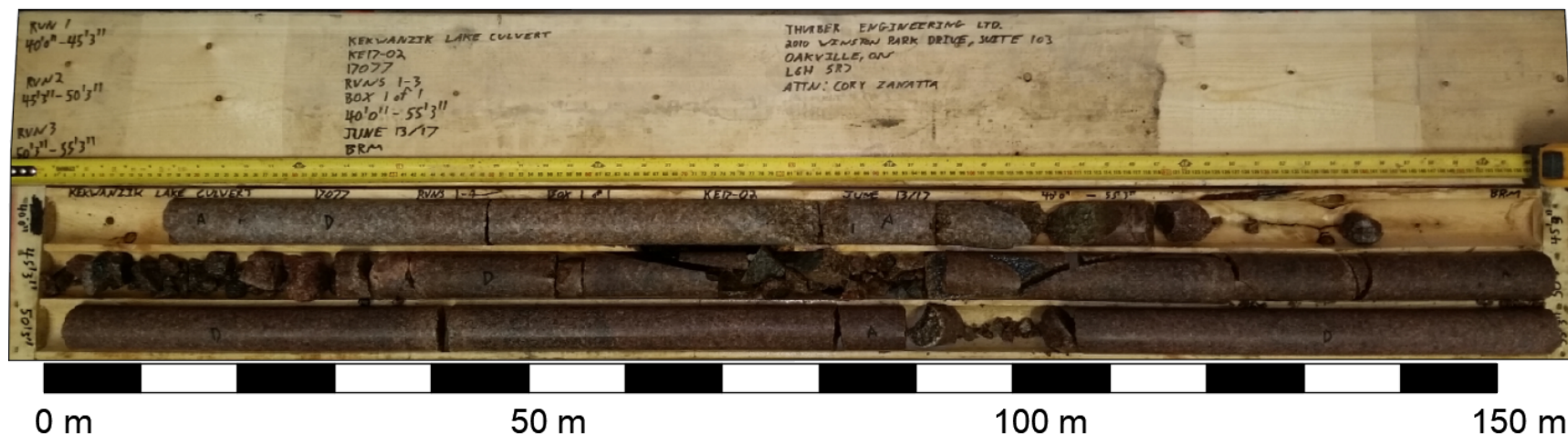
* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

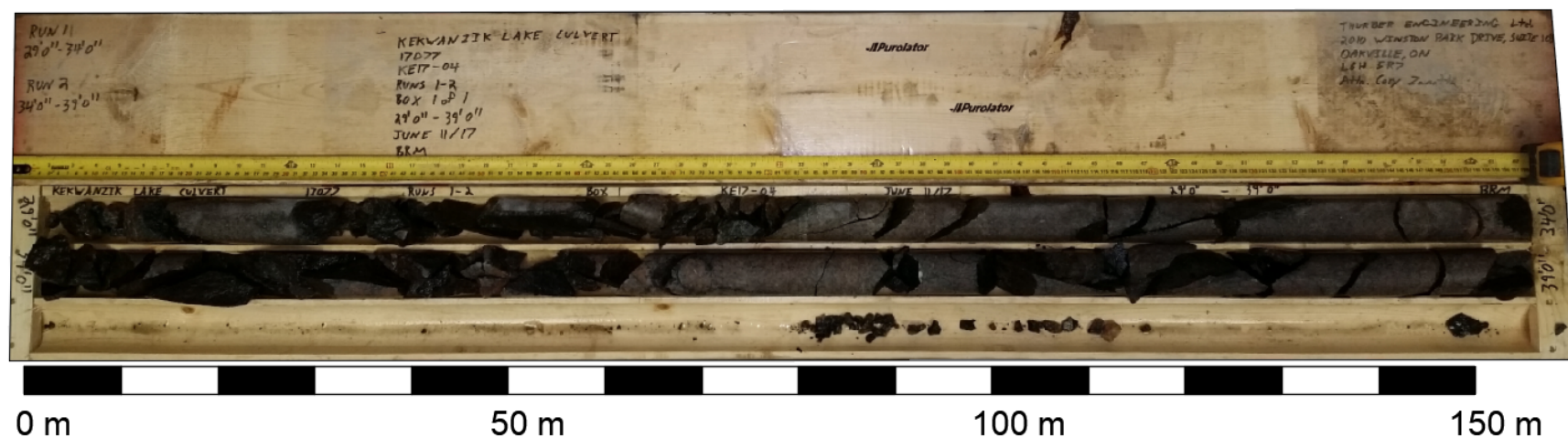
* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24.

