

**FOUNDATION INVESTIGATION AND DESIGN REPORT
WHITNEY LAKE CULVERT REPLACEMENT
NEW LISKEARD DISTRICT, ONTARIO
G.W.P. 5197-13-00, SITE NO. 47-275/C**

Geocres Number: 31M-118

Report to

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TABLE OF CONTENTS

PART 1 FACTUAL INFORMATION

1	INTRODUCTION.....	1
2	SITE DESCRIPTION.....	1
3	SITE INVESTIGATION AND FIELD TESTING	2
4	LABORATORY TESTING	3
5	DESCRIPTION OF SUBSURFACE CONDITIONS.....	3
5.1	General.....	3
5.2	Asphalt.....	4
5.3	Peat and Marl.....	4
5.4	Fill.....	4
5.5	Sand to Gravelly Sand Till	5
5.6	Groundwater Conditions.....	6
6	CORROSIVITY AND SULPHATE TEST RESULTS	6
7	MISCELLANEOUS.....	7
8	GENERAL	9
9	CULVERT FOUNDATIONS	10
9.1	Summary of Subsurface Conditions	10
9.2	Subgrade Preparation.....	10
9.3	Culvert Alternatives.....	11
9.4	Pipe Culvert	12
9.5	Concrete Box Culvert	12
9.6	Frost Cover	13
10	EXCAVATION AND GROUNDWATER CONTROL	13
11	CULVERT BACKFILL AND LATERAL EARTH PRESSURES	14
12	EMBANKMENT RECONSTRUCTION	15
13	EROSION PROTECTION.....	15
14	TEMPORARY PROTECTION SYSTEM.....	16

15 CORROSION AND SULPHATE ATTACK POTENTIAL 17

16 CONSTRUCTION CONCERNS 17

17 CLOSUREP..... 18

APPENDICES

Appendix A	Record of Borehole Sheets
Appendix B	Geotechnical Laboratory Test Results
Appendix C	Selected Site Photographs
Appendix D	Borehole Locations and Soil Strata Drawing
Appendix E	List of OPSS and OPSD Documents Relevant to Project
Appendix F	Comparison of Foundation Alternatives

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) at the culvert on Highway 11 at Whitney Lake, located in the Town of Latchford, New Liskeard District, Ontario.

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

Thurber was retained by MMM Group Limited to carry out this foundation investigation under the MTO Assignment Number 5014-E-0019.

2 SITE DESCRIPTION

The culvert site is located on Highway 11, 22.6 km south of the Highway 11/11B south junction in the Gillies Township, New Liskeard District, Ontario. This culvert equalizes the flow and water levels of Whitney Lake on both sides of the Highway 11 crossing. Highway 11 is oriented in the north-south direction at the culvert site.

Based on the terms of reference, the existing structure consists of a 21.2 m long and 3.1 m wide cast-in-place concrete box, with approximately 0.9 m of fill above the culvert. The culvert was constructed in 1938 and has no previous records of rehabilitation. The culvert is proposed for full replacement.

The grade level of Highway 11 at the existing culvert is at approximate Elevation 326.3 m.

At the culvert location, the highway crosses a swampy area with a seasonally fluctuating water level. To the north of the culvert inlet, the area is low lying with a growth of tall grass and shrubs. The area immediately surrounding the body of water is heavily treed. The local topography is of moderate relief with visible bedrock outcrops to the west and east of the highway. A pipeline corridor is located approximately 120 m west of Highway 11. Photographs in Appendix C show the general nature of the site at the existing culvert.

The site lies within the physiographical area of Cobalt Embayment. Surficial geology at the site is featured by glacio-lacustrine silts and clays and swamp deposits consisting of peat, muck and marl. The bedrock consists typically of Ordovician sedimentary rocks of Liskeard Group.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing program was carried out between February 22 and March 11, 2016. The program consisted of drilling and sampling 3 boreholes (numbered WL-01 to WL-03) to depths ranging from 1.5 to 9.8 m. Borehole WL-01 was located near the culvert outlet and Boreholes WL-02 and WL-03 were drilled from the top of the road embankment. A Dynamic Cone Penetration Test (DCPT) was carried out below the sampled portion of Borehole WL-03 to a cone refusal depth of 10.2 m. A raft and a portable rig was mobilized to the site on July 22, 2016 to drill Borehole WL-04 in the lake at the west end of the culvert. Borehole WL-04 was drilled and sampled to a depth of 5.4 m.

Prior to the start of drilling, the borehole locations were marked/staked in the field and utility clearances were obtained. The coordinates and ground surface elevations for the boreholes were derived from topographic plans provided to Thurber by MMM Group Limited. The approximate borehole locations are shown on the Borehole Locations and Soil Strata drawing included in Appendix D.

A track-mounted CME 45 hi-torque drill rig was used to advance Boreholes WL-02 and WL-03 to the target depth using NW casing/wash boring techniques. Due to difficult access for a conventional drill rig beyond the road embankment, a portable tripod drill rig was used to advance Boreholes WL-01 and WL-04 to the target depths. Soil samples were obtained at selected intervals using a 50 mm diameter split spoon sampler in conjunction with Standard Penetration Testing (SPT) procedures as per ASTM D-1586-99.

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

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Upon completion of drilling and final water level readings, boreholes were decommissioned in general accordance with MOE Regulation 903 amended by Ontario Reg. 372.

The details regarding borehole completion are summarized in Table 3.1.

Table 3.1 - Borehole Completion and Backfilling Details

Borehole	Borehole Depth/ Elevation (m)	Borehole Backfilling Details
WL-01	1.5 / 323.0	Bentonite holeplug from 1.5 m to ground surface.
WL-02	9.8 / 316.4	Bentonite holeplug and cuttings from 9.8 m to 0.3 m and asphalt coldpatch to ground surface.
WL-03	9.3 / 317.1	Bentonite holeplug and cuttings from 9.3 m to 0.3 m, concrete to 0.2 m, then asphalt coldpatch to ground surface.
WL-04	5.4 / 319.1	Bentonite holeplug to the lake surface.

The results of the field drilling and sampling are presented on the Record of Borehole sheets in Appendix A.

4 LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size analysis and Atterberg Limits testing. All the laboratory tests were carried out to MTO and / or ASTM Standards, as appropriate. The results of the laboratory testing are summarized on the Record of Borehole sheets in Appendix A and are presented on the figures included in Appendix B.

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the structure, a sample of the existing embankment fill soil, and a sample of surface water from the lake upstream of the culvert were collected. The samples were submitted to AGAT Laboratories in Mississauga, Ontario for analytical testing of corrosivity parameters and sulphate. The results of the analytical testing are summarized in Sec. 6 below and are presented in Appendix B

5 DESCRIPTION OF SUBSURFACE CONDITIONS

5.1 General

Reference is made to the Record of Borehole sheets in Appendix A for details of the soil stratigraphy encountered in the boreholes. A stratigraphic profile for this culvert site is presented on the Borehole Locations and Soil Strata Drawing in Appendix D for illustrative purposes. An overall description of the stratigraphy is given in the following paragraphs; however, the factual data presented in the records of boreholes governs any interpretation of the site conditions.

