



THURBER ENGINEERING LTD.

**DETAILED FOUNDATION INVESTIGATION AND DESIGN REPORT
CAMPROAD CREEK CULVERT REPLACEMENT
HIGHWAY 11, UNSURVEYED TERRITORY
THUNDER BAY DISTRICT, ONTARIO
LATITUDE: 49.584064°, LONGITUDE: -87.970042°**

G.W.P. 6802-14-00, W.P. 6802-14-01, SITE No. 48C-179/C

GEOCRES Number: 42E-30

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	Topsoil.....	5
5.2	Asphalt	5
5.3	Gravelly Sand to Sand and Gravel Fill	5
5.4	Sand.....	6
5.5	Sand and Silt	7
5.6	Sand and Gravel to Gravelly Sand.....	7
5.7	Silt	8
5.8	Sandy Silt	8
5.9	Lower Sand and Gravel	9
5.10	Bedrock.....	10
5.11	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.....	16
9.2	Frost Cover.....	16
9.3	Subgrade Preparation.....	16
9.4	Settlement	17
10.	EXCAVATION AND GROUNDWATER CONTROL.....	17
11.	STREAM DIVERSION PIPE	18
12.	CULVERT BACKFILL AND LATERAL EARTH PRESSURES.....	19
13.	SEISMIC CONSIDERATIONS	20
14.	COFFERDAMS.....	21
15.	TEMPORARY PROTECTION SYSTEM	21
16.	TEMPORARY MODULAR BRIDGE	22



17. EMBANKMENT RESTORATION	24
18. SCOUR AND EROSION PROTECTION	25
19. CORROSION AND SULPHATE ATTACK POTENTIAL	25
20. CONSTRUCTION CONCERNS	25
21. CLOSURE	26

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 Analysis Figures



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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual data obtained from a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) for the proposed replacement of the Camproad Creek Culvert on Highway 11, located in the Township of Summers, 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 was retained by Hatch to carry out this detailed foundation investigation under the Ministry of Transportation Ontario (MTO) Agreement Number 6016-E-0008.

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

- Preliminary Foundation Investigation and Design Report, Camproad Creek Culvert Replacement, Highway 11, Unsurveyed Territory, Thunder Bay District, Ontario, GEOCRES Number 42E-29, 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 11, approximately 2 km south of the town of Beardmore, Ontario. The existing culvert allows Camproad Creek (also known as Warneford Creek) to flow in a westerly direction under Highway 11, where it meets Blackwater River to the west. Highway 11 generally runs in a north-south direction at the culvert site.

Client: Hatch

Date: November 12, 2018

File No.: 15595

Page: 1 of 26

E file: H:\15000-15999\15595 Replace 9 Culverts 6016-E-0008\Reports and Memos\Camproad Creek\Detailed Design\FINAL\Camproad Creek Detailed FIDR - FINAL Nov 12-2018.docx



Based on the Ontario Structure Inspection Manual (OSIM) prepared by MTO on November 20, 2014, the existing culvert is a corrugated steel pipe culvert that has a diameter of 4.5 m and is 38.4 m long. The culvert barrel has rusting and section loss of the steel between the low and high water level, severe corrosion of joint laps and bolts, and deformation of the inlet and outlet of the culvert.

The grade level of Highway 11 at the existing culvert centreline is at an elevation of approximately 306.7 m. The invert elevation at the inlet (east) is 299.7 m and the invert elevation at the outlet (west) is 299.5 m. The elevation of the water flowing through the creek on November 7, 2015, was reported to be approximately 301.0 m upstream of the inlet and 299.4 m downstream of the outlet.

The area on either side of the creek near the inlet and outlet of the culvert is vegetated with grass, and midsized trees, and the overall surrounding area is densely forested. On the east side of Highway 11, a paved highway rest area is located approximately 50 m south of the inlet and a cleared hydro corridor is located approximately 100 m north of the inlet. A railway corridor is located approximately 65 m west of the outlet. Photographs in Appendix D show the culvert and the surrounding area.

Based on published geological information, the site generally lies within an alluvial plain with sand and gravel deposits and is bounded by bedrock ridges to the east of the highway and west of Blackwater River. The bedrock at the site consists of mafic to intermediate metavolcanic rocks.

3. INVESTIGATION PROCEDURES

The current detailed field investigation for this project was carried out from June 20 to 22, 2018 and from July 12 to 18, 2018, and consisted of drilling and sampling four (4) boreholes, denoted as Boreholes 18-06 to 18-09, to depths ranging from 9.8 to 20.4 m below the existing ground surface. Boreholes 18-06 and 18-07 were located within the paved section of Highway 11 at the locations of proposed abutments for a temporary modular bridge, and Boreholes 18-08 and 18-09 were located near the inlet and outlet of the existing culvert near the locations of proposed cofferdams.

The previous preliminary investigation for this project was carried out between August 26 to 27 and between October 25 to 28, 2017, during which time seven (7) boreholes denoted as Boreholes 17-48 to 17-54 were drilled to depths of between 3.7 m and 14.3 m below the existing ground surface.



The Record of Borehole sheets for the boreholes from the current and previous preliminary investigations are included in Appendix A. The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawing provided 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. A truck-mounted CME 55 drill rig with NW casing was used to drill Boreholes 18-06 and 18-07, and a portable Hilti drill and tripod equipment using wash boring techniques was used to drill Boreholes 18-08 and 18-09. In all boreholes, soil samples were obtained at selected intervals with a 50 mm outside diameter split spoon sampler driven in conjunction with the Standard Penetration Test (SPT). An NQ core barrel was used to advance Borehole 18-07 into bedrock. The results of the boreholes are presented on the Record of Borehole sheets in Appendix A.

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 and rock samples for transport to Thurber's laboratory for further examination and testing.

Groundwater conditions were observed in the open boreholes throughout the drilling operations and in standpipe piezometers that were installed in Boreholes 18-06, 18-07, and 18-08. The boreholes in which no standpipe piezometers were installed were backfilled in general accordance with Ontario Regulation 903, as amended by Regulation 128/03. The piezometers were decommissioned upon completion of the field investigation in general accordance with Ontario Regulation 903, as amended by Regulation 128/03. Piezometers were also installed in Boreholes 17-48 and 17-50 during the preliminary investigation.

Details of the piezometer installations and borehole completion are summarized in Table 3.1 below.

Table 3.1 – Borehole Completion Details

Borehole Number	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
18-06	20.4 / 287.4	19.8 / 288.0	Sand to 18.0 m, then bentonite holeplug to 0.3 m, then sand and gravel to 0.15 m, then asphalt to surface.



Borehole Number	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
18-07	19.1 / 286.9	15.2 / 290.7	Bentonite holeplug to 15.3 m, then sand to 13.7 m, then bentonite holeplug to 0.3, then sand and gravel to 0.15 m, then asphalt to surface.
18-08	9.8 / 292.6	9.4 / 293.0	Borehole caved from 9.8 to 9.4 m, then sand to 7.6 m, then bentonite holeplug to surface.
18-09	9.8 / 292.1	None Installed	Borehole caved to 1.8 m, then bentonite holeplug and cuttings to surface.
17-48	14.3/297.0	13.7/287.6	Sand to 9.8 m then bentonite holeplug to surface
17-49	14.3/292.7	None Installed	Bentonite holeplug and cuttings to 0.9 m below surface, then concrete to 0.15 below surface and asphalt to surface
17-50	10.3/291.2	7.9/293.7	Bentonite and cuttings to 7.9 m, then sand to 4.7 m and cutting to surface
17-51	3.7/302.6	None Installed	Bentonite holeplug and cuttings to 0.9 m below surface, then concrete to 0.15 below surface and asphalt to surface
17-52	3.7/302.4	None Installed	Bentonite holeplug and cuttings to 0.9 m below surface, then concrete to 0.15 below surface and asphalt to surface
17-53	3.7/302.1	None Installed	Bentonite holeplug and cuttings to 0.9 m below surface, then concrete to 0.15 below surface and asphalt to surface
17-54	11.3/290.5	None Installed	Bentonite and cutting to surface.

It should be noted that caving occurred in Boreholes 18-08 and 18-09 in the silty soils.

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 point load testing on bedrock, where appropriate. Laboratory testing 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 fill, and a sample of the surface water from the creek upstream of the existing culvert were collected and submitted to SGS Canada Inc., a CALA accredited analytical laboratory in Lakefield, Ontario, for analytical testing of corrosivity parameters. The results of the analytical testing are summarized in this report and also presented in Appendix B.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

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 and gravelly sand fill or sand and silt overlying varying thicknesses of sand, silt, sandy silt, which were underlain by metavolcanics bedrock. Descriptions of the individual strata are presented below.

5.1 Topsoil

Boreholes 18-08, 18-09 and 17-48 encountered 0.15 to 0.6 m of topsoil at the ground surface. At Borehole 17-48, the topsoil was mixed with sand and silt and trace gravel. An SPT 'N' value of 27 blows per 0.3 m of penetration was recorded in the topsoil / sand and silt mixture at Borehole 17-48, indicating a compact density. The moisture content was measured as 11 to 27 percent.

5.2 Asphalt

Boreholes 17-49, 17-51, to 17-53, 18-06 and 18-07 were drilled through the travelled lanes of Highway 11 and encountered a layer of asphalt that ranged in thickness from 125 mm to 225 mm.

5.3 Gravelly Sand to Sand and Gravel Fill

Embankment fill material was encountered below the asphalt in Boreholes 17-49, 17-51 to 17-53, 18-06 and 18-07. The fill ranged in thickness from 5.9 to 7.8 m in Boreholes 17-49, 18-06 and 18-07, and extended to depths of 6.1 to 8.0 m (Elevation 299.0 to 300.0 m). Boreholes 17-51 to 17-53 were terminated within the fill at a depth of 3.7 m each (Elevation 302.6 m to 302.1 m).



The fill ranged in composition from sand and gravel to sand with some gravel (typically gravelly sand) and contained occasional boulders and sandy silt zones.

Boreholes 17-51 to 17-53 were drilled to assess the existence and extent of any frost taper near the culvert. Based on the results of the field investigation, the granular base/subbase material extended below the frost penetration depth and a defined frost taper was not observed at the culvert location.

SPT 'N' values within the fill ranged from 8 to 123 blows per 0.3 m of penetration, indicating a loose to very dense relative density (typically compact to dense). Moisture contents between 4 percent and 19 percent were measured in the cohesionless fill.

The results of grain size distribution analyses carried out on selected samples of the gravelly sand to sand and gravel fill are presented on the Record of Borehole sheets included in Appendix A and on Figures B1 and B2 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	17 to 51
Sand	37 to 77
Silt and Clay	3 to 19

5.4 Sand

A layer of native sand containing some silt, trace gravel, and trace to some organics was encountered below the topsoil in Boreholes 18-08 and 18-09. The sand layer was 0.6 to 1.3 m thick and extended to depths from 0.8 to 1.5 m (Elevation 300.4 to 301.6 m).

The sand ranged from very loose to dense, based on SPT 'N' values ranging from 3 to 47 blows per 0.3 m of penetration. Measured moisture contents within the sand deposit varied from 5 percent to 19 percent.

The results of a grain size distribution analysis test carried out on a selected sample of the sand is presented on the Record of Borehole sheets included in Appendix A and on Figure B3 of Appendix B. The results of the grain size distribution analysis are summarized below:



Soil Particle	Percentage (%)
Gravel	1
Sand	79
Silt	17
Clay	3

5.5 Sand and Silt

A sand and silt layer with some gravel and trace clay was encountered at the surface of Boreholes 17-50 and 17-54, and below the sand in Borehole 18-08. This layer ranged in thickness from 0.3 m to 4.6 m and extended to depths ranging from 2.4 to 4.6 m (Elevation 297.2 to 299.4 m).

SPT 'N' values within the sand and silt deposit ranged from 3 to 47 blows per 0.3 m of penetration, indicating a very loose to dense relative density. Measured moisture contents within the sand and silt deposit varied from 6 percent to 21 percent.

The results of grain size distribution analysis testing carried out on a selected sample of the sand and silt are presented on the Record of Borehole sheets included in Appendix A and on Figure B4 of Appendix B. The results of the grain size distribution analysis are summarized below:

Soil Particle	Percentage (%)
Gravel	11
Sand	44
Silt	39
Clay	6

5.6 Sand and Gravel to Gravelly Sand

A 0.8 to 2.1 m thick layer of sand and gravel to gravelly sand with trace to some silt, was encountered below the topsoil in Borehole 17-48 and below the sand in Boreholes 18-08 and 18-09. The sand and gravel to gravelly sand extended to depths of 2.3 to 2.7 m (Elevation 298.6 to 299.7 m).

SPT 'N' values within the sand and gravel to gravelly sand deposit ranged from 12 to 33 blows per 0.3 m of penetration, indicating a compact to dense relative density. Measured moisture contents varied between 2 percent and 12 percent.



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

Soil Particle	Percentage (%)
Gravel	24 to 43
Sand	49 to 64
Silt and Clay	6 to 12

5.7 Silt

The fill and upper native sand, sand and silt and gravelly sand layers were underlain by a thick deposit of silt containing trace sand to sandy, trace clay and trace gravel. Where fully penetrated, the silt deposit ranged from 5.3 to 10.5 m thick in Boreholes 17-48, 18-06, 18-07 and 18-09, and extended to depths from 7.6 to 18.3 m (Elevation 289.5 to 294.3 m). Boreholes 17-49, 17-50, 17-54 and 18-08 were terminated within the silt at depths ranging from 9.8 m to 14.3 m (Elevation 290.5 to 292.7 m).

SPT 'N' values within the silt deposit ranged from 3 to 58 blows per 0.3 m of penetration, indicating a very loose to very dense relative density (typically compact). Measured moisture contents within the silt deposit varied between 13 percent and 24 percent.

The results of grain size distribution analyses carried out on selected samples of the silt are presented on the Record of Borehole sheets included in Appendix A and on Figures B6 and B7 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 6
Sand	0 to 35
Silt	60 to 94
Clay	5 to 9

5.8 Sandy Silt

A layer of sandy silt with trace clay and trace gravel was encountered below the silt deposit in Boreholes 17-48, 18-06 and 18-09. These boreholes were terminated within the sandy silt layer at depths ranging from 9.8 to 20.4 m (Elevation 287.0 to 292.1 m).



The SPT 'N' values recorded in the sandy silt ranged from 8 to 59 blows per 0.3 m penetration indicating a loose to very dense relative density. The sandy silt had a measured moisture content ranging from 13 percent to 22 percent.