Core Photo 1: Borehole KE17-02 Run 1 to Run 3 (12.2 m to 16.8 m)



Core Photo 2: Borehole KE17-04 Run 1 to Run 2 (8.8 m to 11.9 m)





Client
SGS LIMS Number
Analysis Package:

Attention: Cory Zanatta
Project#: 17077
Thurber Engineering Ltd.
CA15302-AUG17
Corrosivity (Soil)

SGS Canada Inc.
185 Concession St. Box 4300
Lakefield, Ont., Canada,
K0L 2H0

Sample ID	Unit	PR17-02 SS7	KE 17-03 SS5	ME 17-03 SS3	TU 17-02 SPT5	CO 17-03 SS4	AG 147-02 SS4
Sample Date/Time		30-Jul-17	30-Jul-17	30-Jul-17	30-Jul-17	30-Jul-17	30-Jul-17
Moisture	%	15.6	7.0	7.7	22.2	15.6	21.0
pH	no unit	8.25	6.40	8.27	8.14	8.65	8.33
Corrosivity Index	none	4.5	1.0	1.0	1.0	4.0	1.0
Soil Redox Potential	mV	325	338	303	301	295	290
Sulphide	mg/L	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Chloride	mg/L	6.9	240	2.4	25	1.2	150
Sulphate	mg/L	26	10	10	1.2	46	6.1
Conductivity	uS/cm	49	269	35	81	83	213
Resistivity (calculated)	ohms.cm	20300	3720	28700	12400	12000	4690

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
Environment, Health and Safety

Certificate of Analysis

SGS Canada Inc.
185 Concession St. Box 4300
Lakefield, Ont., Canada, K0L 2H0



Client
SGS LIMS Number
Analysis Package:

Attention: Cory Zanatta
Project#: 17077 Hwy 599
Thurber Engineering Ltd.
CA15314-JUN17
Corrosivity (Solution)

Sample ID	Unit	RL	Tug Creek	Pratt Creek	Mile Creek	Cobb Bay	Kekwanzik Lake	Agimak River
			10-Jun-17 12:10	10-Jun-17 12:30	10-Jun-17 10:40	10-Jun-17 11:20	10-Jun-17 12:45	10-Jun-17 13:10
Sample Date/Time								
Temperature Upon Receipt	°C		10.0	10.0	10.0	10.0	10.0	10.0
Soil Redox Potential	mV		334	272	352	301	312	345
Sulphide	mg/L	0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
pH	no unit	0.05	7.78	7.81	7.62	7.70	7.38	7.26
Chloride	mg/L	0.04	2.1	2.9	2.7	1.7	8.8	7.8
Sulphate	mg/L	0.04	0.3	1.2	0.8	0.6	2.0	1.9
Conductivity	µS/cm	2	100	78	63	78	67	56
Resistivity (calculated)	ohms.cm		9990	12700	15800	12800	15000	17700

Corrosivity Index is based on the AWWA
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
Environment, Health and Safety

Data reported represents the sample submitted to SGS. Reproduction of this analytical report in full or in part is prohibited without prior written approval. Please refer to SGS General Conditions of Services located at http://www.sgs.com/terms_and_conditions_service.htm. (Printed copies are available upon request.). Test Method information available upon request. "Temperature Upon Receipt" is representative of the whole shipment and may not reflect the temperature of individual samples.