In general, the subsurface conditions encountered in the boreholes located on the road embankment consist of asphalt pavement underlain by sand to gravelly sand fill overlying a deposit of sand to gravelly sand till. Near the east end of the culvert, peat was encountered from surface to the borehole refusal depth. Near the west end of the culvert, the peat was underlain by marl that was further underlain by sand to gravelly sand till. More detailed descriptions of the individual strata are presented below.

5.2 Asphalt

Boreholes WL-02 and WL-03 drilled from the top of the embankment encountered 225 mm and 100 mm, respectively, of asphalt. The thickness of the asphalt may indicate some maintenance works carried out at the culvert, and asphalt thickness may vary in other areas.

5.3 Peat and Marl

A layer of fibrous peat was encountered in Boreholes WL-01 and WL-04. The peat was 1.5 m thick and extended from the ground surface in Borehole WL-01. In Borehole WL-04, drilled in the lake, the peat was encountered below 0.4 m of lake water and was 1.2 m thick.

In Borehole WL-01, the SPT N-values of 7 and 8 blows per 0.3 m penetration were measured in the peat indicating a firm consistency, although, the values were probably influenced by a frozen ground conditions at the time of field investigation. The SPT-N values of zero were obtained in the peat in Borehole WL-04 indicating a very soft consistency. Measured moisture contents of the samples tested ranged from 355% to 1643%.

Borehole WL-01 met refusal on probable cobbles, boulders or bedrock below the 1.5 m of peat, and several attempts were made to penetrate this layer, however the attempts were unsuccessful. A bedrock outcrop is visible a short distance to the north of the culvert and outcrops are visible to the south also.

The peat in Borehole WL-04 was underlain by a marl deposit approximately 2.3 m in thickness. The underside of the marl deposit was at 3.9 m depth below the water level in the lake or at Elev. 320.6. The deposit was light grey with trace of white shells and occasional rootlets. The SPT-N values of zero blows per 0.3 m of penetration were obtained in the marl indicating a very soft consistency, except for the lowest zone of the deposit, where a value of 7 blows per 0.3 m of penetration was obtained at the transition zone to sand and gravel. Measured moisture contents of the samples tested ranged from 194% to 213%.

5.4 Fill

Embankment fill was encountered in Boreholes WL-02 and WL-03 underlying the asphalt. This fill typically consists of brown to grey sand to gravelly sand with trace to some silt and occasional cobbles, boulders and silty sand seams. The thickness of the embankment fill at

the respective boreholes were 3.6 and 3.9 m with a lower boundary at depths of 3.8 and 4.0 m (base Elevation 322.4).

A 400 mm boulder was encountered underlying the fill in Borehole WL-03 with a base at Elevation 322.0.

SPT N-values measured in the embankment fill ranged from 4 blows per 0.3 m penetration to 100 blows per 0.13 m penetration, typically ranging from 13 to 26 blows per 0.3 m penetration, indicating a compact relative density. The higher 'N' values were encountered closer to the road surface and may be attributed to the presence of cobbles or frozen ground conditions. Measured moisture contents of the recovered fill samples ranged between 4% and 25%.

The results of grain size analyses conducted on samples of the fill are presented in Figure B1 in Appendix B. These results are summarized in the following table.

Soil Particles	%
Gravel	0 to 28
Sand	63 to 86
Silt	17
Clay	3
Silt and Clay	9 to 13

5.5 Sand to Gravelly Sand Till

A deposit of sand to gravelly sand till was encountered below the fill in Boreholes WL-02 and WL-03, and underlying the marl deposit in Borehole WL-04. The deposit contains trace to some silt, trace clay and occasional cobbles and boulders. Boreholes WL-02 and WL-03 were terminated in the till at depths of 9.8 and 9.3 m respectively (Elevations 316.4 and 317.1). Refusal to casing penetration was encountered at Borehole WL-04, probably on cobbles or boulder.

SPT N-values measured in the till ranged from 7 blows per 0.3 m penetration to in excess of 100 blows per 0.15 m penetration, indicating a loose to very dense relative density. The higher 'N' values indicated the presence of cobbles and boulders, which often had to be cored in order to advance the boreholes. Measured moisture contents of the samples ranged from 7% to 12%.

The results of a grain size analyses conducted on a sample of the sand to gravelly sand till is presented on Figure B2 in Appendix B. These results are summarized in the following table.

Soil Particles	%
Gravel	31
Sand	44
Silt and Clay	25

The appearance of this deposit resembled the embankment fill, and the exact boundary between the fill materials and till was difficult to establish. However, based on the general configuration of the terrain, the deposit was classified as a native deposit (till).

5.6 Groundwater Conditions

The water levels in select boreholes were measured upon completion of drilling. However, water was used during the wash-boring and coring operations and therefore the measured water levels may not reflect prevailing groundwater levels at the site. The water level depths and elevations measured are presented in Table 5.1 below.

Table 5.1 – Water Level Measurements in Open Boreholes

Borehole	Date of Reading	Water Level	
		Depth (m)	Elevation (m)
WL-01	March 11, 2016	0.5	324.0
WL-03	March 11, 2016	3.0	323.4
WL-04	July 22, 2016	-	324.5 ^{*)}

^{*)} Approximate water level in the lake

The groundwater level should be assumed to coincide with the lake water level, which was reported to be at Elev. 324.5 on June 7, 2015. The typical water level was indicated to be at Elev. 324.1 on the General Arrangement drawing dated April 2016. The groundwater levels are expected to vary seasonally and are subject to severe weather events.

6 CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the surface water from the lake was 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	Units	Whitney Lake Water
Sulphide	mg/L	<0.05
Chloride	mg/L	40.5
Sulphate	mg/L	6.95
pH	pH Units	7.27
Electrical Conductivity	µS/cm	201
Resistivity	ohm.cm	4980
Redox Potential	mV	395

7 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained 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 MMM Group Limited.

Eastern Ontario Diamond Drilling of Hawkesbury, Ontario supplied and operated a track-mounted CME-45 drill rig and portable tripod drill rig to carry out the drilling, sampling and in-situ testing operations of Boreholes WL-01 to WL-03. Ohlmann Geotechnical Services (OGS) Inc. of Almonte, Ontario supplied and operated a raft and portable tripod rig to carry out the drilling, sampling and in-situ testing operations of Borehole WL-04. The drilling and sampling operations in the field were supervised on a full time basis by Mr. Amir Fereidouni, Mr. George Azzopardi and Mr. Troy MacKinnon of Thurber. Geotechnical laboratory testing was carried out by Thurber in its MTO-approved laboratory. Overall supervision of the field program was carried out by Mr. Stephane Loranger, CET.

Ms. Deanna Pizycki, EIT, interpreted the data and prepared the report. The report was reviewed by Mr. Alastair Gorman, M.Sc., P.Eng., and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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PART 2 ENGINEERING DISCUSSION AND RECOMMENDATIONS

8 GENERAL

This report presents interpretation of the geotechnical data in the factual report and provides foundation recommendations for the design of the replacement of the existing Whitney Lake Culvert on Highway 11, located 22.6 km south of the Highway 11/11B south junction in the Gillies Township, New Liskeard District, Ontario.

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

Based on the terms of reference, the existing structure consists of a 21.2 m long and 3.1 m wide cast-in-place concrete culvert, with approximately 0.9 m of fill above the culvert. The existing culvert is aligned at approximately 55 degrees skew to the existing highway centreline. As indicated in the terms of reference, the culvert was constructed in 1938 and has no previous records of rehabilitation. This culvert equalizes the flow and water level of Whitney Lake on both sides of the Highway 11 crossing.