The results of grain size distribution analyses carried out on selected samples of the sandy silt are presented on the Record of Borehole sheets included in Appendix A and on Figure B8 of Appendix B. The results of the grain size distribution analysis are summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 2
Sand	25 to 29
Silt	63 to 69
Clay	6

5.9 Lower Sand and Gravel

A 3.5 m thick lower layer of sand and gravel with trace silt was encountered below the silt in Borehole 18-07, overlying the bedrock. The lower sand and gravel extended to a depth of 16.2 m (Elevation 289.7 m). A 0.9 m thick layer of boulders was encountered within the sand and gravel at a depth of 14.6 to 15.5 m.

SPT 'N' values within the lower sand to gravel deposit ranged from 14 to 46 blows per 0.3 m of penetration, indicating a compact to dense relative density. Measured moisture contents within the sand and gravel deposit varied between 6 percent and 21 percent.

The results of a grain size distribution analyses carried out on a sample of the lower sand and gravel are presented on the Record of Borehole sheets included in Appendix A and on Figure B9 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	51
Sand	45
Silt and Clay	4



5.10 Bedrock

Metavolcanic bedrock was encountered in Borehole 18-07 at a depth of 16.2 m (Elevation 289.7 m). The bedrock was confirmed by coring 2.9 m. The bedrock was generally described as fresh. The borehole was terminated within the bedrock at a depth of 19.1 m (Elevation 286.9 m).

Total Core Recovery (TCR) in the bedrock was 100% with Solid Core Recovery (SCR) ranging from 65% to 85%. The Rock Quality Designation (RQD) determined from the recovered cores ranged from 9% to 68%, indicating very poor to fair quality (typically fair). Average unconfined compressive strengths (UCS) of the rock ranged between 12 to 149 MPa based on correlations with the point load tests (PLT), indicating that the rock ranged from weak to very strong.

The point load test results and photographs of the bedrock core are included in Appendix B.

5.11 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 Boreholes 18-06 to 18-08, 17-48 and 17-50 to monitor the groundwater level at the site. The groundwater levels measured in the open boreholes and in the standpipe piezometers are summarized in Table 5.1 below.

Table 5.1 – Groundwater Measurements

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
18-06	June 22, 2018 July 25, 2018	Dry 7.0	Dry 300.8	Standpipe piezometer
18-07	June 21, 2018 June 22, 2018 July 25, 2018	5.3 5.3 5.7	300.6 300.6 300.2	Standpipe piezometer
18-08	July 13, 2018 July 14, 2018	1.4 1.6	301.0 300.8	Standpipe piezometer
18-09	July 12, 2018	1.5	300.4	Open borehole
17-48	August 28, 2017	1.5	299.8	Standpipe piezometer
17-49	August 26, 2017	8.0	299.0	Open borehole
17-50	October 27, 2017 October 28, 2017	1.3 1.3	300.3 300.3	Standpipe piezometer
17-51	August 26, 2017	Dry	Dry	Open borehole
17-52	August 26, 2017	Dry	Dry	Open borehole
17-53	August 26, 2017	Dry	Dry	Open borehole
17-54	October 27, 2017	2.4	299.4	Open Borehole

The surface elevation of the water flowing through the creek on November 7, 2015, was reported to be approximately 301.0 m upstream of the inlet and 299.4 m downstream of the outlet.

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 gravelly sand fill from Borehole 17-49, 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	
			17-49, SS#6, 4.6 m – 5.2 m	Camproad Creek
			(Fill)	(Creek Water)
Sulphide	%	mg/L	<0.02	<0.006
Chloride	mg/L	mg/L	160	31
Sulphate	mg/L	mg/L	15	2.3
pH	No unit	No unit	9.65	7.91
Electrical Conductivity	µS/cm	µS/cm	322	243
Resistivity	Ohms.cm	Ohms.cm	3110	4120
Redox Potential	mV	mV	243	250

7. MISCELLANEOUS

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

OGS Inc. of Almonte, Ontario, and Downing Drilling of Hawkesbury, Ontario, supplied and operated the drilling, sampling and in-situ testing equipment for the current field 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 Farrant, P.Eng. of Thurber.

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. Analytical laboratory testing was carried out by SGS Canada Inc. Interpretation of the field data and preparation of this report was carried out by Mr. 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.



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GEOCRES No: 42E-30

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 Camroad Creek Culvert replacement on Highway 11, located in the Township of Summers, 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 corrugated steel pipe culvert. The culvert has a diameter of 4.5 m and is 38.4 m long. The estimated culvert invert is at approximate Elevation 299.7 m at the inlet (east) and 299.5 m at the outlet (west). The existing road grade at the culvert location is at approximate Elevation 306.7 m, and there is approximately 2.5 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

Client: Hatch

Date: November 12, 2018

File No.: 15595

Page: 14 of 26

E file: H:\15000-15999\15595 Replace 9 Culverts 6016-E-0008\Reports and Memos\Camroad Creek\Detailed Design\FINAL\Camroad Creek Detailed FIDR - FINAL Nov 12-2018.docx



plate corrugated steel pipe (SPCSP) culverts are the preferred replacement option. The new pipes will each have a diameter of 3.67 m, with invert levels (underside of the pipe) at approximate Elevations of 298.87 and 298.60 m at the inlet and outlet, respectively.

The new twin SPCSP culvert replacements will be constructed generally along the same alignment as the existing CSP culvert. No grade raise or embankment widening is proposed for the culvert replacement. No headwalls or wingwalls are proposed.

A temporary creek diversion pipe is to be located approximately 8 m south of the culvert centreline while the culvert is being installed. The invert level of the diversion pipe is at approximate Elevation 299.5 m. A temporary modular bridge is proposed to accommodate vehicular traffic during installation of the replacement culvert, and temporary roadway protection may also be used.

9. CULVERT FOUNDATION DESIGN

In general, the subsurface conditions encountered in the boreholes consisted of asphalt overlying gravelly sand to sand and gravel fill, underlain by native silt and sandy silt.

Water levels in the open boreholes and piezometers ranged from Elevation 299.0 m to 301.0 m. The creek water level reported on November 7, 2015 is approximately 301.0 m upstream of the inlet and 299.4 m downstream of the outlet.

The invert level of the proposed SPCSPs is at approximate Elevation 298.7 to 299.0 m. The founding soils encountered at this level generally consist of compact silt. There will be approximately 4 m of fill above the proposed replacement culvert.

Foundation design aspects for the replacement culvert include subgrade conditions and preparation, settlement of foundation soils under the imposed loads, lateral earth pressures, temporary modular bridge foundation design, groundwater control, cofferdams, staged construction, and restoration of the roadway embankment.

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 where applicable.



9.1 Foundations

Replacement of the culvert with twin SPCSPs on the same alignment is being considered for this site. Since there is no proposed grade raise or embankment widening, 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 SPCSPs should be placed on a minimum 300 mm thick layer of bedding material conforming to Ontario Provincial Standard Specification (OPSS) OPSS.PROV 1010 Granular A or Granular B Type II requirements as per OPSD 802.014 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 1860 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 298.4 to 298.7 m, which corresponds to compact silt subgrade. Any loose soil, cobbles and boulders, and any 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 2.5 m based on OPSD 3090.100. The twin SPCSPs do not require frost cover / protection.

Based on the results of the field investigation, the existing embankment and underlying subgrade soil at the culvert location comprise gravelly sand to sand and gravel material to below the frost penetration depth; therefore, construction of new frost tapers does not appear warranted as part of the culvert replacement.

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, 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.

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

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

9.4 Settlement

The replacement culvert will be constructed approximately on the same alignment and with similar opening size as the existing culvert with no grade raise on the overlying embankment or embankment widening. Therefore, changes in the loading conditions on the foundation soils consisting of compact silt 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 foundation settlements will essentially be complete at the end of construction.

If the final design involves embankment widening or grade raise, foundation soil settlement 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, native sands and silt at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level.

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 extended into the sand, sand and gravel to gravelly sand and silt.



Installation of the culvert must be carried out in the dry. Excavation for culvert replacement will be carried out below the creek water level, and diversion of the creek flow will be required. Given the relatively high permeability of the embankment fill materials and native cohesionless soils, water inflow / seepage into the excavation should be anticipated. A combination of creek diversion and sheet pile cofferdam enclosures along with the use of sumps / pumps within an enclosure will be required to maintain dry excavations during the course of staged construction. Recommendations for cofferdam design are provided in Sections 14 and 15 below. The dewatering scheme must be effective to lower the groundwater level at least 0.5 m below the final subgrade level to avoid base boiling in the native silty soils.

The invert level of the proposed CSP to be used as a diversion pipe for the twin box culvert replacement will also be below the groundwater table. Dewatering will also be required for the construction and installation of the diversion pipe, and during excavation of the temporary slopes in front of the temporary modular bridge abutment footings.

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 FOUN003 should be "N/A". Considering the conditions on site, a design Engineer and design-checking Engineer with a minimum of 5 years of experience in designing systems of similar nature and scope to the required work is required, and thus Designer Fill-In ***** in SP517F01 should be "Yes".

Suggested wording for an NSSP in this regard is included in Appendix E. Further assessment of dewatering requirements and the need for a Permit to Take Water (PTTW) should be carried out by specialists experienced in the field.

11. STREAM DIVERSION PIPE

A temporary CSP stream diversion pipe is proposed to accommodate creek water flow during culvert replacement, as indicated on the general arrangement drawings. The diversion pipe is shown to be located approximately 8 m south of the culvert centreline, with the invert level at an approximate Elevation of 299.5 m. Based on Borehole 18-07, located on the highway near the diversion pipe alignment, the pipe invert is expected to lie within native compact silt.



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

The stream diversion pipe could be installed within the temporary open cut excavations, or within a shored excavation using a trench box. The installation of the diversion pipe in open cut should follow OPSD 802.014 and OPSS 421.

12. CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the culvert should consist of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS.PROV 1010. Reference should be made to the backfill arrangements stipulated in OPSD 802.010 or 802.014 as appropriate. Backfilling for the culvert should be in accordance with OPSS.PROV 401 for a CSP. 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 any culvert walls 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 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 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 decreasing to 0 kPa at a depth of 1.7 m for Granular B Type I, or at a depth of 2.0 m for Granular A or B Type II.

13. SEISMIC CONSIDERATIONS

In accordance with the CHBDC 2014, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy. Based on the stratigraphy of the site, the area corresponds to a Seismic Site Class D in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC. The peak ground acceleration, PGA, for a 2% in 50 year probability of exceedance at this site is 0.034 g as per the National Building Code of Canada (NBCC), for a reference Site Class C. This value is amplified to 0.044 g for Site Class D.

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 or Type III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$
Active (K_{AE}) ^{1,2}	0.29	0.32
Passive (K_{PE})	3.6	3.2
At Rest (K_{OE}) ³	0.49	0.53

Note 1: Mononobe and Okabe, 1929, World Engineering Congress 9: 179-187

Note 2: Passive case assumes a horizontal surface in front of the wall.

Note 3: Wood, J.H. 1973, Earthquake Induced Soil Pressures on Structures, PhD Thesis, California Institute of Technology, Pasadena, CA

The site is underlain by generally compact silt. In view of the low potential for seismic activity in the area, liquefaction is not considered to be a concern at this site.

14. COFFERDAMS

Construction of cofferdams will be required to construct the culvert replacement in the dry. It is recommended that the temporary culvert excavations be enclosed within a water tight enclosure. Due to the presence of highly permeable cohesionless foundation soils and the high water table, a sand bag cofferdam system may not be as effective where work is required below the creek level. Interlocking sheet piles are however considered to be feasible for cofferdam construction in this situation. The recommendations provided in Section 15 below for Temporary Protection Systems are also applicable to sheet piled cofferdams. The sheet piles for the cofferdams should extend deep enough to penetrate a sufficient distance in the native silt layer to reduce the upward seepage flow into the culvert excavation.

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. The dewatering system must be effective to lower the water table a minimum of 0.5 m below the final culvert subgrade.

15. TEMPORARY PROTECTION SYSTEM

Temporary roadway protection systems 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.



It should be noted that embankment fill at this culvert site is up to 8 m in height and the roadway protection system to retain this height of fill may require tie backs, struts or raker support to limit the lateral deformation of the roadway protection system.

The soil parameters in Table 15.1 may apply for design of the temporary roadway protection system with horizontal backfill. The presence of occasional cobbles may impact driving of sheet or soldier piles.

Table 15.1 –Soil Parameters for Temporary Protection System Design

Soil Parameter	Sand and Gravel to Gravelly Sand Fill	Native Sand to Sand and Gravel	Native Silt to Sandy Silt
ϕ (angle of internal friction)	32°	32°	28°
γ (total unit weight)	20 kN/m ³	20 kN/m ³	19 kN/m ³
γ_w (submerged unit weight)	10 kN/m ³	10 kN/m ³	9 kN/m ³
K_a	0.31	0.31	0.36
K_p	3.3	3.3	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 no incur damage to the subgrade of the newly installed culvert.

The design of 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.

16. TEMPORARY MODULAR BRIDGE

Since the temporary roadway protection for an 8 m deep temporary excavation may require additional measures such as bracing, an inline temporary modular bridge is another viable option



at this site during replacement of the culvert for traffic staging purposes. The design of the temporary bridge is the responsibility of the contractor. The contractor must retain a Professional Engineer, experienced in bridge design, to design the temporary bridge.

Boreholes 18-06 and 18-07 were drilled near the potential abutments of the temporary modular bridge.

The modular bridge may be supported on precast concrete bearing pads founded on engineered granular fill pads. The granular fill pads should be a minimum of 1 m thick and consist of OPSS Granular A or Granular B Type II, placed in 150 mm thick lifts and compacted to 100% of the SPMDD at $\pm 2\%$ of Optimum Moisture Content (OMC).

The minimum footing width should be 1.5 m and the footing should be embedded a minimum of 0.5 m below the finished grade in front of the footing. The front edge of the footing should be set back a minimum of 2 m from the crest of the temporary excavation slope at the top of the footing level.

The recommended geotechnical resistance at the ULS and SLS for a minimum 1.5 m wide concrete pad footing founded on the engineered granular fill at or below Elev. 304.5 m for the north abutment, are given below:

- Factored Geotechnical Resistance at ULS of 225 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 150 kPa

Resistance to lateral forces/sliding resistance between the concrete pad and the underlying Granular A or B Type II engineered fill should be calculated assuming an ultimate coefficient of friction of 0.55.