Appendix C

Selected Site Photographs



Photo 1: Highway 599 at Kekwanzik Creek Culvert looking north



Photo 2: Highway 599 at Kekwanzik Creek Culvert looking south



Photo 3: Kekwanzik Creek Culvert outlet

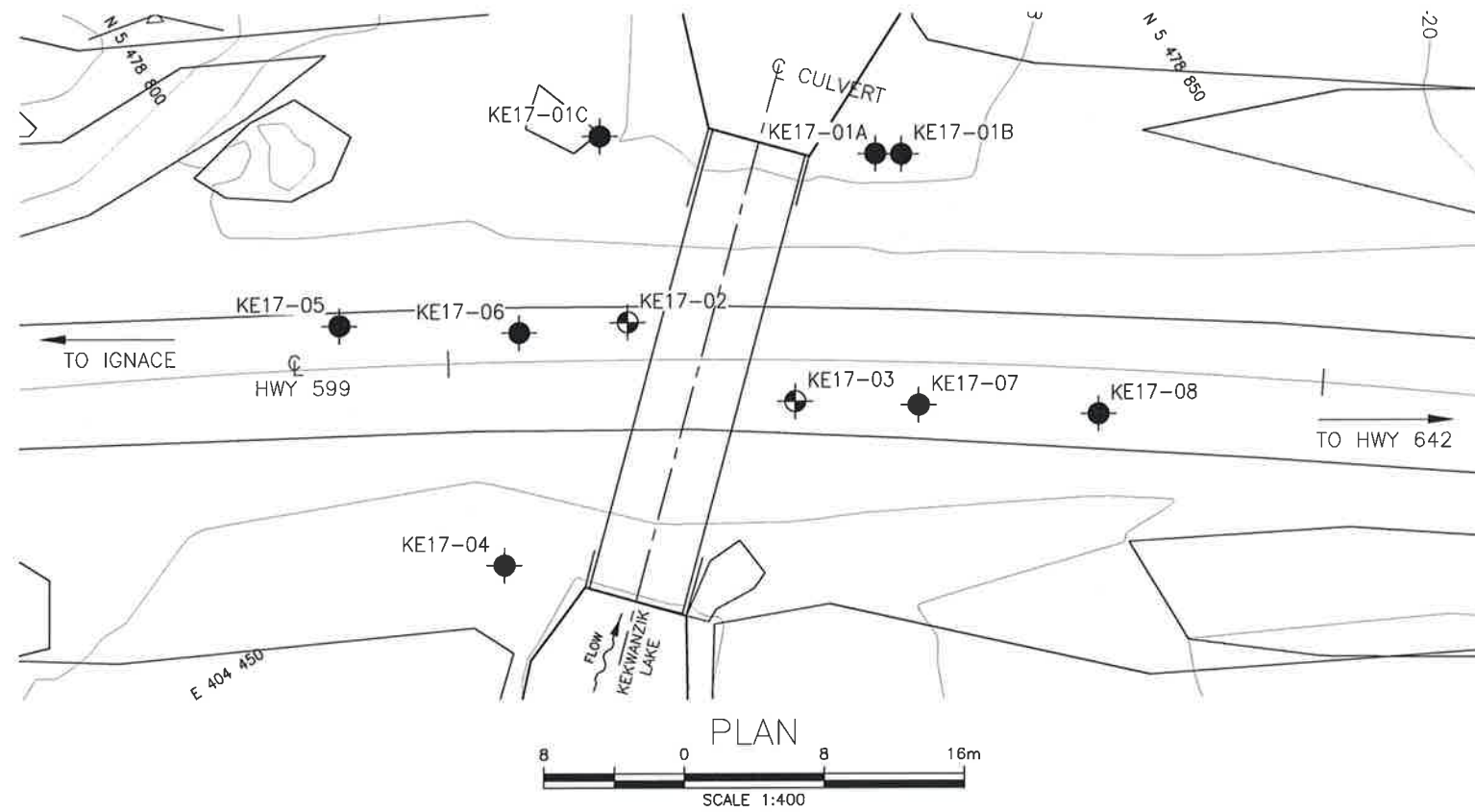


Photo 4: Kekwanzik Creek Culvert inlet



Appendix D

Borehole Locations and Soil Strata Drawing



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



CONT No 2017-6036
WP No 6837-14-01

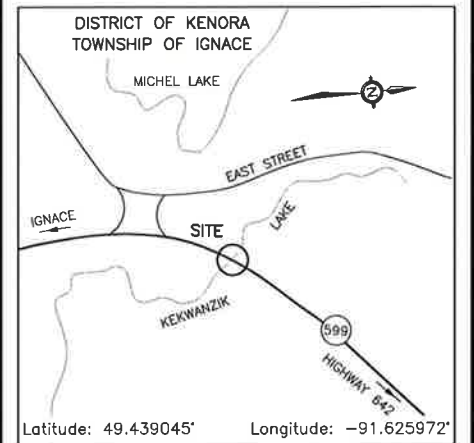
HIGHWAY 599
KEKWANZIK LAKE CULVERT
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET
24

HATCH








THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

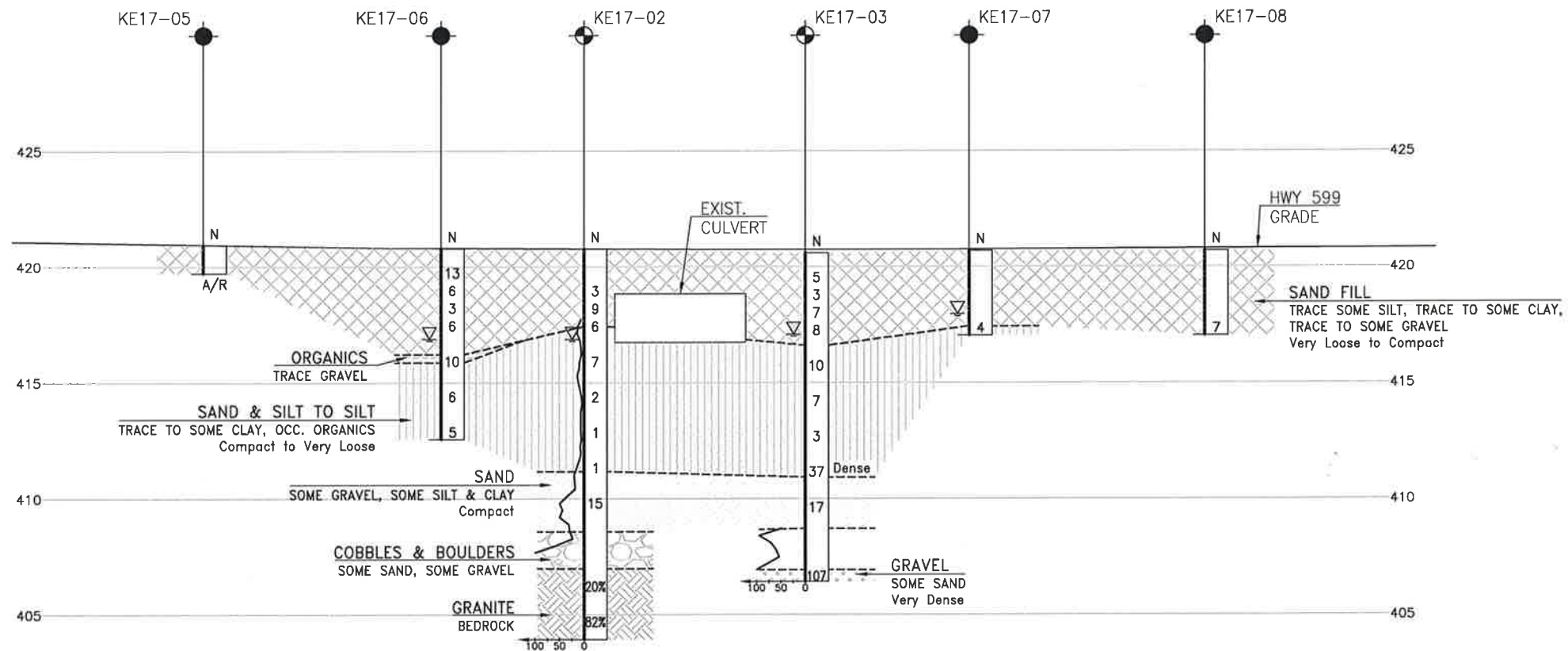
	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
KE17-01A	417.5	5 478 833.0	404 445.2
KE17-01B	417.6	5 478 834.2	404 446.0
KE17-01C	418.2	5 478 820.2	404 435.8
KE17-02	420.8	5 478 815.9	404 445.7
KE17-03	420.6	5 478 821.5	404 454.6
KE17-04	418.5	5 478 802.5	404 453.6
KE17-05	420.9	5 478 801.9	404 437.0
KE17-06	420.8	5 478 810.3	404 442.8
KE17-07	420.7	5 478 827.4	404 458.6
KE17-08	420.7	5 478 835.7	404 464.5