The Preliminary General Arrangement drawing dated April 2016 indicates that the proposed replacement culvert will consist of three 1500 mm ID precast concrete pipes and will be located on a new alignment, which will be perpendicular to the Highway 11 embankment and will start at the east end of the existing culvert. The culvert invert is indicated at Elev. 323.65 on the east side and at Elev. 323.71 on the west side. This equalization culvert will be 22.0 m in length.

The finish road grade at the culvert location is shown at Elev. 326.2, which indicates approximately 0.9 m of soil cover above the culvert, and no grade raise will be required to accommodate the replacement culvert.

Staged construction is proposed to maintain the Highway 11 traffic during installation of the culvert.

The discussions and recommendations presented in this report are based on the factual data obtained during the course of the investigation. The preliminary General Arrangement drawing used for preparation of this report was provided by MMM Group Limited.

9 CULVERT FOUNDATIONS

9.1 Summary of Subsurface Conditions

In general, the subsurface conditions encountered in the boreholes advanced from the top of the road embankment consisted of asphalt underlain by sand to gravelly sand fill, which in turn was underlain by a deposit of sand to gravelly sand till. The fill was estimated to be 3.6 m and 3.9 m thick with a lower boundary at depths of 3.8 and 4.0 m (Elevation 322.4 m). A 400 mm boulder was encountered directly underlying the fill in Borehole WL-03, with a base at Elevation 322.0. Underlying the embankment fill was a till consisting of sand to gravelly sand with trace to some silt, trace gravel and occasional cobbles and boulders. This till was encountered to depths investigated in the boreholes of 5.4 m to 9.8 m.

Near the east end of the culvert, a 1.5 m layer of fibrous peat was encountered at the ground surface. Directly beneath the peat, a refusal to penetration was encountered probably on cobbles/boulders or possible bedrock, and several attempts were made to penetrate this layer with refusal to penetration at each attempt. In the area of the west end of the new culvert alignment, a peat layer was 1.2 m thick and it was underlain by approximately 2.3 m thick light grey marl deposit. The underside of the marl was at 3.9 m depth below the water level in the lake.

The water level in the open boreholes were measured at a depth of 0.5 m in Borehole WL-01 and at 3.0 m in Borehole WL-03, corresponding to Elev. 324.0 and 323.4, respectively. The groundwater level should be assumed to coincide with the lake water level, which was reported to be at Elev. 324.1 in the Preliminary General Arrangement drawing.

9.2 Subgrade Preparation

Performance of the replacement culvert will depend on the preparation of the subgrade. After the excavation reaches the design subgrade level, the exposed surface should be inspected to confirm that the subgrade is suitable and uniformly competent. Any topsoil, alluvial peat, marl, recent lacustrine deposits or other unsuitable materials within the culvert replacement

footprint should be removed and replaced with suitable granular material compacted as per OPSS.PROV 501.

Swampy terrain was observed on both sides of the highway in the area of the replacement culvert. Approximately 1.5 m of peat was encountered at the location of Borehole WL-01, located near the east end of the existing culvert, and 1.2 m of peat underlain by 2.3 m of marl was encountered in Borehole WL-04 located in the vicinity of the west end on the proposed culvert. Borehole WL-04 was drilled from a raft moored against the embankment, as shown on Photograph 5 in Appendix C, but did not encounter embankment fill. Boreholes WL-02 and WL-03 did not encounter peat or marl, indicating that these materials were removed under most of the embankment during the original construction.

It is possible, though not confirmed, that peat is present in the subgrade at either end of the culvert and that the peat will be underlain by marl at the west end. It is important that the subgrade excavation be inspected and that all peat and marl be removed and be replaced by suitable backfill

The thickness of peat may vary across the site. It is possible that the peat can be present at the ends of the proposed culvert. Peat thicknesses were measured to be 1.5 to 1.6 m in Boreholes WL-01 and WL-04. In order to achieve the a uniform, competent founding subgrade, any peat encountered must be excavated from the culvert footprint and all subexcavated areas backfilled to the design subgrade level with the granular fill material such as Granular B Type II.

The work must be carried out in accordance with OPSS.PROV 902.

The culvert installation and subgrade preparation must be carried out in the dry, and the dewatering during construction should be effective to maintain the water level below the final subgrade level. Reference should be made to specifications in OPSS.PROV 517 and OPSS.PROV 518.

Once the subgrade is prepared, the construction equipment should not travel on the subgrade.

9.3 Culvert Alternatives

Based on the Preliminary General Arrangement Drawing provided by MMM, the replacement will consist of three 1500 mm diameter concrete pipes installed on the new alignment perpendicular to the highway embankment.

In addition to the option of three 1500 mm concrete pipes according to the Preliminary General Arrangement drawing, recommendations for a concrete box (closed) culvert are also provided.

Based on the noted drawing, no associated head walls/retaining walls are being considered in the design.

From a foundations perspective, either of the above options is considered to be feasible. An open footing culvert option is not recommended due to the greater depth of excavation that would be required.

9.4 Pipe Culvert

On the Preliminary General Arrangement drawing, the invert of the culvert is indicated at Elev. 323.7 on the west side and Elev. 323.6 on the east side, which falls within the embankment fill materials. The culverts could be founded on the existing compact, granular embankment fill. A layer of 300 mm of granular bedding material as per OPSS 802.031 conforming to OPSS.PROV 1010 Granular A or B Type II should be placed under the base of the pipe culvert.

Following inspection and subgrade approval, the bedding material should be placed as soon as practical on the approved, dry subgrade for protecting the subgrade from disturbance during construction.

The modulus of subgrade reaction “k” of 40 MN/m³ could be used in the design of the pipe culverts placed on the compact sand fill subgrade. This assumes that all peat and organics will be removed from the pipe subgrade and replaced with granular fill compacted as per OPSS.PROV 501.

9.5 Concrete Box Culvert

A precast concrete box culvert can be founded on the compact granular embankment fill below the level of existing peat and any unsuitable materials, where encountered. All boulders and large cobbles should be removed from the founding surface.

A minimum thickness of 300 mm of granular bedding material conforming to OPSS.PROV 1010 Granular A or B Type II material, plus a 75 mm levelling layer, should be provided under the base of the box culvert as per OPSD 803.010. The bedding material should be placed as soon as practical on the approved subgrade for protecting the subgrade from disturbance during construction. Subgrade preparation, placement of bedding material and culvert construction must be carried out in the dry.

A box culvert placed on the compact embankment fill at or below Elev. 323.5 can be designed for the following factored geotechnical resistance at the Ultimate Limit State (ULS) and the geotechnical reaction at Serviceability Limit State (SLS):

- Factored Geotechnical Resistance at ULS of 270 kPa
- Geotechnical Reaction at SLS (less than 25 mm settlement) of 180 kPa

A consequence factor of 1 was utilized in this design adopting the typical consequence level. Geotechnical resistance factors of 0.5 for bearing, and 0.8 for settlement both for typical

degree of understanding were used to obtain the above values, as per CHBDC, 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 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 must be reduced in accordance with the CHBDC 2014, Clause 6.10.3 and Clause 6.10.4.

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

Resistance to lateral forces/sliding between concrete and the underlying bedding material should be evaluated in accordance with the CHBDC assuming an ultimate/unfactored coefficient of friction of 0.5.