In order to achieve a stability safety factor of 1.3, the temporary excavation slope in front of the temporary modular bridge abutment footings should be no steeper than 2H:1V, as shown in Figure 1 in Appendix F. This will require the temporary modular bridge to be approximately 52 m long. Steeper temporary excavation slopes, including 1.5H:1V, do not achieve a stability safety factor of 1.3, as shown on Figure 2 in Appendix F. The temporary excavation slope for the modular bridge must be protected from erosion by covering the slope with tarp. The contractor may choose to drive sheet piles in front of the abutment footings to shorten the temporary modular bridge. Dewatering will be required during excavation of the temporary slopes, as described in Section 10.



In order to accommodate the installation and removal of the stream diversion pipe, a short term temporary excavation slope of 1H:1V may be necessary, as shown on the General Arrangement drawing. As shown on Figure 3 in Appendix F, the temporary 1H:1V slope for at the diversion pipe would have a stability factor of safety of 1.28, which is considered acceptable for a very short term excavation. The temporary 1H:1V slope must be dewatered in advance of the excavation and protected against sloughing / erosion as well as significant moisture change. The excavation and backfilling should be carried out in short sections of approximately 3 to 5 m long before proceeding with the next section in order to minimize the potential for cut slope instability and movement. To backfill behind and above the diversion pipe, a sheet pile at the toe of the 2H:1V cut slope will need to be in place prior to excavation for the diversion pipe (as shown on the General Arrangement drawing). Immediately following the installation and removal of the diversion pipe, the 2H:1V cut slope excavation slope must be reinstated until the highway embankment is backfilled and restored.

It is recommended that the contractor retain a geotechnical consultant who is RAQs qualified at the medium complexity level (RAQs Category – Geotechnical Structures and Embankment – Medium Complexity) to design the footings and stable slopes in front of the footings for the temporary modular bridge. All final reports and drawings must be sealed and signed by a Professional Engineer, who shall also be a RAQs Designated Contact. An NSSP for this effect is attached in Appendix E.

17. EMBANKMENT RESTORATION

Provided that the embankment is reconstructed with side slopes inclined not steeper than 2H:1V, the restored embankment slopes should remain stable. As discussed in Section 9.4, and if there is no grade raise or embankment widening, settlement of the embankment under the restored embankment will be less than 25 mm.

Embankment restoration after completion of the culvert replacement should be carried out in accordance with OPSS PROV 206. 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.



18. 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 OPSP 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.

Selection of streambed material should be in accordance with OPSS 1005.

19. CORROSION AND SULPHATE ATTACK POTENTIAL

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

- The potential for corrosion or sulphate attack on concrete foundations from the surrounding soil or surface water is considered to be negligible due to the low concentration of sulphate and chloride in the samples tested. The effect of road deicing salt should also be considered while selecting the class of concrete.
- The potential for soil or surface water corrosion on metal is considered to be mild to moderate.
- Appropriate protection measures are recommended if metal structural elements are used. The effect of road deicing salt should be considered while selecting the corrosion protection measures.

20. CONSTRUCTION CONCERNS

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

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

21. CLOSURE

Engineering analysis and preparation of this report was carried out by 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.

Mark Farrant, P.Eng.
Geotechnical Engineer



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

Client: Hatch

File No.: 15595

E file: H:\15000-15999\15595 Replace 9 Culverts 6016-E-0008\Reports and Memos\Camproad Creek\Detailed Design\FINAL\Camproad Creek Detailed FIDR - FINAL Nov 12-2018.docx

Date: November 12, 2018

Page: 26 of 26



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			

EXPLANATION OF ROCK LOGGING TERMS

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




<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Very thinly bedded	20 to 60mm				
Laminated	6 to 20mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Thinly Laminated	Less than 6mm				
<u>TERMS</u>		Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.				
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen				
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.				

RECORD OF BOREHOLE No 18-06

1 OF 3

METRIC

W.P. 6802-14-01 LOCATION Camroad Creek Culvert, MTM NAD 83 Zone 14 N 5 494 515.7 E 234 669.9 ORIGINATED BY BRM
DIST Thunder Bay HWY 11 BOREHOLE TYPE NW Casing COMPILED BY MP
DATUM Geodetic DATE 2018.06.22 - 2018.06.22 LATITUDE 49.58432208 LONGITUDE -87.96993124 CHECKED BY MEF

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														
307.8	GROUND SURFACE							20	40	60	80	100										
0.0	ASPHALT (175mm)							20	40	60	80	100										
300.8	GRAVEL, some sand Very Dense Dark Brown Moist (FILL) Gravelly SAND, some silt Very Dense Brown Moist (FILL)		1	SS	100																	
0.3																						
			2	SS	54																	
			3	SS	50/ 0.150																	
			4	SS	55																	
304.8																						
3.0	Sandy SILT, trace gravel Compact Reddish Brown Wet (FILL)		5	SS	20																	
304.0																						
3.8	SAND and GRAVEL, some silt Compact to Dense Brown Wet (FILL)																					
			6	SS	37																	
			7	SS	13																	
300.0																						
7.8	SILT, trace sand to sandy, trace clay Compact to Dense Grey Wet		8	SS	13																	
			9	SS	20																	

Continued Next Page

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

RECORD OF BOREHOLE No 18-06

2 OF 3

METRIC

W.P. 6802-14-01 LOCATION Camroad Creek Culvert, MTM NAD 83 Zone 14 N 5 494 515.7 E 234 669.9 ORIGINATED BY BRM
 DIST Thunder Bay HWY 11 BOREHOLE TYPE NW Casing COMPILED BY MP
 DATUM Geodetic DATE 2018.06.22 - 2018.06.22 LATITUDE 49.58432208 LONGITUDE -87.96993124 CHECKED BY MEF

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								
Continued From Previous Page							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%) W _P W W _L				
							297									
			10	SS	29											
			11	SS	19											
			12	SS	24											

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC

[illegible]

RECORD OF BOREHOLE No 18-07

1 OF 3

METRIC

W.P. 6802-14-01 LOCATION Camroad Creek Culvert, MTM NAD 83 Zone 14 N 5 494 467.3 E 234 648.8 ORIGINATED BY BRM
 DIST Thunder Bay HWY 11 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.06.20 - 2018.06.20 LATITUDE 49.58388376 LONGITUDE -87.9702138 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w _P w w _L				GR	SA	SI	CL
305.9	GROUND SURFACE																		
0.0	ASPHALT (150mm)																		
0.2	SAND and GRAVEL, trace silt Very Dense Dark Brown Moist (FILL)		1	SS	88								○					37 56 7 (SI+CL)	
305.1																			
0.8	Gravelly SAND, trace silt Very Dense to Compact Brown Moist (FILL)		2	SS	45								○						
			3	SS	57								○						
			4	SS	11								○					21 76 3 (SI+CL)	
302.5			5	SS	40								○						
3.4	Sandy SILT Dense Brown Moist (FILL)																		
301.5																			
4.4	BOULDER (FILL)																		
300.7																			
5.2	SAND and GRAVEL Compact Brown Wet (FILL)		6	SS	26								○						
299.8																			
6.1	SILT, trace sand, trace clay Compact to Dense Grey Wet		7	SS	37								○						
			8	SS	19								○					0 5 89 6	
			9	SS	17								○						

Continued Next Page

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

METRIC

[illegible]

ONTMT4S2 MTO-15595.GPJ 2017TEMPLATE(MTO).GDT 8/10/18

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

METRIC

[illegible]

RECORD OF BOREHOLE No 18-08

1 OF 2

METRIC

W.P. 6802-14-01 LOCATION Camroad Creek Culvert, MTM NAD 83 Zone 14 N 5 494 507.1 E 234 632.4 ORIGINATED BY JM
DIST Thunder Bay HWY 11 BOREHOLE TYPE Wash Boring COMPILED BY MP
DATUM Geodetic DATE 2018.07.18 - 2018.07.18 LATITUDE 49.58424025 LONGITUDE -87.97044729 CHECKED BY MEF

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											
302.4	GROUND SURFACE							20	40	60	80	100							
0.0	TOPSOIL: (150mm)																		
0.2	SAND, some silt, trace gravel, trace to some organics		1	SS	8		302												
301.6	Loose																		
0.8	Brown																		
	Moist																		
	SAND and GRAVEL to Gravelly		2	SS	27		301												
	SAND, trace to some silt, occasional cobbles																		
	Compact to Dense																		
	Brown		3	SS	33														
	Moist																		
299.7			4	SS	27		300												
2.7	SAND and SILT, some gravel																		
299.4	Compact																		
3.0	Brown to Grey																		
	Moist		5	SS	16		299												
	SILT, some sand, trace clay, trace gravel																		
	Compact																		
	Grey																		
	Wet																		
			6	SS	20		298												
			7	SS	22		296												
			8	SS	18		294												
			9	SS	20		293												
292.6																			
9.8	END OF BOREHOLE AT 9.8m.																		

Continued Next Page

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

RECORD OF BOREHOLE No 18-08

2 OF 2

METRIC

W.P. 6802-14-01 LOCATION Camproad Creek Culvert, MTM NAD 83 Zone 14 N 5 494 507.1 E 234 632.4 ORIGINATED BY JM
 DIST Thunder Bay HWY 11 BOREHOLE TYPE Wash Boring COMPILED BY MP
 DATUM Geodetic DATE 2018.07.18 - 2018.07.18 LATITUDE 49.58424025 LONGITUDE -87.97044729 CHECKED BY MEF


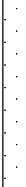



SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
	Continued From Previous Page																
	Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.5m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2018.07.13 1.4 301.0 2018.07.14 1.6 300.8																

RECORD OF BOREHOLE No 18-09

1 OF 2

METRIC

W.P. 6802-14-01 LOCATION Camroad Creek Culvert, MTM NAD 83 Zone 14 N 5 494 496.3 E 234 689.6 ORIGINATED BY JM
DIST Thunder Bay HWY 11 BOREHOLE TYPE BW Casing COMPILED BY MP
DATUM Geodetic DATE 2018.07.12 - 2018.07.12 LATITUDE 49.5841493 LONGITUDE -87.96965436 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
301.9	GROUND SURFACE							20	40	60	80	100						
0.0	TOPSOIL: (150mm)																	
0.2	SAND, some silt, trace gravel, trace to some organics, trace rootlets, trace clay Very Loose to Dense Brown Moist		1	SS	3	▽	301										1 79 17 3	
			2	SS	47													
300.4																		
1.5	SAND and GRAVEL, trace silt Dense Brown Moist to Wet		3	SS	31		300											
299.6																		
2.3	SILT, trace sand, trace clay, trace gravel Compact Grey Wet		4	SS	21	▽	299										0 9 85 6	
			5	SS	15		298											
			6	SS	21		297											
								296										
			7	SS	17		295											
294.3																		
7.6	Sandy SILT, trace clay Compact Grey Wet		8	SS	22	▽	294										0 25 69 6	
			9	SS	12		293											
292.1																		
9.8	END OF BOREHOLE AT 9.8m.																	

Continued Next Page

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

RECORD OF BOREHOLE No 18-09

2 OF 2

METRIC

W.P. 6802-14-01 LOCATION Camproad Creek Culvert, MTM NAD 83 Zone 14 N 5 494 496.3 E 234 689.6 ORIGINATED BY JM
 DIST Thunder Bay HWY 11 BOREHOLE TYPE BW Casing COMPILED BY MP
 DATUM Geodetic DATE 2018.07.12 - 2018.07.12 LATITUDE 49.5841493 LONGITUDE -87.96965436 CHECKED BY MEF

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			20	40	60	80	100					
	Continued From Previous Page BOREHOLE CAVED TO 1.8m AND WATER LEVEL AT 1.5m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																

ONTMT452 MTO-15595.GPJ 2017TEMPLATE(MTO).GDT 8/10/18

RECORD OF BOREHOLE No 17-48

1 OF 2

METRIC

W.P. 6802-14-01 LOCATION Camproad Creek Culvert, MTM NAD 83 Zone 14 N 5 494 473.3 E 234 622.2 ORIGINATED BY TTB
 HWY 11 BOREHOLE TYPE Solid Stem Augers/Washboring COMPILED BY MP
 DATUM Geodetic DATE 2017.08.27 - 2017.08.27 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 (%)			
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				GR	SA	SI	CL
301.3	GROUND SURFACE							20	40	60	80	100							
0.0	TOPSOIL, mixed with sand and silt, trace gravel, trace rootlets Compact Brown Moist		1	SS	27		301							○					
300.7																			
0.6	Gravelly SAND, trace silt, occasional cobbles and wood pieces Compact Brown Moist		2	SS	13		300							○					
			3	SS	20		299							○				34 60 6 (SI+CL)	
	Wet																		
298.6			4	SS	12		298							○				6 16 71 7	
2.7	SILT, trace to some sand, trace clay, trace gravel Compact to Loose Grey Wet		5	SS	13		297												
			6	SS	14		296							○					
			7	SS	9		295							○					
			8	SS	17		294							○				0 0 94 6	
							293												
			9	SS	16		292							○					

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-48

2 OF 2

METRIC

W.P. 6802-14-01 LOCATION Camproad Creek Culvert, MTM NAD 83 Zone 14 N 5 494 473.3 E 234 622.2 ORIGINATED BY TTB
 HWY 11 BOREHOLE TYPE Solid Stem Augers/Washboring COMPILED BY MP
 DATUM Geodetic DATE 2017.08.27 - 2017.08.27 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					WATER CONTENT (%)						
						20	40	60	80	100	20	40	60				
289.6	Continued From Previous Page		10	SS	8												
11.7	Sandy SILT, trace clay Compact to Loose Grey Wet		11	SS	16												
287.0			12	SS	8											0 29 65 6	
14.3	END OF BOREHOLE AT 14.3m. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.08.28 1.5 299.8																



ONTMT4S MTO-15595.GPJ 2017TEMPLATE(MTO).GDT 3/6/18

RECORD OF BOREHOLE No 17-49

1 OF 2

METRIC

W.P. 6802-14-01 LOCATION Camproad Creek Culvert, MTM NAD 83 Zone 14 N 5 494 497.5 E 234 659.9 ORIGINATED BY TTB
 HWY 11 BOREHOLE TYPE Solid Stem Augers/Washboring COMPILED BY MP
 DATUM Geodetic DATE 2017.08.26 - 2017.08.26 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 (%)							
								20 40 60 80 100					w _P w w _L							
307.0	GROUND SURFACE							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
0.0	ASPHALT (225mm)							20 40 60 80 100					20 40 60							
0.2	Gravelly SAND, trace to some silt Very Dense Brown Dry (FILL)		1	SS	123									○						
			2	SS	62		306							○						22 65 13 (SI+CL)
			3	SS	55		305							○						
			4	SS	24		304							○						
	Becomonig compact		5	SS	12									○						21 70 9 (SI+CL)
			6	SS	12		303							○						
			7	SS	10		302							○						
			Switched to washboring	8	SS	50		301							○					
					300															
299.0																				
8.0	SILT, trace to some sand, trace clay Very Dense to Compact Brown Wet						299						○							
							298						○							
	Becoming grey		9	SS	13									○					0 14 79 7	

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-49

2 OF 2

METRIC

W.P. 6802-14-01 LOCATION Camproad Creek Culvert, MTM NAD 83 Zone 14 N 5 494 497.5 E 234 659.9 ORIGINATED BY TTB
 HWY 11 BOREHOLE TYPE Solid Stem Augers/Washboring COMPILED BY MP
 DATUM Geodetic DATE 2017.08.26 - 2017.08.26 CHECKED BY NLB

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w _P w w _L				
	Continued From Previous Page							20 40 60 80 100								
			10	SS	24		296									
							295									
			11	SS	14											
							294									
			12	SS	16		293								0 0 94 6	
292.7 14.3	END OF BOREHOLE AT 14.3m. BOREHOLE OPEN TO 14.3m AND WATER LEVEL AT 8.1m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.9m, DRY CEMENT TO 0.15m AND COLD-PATCH ASPHALT TO SURFACE.															