-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.
- 3) Coordinate system is MTM NAD 83 Zone 16.

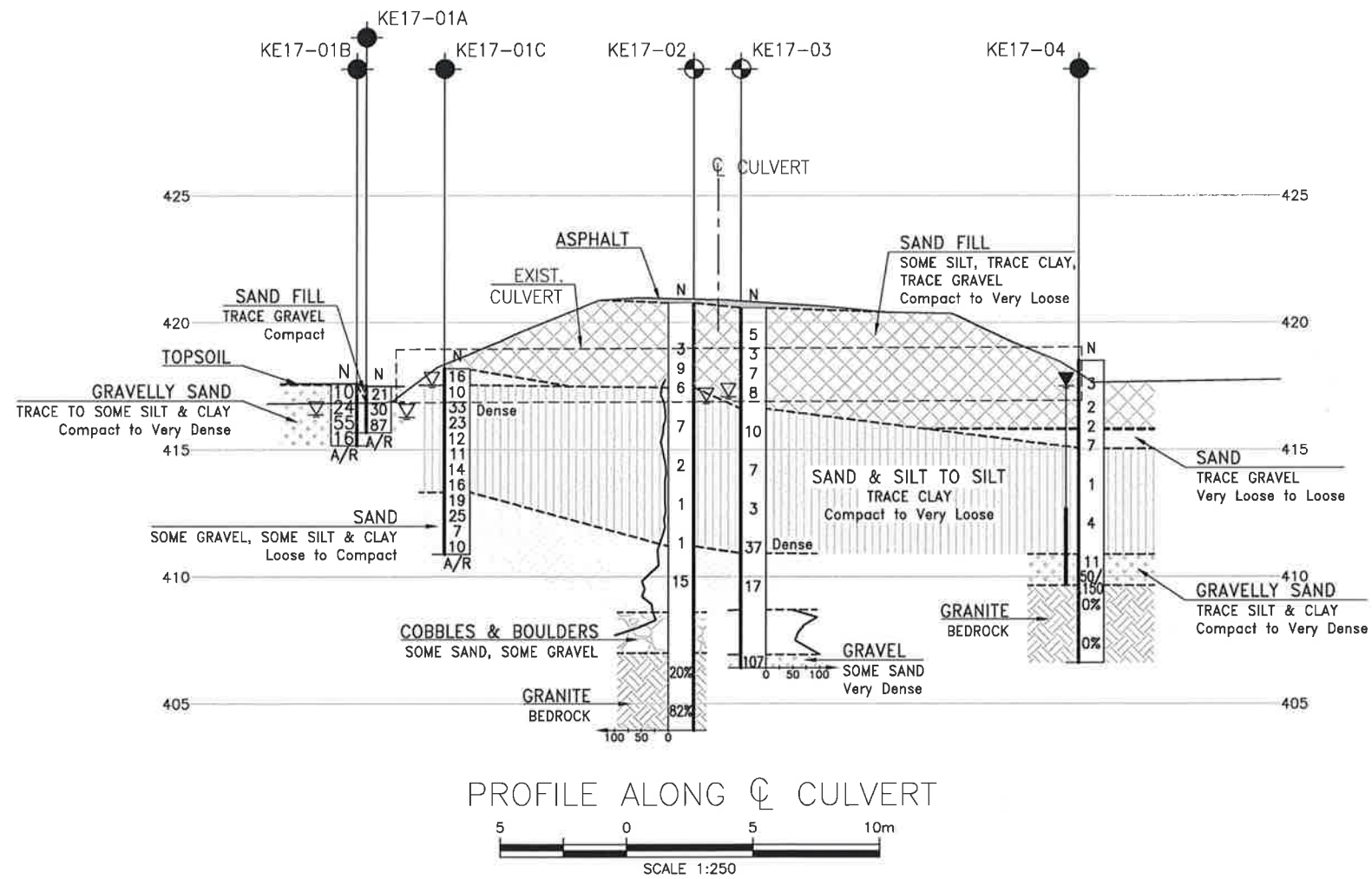
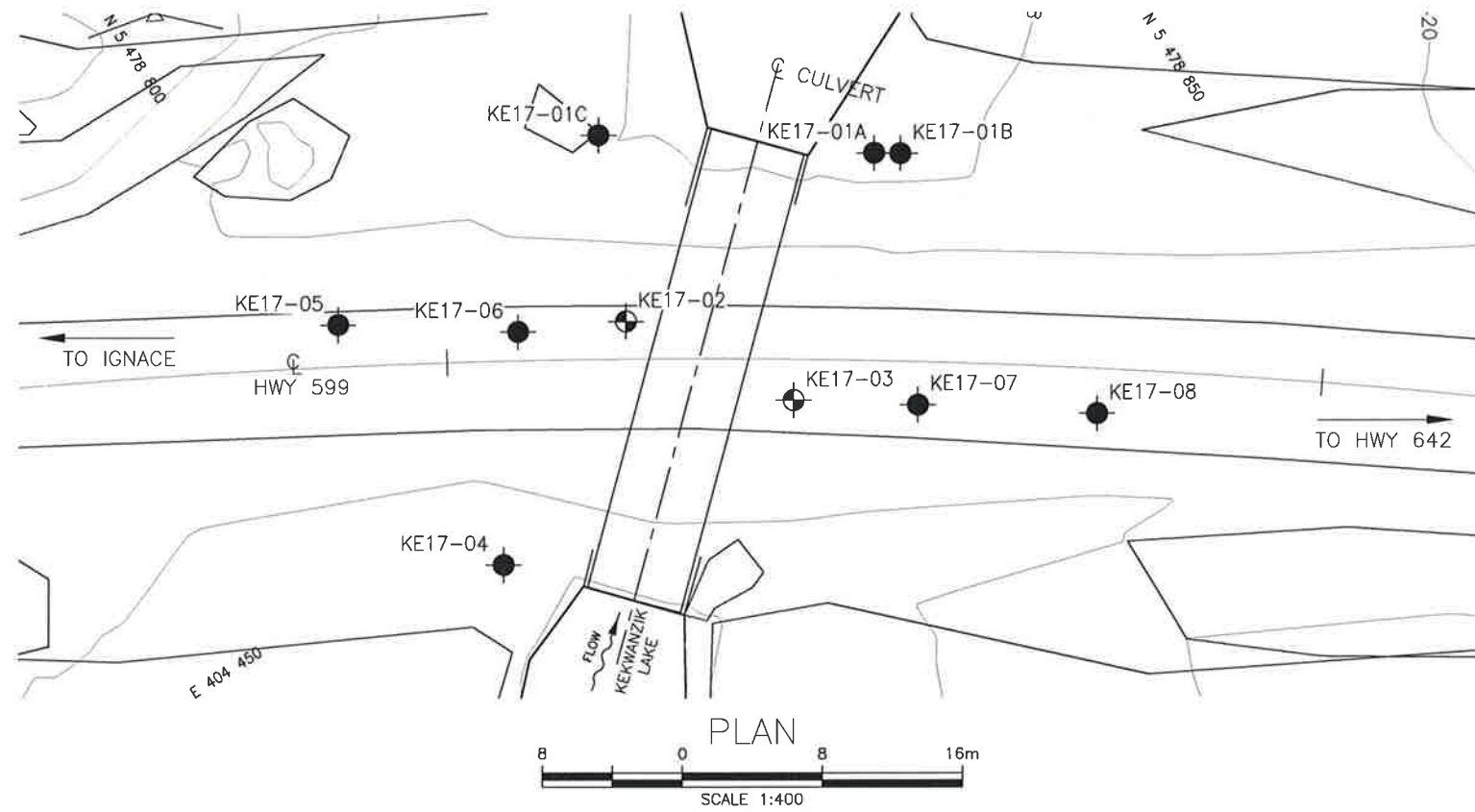
GEOCRES No. 52G-17



