



THURBER ENGINEERING LTD.

**DETAILED FOUNDATION INVESTIGATION AND DESIGN REPORT
BLACKBIRD CREEK CULVERT REPLACEMENT
HIGHWAY 17, UNSURVEYED TERRITORY
THUNDER BAY DISTRICT, ONTARIO
LATITUDE: 48.845825°, LONGITUDE: -87.037083**

G.W.P. 6808-14-00, W.P. 6808-14-01, SITE No. 48E-052C

GEOCRES Number: 42D-54

Report

to

HATCH

Date: November 12, 2018
File: 15595



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	Asphalt	5
5.2	Sand to Sand and Gravel Fill	5
5.3	Silty Sand to Sand and Silt Fill	6
5.4	Topsoil	7
5.5	Upper Silty Sand to Sandy Silt	7
5.6	Silty Clay	8
5.7	Lower Silt to Silty Sand	9
5.8	Sand and Gravel to Sand	9
5.9	Silty Clay to Clayey Silt Till	10
5.10	Groundwater Conditions	10
6.	CORROSIVITY AND SULPHATE TEST RESULTS	11
7.	MISCELLANEOUS	12

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8.	GENERAL	14
9.	CULVERT FOUNDATION DESIGN	15
9.1	Foundations	15
9.2	Frost Cover	16
9.3	Subgrade Preparation	16
9.4	Settlement	17
10.	EXCAVATION AND GROUNDWATER CONTROL	17
11.	CULVERT BACKFILL AND LATERAL EARTH PRESSURES	18
12.	SEISMIC CONSIDERATIONS	19
13.	COFFERDAMS	20
14.	TEMPORARY PROTECTION SYSTEM	21
15.	TEMPORARY MODULAR BRIDGE	22
16.	EMBANKMENT RESTORATION	22
17.	SCOUR AND EROSION PROTECTION	23
18.	CORROSION AND SULPHATE ATTACK POTENTIAL	23



19. CONSTRUCTION CONCERNS.....	24
20. CLOSURE	24

APPENDICES

Appendix A	Record of Borehole Sheets
Appendix B	Laboratory Test Results
Appendix C	Borehole Locations and Soil Strata Drawing
Appendix D	Site Photographs
Appendix E	List of Specifications and Suggested Wording for NSSP
Appendix F	Stability Analyses Results



**DETAILED FOUNDATION INVESTIGATION AND DESIGN REPORT
BLACKBIRD CREEK CULVERT REPLACEMENT
HIGHWAY 17, UNSURVEYED TERRITORY
THUNDER BAY DISTRICT, ONTARIO
G.W.P. 6808-14-00, W.P. 6808-14-01, SITE No. 48E-052C**

GEOCRES Number: 42D-54

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 detailed design of the proposed Blackbird Creek Culvert replacement. The Blackbird culvert is located on Highway 17, east of the township of Terrace Bay, in the District of Thunder Bay, Ontario. Thurber previously completed a preliminary foundation investigation at the culvert site in 2018.

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

Thurber carried out the investigation as a sub-consultant to Hatch under the Ministry of Transportation Ontario (MTO) Agreement Number 6016-E-0008.

The preliminary investigation conducted by Thurber is described in the following report:

- Preliminary Foundation Investigation and Design Report, Blackbird Creek Culvert Replacement, Highway 17, Unsurveyed Territory, Thunder Bay District, Ontario, GEOCRES Number 42D-50, prepared by Thurber Engineering Ltd.

The borehole logs from the preliminary investigation are included in this report.

2. SITE DESCRIPTION

The site is located along Highway 17, approximately 9 km east of the township of Terrace Bay, Ontario. The culvert allows Blackbird Creek to flow from a southerly to northerly direction under



Highway 17. Highway 17 generally runs in a northeast-southwest direction at the culvert site with the culvert running perpendicular to the roadway.

Based on the Ontario Structure Inspection Manual (OSIM) prepared by MTO on November 20, 2014, the existing culvert is a cast in place concrete box culvert that is 6.1 m wide, 1.8 m high and 30.6 m long. The culvert barrel is in overall poor condition with light to medium erosion along the bottom 0.7 m of both side walls. The side wall erosion is severe in some locations. There is a 750 mm long crack near the inlet on the west wall. Medium scaling and cracking were observed in the soffit, and severe scaling was observed on the southeast wall. The water level in the creek on June 7, 2016 was reported at approximate Elevation 205.6 m upstream of the inlet and 204.6 m downstream of the outlet.

The grade level of Highway 17 at the existing culvert is at an elevation of 209 m. The invert elevation (southeast) is approximately 204.4 m, and the outlet elevation (northwest) is approximately 204.2 m. The height of fill above the existing culvert is approximately 3 m.

The area on either side of the creek near the inlet and outlet of the culvert is vegetated with tall grass and trees, and the overall surrounding area is densely forested. There are also pine trees and grass growing on top of the culvert at the inlet and outlet. Photographs in Appendix D show the culvert and the surrounding area.

The site lies within the physiographic region known as the Wawa Subprovince of the Superior Province of the Canadian Shield. Based on Ontario Geological Survey (OGS) Map 2518, titled "Surficial Geology of Northern Ontario", dated 1987, the site is located in an area of "bare bedrock with thin glacial sediment cover". Based on OGS Map 2545, titled "Bedrock Geology of Ontario", dated 1991, the bedrock is of the Archean age and consists of intrusive rocks, mainly massive to foliated granodiorite and granite.

3. INVESTIGATION PROCEDURES

The current investigation and field testing program was carried out between June 25 and July 16, 2018, and consisted of drilling and sampling five (5) boreholes, designated as Boreholes 18-01 to 18-05, to depths ranging from 2.9 m to 20.1 m below the existing ground surface. A Dynamic Cone Penetration Test (DCPT) conducted at the base of Borehole 18-03 extended the borehole to a depth of 15.8 m from 12.8 m. Boreholes 18-01 and 18-02 were drilled within the paved portion of Highway 17 near the locations of the abutments for a potential temporary modular bridge, approximately 30 m to the north, and 12 m to the south, of the existing culvert, respectively. Boreholes 18-03, 18-04 and 18-05 were drilled near the inlet and outlet of the proposed culvert



alignment and to delineate peat thickness along the new alignment.

The previous preliminary investigation for this project was carried out between August 20 and September 17, 2017, during which time four boreholes denoted as Boreholes 17-34 to 17-37 were drilled at selected locations at the culvert site to depths of between 2.1 m and 18.9 m.

The Record of Borehole sheets for the boreholes from the current and previous preliminary investigation are included in Appendix A. The approximate locations of the boreholes from both investigations are shown on the Borehole Locations and Soil Strata Drawings included in Appendix C.

Utility clearances were obtained prior to the start of drilling. The ground surface elevations for the boreholes were estimated from topographic drawings provided to Thurber by Hatch. The boreholes drilled from the Highway platform from the current investigation were drilled using a truck-mounted drill rig using wash boring drilling techniques, Borehole 18-03 was drilled using a portable Hilti drill and tripod equipment using wash boring techniques, and Boreholes 18-04 and 18-05 were sampled using hand held sampling equipment with a 22 kg hammer. 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).

The field investigation was supervised on a full-time basis by a member of Thurber's technical staff who directed the drilling, sampling and in-situ testing operations, logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing.

Piezometers were installed as part of the current investigation in Boreholes 18-01, 18-02, and 18-03 and water level readings were taken throughout the investigation. The piezometers were decommissioned at the completion of the field investigation. The remaining boreholes were backfilled in general accordance with Ontario regulation 903, as amended. A piezometer was also installed in Borehole 17-36 drilled during the preliminary investigation.

Completion details of the borehole are summarized in Table 3.1 below.



Table 3.1 – Borehole Completion Details

Borehole Number	Borehole-DCPT Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
18-01	20.1 / 188.8	15.2 / 193.7	Bentonite holeplug to 15.5 m, sand to 13.4 m, bentonite holeplug to 0.2 m then asphalt to surface.
18-02	19.9 / 189.1	19.8 / 189.2	Sand to 18.0 m, bentonite holeplug to 0.2 m then asphalt to surface.
18-03	15.8 / 190.0	3.0 / 202.8	Borehole caved to 9.1 m, then backfilled with bentonite holeplug to 3.4 m, sand to 1.2 m then bentonite holeplug to surface.
18-04	3.7 / 202.0	None Installed	Borehole backfilled with cuttings to surface.
18-05	2.9 / 203.4	None Installed	Borehole backfilled with cuttings to surface.
17-34	15.3/190.1	None Installed	Bentonite holeplug and cuttings to surface and covered with gravel
17-35	18.9/190.1	None Installed	Cuttings to 0.9 m, then dry cement to 0.1 m and asphalt to surface
17-36	15.8/190.1	11.2/194.7	Sand to 7.9 m, then bentonite holeplug and cuttings to surface
17-37	2.1/206.9	None Installed	Cuttings to 0.75 m, then concrete to 0.15 m and asphalt to surface

4. LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size distribution analyses (hydrometer and/or sieve) and Atterberg Limits testing, where appropriate. Laboratory testing

Client: Hatch

Date: November 12, 2018

File No.: 15595

Page: 4 of 25

E file: H:\15000-15999\15595 Replace 9 Culverts 6016-E-0008\Reports and Memos\Blackbird Creek\Detailed

Design\FINAL\Blackbird Creek Culvert FIDR FINAL - Nov 12-2018.docx



results are summarized on the Record of Borehole sheets included 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, during the previous investigation, a sample of the existing native soil, and a sample of the surface water from the creek 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

Details of the encountered soil stratigraphy are presented on 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 must be used for interpretation of the site conditions. It should be recognized and expected that soil conditions may vary between and beyond borehole locations.

In general, the subsurface conditions encountered in these boreholes consisted of asphalt, large thicknesses of topsoil and fill overlying varying thicknesses of silty sand, which was in turn underlain by silty clay and lower silty sand and sand layers. Descriptions of the individual strata are presented below.

5.1 Asphalt

Boreholes 18-01, 18-02, 17-35 and 17-37 were drilled through the paved sections of Highway 17 and encountered approximately 100 to 175 mm thick layer of asphalt.

5.2 Sand to Sand and Gravel Fill

Sand and gravel to sand fill with some gravel and containing trace to some silt, and trace clay was encountered in all Boreholes drilled within the paved sections of Highway 17 beneath the asphalt structure. The sand and gravel to sand fill layer was approximately 0.8 m to 1.4 m thick and extended to depths of between 1.0 m and 1.5 m (Elevations 207.9 m and 207.5 m).



SPT 'N' values in the sand and gravel to sand fill ranged from 64 blows for 0.3 m penetration to 50 blows for 0.15 m penetration indicating a very dense condition. Measured moisture contents in the sand and gravel to sand fill ranged from 4 to 8 percent.

The results of grain size distribution analyses carried out on selected samples of the sand to sand and gravel fill are presented on the Record of Borehole sheets included in Appendix A and on Figure B1 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	13 to 42
Sand	50 to 68
Silt	14 to 15
Clay	4 to 5
Silt and Clay	8

5.3 Silty Sand to Sand and Silt Fill

Silty sand to sand and silt fill, containing trace clay and trace gravel, was encountered in Boreholes 18-01, 18-02, 17-35, and 17-37 beneath the sand to sand and gravel fill at depths of between 1.0 m to 1.5 m (Elevations 207.9 m to 207.5 m). Where fully penetrated the silty sand to sand and silt fill layer was approximately 1.2 m to 1.7 m thick and extended to depths of between 2.2 m to 3.1 m (Elevations 206.7 m to 205.9 m). Borehole 17-37 was terminated in the sand and silt fill layer at a depth of approximately 2.1 m (Elevation 206.9 m).

SPT 'N' values in the silty sand to sand and silt fill ranged from 10 to 46 blows for 0.3 m penetration indicating a compact to dense condition. Measured moisture contents in the silty sand to sand and silt fill ranged from 11 to 19 percent.

The results of grain size distribution analyses carried out on selected samples of the silty sand to sand and silt are presented on the Record of Borehole sheets included in Appendix A and on Figure B2 of Appendix B. The results of the grain size distribution analyses are summarized below:



Soil Particle	Percentage (%)
Gravel	0 to 9
Sand	34 to 60
Silt	24 to 63
Clay	3 to 7

5.4 Topsoil

Surficial topsoil, containing sand, silt and rootlets, was encountered in Boreholes 18-03, 18-04, 18-05, 17-34 and 17-36. The surficial topsoil was approximately 50 mm to 600 mm thick. A buried layer of topsoil, containing sand, silt, rootlets and wood fragments was encountered in Boreholes 17-35 at a depth of approximately 3.1 m (Elevation 205.9 m) and was approximately 2.5 m thick, extending to a depth of approximately 5.6 m (Elevation 203.4 m).