ONTMT4S MTO-15595.GPJ 2017TEMPLATE(MTO).GDT 3/6/18

RECORD OF BOREHOLE No 17-50

1 OF 2

METRIC

W.P. 6802-14-01 LOCATION Camproad Creek Culvert, MTM NAD 83 Zone 14 N 5 494 483.7 E 234 675.7 ORIGINATED BY JHP
 HWY 11 BOREHOLE TYPE AB Casing/Hand Augers COMPILED BY MP
 DATUM Geodetic DATE 2017.10.25 - 2017.10.26 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	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)					
301.5	GROUND SURFACE							20	40	60	80	100					GR	SA	SI	CL		
0.0	SAND and SILT , some gravel, trace clay, trace organics, occasional cobbles Loose to Dense Brown Wet		1	SS	10		301															
			2	SS	21																	
			3	SS	20		300															
			4	SS	47																	
299.1							299															
2.4	SILT , trace sand, trace clay Very Loose to Compact Grey Wet		5	SS	8																	
			6	SS	3		298											0	2	91	7	
				7	SS	15		297														
							296															
				8	SS	18		295														
							294															
				9	SS	19													0	0	91	9
							293															
				10	SS	25		292														

Continued Next Page

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

RECORD OF BOREHOLE No 17-50

2 OF 2

METRIC

W.P. 6802-14-01 LOCATION Camproad Creek Culvert, MTM NAD 83 Zone 14 N 5 494 483.7 E 234 675.7 ORIGINATED BY JHP
 HWY 11 BOREHOLE TYPE AB Casing/Hand Augers COMPILED BY MP
 DATUM Geodetic DATE 2017.10.25 - 2017.10.26 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									
	Continued From Previous Page																
291.2																	
10.3	END OF BOREHOLE AT 10.3m UPON REFUSAL. Piezometer installation consists of 50mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.10.27 1.3 300.2 2017.10.28 1.3 300.2																

RECORD OF BOREHOLE No 17-51

1 OF 1

METRIC

W.P. 6802-14-01 LOCATION Camproad Creek Culvert, MTM NAD 83 Zone 14 N 5 494 480.1 E 234 650.7 ORIGINATED BY TTB
 HWY 11 BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2017.08.26 - 2017.08.26 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										
306.3	GROUND SURFACE							20	40	60	80	100						
0.0	ASPHALT (125mm)							20	40	60	80	100						
0.1	SAND and GRAVEL, trace silt Brown Dry (FILL)		1	GS			306											
							305											
							304											
	Loose		1	SS	8		303											
302.6																		
3.7	END OF BOREHOLE AT 3.7m. BOREHOLE BACKFILLED WITH CUTTINGS TO 0.9m, DRY CEMENT TO 0.15m AND COLD-PATCH ASPHALT TO SURFACE.																	

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

RECORD OF BOREHOLE No 17-52

1 OF 1

METRIC

W.P. 6802-14-01 LOCATION Camproad Creek Culvert, MTM NAD 83 Zone 14 N 5 494 471.3 E 234 646.1 ORIGINATED BY TTB
 HWY 11 BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2017.08.26 - 2017.08.26 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									
306.1	GROUND SURFACE																
0.0	ASPHALT (225mm)						306										
0.2	SAND, some gravel, trace silt Brown Moist (FILL)		1	GS			305										
							304										
	Compact		1	SS	10		303										
302.4																17 77 6 (SI+CL)	
3.7	END OF BOREHOLE AT 3.7m. BOREHOLE BACKFILLED WITH CUTTINGS TO 0.9m, DRY CEMENT TO 0.15m AND COLD-PATCH ASPHALT TO SURFACE.																

ONTMT4S MTO-15595.GPJ 2017TEMPLATE(MTO).GDT 1/31/18

RECORD OF BOREHOLE No 17-53

1 OF 1

METRIC

W.P. 6802-14-01 LOCATION Camproad Creek Culvert, MTM NAD 83 Zone 14 N 5 494 462.3 E 234 641.6 ORIGINATED BY TTB
 HWY 11 BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2017.08.26 - 2017.08.26 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									
305.8	GROUND SURFACE																
0.0	ASPHALT (175mm)																
0.2	Gravelly SAND, some silt Brown Moist (FILL)		1	GS												25 56 19 (SI+CL)	
	Compact		1	SS	13												
302.1																	
3.7	END OF BOREHOLE AT 3.7m. BOREHOLE BACKFILLED WITH CUTTINGS TO 0.9m, DRY CEMENT TO 0.15m AND COLD-PATCH ASPHALT TO SURFACE.																

RECORD OF BOREHOLE No 17-54

1 OF 2

METRIC

W.P. 6802-14-01 LOCATION Camproad Creek Culvert, MTM NAD 83 Zone 14 N 5 494 487.1 E 234 638.4 ORIGINATED BY JHP
 HWY 11 BOREHOLE TYPE AB Casing/Hand Augers COMPILED BY MP
 DATUM Geodetic DATE 2017.10.27 - 2017.10.28 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 (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	20	40	60	80	100	W _P	W		W _L			
301.8	GROUND SURFACE																			
0.0	SAND and SILT , some gravel, trace clay Very Loose to Dense Brown Moist		1	SS	3								○							
			2	SS	14								○						11 44 39 6	
			3	SS	11								○							
			4	SS	33								○							
			5	SS	31								○							
			6	SS	24									○						
	Wet																			
297.2																				
4.6	SILT , trace sand, trace clay Compact to Very Dense Grey Wet		7	SS	24								○						0 4 88 8	
			8	SS	35									○					0 4 90 6	
			9	SS	58									○						

Continued Next Page

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

RECORD OF BOREHOLE No 17-54

2 OF 2

METRIC

W.P. 6802-14-01 LOCATION Camproad Creek Culvert, MTM NAD 83 Zone 14 N 5 494 487.1 E 234 638.4 ORIGINATED BY JHP
 HWY 11 BOREHOLE TYPE AB Casing/Hand Augers COMPILED BY MP
 DATUM Geodetic DATE 2017.10.27 - 2017.10.28 CHECKED BY NLB

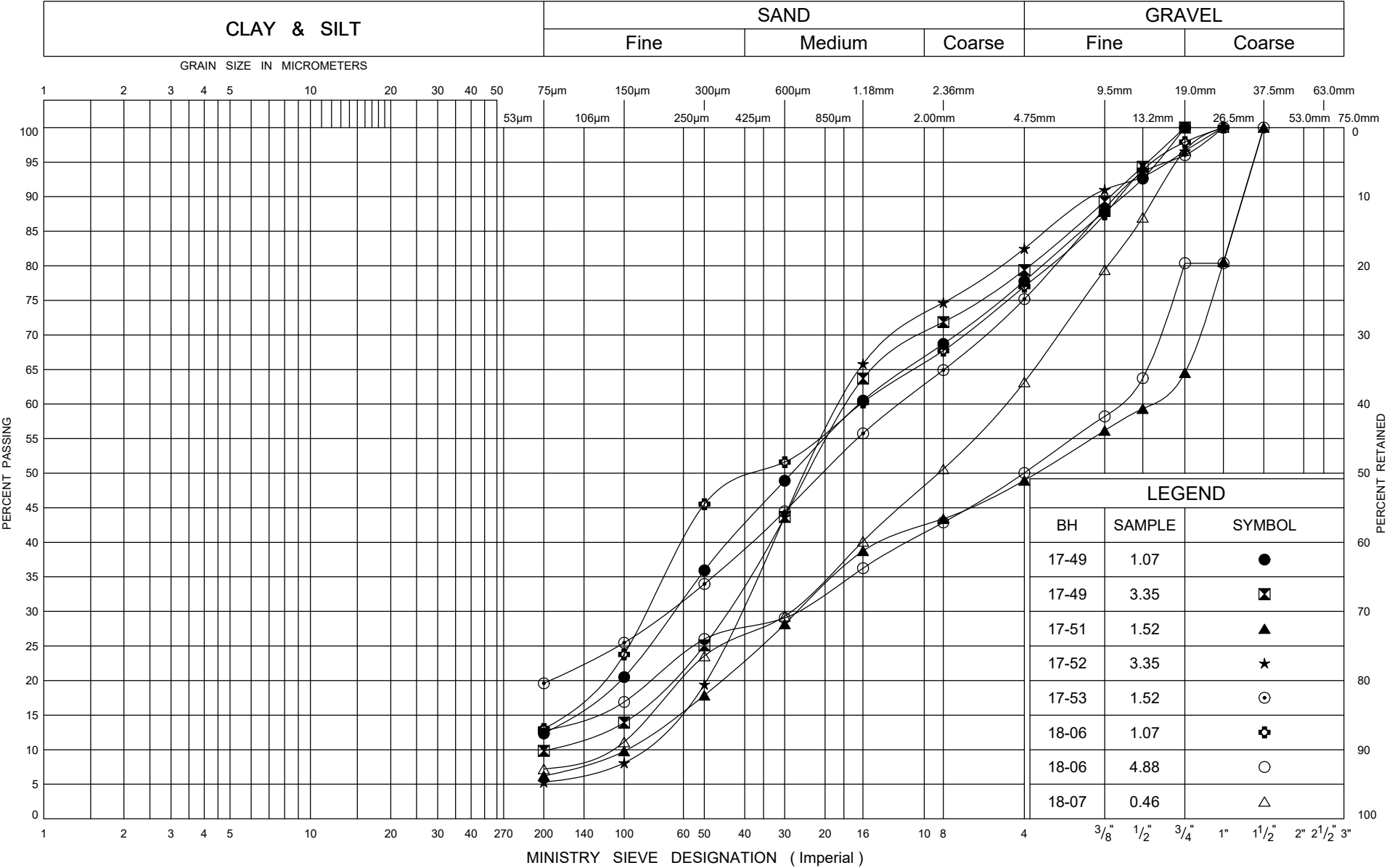
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
	Continued From Previous Page																
290.5			10	SS	34		291										
11.3	END OF BOREHOLE AT 11.3m. BOREHOLE OPEN TO 2.4m AND WATER LEVEL AT 2.4m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																