PROFILE ALONG C℄ HWY 599



REVISIONS									
	DATE	BY	DESCRIPTION						
DESIGN	RPR	CHK	JPL	CODE	LOAD	DATE	JAN 2018		
DRAWN	AN	CHK	RPR	SITE 48W-243C	STRUCT	DWG	2		



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

CONT No 2017-6036
WP No 6837-14-01

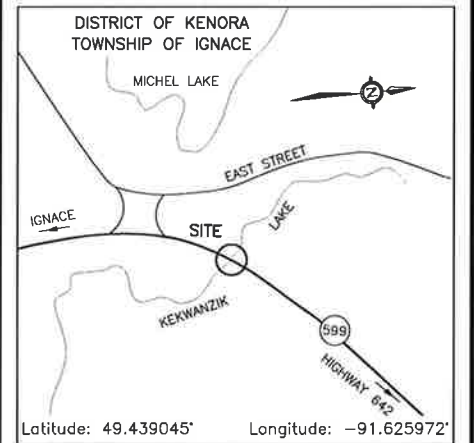
HIGHWAY 599
KEKWANZIK LAKE CULVERT
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET
25

HATCH








THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

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

NO	ELEVATION	NORTHING	EASTING
KE17-01A	417.5	5 478 833.0	404 445.2
KE17-01B	417.6	5 478 834.2	404 446.0
KE17-01C	418.2	5 478 820.2	404 435.8
KE17-02	420.8	5 478 815.9	404 445.7
KE17-03	420.6	5 478 821.5	404 454.6
KE17-04	418.5	5 478 802.5	404 453.6
KE17-05	420.9	5 478 801.9	404 437.0
KE17-06	420.8	5 478 810.3	404 442.8
KE17-07	420.7	5 478 827.4	404 458.6
KE17-08	420.7	5 478 835.7	404 464.5

-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.
- 3) Coordinate system is MTM NAD 83 Zone 16.