SPT 'N' values within in the topsoil ranged from 4 to 9 blows per 0.3 m penetration, indicating a loose condition. Measured moisture contents in the topsoil ranged from 11 to 65 percent.

5.5 Upper Silty Sand to Sandy Silt

An upper layer of silty sand to sandy silt, containing trace to some clay, trace gravel, and trace organics near the surface, was encountered in Boreholes 18-01, 18-03, 17-34, and 17-36 at depths of between 0.1 m to 2.2 m (Elevations 206.7 m to 203.9 m). The silty sand to sandy silt was approximately 0.8 m to 3.9 m thick and extended to depths of between 1.4 m to 6.1 m (Elevations 204.5 m to 201.3 m).

SPT 'N' values in the silty sand to sandy silt ranged from 1 to 11 blows per 0.3 m penetration, indicating a very loose to compact condition. Measured moisture contents ranged from 8 to 46 percent.

The results of grain size distribution analyses testing carried out on selected samples of the silty sand to sandy silt are presented on the Record of Borehole sheets included in Appendix A and on Figure B3 Appendix B. The results of the grain size distribution analyses are summarized below:



Soil Particle	Percentage (%)
Gravel	0 to 1
Sand	30 to 58
Silt	29 to 64
Clay	5 to 13

5.6 Silty Clay

Silty clay with sand to trace sand and trace gravel was encountered in Boreholes 18-01 to 18-05 and 17-34 to 17-36 at depths of between 0.1 m to 6.1 m (Elevations 206.2 m to 201.3 m). Where fully penetrated the silty clay was 6.7 m to 10.7 m thick and extended to depths of between 9.1 m and 14.0 m (Elevations 196.7 m and 192.9 m). Boreholes 18-04 and 18-05 were terminated with the silty clay layer at depths of 3.7 m and 2.9 m (Elevations 202.0 m and 203.4 m), respectively.

SPT 'N' values in the silty clay ranged from 0 (weight of hammer) to 20 blows per 0.3 m penetration, however typical values ranged from 0 to 5 blows. In-situ vane shear tests were conducted in the silty clay and measured undrained shear strengths of between 7 and 57 kPa (typically 10 to 50 kPa). The results of the SPTs and vane shear tests indicate the silty clay is very soft to firm. The sensitivity of the silty clay was measured to range between 1.1 and 3.5, indicating low to medium sensitivity. Measured moisture contents in the silty clay range from 20 to 75 percent.

The results of grain size distribution analyses and Atterberg Limits testing carried out on selected samples of the silty clay are presented on the Record of Borehole sheets included in Appendix A and on Figures B4 and B6 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	0
Sand	0 to 1
Silt	15 to 75
Clay	25 to 84

The results of Atterberg Limits testing are summarized below:



Index Property	Percentage (%)
Plastic Limit	17 to 25
Liquid Limit	28 to 74
Plasticity Index	10 to 49

The results of the Atterberg Limits testing indicate the layer to be of low to high plasticity with group symbols CL, CI and CH.

5.7 Lower Silt to Silty Sand

A lower layer of Silty Sand to silt with some sand and containing trace clay and trace gravel, was encountered in Boreholes 18-01 to 18-03, and 17-34 to 17-36 at depths of between 9.1 m and 14.0 m (Elevations 196.7 m and 192.9 m). The lower silt to silty sand was approximately 1.6 to 4.9 m thick and extended to depths of between 10.7 m and 18.3 m (Elevations 195.1 m to 190.6 m).

SPT 'N' values within the silt to silty sand ranged from 0 (weight of hammer) to 20 blows per 0.3 m penetration, indicating a very loose to compact condition. Measured moisture contents in the silt to silty sand ranged from 15 percent to 27 percent.

The results of grain size distribution analyses testing carried out on selected samples of the lower silt to silty sand are presented on the Record of Borehole sheets included in Appendix A and on Figure B3 Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 1
Sand	10 to 75
Silt	56 to 83
Clay	7
Silt and Clay	24

5.8 Sand and Gravel to Sand

A lower layer of sand and gravel to sand with trace to some gravel was encountered in Boreholes 18-03, 17-34, 17-35, and 17-36 at depths of between 10.7 m and 17.1 m (Elevations 195.1 m and 190.6 m). These four boreholes were terminated within the sand and gravel to sand layer at depths of between 12.8 m and 18.9 m (Elevations 193.0 m to 190.1 m).



SPT 'N' values within the sand and gravel to sand ranged from 6 to over 100 blows per 0.3 m of penetration, indicating a loose to very dense condition. Measured moisture contents within the sand and gravel to sand deposit varied between 4 percent and 23 percent.

The results of grain size distribution analyses testing carried out on a selected sample of the sand and gravel to sand are presented on the Record of Borehole sheets included in Appendix A and on Figure B5 Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	4
Sand	87
Silt and Clay	9

5.9 Silty Clay to Clayey Silt Till

Silty clay to clayey silt till, containing trace sand, trace gravel, and occasional cobbles and boulders was encountered in Boreholes 18-01 and 18-02 at depths of 18.3 m and 18.6 m (Elevations 190.6 m and 190.4 m), respectively. Both boreholes were terminated in the silty clay to clayey silt till at depths of 20.1 m and 19.9 m (Elevations 188.8 m and 189.1 m). A boulder layer, 0.6 m thick was encountered in BH 18-02 between Elevations 189.8 m to 189.2 m.

SPT 'N' values in the silty clay to clayey silt till ranged from 50 blows per 150 mm to 50 blows per 75 mm of penetration indicating a hard consistency. Measure moisture contents in the silty clay to clayey silt till ranged from 5 to 11 percent.

5.10 Groundwater Conditions

Groundwater conditions were observed during drilling operations, and groundwater levels were measured in the open boreholes upon completion of drilling. Standpipe piezometers were installed in Borehole 18-01, 18-02, 18-03 and 17-36 to monitor the groundwater level at the site. The groundwater levels measured in the open boreholes and in the standpipe piezometer are summarized below.

Table 5.1 – Groundwater Measurements

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
18-01	June 26, 2018	1.0	207.9	Standpipe piezometer
	July 24, 2018	0.7	208.2	
18-02	June 25, 2018	0.7	208.3	Standpipe piezometer
	June 26, 2018	0.8	208.2	
	July 24, 2018	0.7	208.3	
18-03	July 16, 2018	0.6	205.2	Standpipe piezometer. Artesian condition in encountered at 11.3 m.
18-04	July 15, 2018	1.4	204.3	Open borehole
18-05	July 15, 2018	0.0	206.3	Open borehole
17-34	August 17, 2017	Dry	Dry	Open borehole
17-35	August 20, 2017	3.7	205.3	Open borehole
17-36	August 28, 2017	0.6	205.3	Standpipe piezometer
17-37	August 20, 2017	Dry	Dry	Open borehole

The creek water level on June 7, 2016, was reported to be Elevation 205.6 m upstream of the inlet and 204.6 m downstream of the outlet.

Artesian conditions were encountered while drilling in Borehole 18-03 at a depth of approximately 11.3 m. The artesian condition was successfully plugged in accordance with Regulation 903, as amended.

The groundwater levels above 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 after periods of significant or prolonged precipitation.

6. CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the native silty sand from Borehole 17-36 and a sample of the creek water 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	
			17-36, SS#2, 0.8 m – 1.4 m	Blackbird Creek
			(Silty Sand)	(Creek Water)
Sulphide	mg/L	mg/L	<0.02	0.08
Chloride	mg/L	mg/L	340	110
Sulphate	mg/L	mg/L	10	180
pH	No unit	No unit	7.99	7.78
Electrical Conductivity	µS/cm	µS/cm	397	1180
Resistivity	Ohms.cm	Ohms.cm	2520	847
Redox Potential	mV	mV	137	224

7. MISCELLANEOUS

Thurber marked the borehole locations in the field and obtained subsurface utility clearances prior to drilling.

Forage Downing Drilling of Hawkesbury, Ontario and Ohlmann Geotechnical Services (OGS) of Almonte, Ontario supplied and operated the drilling, sampling and in-situ testing equipment for the current investigation. The field investigation was supervised on a full-time basis by Mr. Ryan McCourt and Ms. Judy Mei of Thurber. Overall supervision of the field program was provided by Mr. Mark Farrent, P.Eng..

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. The coordinate system MTM NAD83 Zone 14 was used for these boreholes.

Routine laboratory testing was carried out at Thurber's geotechnical laboratory. Interpretation of the field data and preparation of this report was carried out by Mr. Cory Zanatta and Mr. Mark Farrant, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



Thurber Engineering Ltd.

Cory Zanatta, P.Eng.
Geotechnical Engineer



Mark Farrant, P.Eng.
Geotechnical Engineer



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



**DETAILED FOUNDATION INVESTIGATION AND DESIGN REPORT
BLACKBIRD CREEK CULVERT REPLACEMENT
HIGHWAY 17, UNSURVEYED TERRITORY
THUNDER BAY DISTRICT, ONTARIO
G.W.P. 6808-14-00, W.P. 6808-14-01, SITE No. 48E-052C**

GEOCRES Number: 42D-54

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8. GENERAL

This report provides an interpretation of the geotechnical data in the factual report and presents detailed foundation design recommendations for the proposed Blackbird Creek Culvert replacement on Highway 17, located east of the township of Terrace Bay, in the District of Thunder Bay, Ontario. This detailed foundation report should be read in conjunction with the Preliminary Foundation Report.

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 contractors must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

Information on the existing culvert site was obtained from the MTO Terms of Reference, and the Ontario Structure Inspection Manual (Inspection Form) prepared by MTO on November 20, 2014. The existing structure is a cast in place concrete box culvert. The culvert measures 6.1 m wide, 1.8 m high and is 30.6 m long. The estimated culvert invert is at approximate Elevation 204.4 m at the inlet (southeast) and 204.2 m at the outlet (northwest). The existing road grade at the culvert location is at approximate Elev. 209 m, which indicates approximately 3.0 m of fill above the culvert.

The preliminary foundation report provided recommendations for both pipe culverts and box culverts. General Arrangement Drawings and discussions with Hatch indicate that twin structural



plate corrugated steel pipe culverts are the preferred replacement option. The twin pipe culverts are to have an interior diameter of 3.99 m. The invert level of the twin pipe culverts are approximately at Elevation 203.33 m and 203.22 m at the inlet and outlet, respectively.

The alignment of the proposed twin pipe culvert replacements will be constructed approximately 5.0 m to the east of the existing culvert alignment. No grade raise or embankment widening is proposed for the culvert replacement. No headwalls or wingwalls are proposed.

Temporary roadway protection will be used to construct the twin culverts in stages.

9. CULVERT FOUNDATION DESIGN

In general, the subsurface conditions encountered in the boreholes consists of sand and gravel and silty sand embankment fill overlying native deposits of buried topsoil and sandy silt to silty sand. The topsoil and sandy silt to silty sand is in turn underlain by a thick deposit of silty clay, which is further underlain by deposits of silt and sand and silty clay till at depth. The groundwater levels, as measured in the piezometers, ranged from 208.3 m to 204.3 m.

The founding soils encountered at the proposed invert level (Elevations 203.33 m to 203.22 m) generally consist of very soft to firm silty clay and very loose to loose silty sand. There is up to approximately 1.7 m of fill above the proposed culvert replacement.

The preliminary investigation report provided foundation recommendations for different types of culverts and these recommendations are not repeated here but may be used for detailed design.

9.1 Foundations

Replacement of the culvert with twin pipe culverts on an alignment located approximately 5 m north of the existing culvert alignment is being considered for this site. It is anticipated that the foundation soils within the culvert footprint will not be subjected to any significant additional loading due to the culvert replacement.

The twin pipe culverts should be placed on uniform foundation subgrade consisting of a minimum of 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements as per OPSD 802.034 or 802.010. The bedding material should be placed on the prepared subgrade as soon as practical, following its inspection and approval. The subgrade preparation, placement, and compaction of the bedding, should be carried out in the dry. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction. A separation layer consisting of a non-woven geotextile should be placed between the subgrade soils and the



bedding material. The geotextile should meet the specifications for the OPSS Class II, and have a fabric opening size (FOS) not greater than 212 μm .