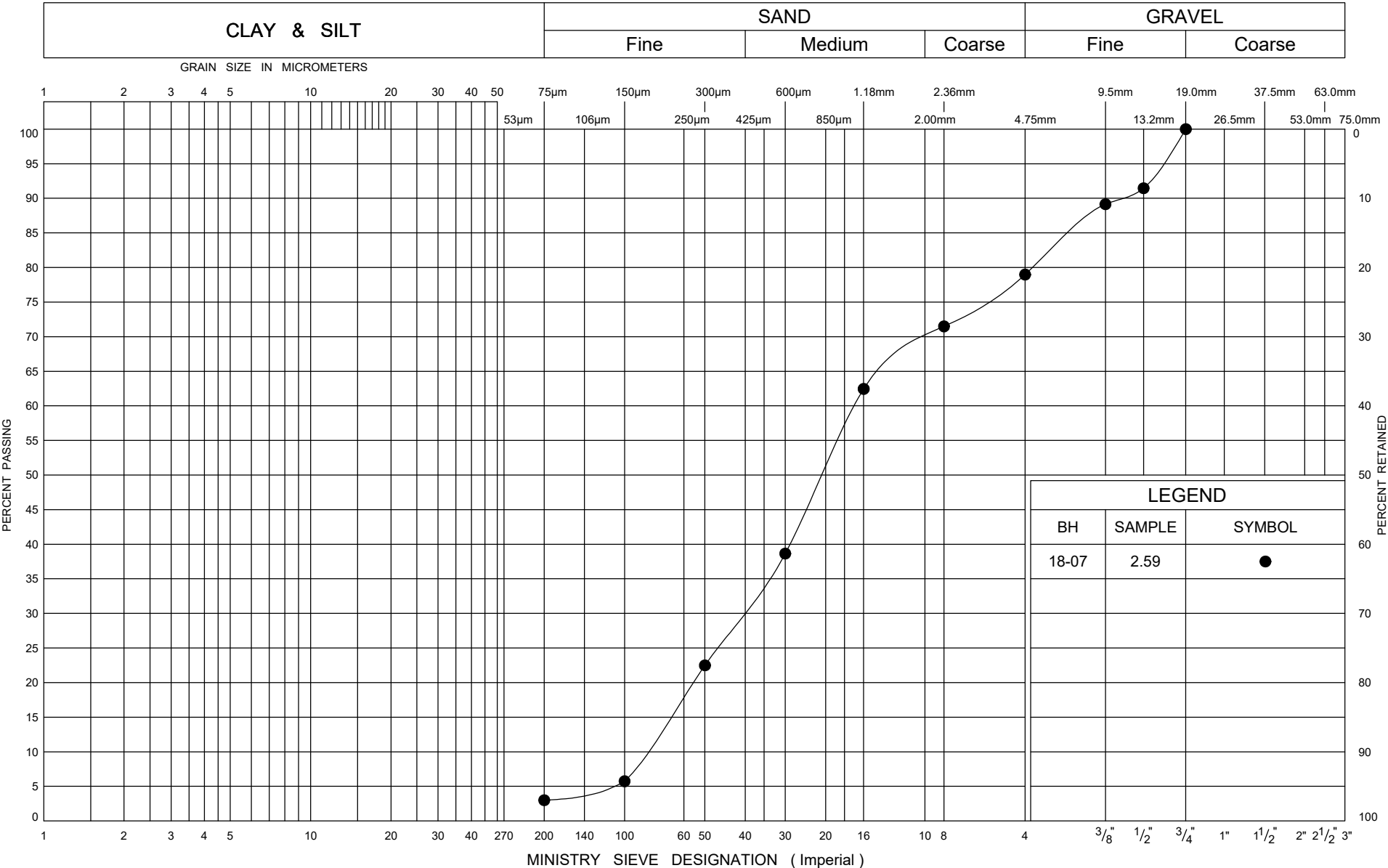
Appendix B

Laboratory Test Results

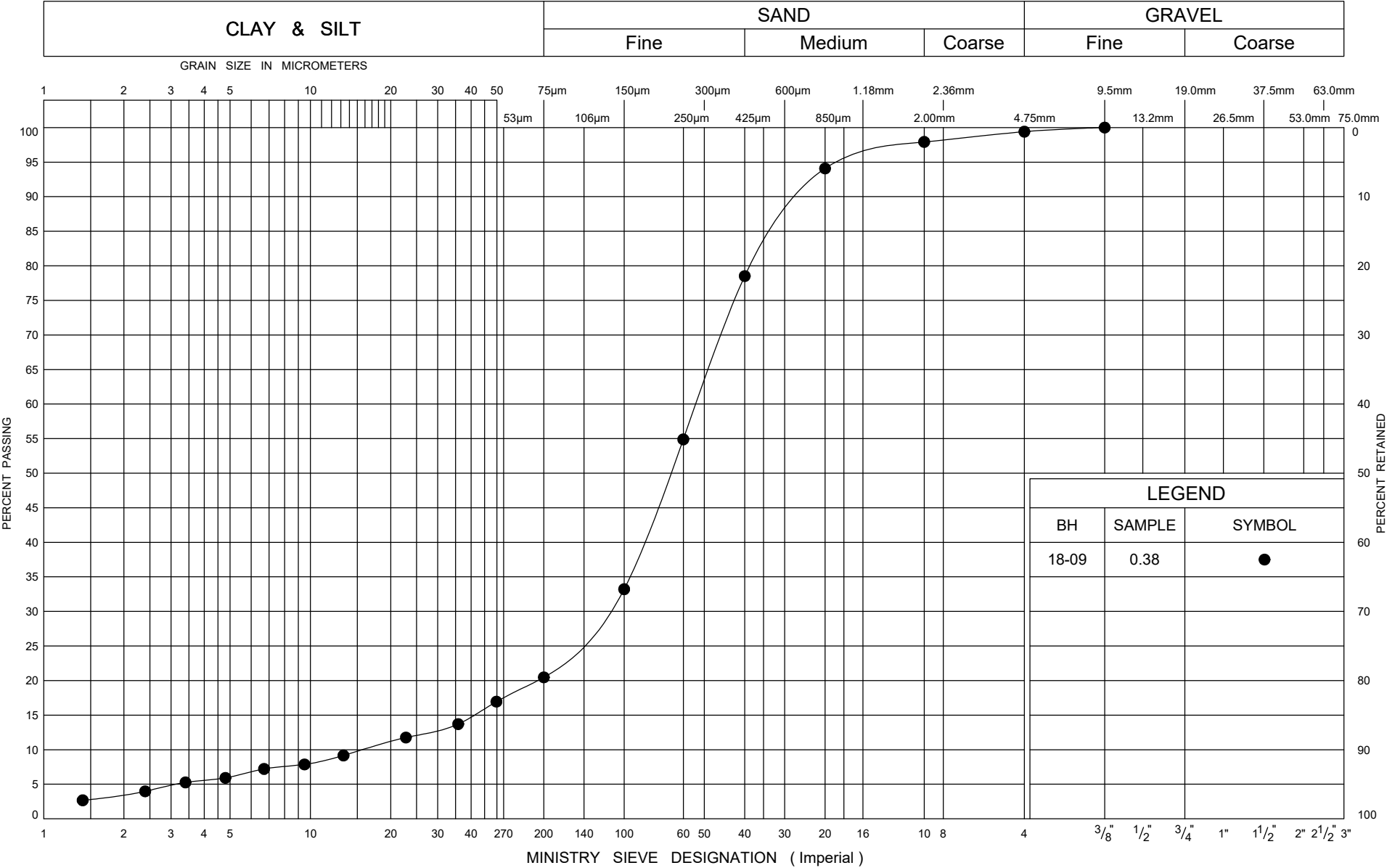
UNIFIED SOIL CLASSIFICATION SYSTEM



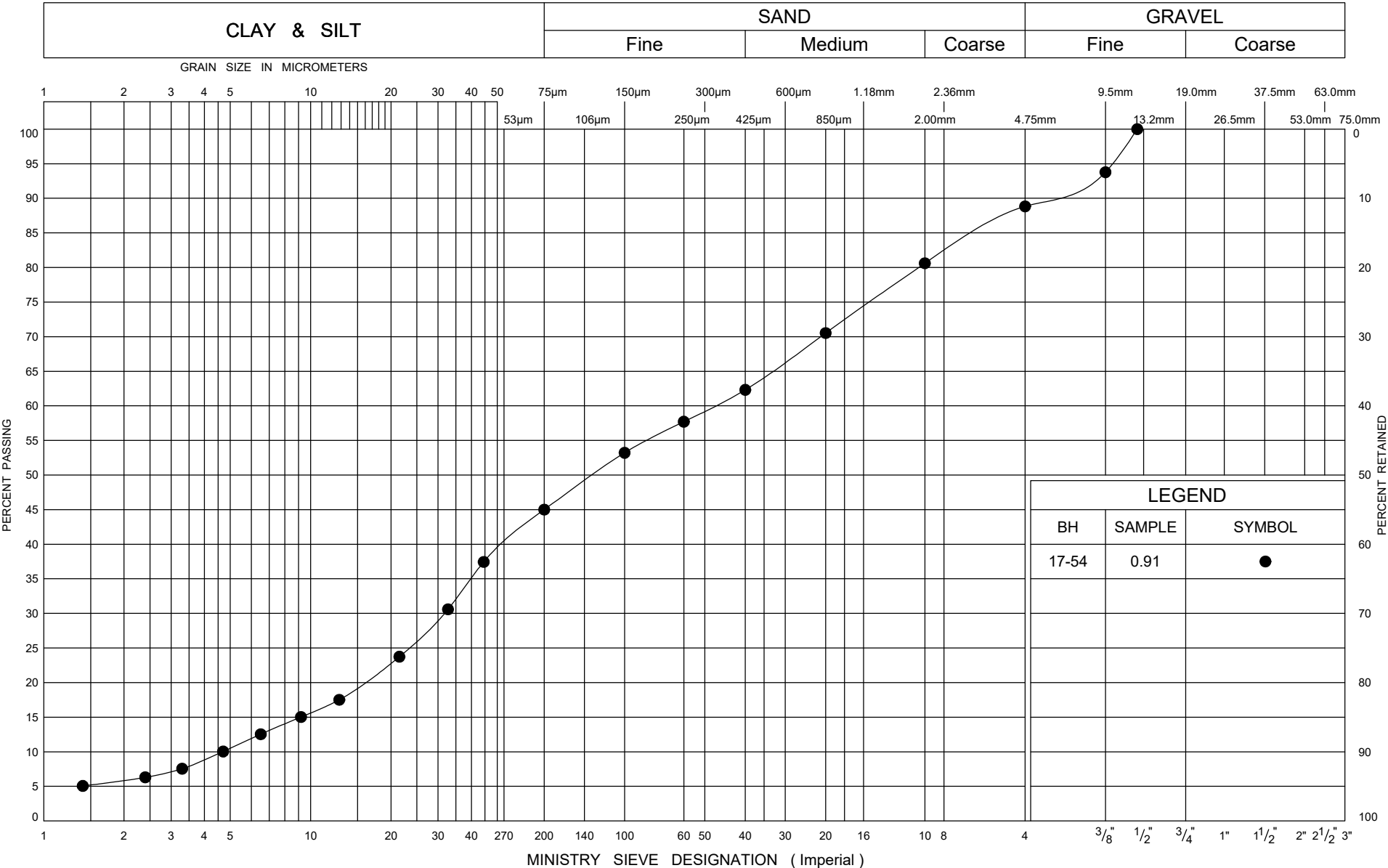
UNIFIED SOIL CLASSIFICATION SYSTEM



UNIFIED SOIL CLASSIFICATION SYSTEM



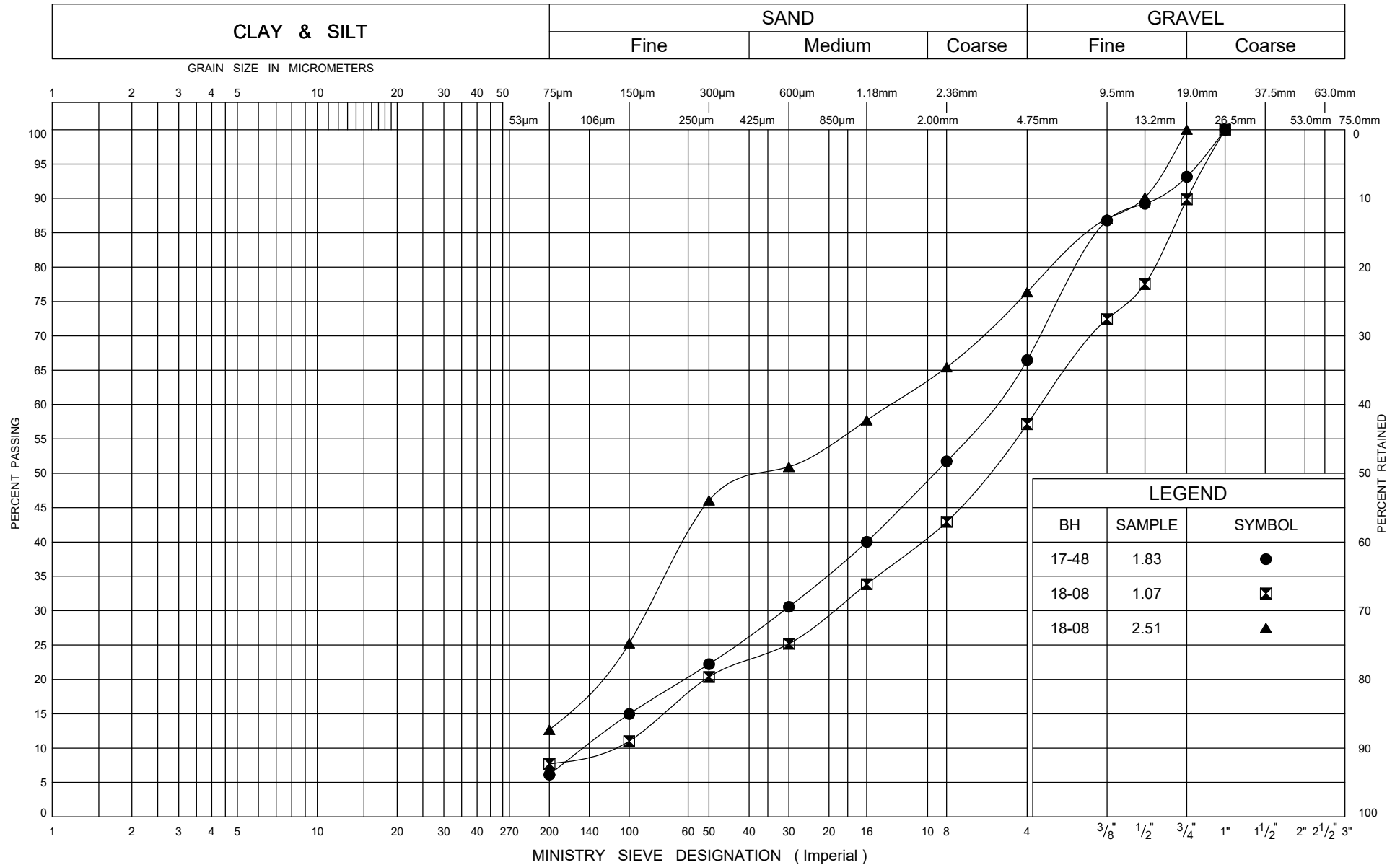
UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION
SAND and SILT