GEOCRES No. 52G-17

[illegible]



Appendix E

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES

Corrugated Steel Pipe (CSP) Culvert	Concrete Box Culvert	Concrete Open Footing Culvert	Driven Sheet Piles Driven to Refusal or to Bedrock
<u>Advantages:</u> i. Ease of construction. ii. CSP's can accommodate small differential settlement along culvert axis iii. Steel pipes are likely to be more cost effective than concrete box or open footing culverts.	<u>Advantages:</u> i. Relatively rapid installation and less disturbance to subgrade soils if pre-cast segments are used. ii. Segmental option can accommodate limited amount of potential differential settlement along culvert axis. iii. Less requirement for soil geotechnical resistances as loading is spread over a larger width. iv. Can accommodate differential settlement.	<u>Advantages:</u> i. Conventional construction. ii. Generally less costly than deep foundation elements. iii. Eliminates bedding requirement. iv. May have less environmental issues such as those involving spawning fish species.	<u>Advantages:</u> i. Minimizes potential for disturbance of streambed. ii. Ease of construction. iii. Provides shoring and foundation elements in one operation. iv. Installation of sheet piles could continue in freezing weather. v. Potentially minimizes volume of excavation. vi. Less expensive than box culvert.
<u>Disadvantages:</u> i. Multiple pipes may be needed to meet hydraulic requirements. ii. CSP cannot be rehabilitated as concrete culverts. iii. Culvert subgrade preparation and bedding placement must be carried out in the dry. iv. Dewatering is required. v. Requires subexcavation of soft or organic material from streambed if encountered.	<u>Disadvantages:</u> i. More expensive than a CSP culvert and sheet pile system. ii. Culvert subgrade preparation and bedding placement must be carried out in the dry. iii. Dewatering is required. iv. Requires subexcavation of soft or organic material from streambed if encountered. v. Requires complete excavation of river bed.	<u>Disadvantages:</u> i. Low available geotechnical resistance in native soils. ii. Requires deeper excavation below the groundwater level. Excavation to base of existing roadway embankment is required for footing construction. iii. High groundwater levels Dewatering will be required. Potential longer dewatering requirements. iv. Potential disturbance of river during excavation. v. Cannot tolerate differential settlement. vi. Shallow foundations close to water would be at risk due to scour, erosion and undermining problems.	<u>Disadvantages:</u> i. Unconventional design. ii. Presence of cobbles and boulders above the bedrock, and possibly within the embankment fill.
RECOMMENDED	RECOMMENDED	NOT RECOMMENDED	FEASIBLE



Appendix F

List of Specifications and Suggested Wording for NSSP



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

- OPSS PROV 206 Construction specification for grading
- OPSS PROV 209 Construction specification for embankments over swamps and compressible soils
- OPSS PROV 501 Construction specification for compacting
- OPSS.PROV 511 Construction specification for rip-rap, rock protection, and granular sheeting
- OPSS.PROV 517 Construction specification for dewatering
- SP 517F01 Amendment to OPSS 517
- OPSS PROV 539 Construction specification for temporary protection systems
- OPSS PROV 804 Construction specification for seed and cover
- OPSS PROV 902 Construction specification for excavating and backfilling - Structures
- OPSS PROV 903 Construction specification for deep foundations
- OPSS PROV 1004 Material specification for aggregates - miscellaneous
- OPSS PROV 1010 Material specification for aggregates - base, subbase, select subgrade, and backfill material
- OPSS PROV 1205 Material specification for clay seal
- OPSD 802.014 Flexible pipe embedment in embankment. original ground: earth or rock
- OPSD 803.031 Frost treatment – pipe culverts, frost penetration line between top of pipe and bedding grade
- OPSD 810.010 General rip-rap layout for sewer and culvert outlets
- OPSD 3090.100 Foundation frost penetration depths for Northern Ontario



2. Suggested Wording for NSSP on Dewatering

Effective dewatering shall be designed and provided by the Contractor during culvert excavation, bedding placement and backfilling to allow the work to proceed in the dry. Excavation below the lake 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 roadway protection systems may encounter obstructions such as cobbles and boulders embedded in the fill and 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. Vibrating equipment is not permitted for installation of sheet piles.

4. NSSP On Use of Vibratory Equipment

The use of vibratory equipment for the installation and removal of temporary or permanent sheet piles and/or H-piles is prohibited at this site.