9.6 Frost Cover

The depth of frost penetration at this site is 2.3 m.

Frost treatment/taper for a culvert should be in accordance with OPSD 803.031 for a pipe culvert and with OPSD 803.010 for a box culvert.

10 EXCAVATION AND GROUNDWATER CONTROL

Excavation for the culvert replacement will be carried out through the existing embankment fill. The excavation will extend below the water level in the lake.

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 cohesionless till at this site are classified as Type 3 soils and all unsupported excavations must be sloped at 1H:1V for the full depth.

The design drawings by MMM indicate that the replacement culverts will lie entirely within the existing highway embankment. Accordingly, the entire subgrade is expected to lie in the existing, cohesionless, embankment fill. However, it should be noted that peat and marl deposits were encountered near east and west ends of the proposed culvert alignment. If encountered within the excavation for the culvert replacement, these deposits will have to be subexcavated and replaced.

Excavation and backfilling for culvert construction should be carried out in accordance with OPSS.PROV 902.

If the base of the excavation will be close to Elev. 323.0 and will be approximately 1.0 m below the lake level. In addition, surface runoff and perched groundwater within the embankment fill may seep into the excavations during culvert replacement. The water level must be depressed below the base of

excavation to sufficient depth to permit construction in the dry and to facilitate compaction of the bedding and backfill materials.

It will be necessary to construct a cofferdam and to employ active dewatering to depress the water level in the work zone. The design of the cofferdam and dewatering system is the responsibility of the Contractor and he should hire a specialist in this field. However, it is possible that driven sheet piles and vacuum wellpoints will be required in the relatively permeable soils at this site.

The relatively permeable soil, possible presence cobbles and boulders and the possibility of shallow bedrock, especially at the east end, may complicate the design and installation of a cofferdam and a dewatering system. Contractors bidding on the work must be alerted to this situation and suggested wording to use in the Contract Documents is included in Appendix E.

11 CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the culvert should consist of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS.PROV 1010. Reference should be made to the backfill arrangements stipulated in OPSD 803.01, 802.032 or 802.010, as appropriate, for the pipe culverts, and to OPSS 422 for precast reinforced concrete box culvert.

All fills should be placed and compacted in accordance with OPSS.PROV 501. The backfill should be maintained equal on both sides of the culvert, with one side not exceeding the other by more than 200 mm of loose placed material. Heavy compaction equipment should not be used adjacent to and over the culvert.

Lateral earth pressures acting on the culvert walls may be assumed to be distributed triangularly and to be governed by the characteristics of the backfill and the underlying soils. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are 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).

Recommended unfactored values of the earth pressure coefficients are shown in the Table 11.1, below. 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.

Table 11.1 – Earth Pressure Coefficients (K)

Wall Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ$; $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I (modified) $\phi = 32^\circ$; $\gamma = 21.2 \text{ kN/m}^3$		Embankment Fill $\phi = 30^\circ$; $\gamma = 20.0 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48	0.33	0.54
At rest (Restrained Wall)	0.43	0.62	0.47	0.70	0.50	0.76
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-	3.0	-

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

12 EMBANKMENT RECONSTRUCTION

The existing highway embankment is up to 4 m in height at the culvert location. Based on available information, no grade raise or embankment widening is planned at this site.

It is recommended that the material used to backfill around the culverts and to reconstruct the embankment should consist of OPSS Granular A or B Type II. If the existing culvert is abandoned by excavation and backfill, this fill should also consist of OPSS Granular A or B Type II.

Embankment reconstruction after culvert replacement should be carried out in accordance with OPSS.PROV 206.

Provided that the granular material is placed as recommended and at the same slope inclination as the existing embankment, the embankment slope should remain stable.

The settlement due to backfill the abandoned culvert or recompression around the new culverts is expected to be completed essentially as the backfilling is completed.

13 EROSION PROTECTION

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

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

Considering that the replacement culvert will serve to equalize the water level in Whitney Lake on both sides of the Highway 11 embankment, placement of a clay seal is not required.

In accordance with OPSD 810.010 a layer of river stone should be placed at both ends of the culvert.

14 TEMPORARY PROTECTION SYSTEM

Temporary protection system will be required for the staged construction of the culvert replacement. The design of the protection system is the responsibility of the Contractor. Since it may be difficult to drive sheet piles at this site due to presence of cobbles and boulders, one option would be to install a soldier piles and lagging system. It is anticipated that the soldier piles will need to be installed in the cohesionless till to develop the required toe resistance.

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

A temporary protection wall may be designed using the parameters given below:

$$\begin{aligned}\gamma &= 20 \text{ kN/m}^3 \\ \gamma_w &= 10 \text{ kN/m}^3 \\ K_a &= 0.33 \text{ (road embankment fill)} \\ &= 0.30 \text{ (sand/gravelly sand till)} \\ K_p &= 3.4 \text{ (sand/gravelly sand till)}\end{aligned}$$

If a watertight cofferdam is designed, full hydrostatic pressure should be considered assuming a water level equal to the water level in the lake.

The actual pressure distribution acting on the protection system is a function of the construction sequence and the relative flexibility of the wall, and these factors should be considered when designing the system. Typically, a triangular earth pressure distribution similar to the one used for culvert lateral pressure design should be used for a cantilevered protection wall.

It should be noted that cobble and boulders were encountered in the fill and in the cohesionless till, and the Contractor should be prepared to advance the protection system in such conditions.

15 CORROSION AND SULPHATE ATTACK POTENTIAL

The results of the corrosivity and sulphate analytical tests conducted on the lake water indicates the following:

- The potential for corrosion or sulphate attack on concrete treatment systems from the surrounding surface water is considered to be negligible due to the low concentration of sulphate in the samples tested.
- The potential for surface water corrosion on metal is considered to be mild.
- Appropriate protection measures are recommended to address the mild potential for corrosion on metal exposed to the lake water.

16 CONSTRUCTION CONCERNS

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

- A suitable dewatering system must be employed to enable construction in the dry and prevent sloughing and instability of the excavation walls.
- The thickness and depth to the base of the peat, marl and soft streambed deposits may vary at locations away from the boreholes.
- Cobbles and boulders were encountered in the embankment fill and in the underlying till; therefore cobbles and boulders should be anticipated and dealt with during construction. These materials may interfere with the excavation and cofferdam installation. The Contractor must be prepared to remove or otherwise penetrate these obstructions.
- Shallow bedrock may occur at the site, particular at the east end
- The Contractor's selection of construction equipment and methodology should include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structures or fill (i.e, as a pad for crane support). Site conditions may limit the type of equipment suitable for use. The design and safety of any temporary works is the responsibility of the Contractor.

17 CLOSURE

The memorandum was prepared by Anna Piascik, P.Eng., and reviewed by Mr. Alastair Gorman, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.