The underside of the bedding layer should be placed at or below Elevation 203.0 m, which corresponds to very soft to firm silty clay and very loose to loose silty sand subgrade. Any buried topsoil, excessively loose soil, large cobbles and boulders, and any soft, very loose organic or other deleterious material encountered during subgrade preparation should be sub-excavated and replaced with compacted granular material to provide a uniformly competent subgrade condition.

9.2 Frost Cover

The depth of frost penetration at this site is approximately 2.2 m based on OPSD 3090.100. The frost cover requirement does not apply to the pipe culverts

As moderately frost susceptible soils were encountered within the existing embankment, and it is anticipated that backfill of the new culvert will be completed using granular material, it is recommended that frost tapers be constructed in accordance with OPSD 803.031. Provided existing granular fill, Granular B Type II (or Type III), or Granular A material shall be used to backfill the excavation, the “d” value should be 1.4 m, and a “k” value should equal to the frost depth of 2.2 m. Frost tapers should be constructed at a minimum slope of 10H:1V.

9.3 Subgrade Preparation

Performance of the replacement culvert will depend on the preparation of the subgrade. After the excavation reaches the design subgrade elevation, the exposed surface should be inspected to confirm that the subgrade is suitable and uniformly competent. Any remaining fill, buried topsoil, organic creek bed deposits, disturbed soils and any deleterious materials within the replacement culvert footprint must be removed and replaced with granular material compacted as per OPSS.PROV 501. If encountered along the culvert alignment, the buried topsoil noted below the embankment fill in Borehole 17-35 must be removed to expose the underlying silty clay at or below Elevation 203.4 m.

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



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

9.4 Settlement

Of the proposed twin culvert replacements, one culvert will be constructed along, and one will be constructed approximately 5 m east of the existing culvert alignment with a larger opening size than the existing culvert with no grade raise on the overlying embankment or embankment widening. Therefore, changes in the loading conditions on the foundation soils consisting of very soft to firm silty clay and very loose to loose silty sand are not expected to be significant. The post-construction settlements after culvert construction and embankment reconstruction at this site are estimated to be less than 25 mm. The post-construction settlements will essentially be complete at the end of construction.

If the final design involves embankment widening or grade raise, foundation soil settlement in the soft foundation clay due to this addition of fill must be assessed to determine the impact of such settlement on the performance of the replacement culvert.

10. EXCAVATION AND GROUNDWATER CONTROL

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill at this site is classified as a Type 3 soil above the water table and Type 4 soils below the water table, and the native buried topsoil, silty clay and silty sand is classified as a Type 4 soil. Surficial alluvial deposits that are anticipated in the inlet and outlet areas should be classified as Type 4 soils.

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

Excavations for culvert replacement will be carried out through the existing embankment fill, and extend into the buried topsoil, native silty sand and silty clay.

Installation of the culvert must be carried out in the dry. Excavation for the culvert replacement will be carried out below the creek water level, and diversion of the creek flow will be required. Although the permeability of the native silty clay is expected to be relatively low, due to the high-water table, water inflow/seepage into the excavation should be anticipated from the embankment fill and the silty sand soils.



A combination of cofferdam enclosures and creek diversion along with pumping from filtered sumps within an enclosure will be required to maintain dry excavations and subgrade during the course of staged construction. Recommendations for cofferdam design are provided in Sections 13 and 14 below. The dewatering scheme must be effective to lower the groundwater level at least 0.5 m below the final subgrade level.

The design of dewatering systems is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility and to design the system in accordance with SP FOUN0003 which amends OPSS 902.

In accordance with SP FOUN0003, the dewatering system is to be designed in accordance with OPSS.PROV 517 and SP517F01. A preconstruction survey is not required, thus Designer Fill-In ***** in SP FOUN0003 should be “No”. Considering the conditions on site, a design Engineer and design-checking Engineer with a minimum of 5 years of experience in designing dewatering systems of similar nature and scope to the required work is required, and thus Designer Fill-In ***** in SP517F01 should be “Yes”.

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 E.

11. CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the culverts should consist of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS PROV 1010. Reference should be made to the backfill arrangements stipulated in OPSD 802.010 or 802.014, as appropriate. Backfilling should be in accordance with OPSS PROV 401 for SPCSP Culverts. All fills should be placed in regular lifts and be compacted in accordance with OPSS PROV 501. The backfill should be placed and compacted in simultaneous lifts on both sides of the culvert, and the top of backfill elevation should not differ more than 500 mm on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and on the roof of the culvert. Compaction equipment to be used adjacent to the culvert should be restricted in accordance with OPSS PROV 501.

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

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



where

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

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

Table 12.1 – Lateral Earth Pressure Coefficients (K)

Loading Condition	OPSS Granular A or Granular B Type II $\phi = 35^\circ$; $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I (modified) or Type III $\phi = 32^\circ$; $\gamma = 21.2 \text{ kN/m}^3$	
	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 creek level.

For rigid structures at-rest horizontal earth pressures should be used for design. Active earth pressures should be used for any unrestrained wall.

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

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

12. SEISMIC CONSIDERATIONS

In accordance with the CHBDC 2014, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy. Based on the stratigraphy, this site corresponds to a Seismic Site Class E 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 0.033 g for a reference Site Class C as per the National Building Code of Canada (NBCC), and a Site Class E would be amplified to 0.060 g.

In accordance with Clause 4.6.5 of the CHBDC 2014, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 13.1 may be used:

Table 13.1 – Earth Pressure Coefficients for Earthquake Loading

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

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

** After Woods

Although the site is underlain by soft to firm silty clay, in view of the low potential for seismic activity in the area, liquefaction is not considered to be a concern at this site.

13. COFFERDAMS

Construction of cofferdams will be required to construct the culvert replacement in the dry. It is recommended that the temporary culvert excavations be carried out within a water tight enclosure. Both sand bag cofferdams systems and interlocking sheet piles with pumping from sumps are considered to be feasible for cofferdam construction at this site. However, due the high water table at the site, the sand bag cofferdam may not be as effective as interlocking sheet piles. The recommendations provided in Section 14 below for Temporary Protection Systems are also applicable to sheet piled cofferdams. The cofferdams should extend deep enough to penetrate a sufficient distance in the silty clay layer.

Further assessment of dewatering requirements and the need for a PTTW should be carried out by specialists experienced in this field, Design of a suitable and effective dewatering system is the responsibility of the Contractor as indicated in Section 10.



14. TEMPORARY PROTECTION SYSTEM

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

Options for roadway protection are a soldier pile-lagging system or interlocking sheet piles.

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

Table 14.1 –Soil Parameters for Temporary Protection System Design

Soil Parameter	Existing Fill	Native Silty Clay	Native Silty Sand to Sandy Silt
Φ (angle of internal friction)	32°	25°	28°
γ (total unit weight)	20 kN/m ³	19 kN/m ³	20 kN/m ³
γ_w (submerged unit weight)	10 kN/m ³	9 kN/m ³	10 kN/m ³
K_a	0.31	0.41	0.36
K_p	3.3	2.5	2.8

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

The temporary protection system may be removed or partially removed upon completion of the work. Care must be taken when removing the sheet piles or soldier piles as to not incur damage to the subgrade of the newly installed culvert.

Based on the General Arrangement drawings the depth of the temporary excavation may exceed 6 m depth. Due to the depth of the excavation and the very soft to firm silty clay on site, the need for bracing to limit lateral deflection of the sheet piles should be assessed. If bracing is required, it should be placed at a location so that it does not interfere with the twin pipe culvert installation.

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.

15. TEMPORARY MODULAR BRIDGE

A temporary modular bridge was also considered at this site for traffic staging purposes during replacement of the culvert. Boreholes 18-01 and 18-02 were drilled near the potential abutments of a temporary modular bridge. A temporary modular bridge may be supported on precast concrete bearing pads founded on engineered granular fill pads within the embankment fill of the Highway. However, the presence of thick soft to firm foundation clay requires a relatively flat temporary excavation slope in front of the temporary modular bridge and a significant offset distance of the footings from the crest of the temporary excavation slope to achieve a Factor of safety (FS) of 1.3. This would have resulted in a relatively long bridge that is not cost effective or practical. As such, further comments on temporary modular bridge foundations and construction have not been provided in this report.

A typical slope stability analysis of the temporary slopes in front of the footings is included in Appendix F on Figure F1 for a 48 m long temporary modular bridge, with temporary excavation slopes ranging from 2H:1V to 3H:1V. The FS for this condition is 1.2 and does not meet the minimum required FS of 1.3.

16. EMBANKMENT RESTORATION

Provided that the embankment is reconstructed with side slopes inclined not steeper than 2H:1V, the restored embankment slope should remain stable. As discussed in Section 9.3, and if there is no grade raise or embankment widening, settlement of the embankment under the existing culvert footprint should be less than 25 mm. A grade raise or embankment widening should be avoided as they will cause settlement of the soft foundation clay.

Embankment restoration after completion of the culvert replacement should be carried out in accordance with OPSS PROV 206 and OPSS PROV 209. The embankment reconstruction material may consist of imported Granular A, Granular B Type II, or Granular B Type III material.

In general, surface vegetation, peat, 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 should be conducted.

17. SCOUR AND EROSION PROTECTION

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

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

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

18. CORROSION AND SULPHATE ATTACK POTENTIAL

The results of the corrosivity and sulphate content analytical tests conducted on the native soil sample and creek water sample indicate the following conditions at the locations tested:

- The potential for corrosion or sulphate attack on concrete foundations from the surrounding native soil is considered to be negligible due to the low concentration of sulphate and chloride in the sample tested. The sulphate level in the water indicates a moderate risk of sulphate attack on concrete. The effect of road deicing salt should be considered while selecting the class of concrete.
- The potential for soil corrosion on metal is considered to be mild. However, the low resistivity measured in the water sample indicates that there is a high risk of corrosion to steel, cast iron and other metal culverts.
- Appropriate protection measures are recommended for metal or concrete structural elements. The effect of road deicing salt should be considered while selecting the corrosion protection measures.



19. CONSTRUCTION CONCERNS

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

- A thick layer of buried topsoil was noted in Borehole 17-35 at Elevation 205.9. This layer and any other organic layer if encountered must be removed from the culvert subgrade.
- A suitable 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 creek may fluctuate and be at a higher elevation at the time of construction than indicated in the report.
- Cobbles or other buried obstructions may be encountered during excavation in the existing embankment fill and may interfere with the installation of the temporary roadway protection system. Suggested wording for an NSSP on obstructions is included in Appendix E.
- The foundation soils at this site consist of a thick deposit of soft to firm clay. The Contractor's selection of construction equipment and methodology should include assessment of the capability of the existing embankment and foundation soils to support the proposed construction equipment and any temporary structures or fill (i.e., as a pad for crane support). Site conditions may limit the type of equipment suitable for use during construction. The design and safety of any temporary works is the responsibility of the Contractor. An NSSP to this effect is included in Appendix E.
- A grade raise or embankment widening should be avoided if possible as they will cause settlement of the soft foundation clay.

20. CLOSURE

Engineering analysis and preparation of this report was carried out by Mr. Cory Zanatta, P. Eng. and Mr. Mark Farrant, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



Thurber Engineering Ltd.