FIG No B4
W P 6802-14-01
Camroad Creek Culvert

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation

GRAIN SIZE DISTRIBUTION

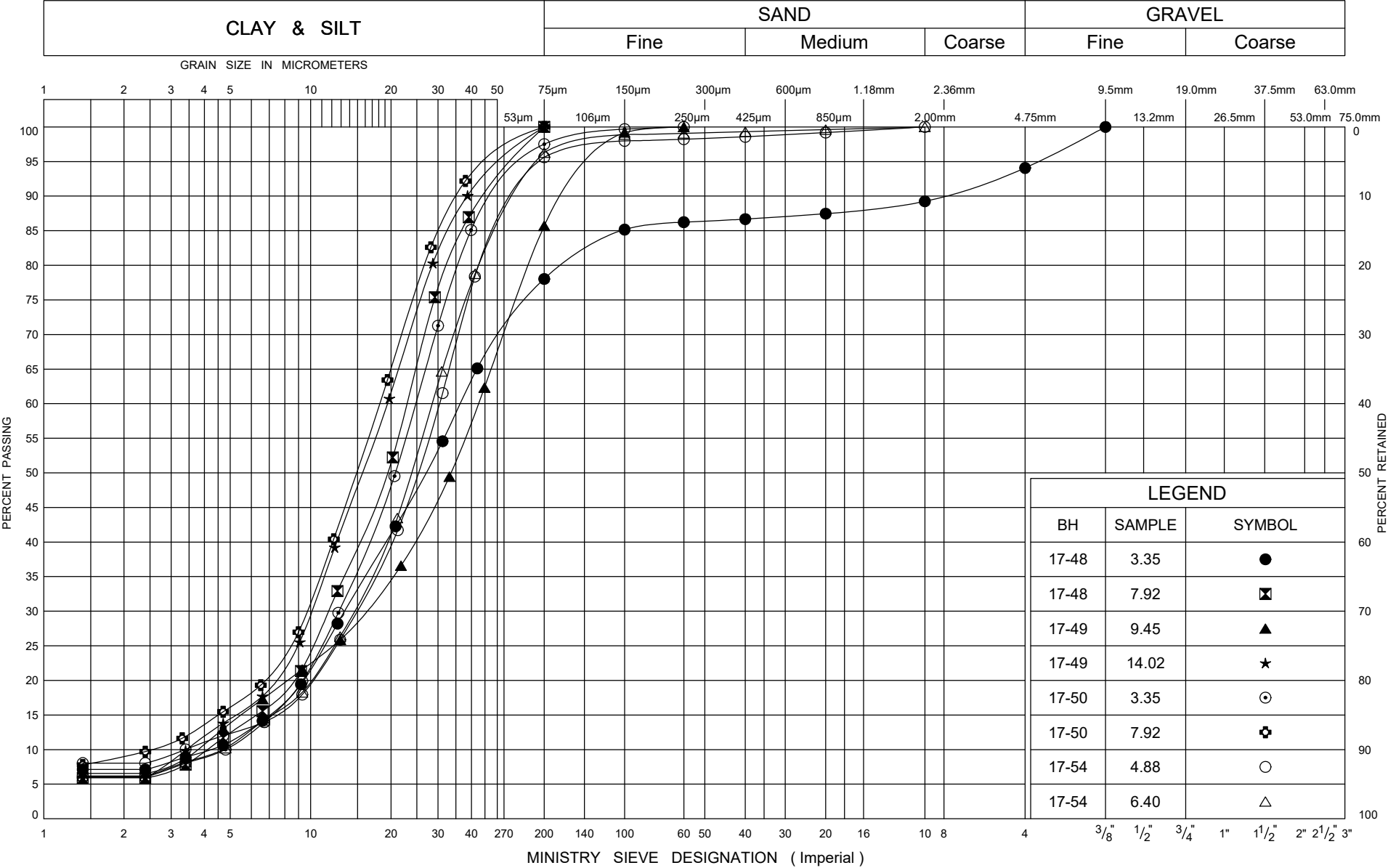
SAND and GRAVEL to Gravelly SAND

FIG No B5

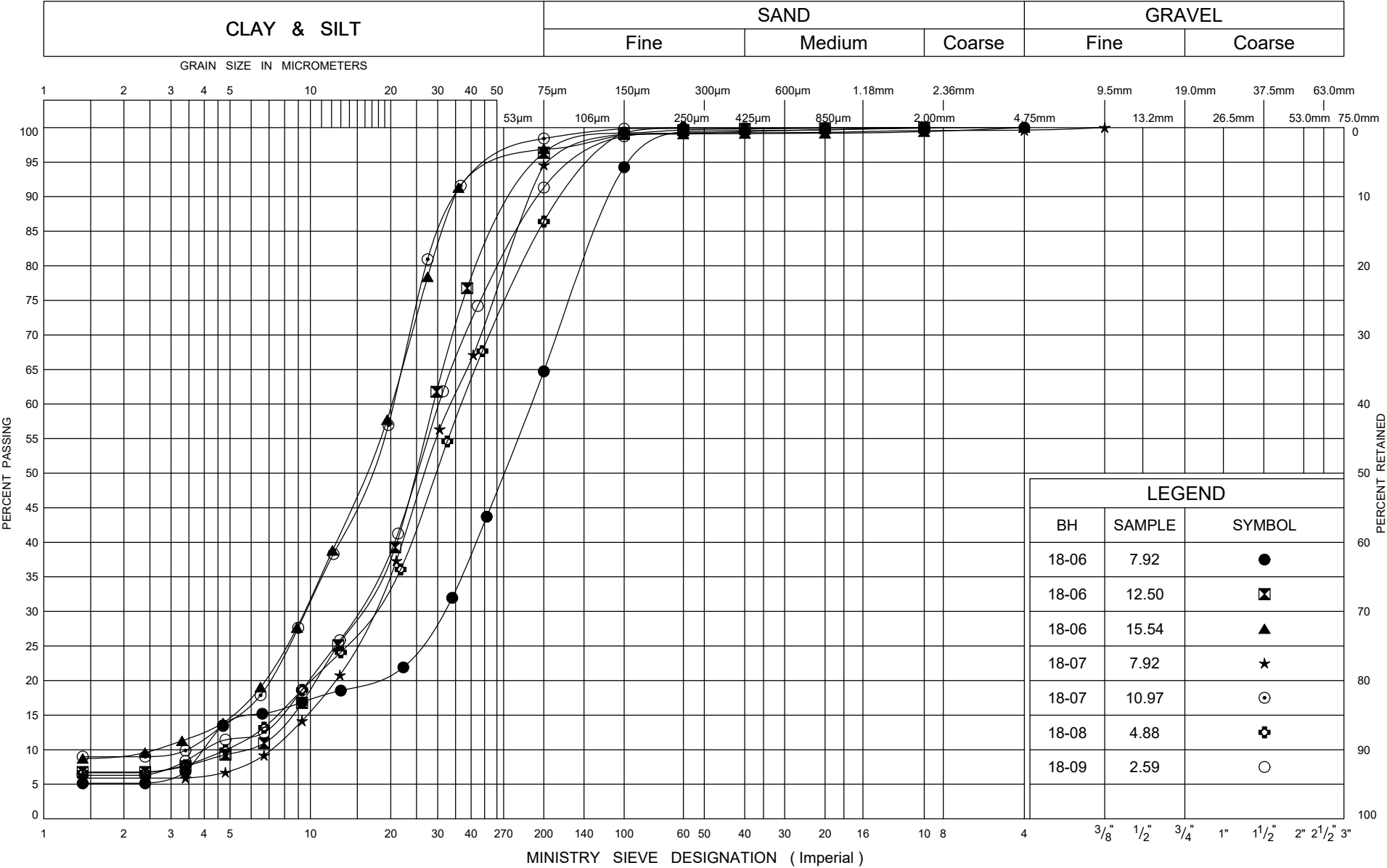
W P 6802-14-01

Camroad Creek Culvert

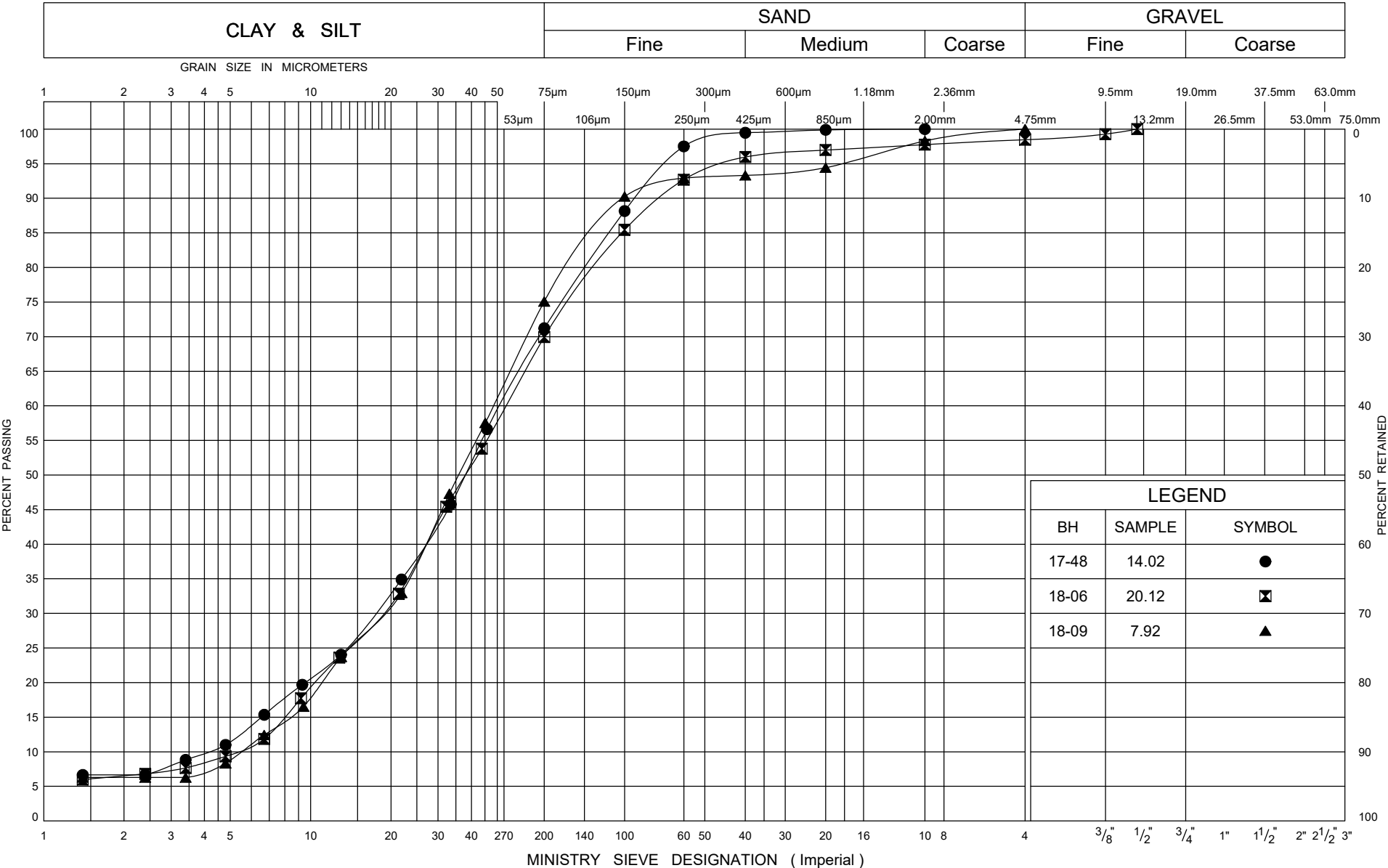
UNIFIED SOIL CLASSIFICATION SYSTEM



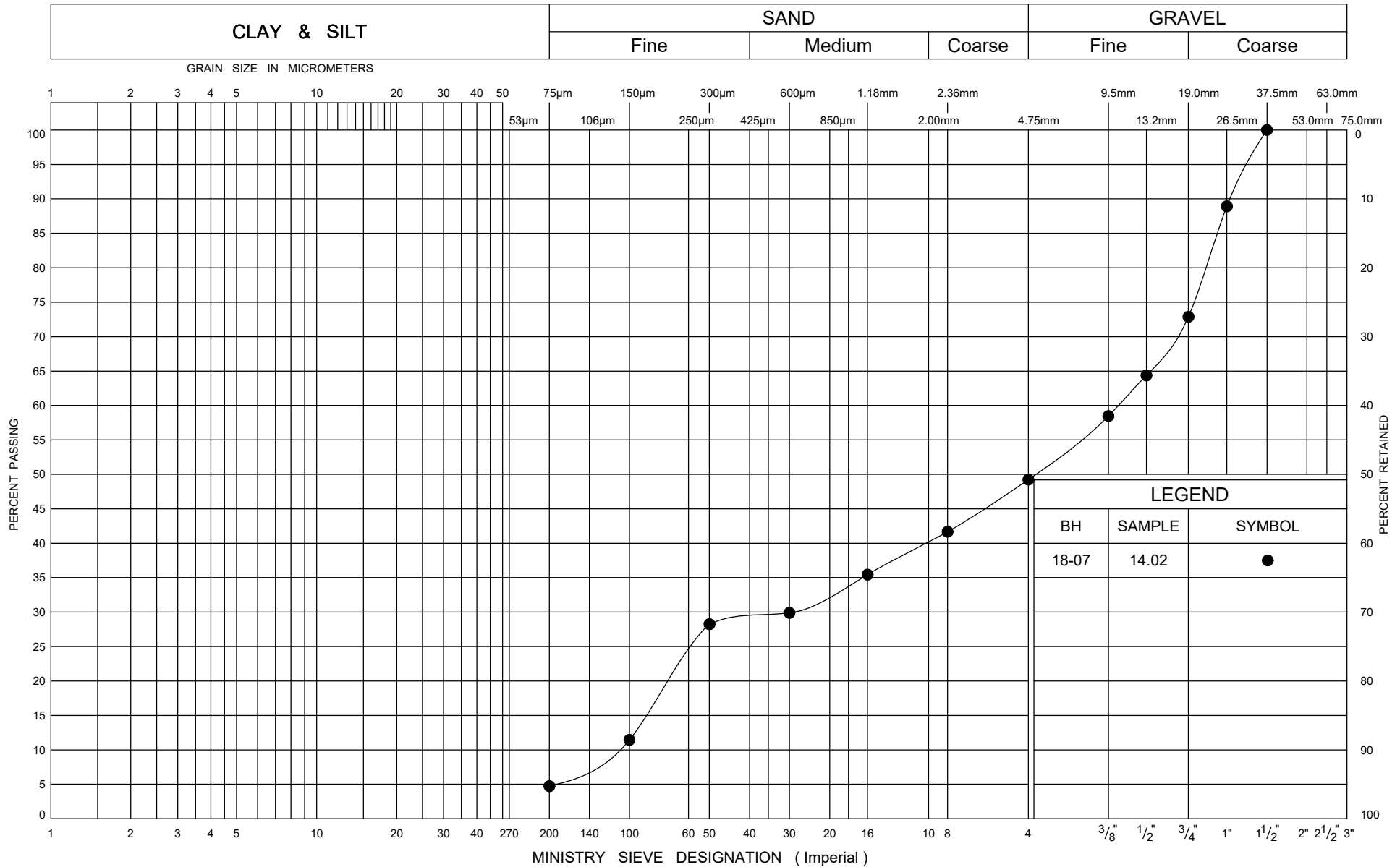
UNIFIED SOIL CLASSIFICATION SYSTEM



UNIFIED SOIL CLASSIFICATION SYSTEM



UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation

GRAIN SIZE DISTRIBUTION

SAND and GRAVEL

FIG No B9

W P 6802-14-01

Camroad Creek Culvert



ASTM D5731-08

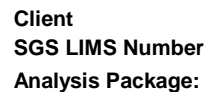
Date Drilled:	June 20/18
Date Tested:	July 5/18
Tester:	RT
Reviewed by:	MEF

[illegible]



Photo 1: Borehole 18-07 Bedrock Core Sample

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



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

Sample ID	Unit	BH-49, SS#6, 15'-17'
-----------	------	-------------------------

Sample Date/Time		26-Aug-17
Moisture	%	3.5
pH	no unit	9.65
Corrosivity Index	none	3.0
Soil Redox Potential	mV	243
Sulphide	mg/L	<0.02
Chloride	mg/L	160
Sulphate	mg/L	15
Conductivity	uS/cm	322
Resistivity (calculated)	ohms.cm	3110

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

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.