Anna Piascik, P.Eng.
Senior Geotechnical Engineer



Alastair Gorman, P.Eng.
Senior Foundation Engineer /Senior Associate



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

Appendix A
Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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


4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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

 Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

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

EXPLANATION OF ROCK LOGGING TERMS


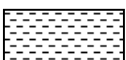

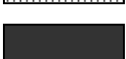

ROCK WEATHERING CLASSIFICATION

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 (MPa)	Approximate Uniaxial Compressive Strength (psi)	Field Estimation of Hardness*
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 WL-01

1 OF 1

METRIC

GWP# 5197-13-00 LOCATION Whitney Lake N 5 230 038.2 E 401 069.1 ORIGINATED BY GA
 HWY 11 BOREHOLE TYPE Tripod COMPILED BY AN
 DATUM Geodetic DATE 2016.03.11 - 2016.03.11 CHECKED BY DJP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL	
324.5	GROUND SURFACE							20	40	60	80	100									
0.0	PEAT , fibrous, trace to some silt, trace clay, trace gravel Firm Dark Brown Wet		1	SS	7		324														
			2	SS	8																
323.0							323														
1.5	END OF BOREHOLE AT 1.5m UPON REFUSAL ON PROBABLE COBBLES, BOULDERS OR BEDROCK. FREE WATER AT 0.5m UPON COMPLETION OF DRILLING. ATTEMPT # 2 END AT 0.6m, ATTEMPT # 3 END AT 0.9m, ATTEMPT # 4 END AT 0.8m, ATTEMPT # 5 END AT 1.2m AND ATTEMPT # 6 END AT 0.5m. ALL ATTEMPTS WITHIN 2.0m RADIUS OF ORIGINAL BOREHOLE AND TERMINATED ON REFUSAL ON PROBABLE COBBLES OR BOULDERS. BOREHOLES BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.																				

+³, ×³: Numbers refer to
Sensitivity


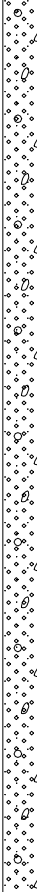
20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No WL-02

1 OF 2

METRIC

GWP# 5197-13-00 LOCATION Whitney Lake N 5 230 026.3 E 401 055.8 ORIGINATED BY AHF
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2016.02.22 - 2016.02.22 CHECKED BY DJP

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						
326.2	GROUND SURFACE													
0.0	ASPHALT: (225mm)													
0.2	SAND , some silt, trace to some gravel, trace clay, occasional gravelly sand and silty sand lenses Loose to Very Dense Grey Moist (FILL)		1	GS										
			2	SS	100/									
					0.125									
			3	SS	21									
			4	SS	13									
	Becoming brown at 3.0m depth		5	SS	4									
322.4														
3.8	SAND to Gravelly SAND , trace to some silt, trace clay, occasional cobbles and boulders Loose to Compact Grey Wet (TILL)													
			6	SS	7									
			7	SS	15									
	NQ Coring from 5.5m to 6.4m depth 380mm boulder at 5.5m depth		8	SS	15									
	Cored 125mm cobbles at 9.0m depth		9	SS	20									
316.4														
9.8	END OF BOREHOLE AT 9.8m.													

Continued Next Page

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

RECORD OF BOREHOLE No WL-02

2 OF 2

METRIC

GWP# 5197-13-00 LOCATION Whitney Lake N 5 230 026.3 E 401 055.8 ORIGINATED BY AHF
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2016.02.22 - 2016.02.22 CHECKED BY DJP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
	BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.3m, AND ASPHALT COLD PATCH TO SURFACE.																

RECORD OF BOREHOLE No WL-03

1 OF 2

METRIC

GWP# 5197-13-00 LOCATION Whitney Lake N 5 230 032.6 E 401 059.8 ORIGINATED BY GA
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2016.03.10 - 2016.03.11 CHECKED BY DJP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa											
326.4	GROUND SURFACE							20	40	60	80	100							
0.0	ASPHALT: (100mm)							20	40	60	80	100							
0.1	SAND to Gravelly SAND, trace silt, occasional cobbles and boulders Very Dense to Compact Brown Wet (FILL) 100mm cobbles at 1.2m depth		1	SS	55		326												
			2	SS	60														
			3	SS	17		325												
			4	SS	19		324												
	Becoming grey at 3.0m depth		5	SS	26		323												
322.4	BOULDER (400mm)																		
4.0							322												
322.0	SAND to Gravelly SAND, trace to some silt, trace clay, occasional cobbles and boulders Compact to Very Dense Grey Wet (TILL) Cored cobbles at 5.2m and 5.8m depth		6	SS	24		321												
4.4			7	SS	50/ 0.0		320												
			8	SS	71		319												
			9	SS	100/ 0.150		318												
			10	SS	129/ 0.150		317												
317.1	End of sampling and start DCPT																		
9.3																			

Continued Next Page

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

RECORD OF BOREHOLE No WL-03

2 OF 2

METRIC

GWP# 5197-13-00 LOCATION Whitney Lake N 5 230 032.6 E 401 059.8 ORIGINATED BY GA
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2016.03.10 - 2016.03.11 CHECKED BY DJP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
316.2																	
10.2	END OF BOREHOLE AT 10.2m. BOREHOLE OPEN TO 10.2m AND WATER LEVEL AT 3.0m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.3m, CONCRETE TO 0.2m, THEN ASPHALT PATCH TO SURFACE.																

RECORD OF BOREHOLE No WL-04

1 OF 1

METRIC

GWP# 5197-13-00 LOCATION Whitney Lake N 5 230 026.3 E 401 047.8 ORIGINATED BY TM
 HWY 11 BOREHOLE TYPE Tripod COMPILED BY AN
 DATUM Geodetic DATE 2016.07.22 - 2016.07.22 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W P	W	W L			WATER CONTENT (%)	
324.5	GROUND SURFACE							20	40	60	80	100						
0.0	WATER																	
324.1																		
0.4	PEAT, fibrous, trace sand, trace gravel Very Soft Brown Wet		1	SS	0		324										358	
			2	SS	0												1643	
322.9							323											
1.6	MARL, trace rootlets, trace shells fragments Very Soft Light Grey Wet		3	SS	0												209	
			4	SS	0		322										213	
			5	SS	0												202	
320.6			6	SS	7		321										194	
3.9	SAND to Gravelly SAND, trace silt Dense Grey Wet (TILL)		7	SS	32		320											
			8	SS	39													
319.1			9	SS	50/													
5.4	END OF BOREHOLE AT 5.4m ON AUGER REFUSAL. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.				0.125													