Cory Zanatta, P. Eng.
Geotechnical Engineer



Mark Farrant, P.Eng.
Geotechnical Engineer



P.K. Chatterji, P.Eng., Ph.D.
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
 Shear Strength Determination by Pocket Penetrometer

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

UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS W _L < 50%	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. (W _L < 30%).
		CI	Inorganic clays of medium plasticity, silty clays. (30% < W _L < 50%).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS W _L > 50%	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

RECORD OF BOREHOLE No 18-01

1 OF 3

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 980.2 E 302 097.2 ORIGINATED BY BRM
DIST TB HWY 17 BOREHOLE TYPE NW Casing COMPILED BY MP
DATUM Geodetic DATE 2018.06.25 - 2018.06.26 LATITUDE 48.84617297 LONGITUDE -87.03682814 CHECKED BY CZ

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					
208.9	GROUND SURFACE												
0.0	ASPHALT: (175mm)												
0.2	Gravelly SAND Very Dense Brown Moist (FILL)		1	SS	100								
207.9			2	SS	86								
1.0	Silty SAND , trace gravel, trace clay Very Dense to Dense Brown Moist (FILL)												
			3	SS	46								
206.7													
2.2	Sandy SILT , trace clay, trace gravel Compact to Very Loose Grey Wet		4	SS	11								
			5	SS	8								
			6	SS	1								
202.8													
6.1	CLAY , some silt, trace sand Very Soft Grey Wet (CH)		7	SS	0								
			8	T									
	</												

Continued Next Page

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

RECORD OF BOREHOLE No 18-01

2 OF 3

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 980.2 E 302 097.2 ORIGINATED BY BRM
 DIST TB HWY 17 BOREHOLE TYPE NW Casing COMPILED BY MP
 DATUM Geodetic DATE 2018.06.25 - 2018.06.26 LATITUDE 48.84617297 LONGITUDE -87.03682814 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL LIMIT MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m 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								
	Continued From Previous Page							20 40 60 80 100								
	CLAY , trace silt Very Soft Grey Wet		9	SS	0		198						○			
							197									
							196									
195.2																
13.7	SILT , some sand, trace clay Very Loose to Loose Grey Wet		10	SS	3		195						○		0 10 83 7	
							194									
			11	SS	6		193						○			
192.6																
16.3	SAND and SILT , trace clay Loose Grey Wet		12	SS	9		192						○		0 37 56 7	
							191									
190.6													○			
18.3	Silty CLAY , trace sand, trace gravel, trace cobbles and boulders Hard Dark Grey Moist (TILL)		13	SS	50/ 0.075		190									
			14	SS	50/		189						○			

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-01

3 OF 3

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 980.2 E 302 097.2 ORIGINATED BY BRM
 DIST TB HWY 17 BOREHOLE TYPE NW Casing COMPILED BY MP
 DATUM Geodetic DATE 2018.06.25 - 2018.06.26 LATITUDE 48.84617297 LONGITUDE -87.03682814 CHECKED BY CZ




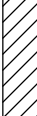
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100	20 40 60					
188.8	Continued From Previous Page													
20.1	END OF BOREHOLE AT 20.1m. WATER LEVEL AT 3.1m UPON COMPLETION. Well installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.5m slotted screen.													

RECORD OF BOREHOLE No 18-02

1 OF 3

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 935.1 E 302 079.9 ORIGINATED BY BRM
DIST TB HWY 17 BOREHOLE TYPE NW Casing COMPILED BY MP
DATUM Geodetic DATE 2018.06.25 - 2018.06.25 LATITUDE 48.84576731 LONGITUDE -87.03706357 CHECKED BY CZ

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
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE								
209.0	GROUND SURFACE																		
0.0	ASPHALT: (100mm)																		
0.1	SAND, some silt, trace clay Very Dense Brown Moist (FILL)		1	SS	50/ 0.150														
			2	SS	94														
207.5																			
1.5	Silty SAND Compact Brown Moist (FILL)		3	SS	28														
			4	SS	32														
206.0																			
3.0	CLAY, some silt, trace sand Very Stiff Grey Wet (CH)		5	SS	20														
				6	SS	0													
				7	T														
	Very Soft to Soft																		
			8	SS	2														
			9	SS	2														

Continued Next Page

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

RECORD OF BOREHOLE No 18-02

2 OF 3

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 935.1 E 302 079.9 ORIGINATED BY BRM
DIST TB HWY 17 BOREHOLE TYPE NW Casing COMPILED BY MP
DATUM Geodetic DATE 2018.06.25 - 2018.06.25 LATITUDE 48.84576731 LONGITUDE -87.03706357 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		<div><div>PLASTIC LIMIT</div><div>NATURAL MOISTURE CONTENT</div><div>LIQUID LIMIT</div></div> <div><div>W_P</div><div>W</div><div>W_L</div></div> <div>WATER CONTENT (%)</div>	UNIT WEIGHT <div>γ</div> kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				
	Continued From Previous Page							<div>○ UNCONFINED</div> <div>● QUICK TRIAXIAL</div>	<div>+ FIELD VANE</div> <div>× LAB VANE</div>			
								20 40 60 80 100		20 40 60		GR SA SI CL
197.4	CLAY, some silt Very Soft to Soft Grey Wet							23				
11.6	Silty CLAY, trace sand Very Soft Grey Moist		10	SS	0					11		0 1 58 41
195.3			11	G								
13.7	Silty SAND, trace clay Loose to Compact Grey Wet											
			12	SS	13							
			13	SS	20							0 22 71 7
190.4												
18.6	Clayey SILT, trace sand, trace gravel Hard Grey Wet (TILL)		14	SS	26							
189.8												
19.2	BOULDER											
189.2												
189.4	Silty CLAY, trace sand, trace gravel		15	SS	50/							

Continued Next Page

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

RECORD OF BOREHOLE No 18-02

3 OF 3

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 935.1 E 302 079.9 ORIGINATED BY BRM
DIST TB HWY 17 BOREHOLE TYPE NW Casing COMPILED BY MP
DATUM Geodetic DATE 2018.06.25 - 2018.06.25 LATITUDE 48.84576731 LONGITUDE -87.03706357 CHECKED BY CZ

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																		
19.9	<p>Continued From Previous Page</p> <p>Hard Grey Moist (TILL)</p> <p>END OF BOREHOLE AT 19.9m. Well installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.5m slotted screen.</p> <p>WATER LEVEL READINGS</p> <table border="1"> <thead> <tr> <th>DATE</th> <th>DEPTH(m)</th> <th>ELEV.(m)</th> </tr> </thead> <tbody> <tr> <td>2018.06.25</td> <td>0.7</td> <td>208.3</td> </tr> <tr> <td>2018.06.25</td> <td>0.8</td> <td>208.2</td> </tr> </tbody> </table>	DATE	DEPTH(m)	ELEV.(m)	2018.06.25	0.7	208.3	2018.06.25	0.8	208.2				0.100												
DATE	DEPTH(m)	ELEV.(m)																								
2018.06.25	0.7	208.3																								
2018.06.25	0.8	208.2																								

RECORD OF BOREHOLE No 18-03

1 OF 2

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 944.8 E 302 104.1 ORIGINATED BY JM
DIST TB HWY 17 BOREHOLE TYPE BW Casing COMPILED BY MP
DATUM Geodetic DATE 2018.07.15 - 2018.07.16 LATITUDE 48.84585465 LONGITUDE -87.03673389 CHECKED BY CZ

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 (%)										
								○ UNCONFINED			+ FIELD VANE			w P					w			w L		
								● QUICK TRIAXIAL			× LAB VANE													
205.8	GROUND SURFACE							20	40	60	80	100												
0.0	TOPSOIL: (125mm)							20	40	60	80	100												
0.1	Silty SAND , trace gravel, trace organics Very Loose to Loose Brown Moist		1	SS	4																			
			2	SS	2																			
			3	SS	5																			
203.4																								
2.4	Silty CLAY Soft Grey Moist		4	SS	6																			
			5	SS	2																			
			6	SS	4																			
			7	SS	0																			
196.7																								
9.1	Silty SAND , trace gravel Very Loose Grey Moist		9	GS	0																			

Continued Next Page

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

RECORD OF BOREHOLE No 18-03

2 OF 2

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 944.8 E 302 104.1 ORIGINATED BY JM
DIST TB HWY 17 BOREHOLE TYPE BW Casing COMPILED BY MP
DATUM Geodetic DATE 2018.07.15 - 2018.07.16 LATITUDE 48.84585465 LONGITUDE -87.03673389 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)	
								○ UNCONFINED	+	FIELD VANE	● QUICK TRIAXIAL						×	LAB VANE
	Continued From Previous Page						20	40	60	80	100	20	40	60				
195.1																		
10.7	SAND and GRAVEL to Sandy GRAVEL , trace silt Loose to Compact Grey Moist to Wet		10	SS	9													
193.0			11	SS	14													
12.8	END OF CASING ADVANCE AT 12.8m. BEGINNING OF DCPT.																	
190.0																		
15.8	END OF DCPT AT 15.8m. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.5m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2018.07.16 0.6 205.2																	

RECORD OF BOREHOLE No 18-04

1 OF 1

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 971.7 E 302 076.7 ORIGINATED BY JM
DIST TB HWY 17 BOREHOLE TYPE Pionjar, 50lb Hammer COMPILED BY MP
DATUM Geodetic DATE 2018.07.15 - 2018.07.15 LATITUDE 48.84609644 LONGITUDE -87.03710742 CHECKED BY CZ

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 (%)		
								20	40	60	80	100						20	40	60
205.7	GROUND SURFACE					▽	205										GR SA SI CL			
0.0	TOPSOIL: (200mm)																			
0.2	Silty CLAY , with organics, some sand Soft to Firm Grey Wet		1	SS	3															
			2	SS	2															
			3	SS	5															
202.0	organic sand seam from 2.6m to 3.2m		4	SS	5															
			5	SS	2															
3.7	END OF BOREHOLE AT 3.7m. WATER LEVEL AT 1.4m UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO SURFACE.																			

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-05

1 OF 1

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 954.5 E 302 104.7 ORIGINATED BY JM
DIST TB HWY 17 BOREHOLE TYPE Pionjar, 50lb Hammer COMPILED BY MP
DATUM Geodetic DATE 2018.07.15 - 2018.07.15 LATITUDE 48.84594188 LONGITUDE -87.03672578 CHECKED BY CZ

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						
206.3	GROUND SURFACE							20	40	60	80	100		
0.0	TOPSOIL: (50mm)													
	Silty CLAY , with organics, some sand		1	SS	2		206							
	Soft													
	Grey													
	Moist		2	SS	4		205							
204.4														
			3	SS	13									
1.9	Silty CLAY , trace sand													
	Stiff													
	Grey													
	Moist		4	SS	11		204							
203.4														
2.9	END OF BOREHOLE AT 3.0m. WATER LEVEL AT GROUND SURFACE UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO SURFACE.													



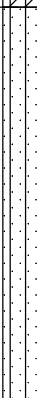

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-34

1 OF 2

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 964.3 E 302 071.6 ORIGINATED BY TY
 HWY 17 BOREHOLE TYPE BW Casing COMPILED BY MP
 DATUM Geodetic DATE 2017.09.17 - 2017.09.17 CHECKED BY NLB

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 (%) GR SA SI CL			
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							
205.4	GROUND SURFACE							20	40	60	80	100								
0.0	TOPSOIL , silt, some sand, roots Loose Dark Brown Moist		1	SS	6		205													
204.8																				
0.6	Silty CLAY , some sand, rootlets Soft Brown Moist		2	SS	3		204													
203.9																				
1.5	Silty SAND , some clay, occasional wood fragments Loose to Very Loose Brown Moist		3	SS	5		203													
			4	SS	6		202													
			5	SS	3		201													
201.3																				
4.1	Silty CLAY , trace to some sand Firm to Very Soft Grey Moist to Wet (CI)		6	SS	5		200													

Continued Next Page

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

RECORD OF BOREHOLE No 17-34

2 OF 2

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 964.3 E 302 071.6 ORIGINATED BY TY
 HWY 17 BOREHOLE TYPE BW Casing COMPILED BY MP
 DATUM Geodetic DATE 2017.09.17 - 2017.09.17 CHECKED BY NLB

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							WATER CONTENT (%) W _P W W _L		
	Continued From Previous Page							20	40	60	80	100	20	40	60		
192.9	Silty CLAY , trace to some sand Soft Grey Wet (CI)		8	SS	3		195										
							194										
							193										
12.5	Silty SAND , trace gravel Compact to Very Loose Grey Moist		9	SS	18		192										
							191										
190.6																	
14.8	SAND , some gravel, some silt Very Dense Grey																
190.1	Wet																
15.3	END OF BOREHOLE AT 15.3m. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS, THEN GRAVEL TO SURFACE.		11	SS	100/ 0.025												

1 75 24
(SI+CL)

RECORD OF BOREHOLE No 17-35

1 OF 3

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 958.4 E 302 086.0 ORIGINATED BY TY
HWY 17 BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
DATUM Geodetic DATE 2017.08.20 - 2017.08.20 CHECKED BY NLB

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																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
209.0	GROUND SURFACE							20	40	60	80	100																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							</

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-35

2 OF 3

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 958.4 E 302 086.0 ORIGINATED BY TY
 HWY 17 BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2017.08.20 - 2017.08.20 CHECKED BY NLB

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																
	Silty CLAY , trace sand Very Soft Grey Wet (CL)																
198																	
197																	
			10	SS	0											0 0 70 30	
196																	
195.0																	
14.0	Silty SAND , trace to some clay, trace gravel Loose Grey Wet																
195																	
194																	
			11	SS	8												
193																	
192																	
17.1	SAND , some gravel, some silt Compact Grey Wet																
191																	
			12	SS	22												
190.1																	
18.9	END OF BOREHOLE AT 18.9m. BOREHOLE OPEN TO 6.0m AND WATER LEVEL AT 3.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO 0.9m, DRY CEMENT TO 0.1m, THEN COLD PATCH																