Certificate of Analysis

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



Client
SGS LIMS Number
Analysis Package:

Attention: Cory Zanatta
Project#: North Superior Lake Area
Thurber Engineering Ltd.
CA15830-AUG17
Corrosivity (Solution)

Sample ID Unit Camproad Creek

Sample Date/Time 27-Aug-17

Moisture	%	NA
pH	no unit	7.91
Corrosivity Index	none	NA
Redox Potential	mV	250
Sulphide	mg/L	<0.006
Chloride	mg/L	31
Sulphate	mg/L	2.3
Conductivity	uS/cm	243
Resistivity (calculated)	ohms.cm	4120

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

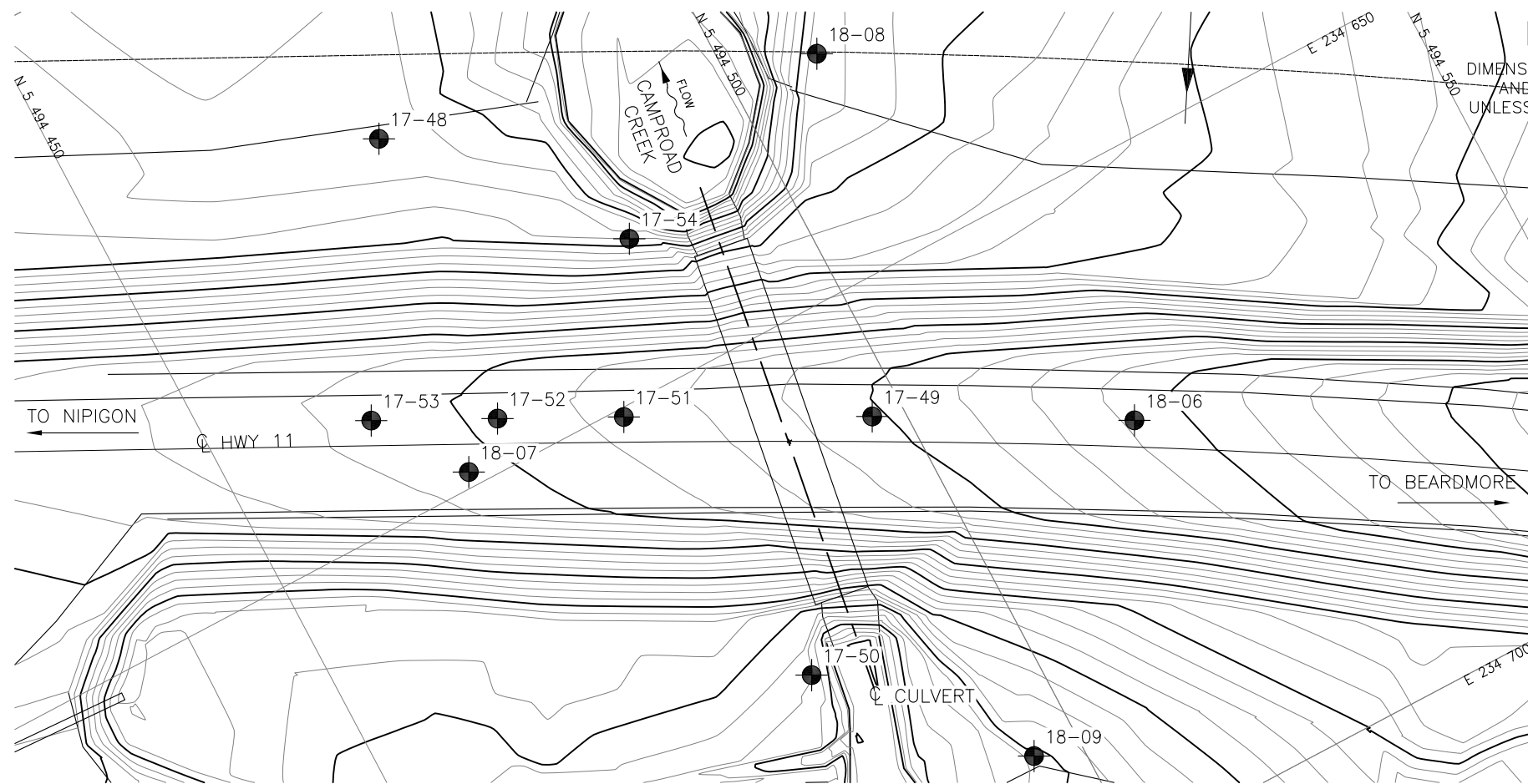
Deanna Edwards B.Sc., C.Chem
Project Specialist
Environment, Health and Safety

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

PLAN

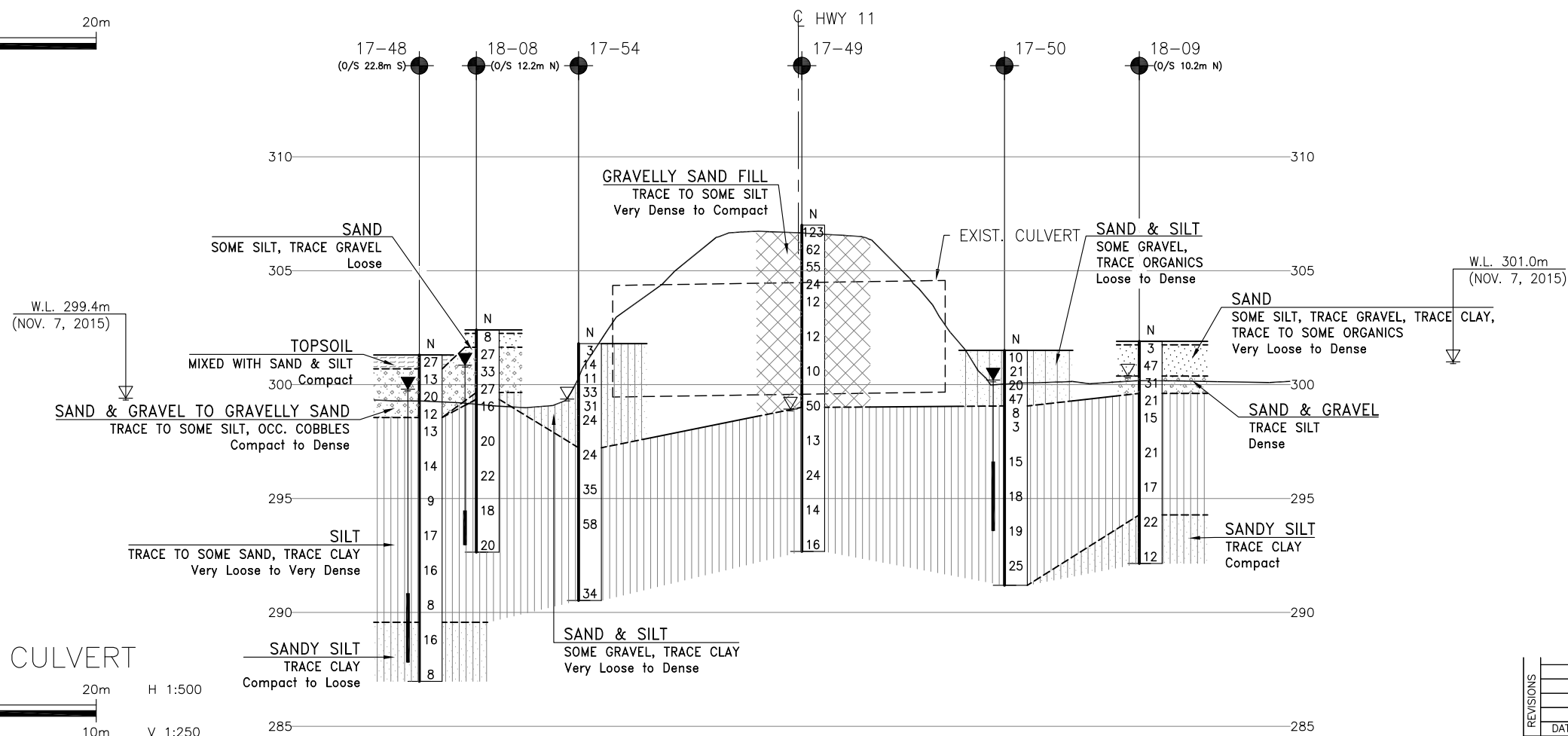


SECTION ALONG Q CULVERT

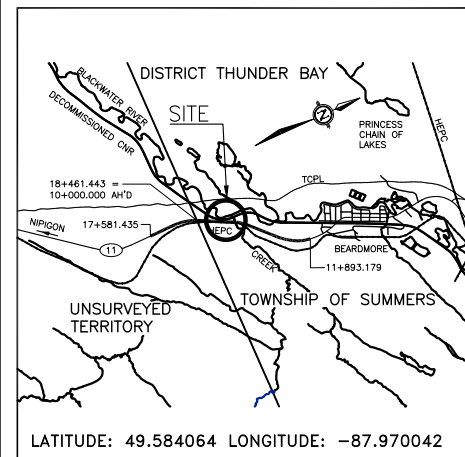


H 1:500

V 1:250

CONT No 2018-6015
WP No 6802-14-01HIGHWAY 11
CAMPROAD CREEK
CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA ISHEET
11

HATCH



LATITUDE: 49.584064 LONGITUDE: -87.970042

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

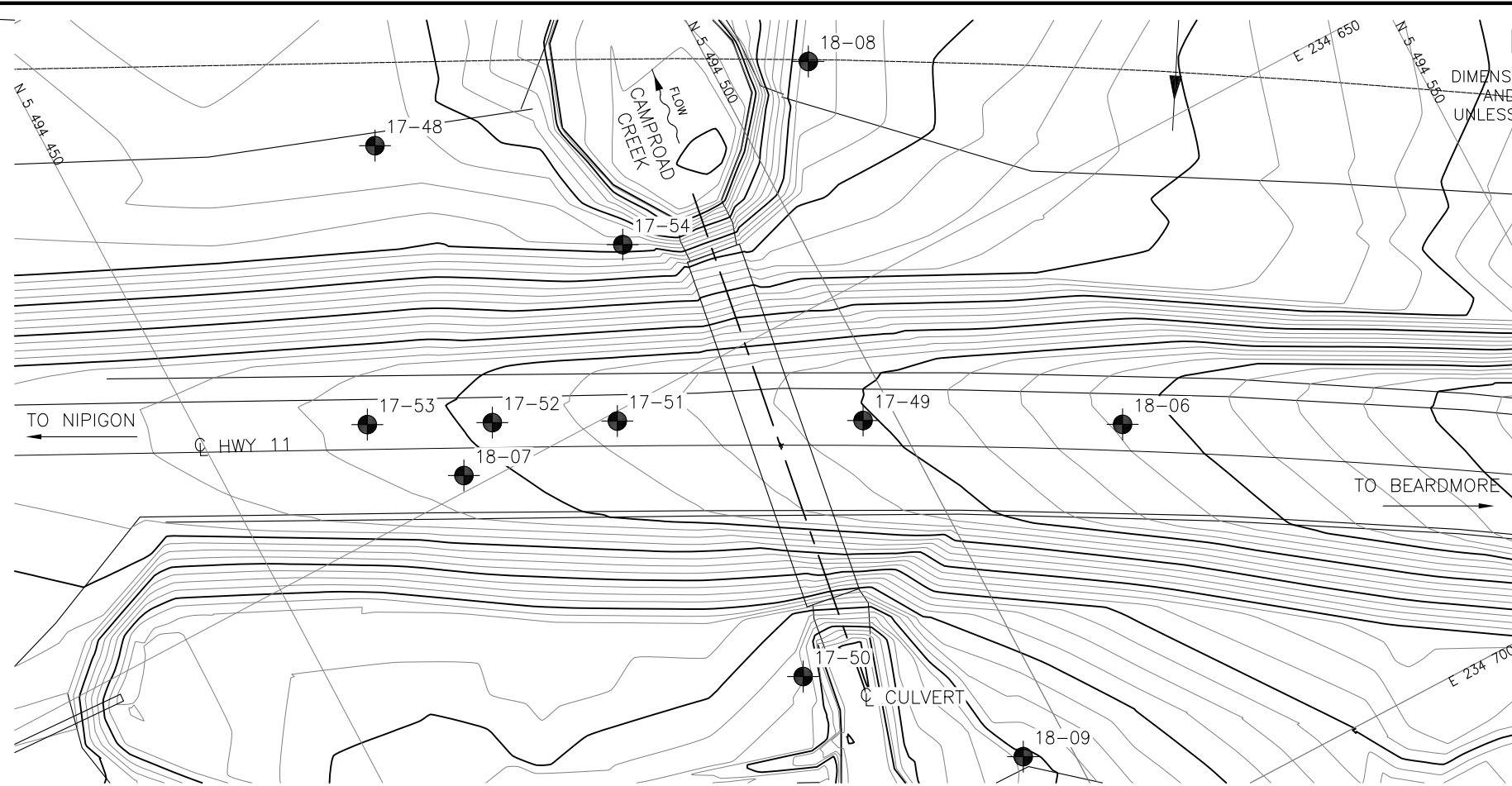
NO	ELEVATION	NORTHING	EASTING
17-48	301.3	5 494 473.3	234 622.2
17-49	307.0	5 494 497.5	234 659.9
17-50	301.5	5 494 483.7	234 675.7
17-51	306.3	5 494 480.1	234 650.7
17-52	306.1	5 494 471.3	234 646.1
17-53	305.8	5 494 462.3	234 641.6
17-54	301.8	5 494 487.1	234 638.4
18-06	307.8	5 494 515.7	234 669.9
18-07	305.9	5 494 467.3	234 648.8
18-08	302.4	5 494 507.1	234 632.4
18-09	301.9	5 494 496.3	234 689.6