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

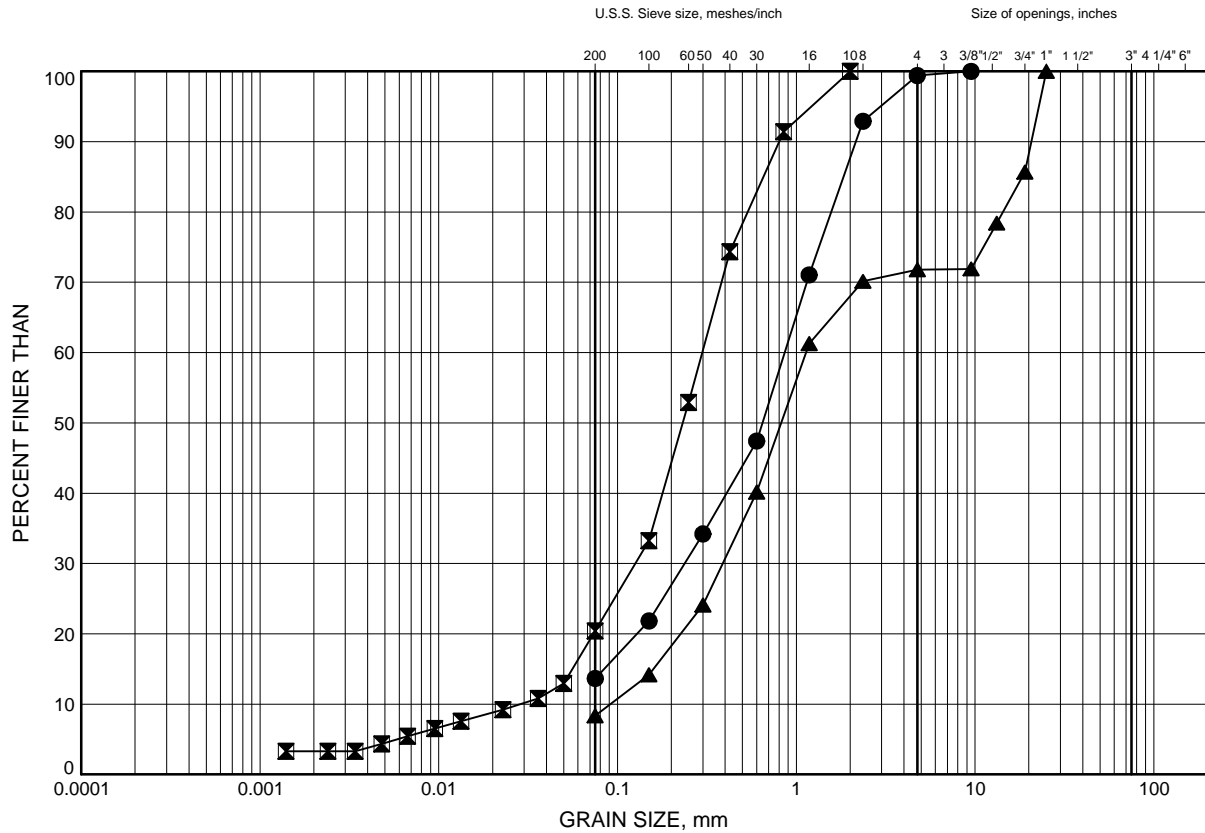
Appendix B

Geotechnical Laboratory Test Results

Whitney Lake GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND to Gravelly SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	WL-02	0.83	325.37
⊠	WL-02	3.35	322.85
▲	WL-03	1.07	325.33

Date March 2016
GWP# 5197-13-00

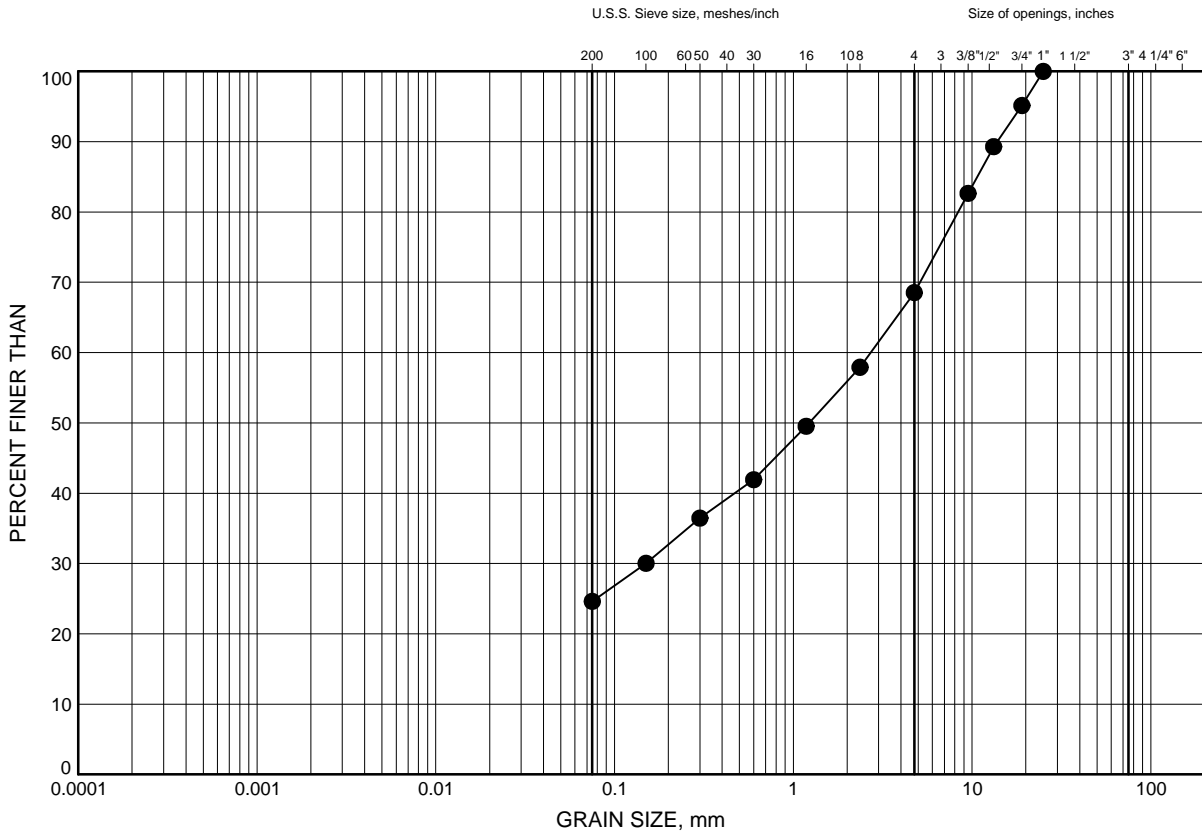


Prep'd AN
Chkd. DJP

Whitney Lake GRAIN SIZE DISTRIBUTION

FIGURE B2

Gravelly SAND (TILL)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	WL-03	7.92	318.48

Date April 2016
GWP# 5197-13-00



Prep'd AN
Chkd. DJP

CLIENT NAME: THURBER ENGINEERING LTD
SUITE 103, 2010 WINSTON PARK DRIVE
OAKVILLE, ON L6H5R7
(905) 829-8666

ATTENTION TO: Deanna Pizycki

PROJECT:

AGAT WORK ORDER: 16T076149

WATER ANALYSIS REVIEWED BY: Amanjot Bhela, Inorganic Coordinator

DATE REPORTED: Mar 18, 2016

PAGES (INCLUDING COVER): 5

VERSION*: 1

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

*NOTES

All samples will be disposed of within 30 days following analysis. Please contact the lab if you require additional sample storage time.



AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 16T076149

PROJECT:

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
<http://www.agatlabs.com>

CLIENT NAME: THURBER ENGINEERING LTD

SAMPLING SITE:

ATTENTION TO: Deanna Pizycki

SAMPLED BY:GA

Corrosivity Package (Water)

DATE RECEIVED: 2016-03-11

DATE REPORTED: 2016-03-18

		SAMPLE DESCRIPTION:		Whitney
		SAMPLE TYPE:		Water
		DATE SAMPLED:		3/9/2016
Parameter	Unit	G / S	RDL	7435580
Sulphide	mg/L		0.05	<0.05
Chloride	mg/L		0.10	40.5
Sulphate	mg/L		0.10	6.95
Electrical Conductivity	uS/cm		2	201
pH	pH Units		NA	7.27
Redox Potential	mV		5	395
Resistivity	ohms.cm			4980

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

Certified By:

Amanjot Bhela



Quality Assurance

CLIENT NAME: THURBER ENGINEERING LTD

AGAT WORK ORDER: 16T076149

PROJECT:

ATTENTION TO: Deanna Pizycki

SAMPLING SITE:

SAMPLED BY:GA

Water Analysis															
RPT Date: Mar 18, 2016			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper
Corrosivity Package (Water)															
Sulphide	7430656		<0.05	<0.05	NA	< 0.05	100%	80%	120%	102%	85%	115%	102%	70%	130%
Chloride	7435391		149	148	0.7%	< 0.10	108%	90%	110%	110%	90%	110%	114%	80%	120%
Sulphate	7435391		10.0	10.0	0.0%	< 0.10	107%	90%	110%	109%	90%	110%	108%	80%	120%
Electrical Conductivity	7436969		2740	2750	0.4%	< 2	104%	80%	120%	NA			NA		
pH	7436969		8.07	8.03	0.5%	NA	99%	90%	110%	NA			NA		
Redox Potential	7435580	7435580	395	395	0.0%	< 5	109%	70%	130%	NA			NA		

Comments: NA signifies Not Applicable.

Duplicate Qualifier: As the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

Certified By:

Amanjot Bhela

Method Summary

CLIENT NAME: THURBER ENGINEERING LTD

AGAT WORK ORDER: 16T076149

PROJECT:

ATTENTION TO: Deanna Pizycki

SAMPLING SITE:

SAMPLED BY:GA

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Water Analysis			
Sulphide	INOR-93-6054	SM 4500 S2- D	SPECTROPHOTOMETER
Chloride	INOR-93-6004	SM 4110 B	ION CHROMATOGRAPH
Sulphate	INOR-93-6004	SM 4110 B	ION CHROMATOGRAPH
Electrical Conductivity	INOR-93-6000	SM 2510 B	PC TITRATE
pH	INOR-93-6000	SM 4500-H+ B	PC TITRATE
Redox Potential		SM 2510 B	REDOX POTENTIAL ELECTRODE
Resistivity		SM 2510 B	EC METER



5835 Coopers Avenue
Mississauga, Ontario L4Z 1Y2
Tel: 905.510.5100 Fax: 905.713.5133

If this is a Drinking Water sample, please use Drinking Water Chain of Custody Form (potable water intended for human consumption)

2. Email:

☐ Regulation 558

☐ CCME

☐ Prov. Water Quality Objectives (PWQO)

☐ Other

AGAT Quote #:

Please note: If quotation number is not provided, client will be billed full price for analysis.

Bill To Same: Yes ☒ No ☐

Company: _____
Contact: _____
Address: _____
Email: _____

Legend

B	Biota
GW	Ground Water
O	Oil
P	Paint
S	Soil
SD	Sediment
SW	Surface Water

☐ Yes ☐ No

☐ Yes ☐ No

Work Order #: 110710149

Custody Seal Intact: ☐ Yes ☐ No ☐ N/A

Notes: _____

Regular TAT 5 to 7 Business Day

Rush TAT (Rush Surcharges Apply)

☐ 3 Business Days ☐ 2 Business Days ☐ 1 Business Day

OR Date Required (Rush Surcharges May Apply):

Please provide prior notification for rush TAT
*TAT is exclusive of weekends and statutory holidays

[illegible]

١٥-٢٧٢٨٦-٥

12.03

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Appendix C
Selected Site Photographs



Photograph 1: Highway Embankment Looking North



Photograph 2: Highway 11 Embankment, Looking South



Photograph 3: Whitney Lake Culvert Inlet, Looking North.



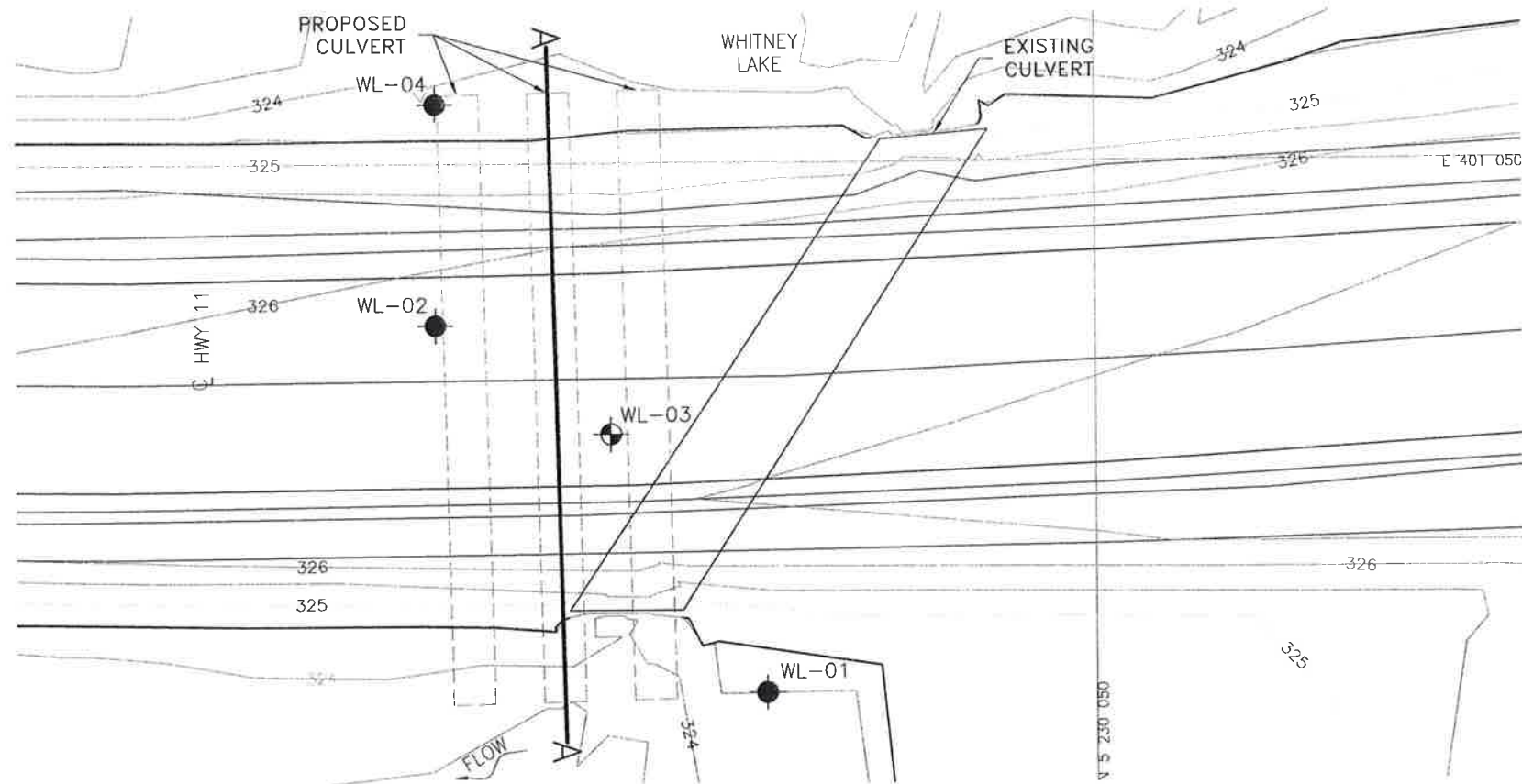
Photograph 4: Whitney Lake Outlet Looking North