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-35

3 OF 3

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 958.4 E 302 086.0 ORIGINATED BY TY
 HWY 17 BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2017.08.20 - 2017.08.20 CHECKED BY NLB

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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
	Continued From Previous Page ASPHALT TO THE SURFACE.							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	20 40 60 W _p W W _L					

ONTMT4S MTO-15595.GPJ 2017TEMPLATE(MTO).GDT 11/24/17

METRIC

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 17-36

2 OF 2

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 932.8 E 302 095.1 ORIGINATED BY TY
 HWY 17 BOREHOLE TYPE Solid Stem Augers/Dynamic Cone Penetration Test COMPILED BY MP
 DATUM Geodetic DATE 2017.08.22 - 2017.08.22 CHECKED BY NLB

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									
195.7	Continued From Previous Page																
10.2	Silty SAND Very Loose Grey Wet		7	SS	0												
193.9																	
12.0	SAND , some silt, trace gravel Loose Grey Wet		8	SS	6												
192.5																	
13.4	End of sampling and start DCPT at 13.4m																
190.1																	
15.8	END OF DCPT AT 15.8m. BOREHOLE OPEN TO 11.3m UPON COMPLETION. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.08.26 0.6 205.3																

ONTMT4S MTO-15595.GPJ 2017TEMPLATE(MTO).GDT 11/8/17

RECORD OF BOREHOLE No 17-37

1 OF 1

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 939.3 E 302 076.6 ORIGINATED BY TY
 HWY 17 BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2017.08.20 - 2017.08.20 CHECKED BY NLB

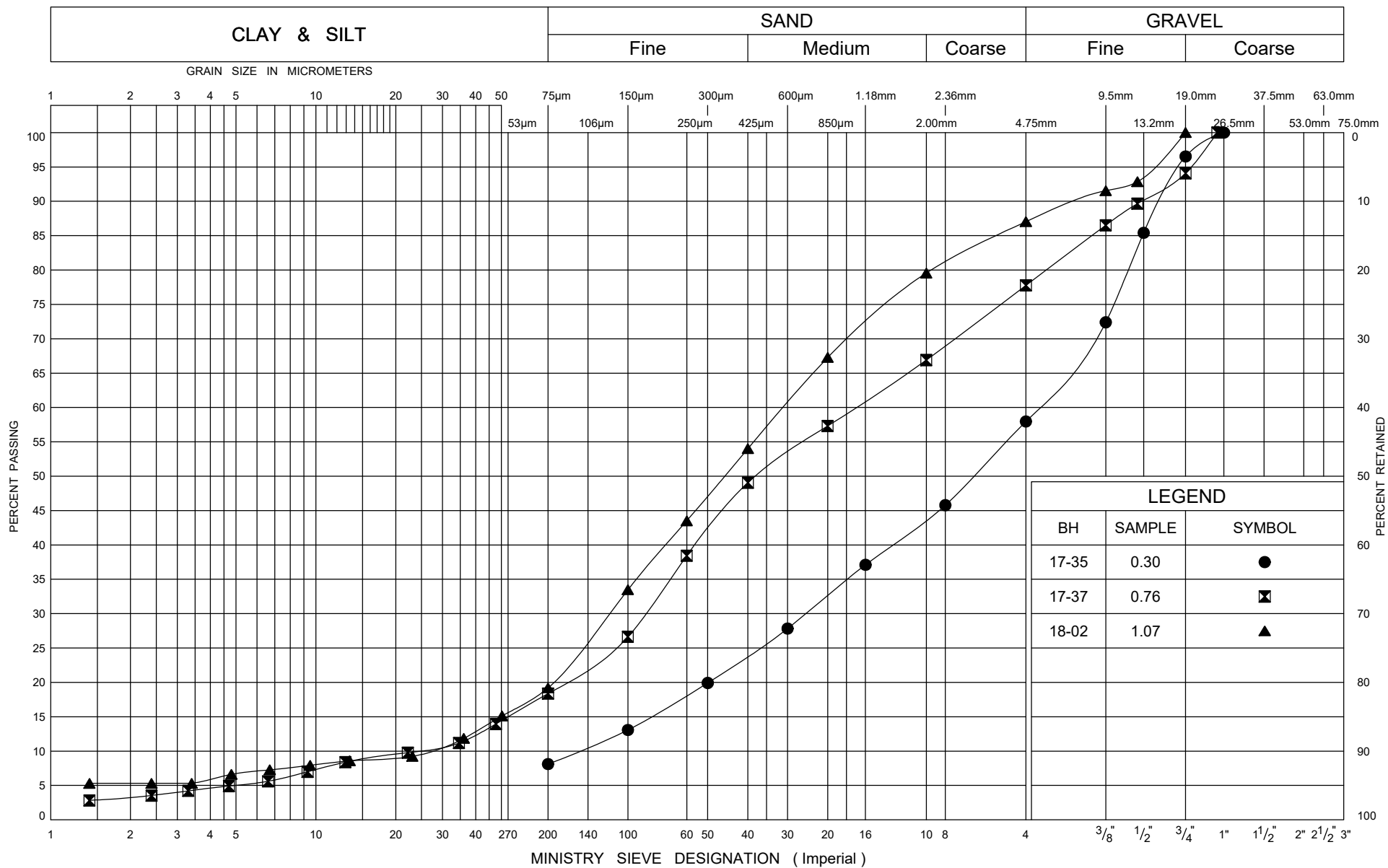
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT							UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa											
209.0	GROUND SURFACE							20	40	60	80	100							
0.0	ASPHALT: (140mm)																		
0.1	Gravelly SAND , some silt, trace clay Brown Dry (FILL)		1	GS			208											22 59 15 4	
207.5																			
1.5	SAND and SILT Compact Brown Moist (FILL)		1	SS	15		207												
206.9																			
2.1	END OF BOREHOLE AT 2.13m. HOLE FILLED WITH CUTTINGS TO 0.6m, DRY CEMENT TO 0.2m, THEN COLD-PATCH ASPHALT TO THE SURFACE.																		

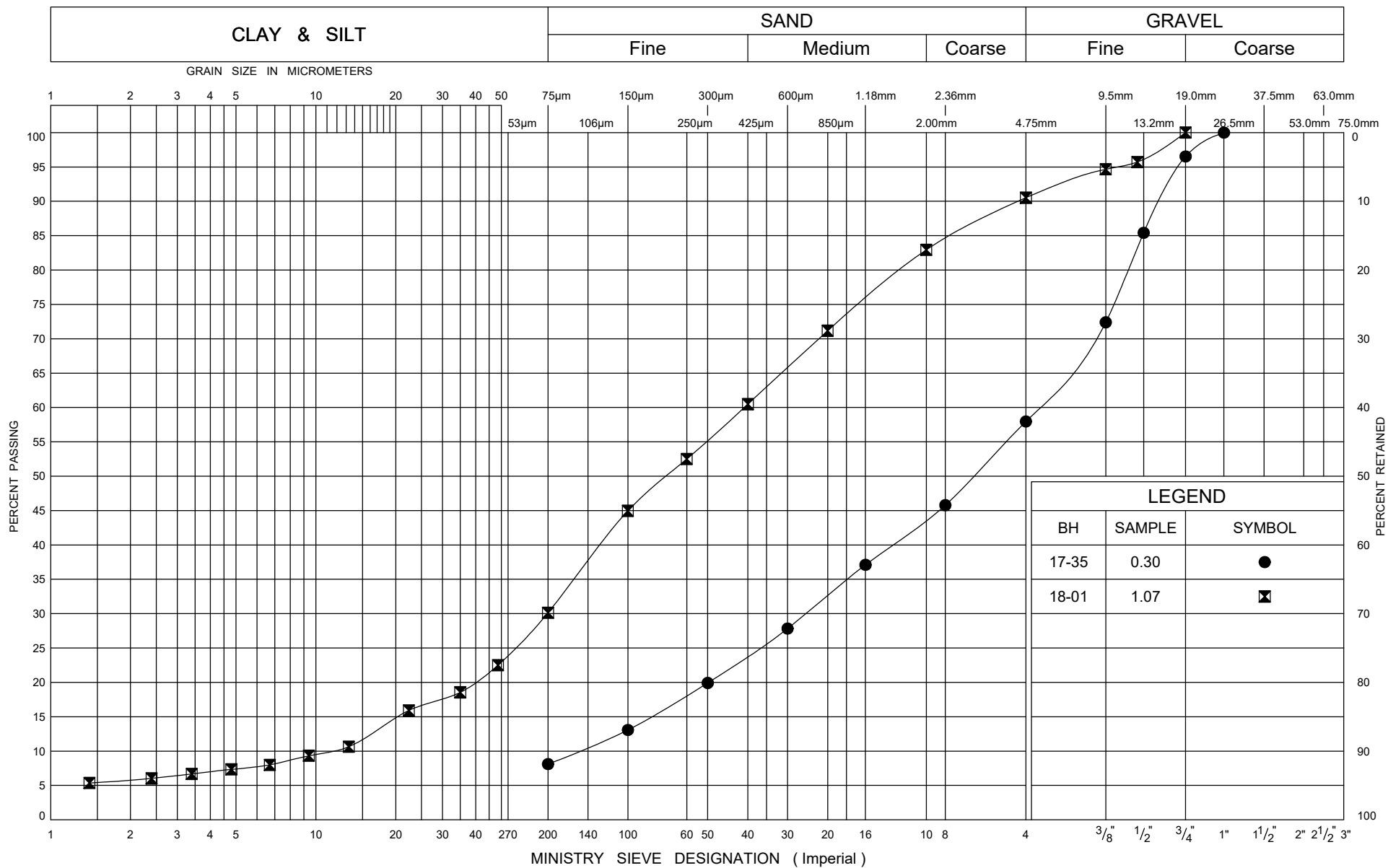
+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

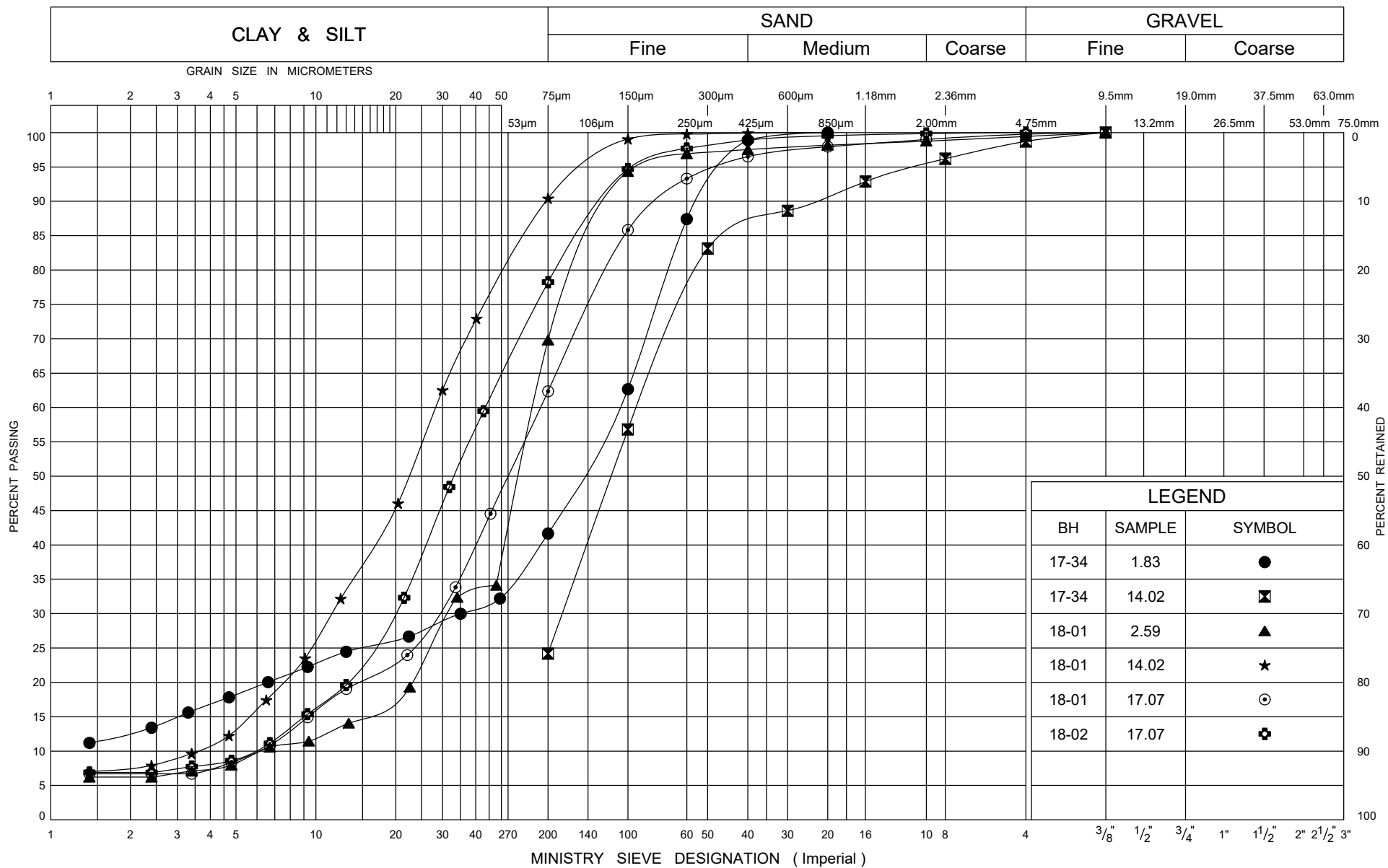


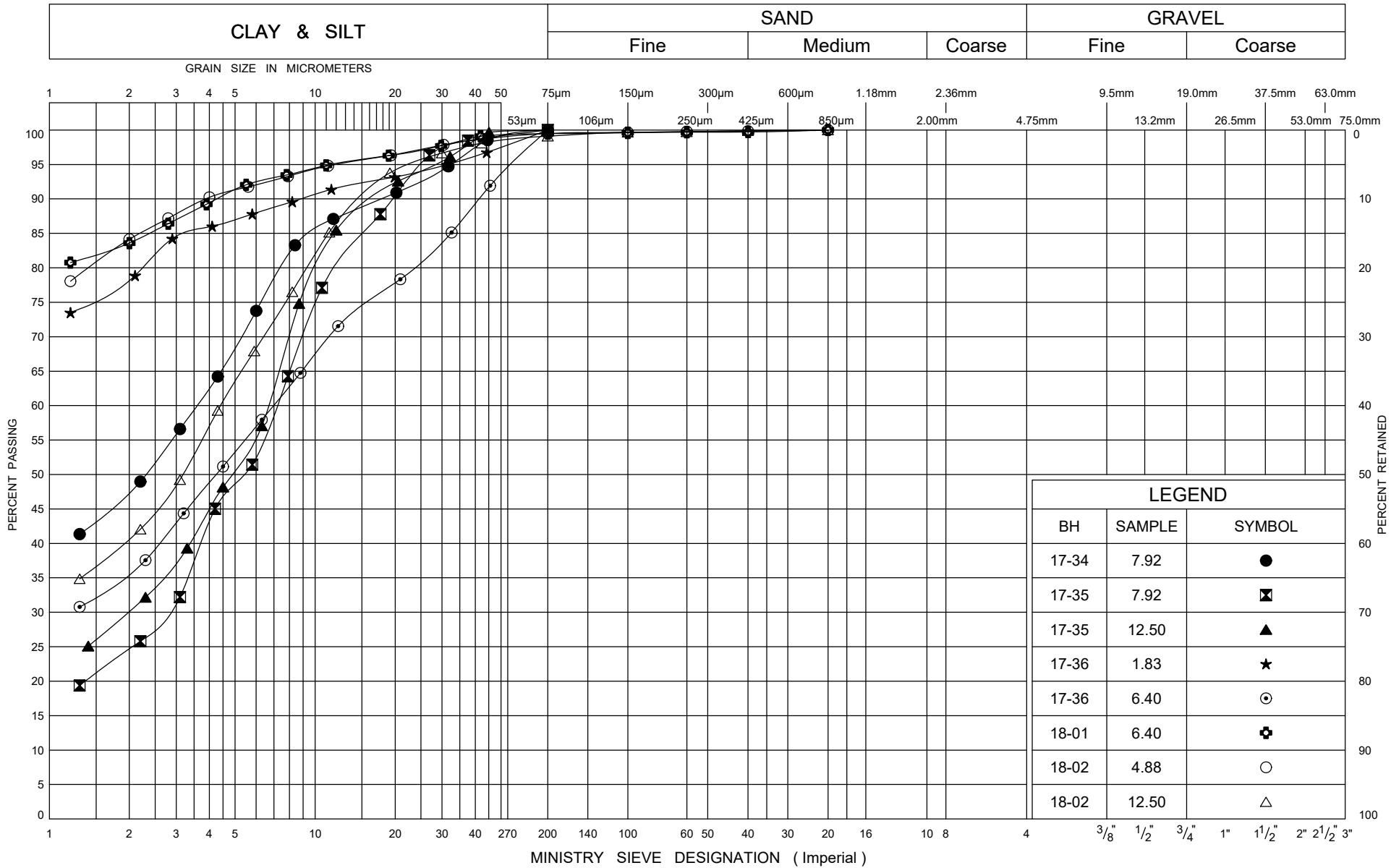
Appendix B

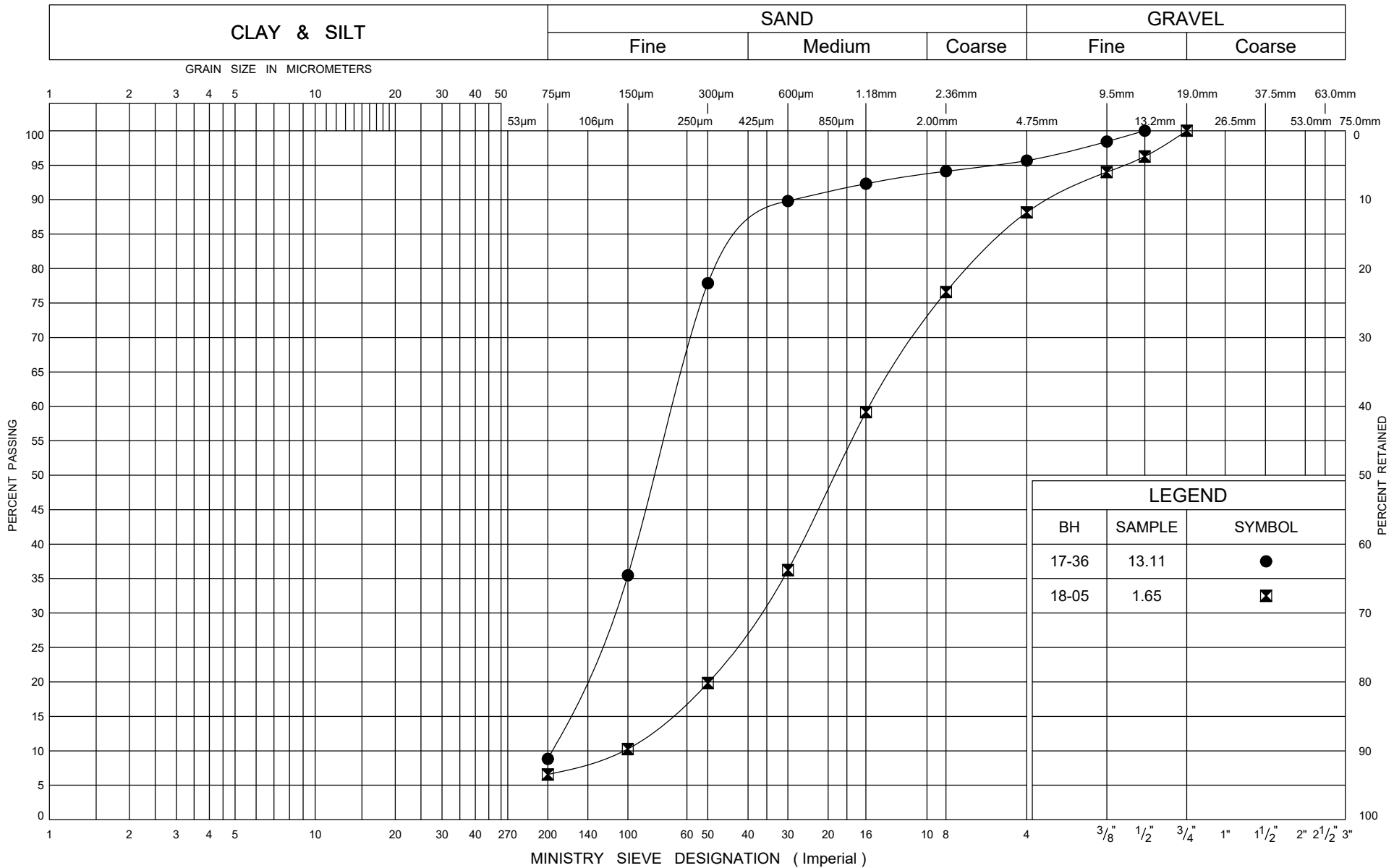
Laboratory Test Results

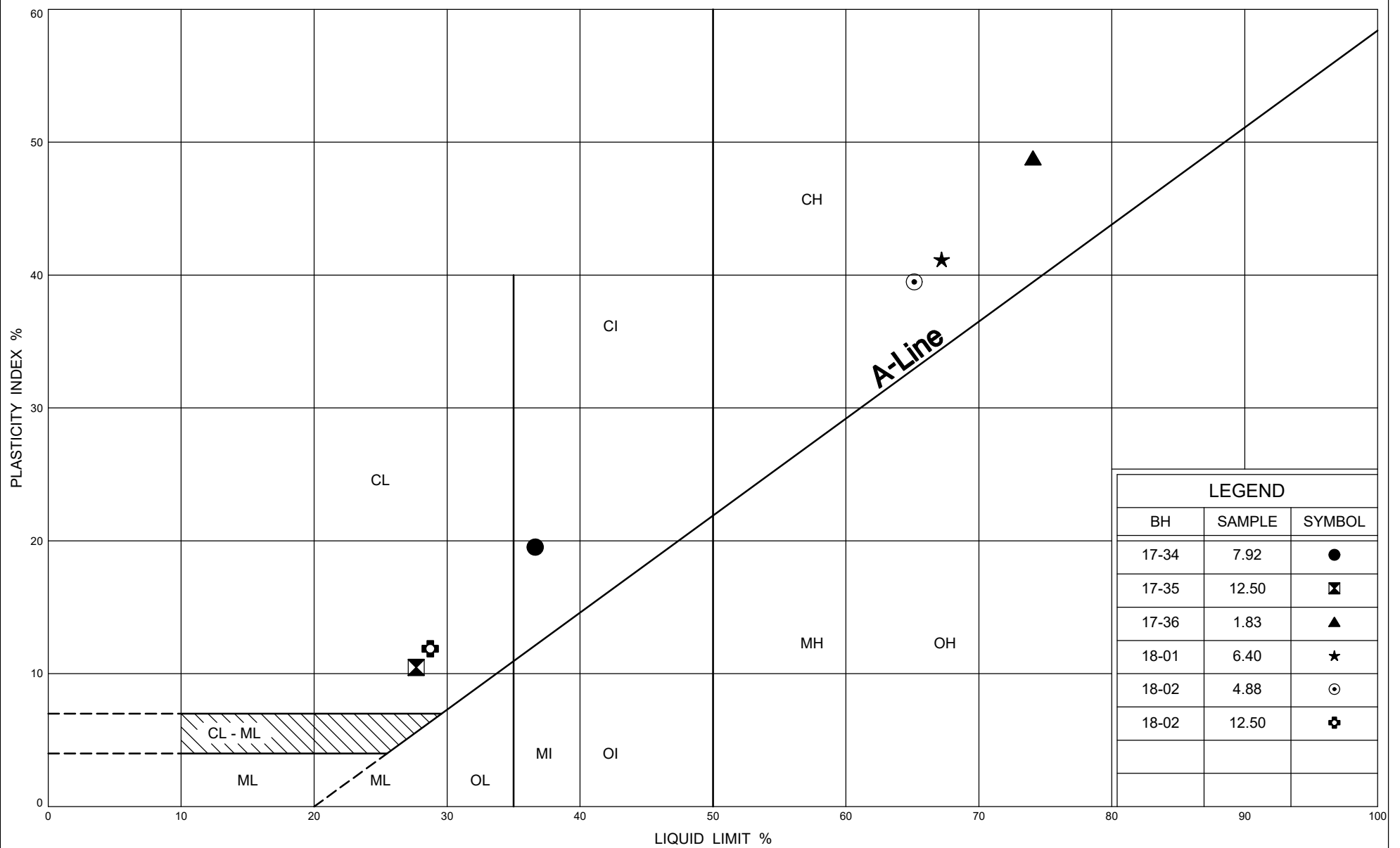












Ministry of
Transportation

PLASTICITY CHART

Silty CLAY

FIG No B6

W P 6808-14-01

BlackBird Creek Culvert

Certificate of Analysis

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



Client
SGS LIMS Number
Analysis Package:

Attention: Mark Farrant
Project#: 15595
Thurber Engineering Ltd.
CA14253-SEP17
Corrosivity (Soil)

Sample ID Unit BH-36, SS#2, 2.5'-
4.5'

Sample Date/Time 22-Aug-17

Moisture	%	27.9
pH	no unit	7.99
Corrosivity Index	none	2.0
Soil Redox Potential	mV	137
Sulphide	mg/L	<0.02
Chloride	mg/L	340.0
Sulphate	mg/L	10
Conductivity	uS/cm	397
Resistivity (calculated)	ohms.cm	2520

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.