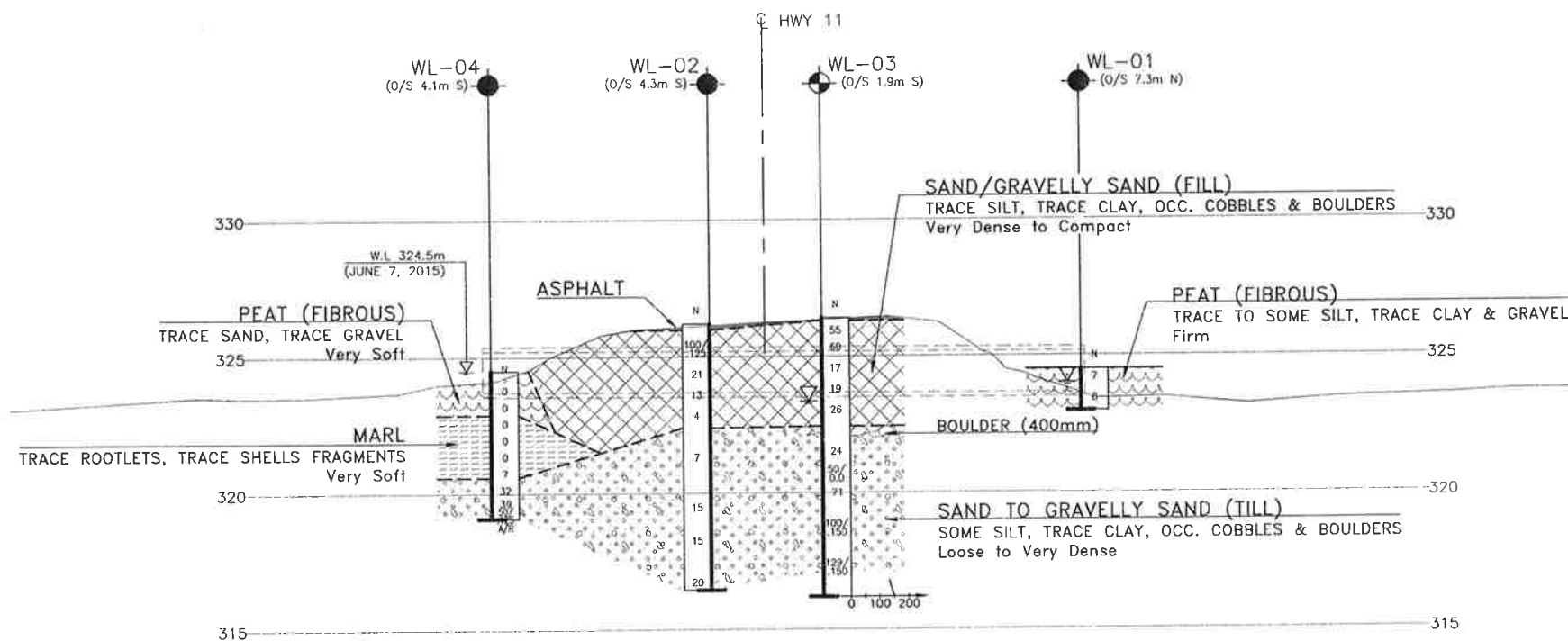
Photograph 5: Drilling Borehole WL-04 with Portable Rig on Barge

Appendix D

Borehole Locations and Soil Strata Drawing



PLAN



SECTION ALONG A-A



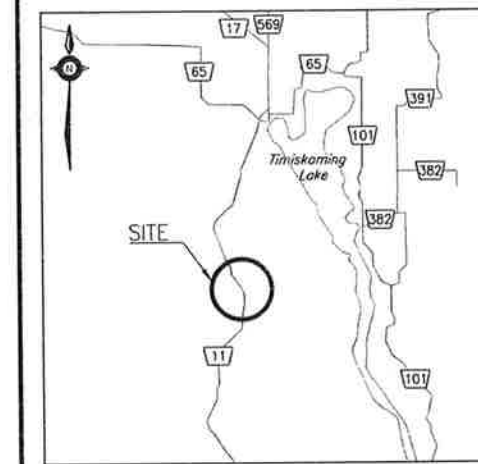
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
GWP No 5197-13-00

HIGHWAY 11
WHITNEY LAKE CULVERT
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



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
↑	Water Level in Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
WL-01	324.5	5 230 038.2	401 069.1
WL-02	326.2	5 230 026.3	401 055.8
WL-03	326.4	5 230 032.6	401 059.8
WL-04	324.5	5 230 026.3	401 047.8

-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- MTM, Zone 10 co-ordinate system was used for boreholes co-ordinates.

GEOCREs No. 31M-118



DATE	BY	DESCRIPTION
DESIGN	DJP	CHK AMP CODE
DRAWN	AN	CHK DJP SITE
		LOAD
		STRUCT
		DWG 1
		DATE AUG 2016

Appendix E

List of OPSS and OPSD Documents Relevant to Project

Suggested Alert Text

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

<ul style="list-style-type: none">• OPSS PROV 206• OPSS PROV 422• OPSS PROV 501• OPSS PROV 517• OPSS PROV 518• OPSS PROV 539• OPSS PROV 804	<ul style="list-style-type: none">• OPSS PROV 902• OPSS PROV 1010• OPSS PROV 1205• OPSD 802.010• OPSD 803.010• OPSD 802.031• OPSD 810.010
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2. Text to Alert Contractors to Ground Conditions

It is recommended that the following, or similar, text be included in the Contract documents.

The Contractor's attention is directed to the stratigraphy and groundwater/surface water conditions at this site. Geotechnical conditions that may affect the design and constructability of temporary and permanent works include, but are not limited to:

- The permeable nature of the embankment fill and the underlying native soil
- The presence of cobbles and/or boulders in the fill and native soil
- The presence of peat and marl in proximity to the culvert footprint
- The possible presence of bedrock at shallow depth, particularly at the east end of the culvert (bedrock outcrops are visible in the vicinity of the site)
- The location of the site in Whitney Lake, requiring excavation below the surface level of the lake
- Groundwater within the embankment will be at or slightly above the lake level
- The lake level and groundwater levels may vary in response to weather and the time of year

Appendix F

Comparison of Foundation Alternatives

COMPARISON OF FOUNDATION ALTERNATIVES

Proposed Works	Concrete or Corrugated Steel Pipe Culvert	Concrete Box Culvert	Concrete Open Footing Culvert
Culvert Replacement	<p>Advantages:</p> <ul style="list-style-type: none"> i. Relatively rapid installation and less disturbance to subgrade soils. ii. Concrete or steel pipes may be more cost effective than concrete box or open footing culverts. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Steel pipes could have shorter design life than concrete culverts 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Relatively rapid installation and less disturbance to subgrade soils if precast concrete units are used. ii. Less requirement for soil geotechnical resistances as loading is spread over a larger width. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. More expensive than CSP or CSPA alternatives. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Relatively rapid installation if precast units are used. ii. May have less environmental issues such as those involving spawning fish species. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Requires higher soil geotechnical resistances to support strip footings. ii. Requires deeper excavation for strip footing construction. iii. Potentially more difficult unwatering requirements.
	RECOMMENDED	FEASIBLE	NOT RECOMMENDED