Client
SGS LIMS Number
Analysis Package:

Attention: Cory Zanatta
Project#: 15595, North Superior Lake Region
Thurber Engineering Ltd.
CA15829-AUG17
Corrosivity (Solution)

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

Sample ID	Unit	Blackbird Creek
Sample Date/Time		21-Aug-17
Moisture	%	NA
pH	no unit	7.78
Corrosivity Index	none	NA
Redox Potential	mV	224
Sulphide	mg/L	0.076
Chloride	mg/L	110
Sulphate	mg/L	180
Conductivity	uS/cm	1180
Resistivity (calculated)	ohms.cm	847

Corrosivity Scale according to AWWA C-105.
An index greater than 10 indicates the
soil matrix may be corrosive to cast iron alloys.

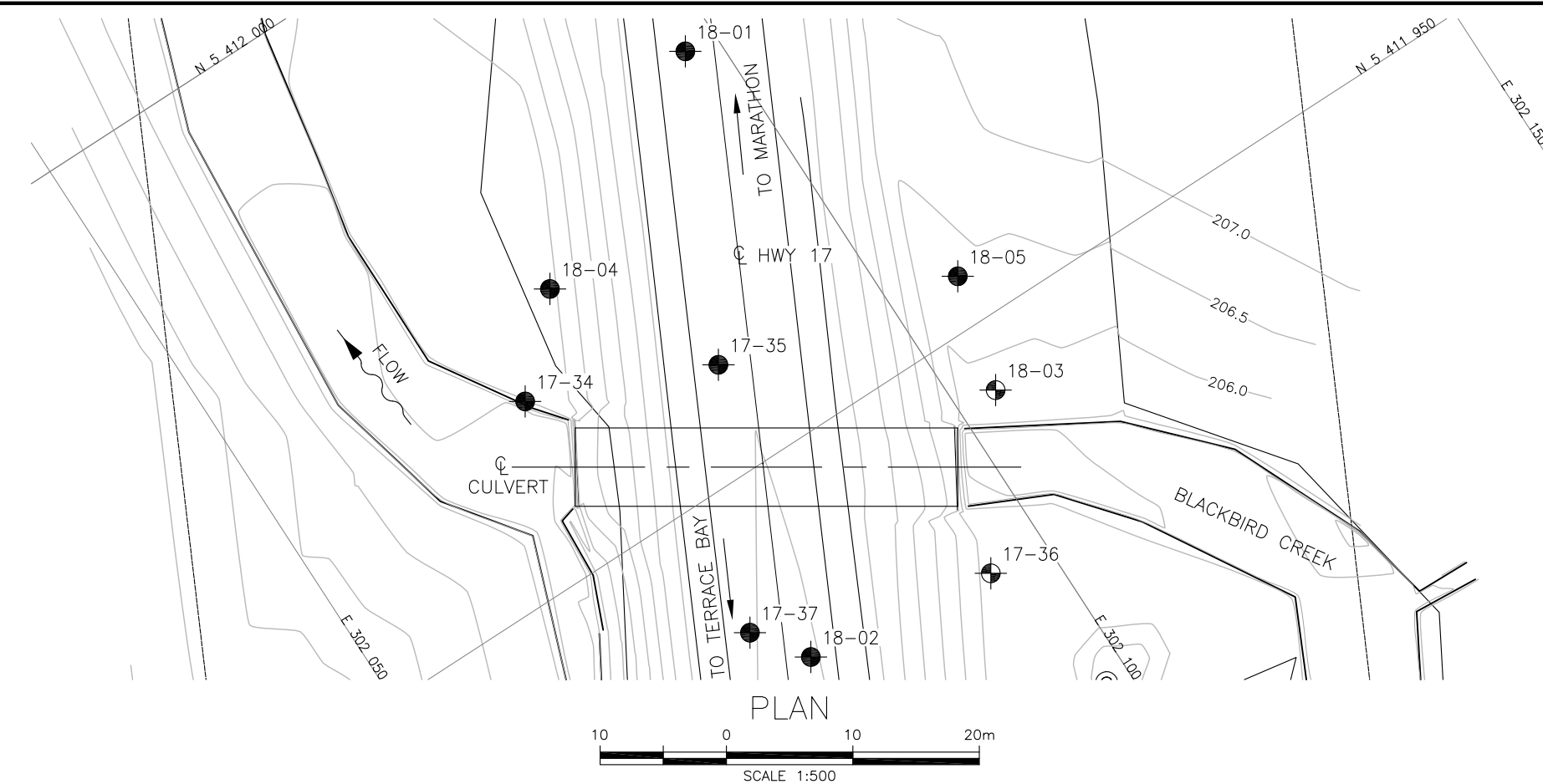
Deanna Edwards B.Sc., C.Chem
Project Specialist
Environment, Health and Safety

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

Borehole Locations and Soil Strata Drawing

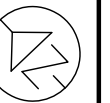


METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN



CONT No 2018-6018
WP No 6808-14-01

HIGHWAY 17
BLACKBIRD CREEK
CULVERT NO. 2
BOREHOLE LOCATIONS AND SOIL STRATA

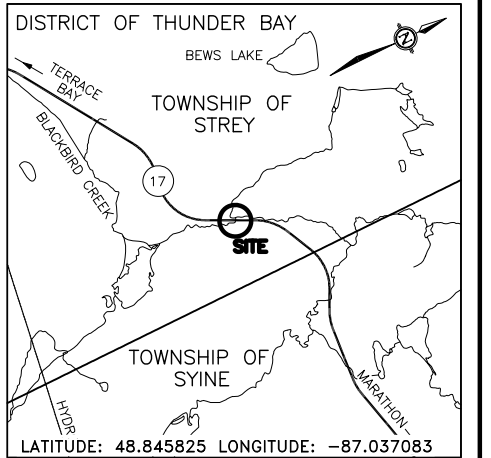


SHEET
9

HATCH



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

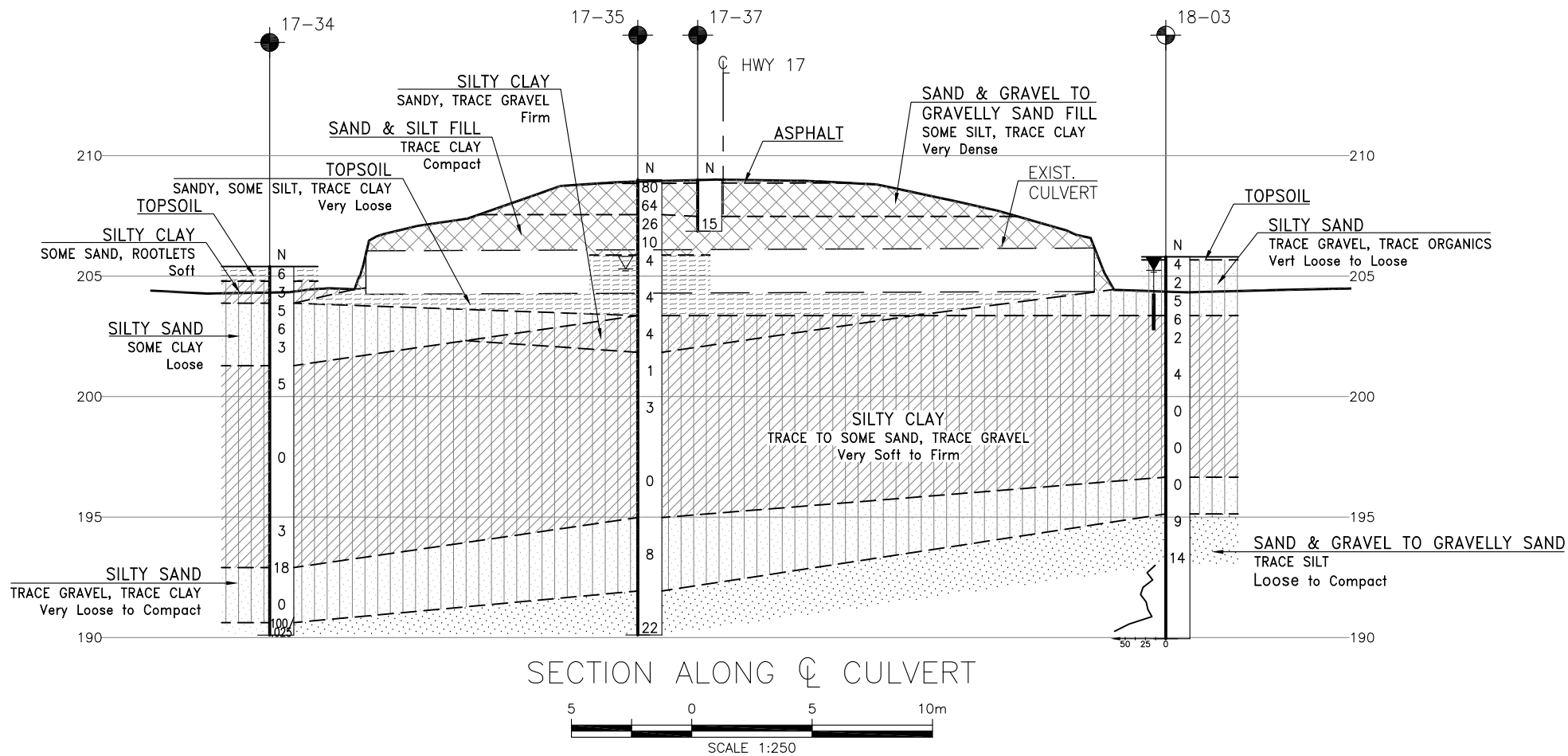
◆	Borehole
◆	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
⊕	Water Level
↑	Head Artesian Water
⊥	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
17-34	205.4	5 411 964.3	302 071.6
17-35	209.0	5 411 958.4	302 086.0
17-36	205.9	5 411 932.8	302 095.1
17-37	209.0	5 411 939.3	302 076.6
18-01	208.9	5 411 980.6	302 097.3
18-02	209.0	5 411 935.0	302 079.6
18-03	205.8	5 411 944.8	302 103.3
18-04	205.7	5 411 970.7	302 078.1
18-05	206.3	5 411 954.0	302 105.7

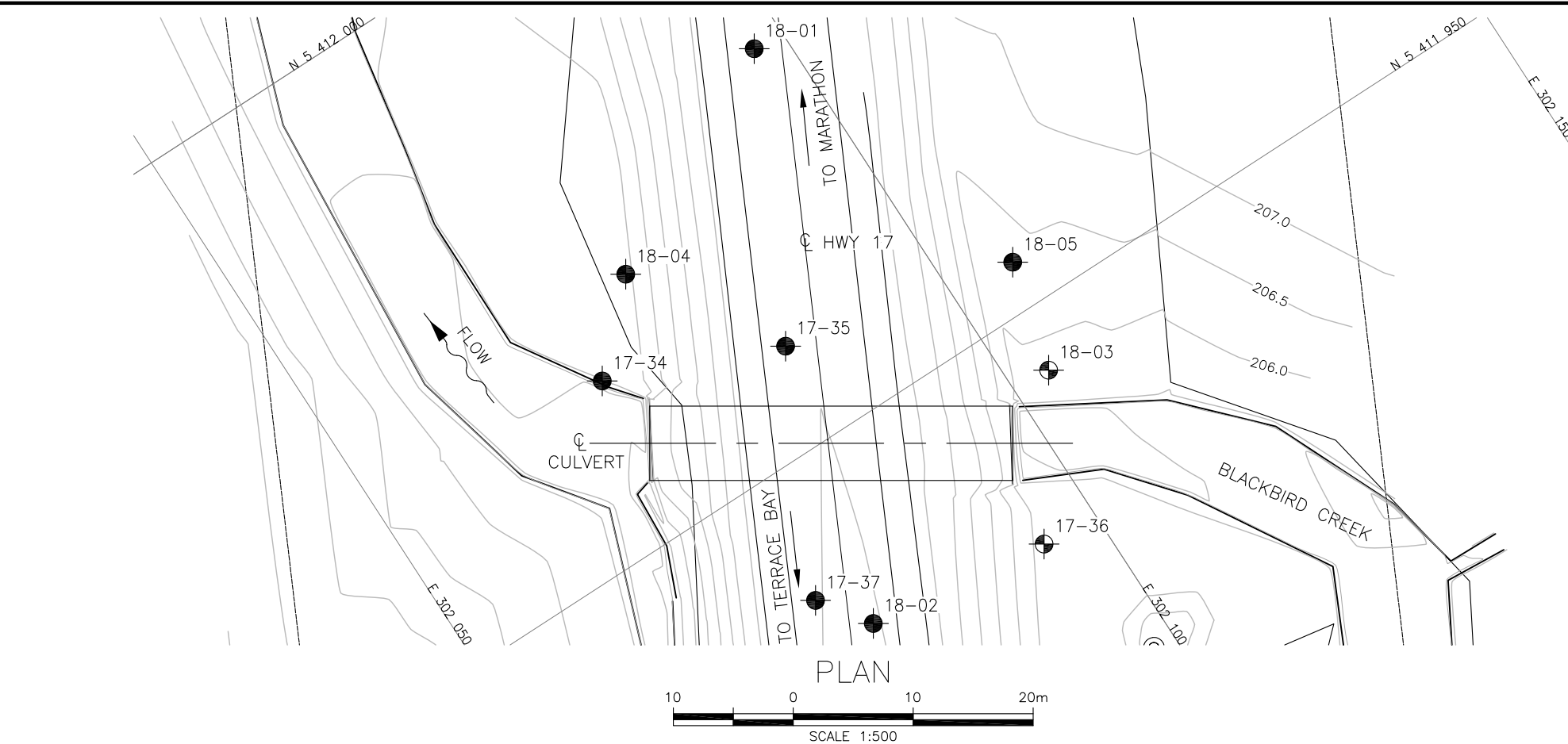
-NOTES-

- 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.
- Coordinate system is MTM NAD 83 Zone 14.

GEOCRES No. 42D-54



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	CZ	CHK MEF	CODE
DRAWN	AN	CHK CZ	SITE 48E-052/C/STRUCT
			LOAD
			DATE
			NOV 2018
			DWG 2

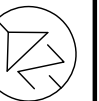


METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN



CONT No 2018-6018
WP No 6808-14-01

HIGHWAY 17
BLACKBIRD CREEK
CULVERT NO. 2
BOREHOLE LOCATIONS AND SOIL STRATA

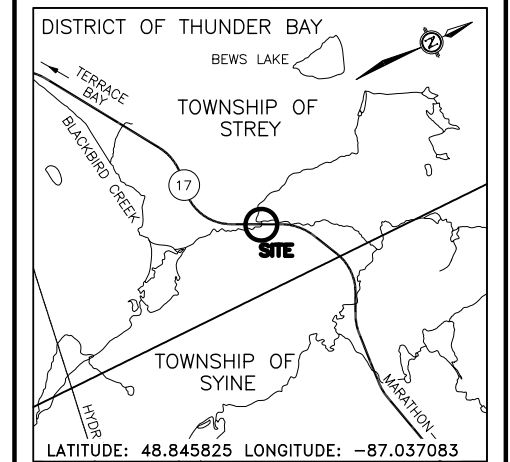


SHEET
10

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
W	Water Level
↑	Head Artesian Water
↓	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

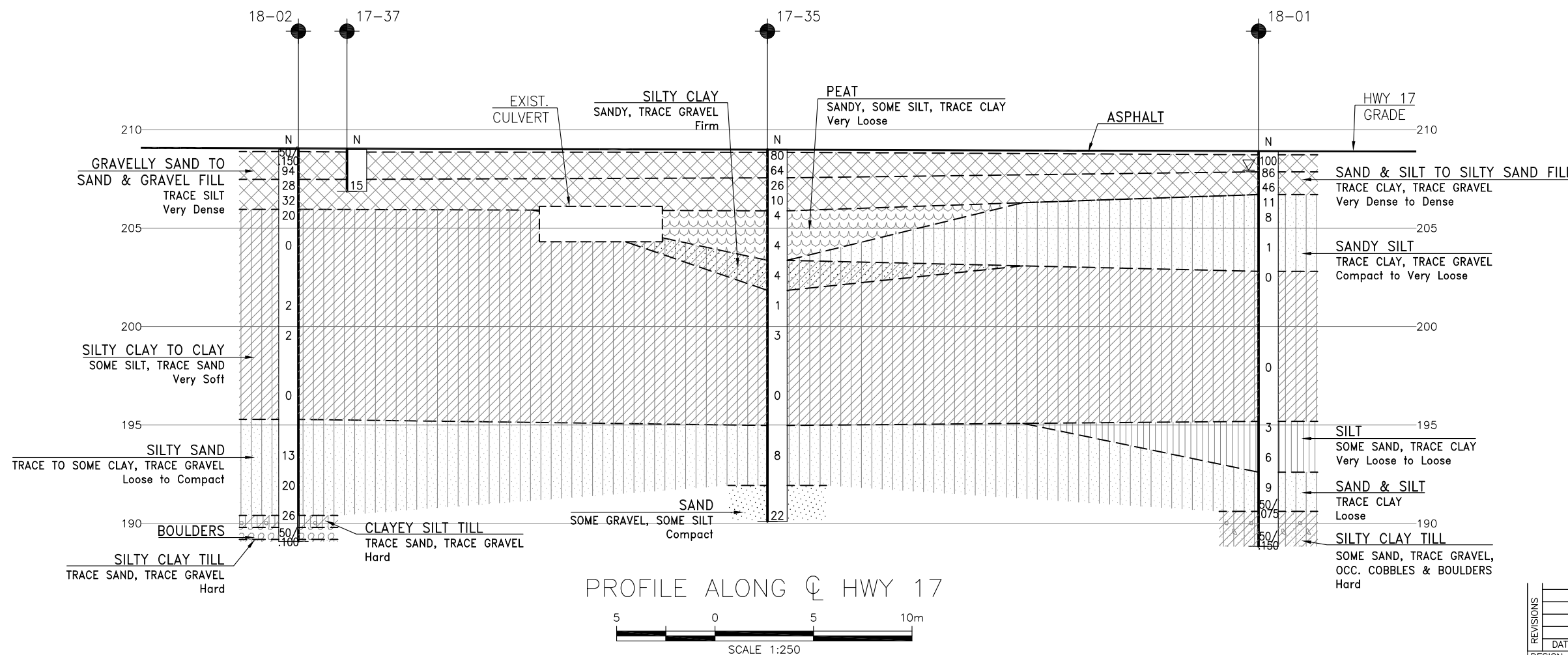
NO	ELEVATION	NORTHING	EASTING
17-34	205.4	5 411 964.3	302 071.6
17-35	209.0	5 411 958.4	302 086.0
17-36	205.9	5 411 932.8	302 095.1
17-37	209.0	5 411 939.3	302 076.6
18-01	208.9	5 411 980.6	302 097.3
18-02	209.0	5 411 935.0	302 079.6
18-03	205.8	5 411 944.8	302 103.3
18-04	205.7	5 411 970.7	302 078.1
18-05	206.3	5 411 954.0	302 105.7

-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.
- Coordinate system is MTM NAD 83 Zone 14.

GEOCRES No. 42D-54

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	CZ	CHK MEF	CODE
DRAWN	AN	CHK CZ	SITE 48E-052/C STRUCT
			LOAD
			DATE NOV 2018
			DWG 3



PROFILE ALONG C HWY 17



Appendix D

Site Photographs



Photo 1: Road approach looking south. Photo taken May 16, 2017.



Photo 2: Road approach looking north. Photo taken October, 2015.



Photo 3: East embankment looking north (inlet). Photo taken June 27, 2017.



Photo 4: East embankment looking south (inlet). Photo taken June 27, 2017.



Photo 5: West embankment looking south (outlet). Photo taken June 27, 2017.



Photo 6: Culvert outlet looking south. Photo taken May 16, 2017.



Photo 7: Culvert inlet looking west. Photo taken May 16, 2017.



Appendix E

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 401 (Construction Specification for Trenching, Backfilling and Compacting)
- OPSS PROV 501 (Construction Specification for Compacting)
- OPSS 511 (Construction Specification for Rip-Rap, Rock Protection, And Granular Sheeting)
- OPSS 517 Construction Specification for Dewatering of Pipeline, Utility, And Associated Structure Excavation
- SP 517F01 Design Storm Return Period and Preconstruction Survey Distance
- OPSS PROV 539 (Construction Specification for Temporary Protection Systems)
- OPSS PROV 804 (Construction Specification for Seed and Cover)
- OPSS 902 (Construction Specification for Excavating and Backfilling – Structures)
- OPSS PROV 1004 (Material Specification for Aggregates – Miscellaneous)
- OPSS PROV 1010 (Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material)
- Special Provision No. 110S13 (Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material)
- OPSS PROV 1205 (Material Specification for Clay Seal)
- OPSD 802.010 (Flexible Pipe Embedment and Backfill, Earth Excavation)
- OPSD 802.034 (Rigid Pipe Bedding and Cover in Embankment, Original Ground: Earth or Rock)
- OPSD 803.010 (Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m)



- 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 Depths for Northern Ontario)
- Special Provision No. FOUN0003 to OPSS 902 (Dewatering Structure Excavations)

2. Suggested Wording for NSSP

- **Suggested Text for NSSP on Obstructions**

Excavations and installation of cofferdams and roadway protection systems may encounter obstructions such as cobbles and boulders embedded in the fill 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 and removal of sheet piles.

- **Suggested Text for NSSP on “Groundwater and Dewatering”**

"The Contractor is notified that the water level may be higher than the water levels shown in the Foundation Investigation Report prepared for this site. While reference should be made to that report for a description of the encountered conditions, the Contractor must satisfy themselves regarding the groundwater levels likely to prevail at the time of construction and be prepared to implement dewatering procedures.

The Contractor is further notified that failure to implement dewatering in advance of excavating below the groundwater table may result in sloughing and boiling of the soil in the excavation and a loss in stability and bearing resistance.

Design and provision of an effective dewatering system is the responsibility of the Contractor. The dewatering system must be effective to lower the groundwater table at a minimum of 0.5 m below the final subgrade level to avoid basal heave and base boiling. The dewatering system is to be designed in accordance with SP FOUN0003, OPSS.PROV. 517 and SP517F01. A dewatering



engineer with a minimum of 5 years of experience in designing dewatering systems shall be retained by the contractor for design of an effective dewatering system. "

- **Suggested text for NSSP on “Use of Heavy Construction Equipment”**

The use of heavy construction equipment and in particular heavy lift cranes may be required during removal of the existing culvert and construction of the new culvert. The impact of the heavy equipment loads on the existing embankment, the soft foundation soils (silty clay) underlying the embankment, and the existing and new culvert foundations must be considered during selection of the methodology and equipment employed for construction.

Prior to commencement of construction, the Contractor shall retain a Geotechnical Consultant to assess the impact of the proposed equipment loads and methodology, and determine requirements and/or restrictions necessary to safely support the loads. All Foundation Engineering services required for this project shall be performed by consultant(s) listed as accepted under the MTO’s RAQS for providing services under the specialty of Geotechnical (Structures and Embankments) – High Complexity.

The assessment shall include, but not be limited to, the following:

- Determining appropriate setbacks for heavy equipment from the existing and new foundations;
- Determining the permissible ground pressure that may be applied to the foundation soils by the equipment; and
- Providing recommendations for crane pad design to distribute the crane loads without causing foundation and creek bank failure.

The Contractor shall submit the findings of the geotechnical assessment and details of the proposed equipment and construction methodology to the Contract Administrator for information purposes a minimum of two weeks prior to the start of construction.



Appendix F

Stability Analyses Results

FIGURE 1 -STATIC STABILITY ANALYSIS BLACKBIRD CULVERT EXCAVATION - 3H:1V & 2H:1V SHORT-TERM CONDITION

File Name: 15595 - Blackbird Culvert Excavation ST 2 m setback-2-incl pad.gsz

Created By: Geoff Lay

Date: 7/20/2018

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Seismic: 0

Fill	21 kN/m ³	0 kPa	32 °
Granular Pad	22 kN/m ³	0 kPa	35 °
Silty Clay	18 kN/m ³	30 kPa	0 °

48 m long bridge
2 m wide footing
2 m thick granular pad