-NOTES-

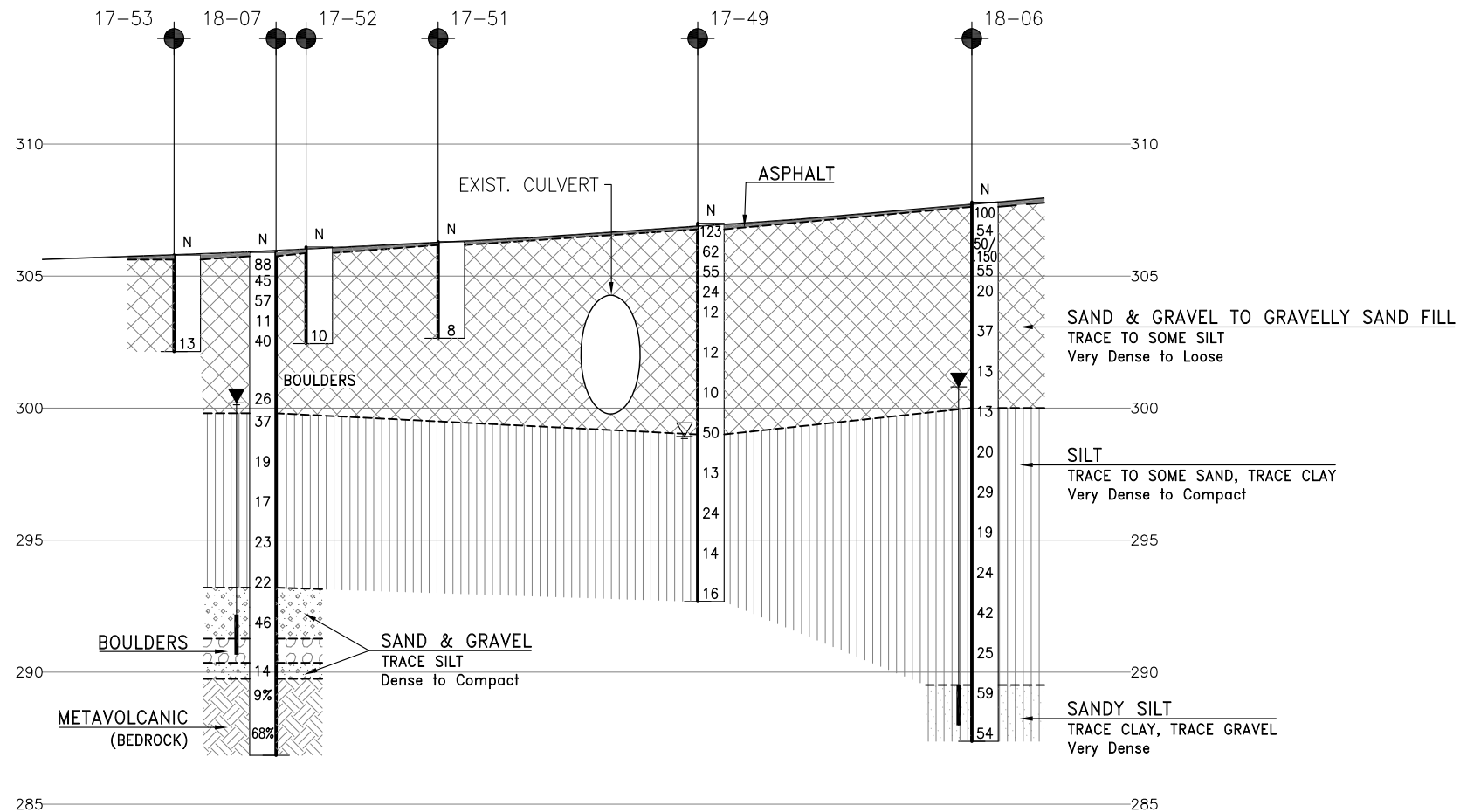
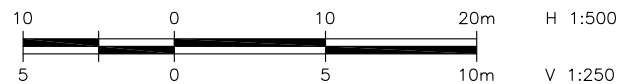
- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- 3) Coordinate system is MTM NAD 83 Zone 14.

GEOCREs No. 42E-30

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	CZ	CHK MEF	CODE
DRAWN	AN	CHK MEF	SITE 48C-179/C/STRUCT
			LOAD
			DATE
			NOV 2018
			DWG 2



SECTION ALONG C_L HWY 11



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

CONT No 2018-6015
WP No 6802-14-01

HIGHWAY 11
CAMPROAD CREEK
CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA II

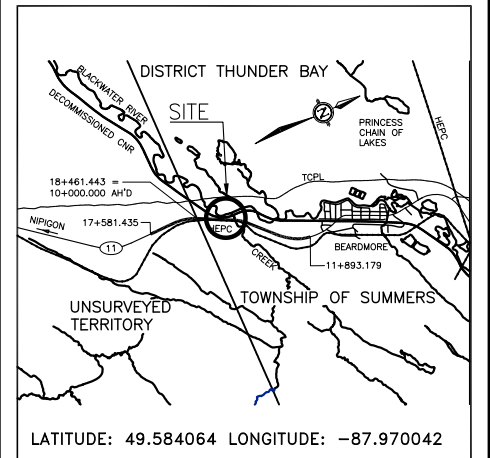


SHEET
12

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

NO	ELEVATION	NORTHING	EASTING
17-48	301.3	5 494 473.3	234 622.2
17-49	307.0	5 494 497.5	234 659.9
17-50	301.5	5 494 483.7	234 675.7
17-51	306.3	5 494 480.1	234 650.7
17-52	306.1	5 494 471.3	234 646.1
17-53	305.8	5 494 462.3	234 641.6
17-54	301.8	5 494 487.1	234 638.4
18-06	307.8	5 494 515.7	234 669.9
18-07	305.9	5 494 467.3	234 648.8
18-08	302.4	5 494 507.1	234 632.4
18-09	301.9	5 494 496.3	234 689.6

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. 42E-30

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	CZ	CHK MEF	CODE
DRAWN	AN	CHK MEF	SITE 48C-179/C/STRUCT
			LOAD
			DATE NOV 2018
			DWG 3



Appendix D

Site Photographs



Photo 1: Road approach looking north (taken June 27, 2017)



Photo 2: Road approach looking south (taken June 27, 2017)



Photo 3: Culvert inlet looking west (taken May 15, 2017)



Photo 4: Culvert barrel looking west (taken May 15, 2017)



Photo 5: Culvert outlet looking north (taken May 15, 2017)



Photo 6: East embankment looking south (inlet) (taken May 15, 2017)



Photo 7: East embankment looking north (inlet) (taken May 15, 2017)



Photo 8: West embankment looking south (outlet) (taken May 15, 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 401 (Construction Specification for Trenching, Backfilling and Compacting)
- OPSS PROV 421 (Construction Specification for Pipe Culvert Installation in Open Cut)
- OPSS PROV 501 (Construction Specification for Compacting)
- OPSS 511 (Construction Specification for Rip-Rap, Rock Protection, And Granular Sheeting)
- OPSS PROV 517 (Construction Specification for Dewatering)
- SP 517F01 Amendment to OPSS 517 (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 1005 (Material Specification for Aggregates – Streambed Material)
- OPSS PROV 1010 (Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material)
- OPSS PROV 1205 (Material Specification for Clay Seal)
- OPSS 1860 (Material Specification for Geotextiles)
- OPSD 802.010 (Flexible Pipe Embedment and Backfill, Earth Excavation)
- OPSD 802.014 (Flexible Pipe Embedment in Embankment)
- 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 will encounter obstructions such as cobbles and boulders embedded in the fill and native soils. Such obstructions may impede excavation progress and/or sheet pile installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions to achieve the design depths. Vibrating equipment is not permitted for installation and removal of sheet piles.

- **Suggested Text for NSSP on Dewatering**

Dewatering will be required to install the new culvert and the diversion pipe in the dry. The design 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 preconstruction survey is not required. 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 Temporary Modular Bridge**

The Contractor is responsible for the detailed design of the Temporary Modular Bridge (TMB) including, but not limited to, slope stability of the temporary excavation slope in front of the TMB abutment footings, determination of bearing capacity for the abutment footings and safe footing set back distance from the open excavation, as well as the performance of the temporary footings throughout construction. As a minimum, modular bridge footings shall be set back a minimum two (2) metres from the top of the temporary excavation. The temporary excavation slope shall be no steeper than two (2) horizontal to one (1) vertical with full dewatering to 500 mm below the final base of the temporary excavation for the duration of time when the temporary modular bridge is in use. The contractor is responsible for retaining a RAQS approved Licensed Geotechnical Engineer with a medium-complexity rating (RAQS Category – Geotechnical Structures and Embankment – Medium Complexity) to confirm all aspects of the modular bridge slope stability and foundation design. All final reports and



drawings must be sealed and signed by a Professional Engineer, who shall also be a RAQs Designated Contact.



Appendix F

Stability Analysis Figures

FIGURE 1 - STATIC STABILITY ANALYSIS CAMPROAD CREEK CULVERT EXCAVATION - 2H:1V LONG-TERM CONDITION

File Name: 15595 -Camroad LT 2m setback-2-1-0.8m ftg depth.gsz

Created By: Geoff Lay

Date: 11/05/2018

Method: Morgenstern-Price

Minimum Slip Surface Depth: 0.1 m

Seismic: 0

Sand and Silt - Loose to Dense 21 kN/m³ 0 kPa 32 °

Silt - Compact 20 kN/m³ 0 kPa 30 °

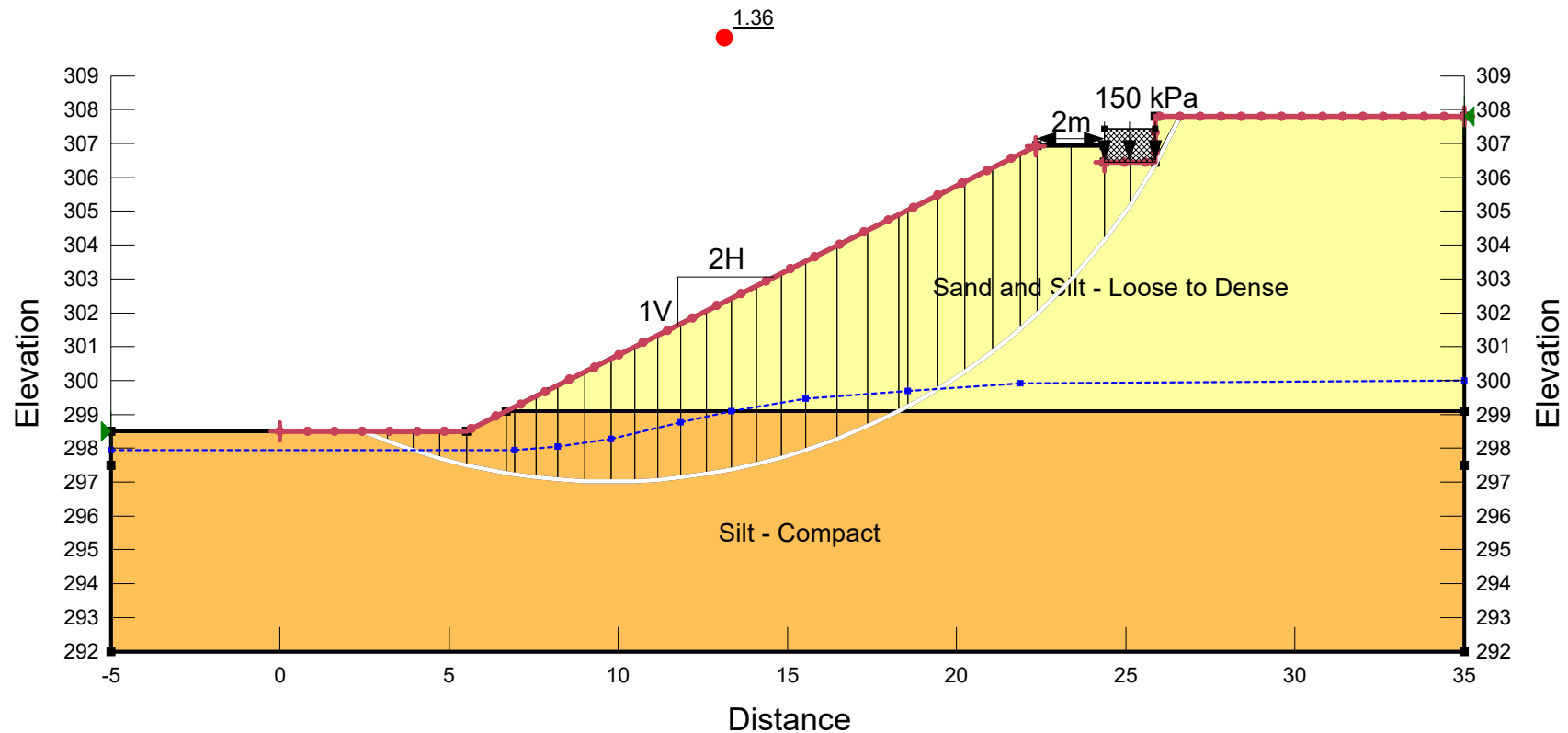
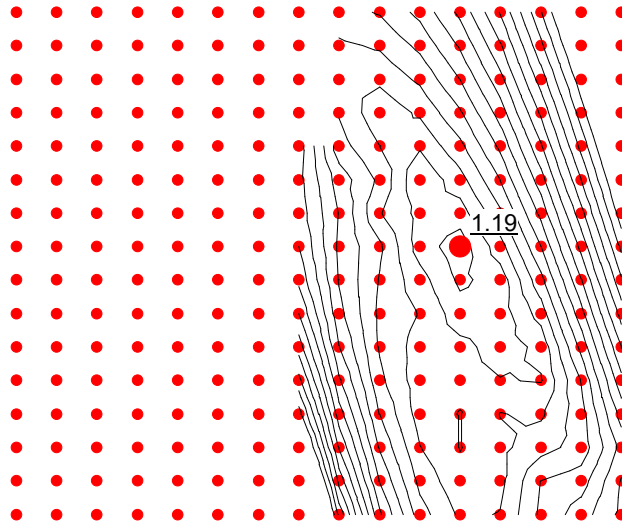


FIGURE 2 - STATIC STABILITY ANALYSIS CAMROAD CULVERT EXCAVATION - 1.5H:1V LONG-TERM CONDITION



File Name: 15595 -Camroad Culvert Excavation LT 2m setback-1.5-1.gsz
Created By: Geoff Lay
Date: 7/20/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0

Sand and Silt - Loose to Dense 21 kN/m³ 0 kPa 32 °
Silt - Compact 20 kN/m³ 0 kPa 30 °

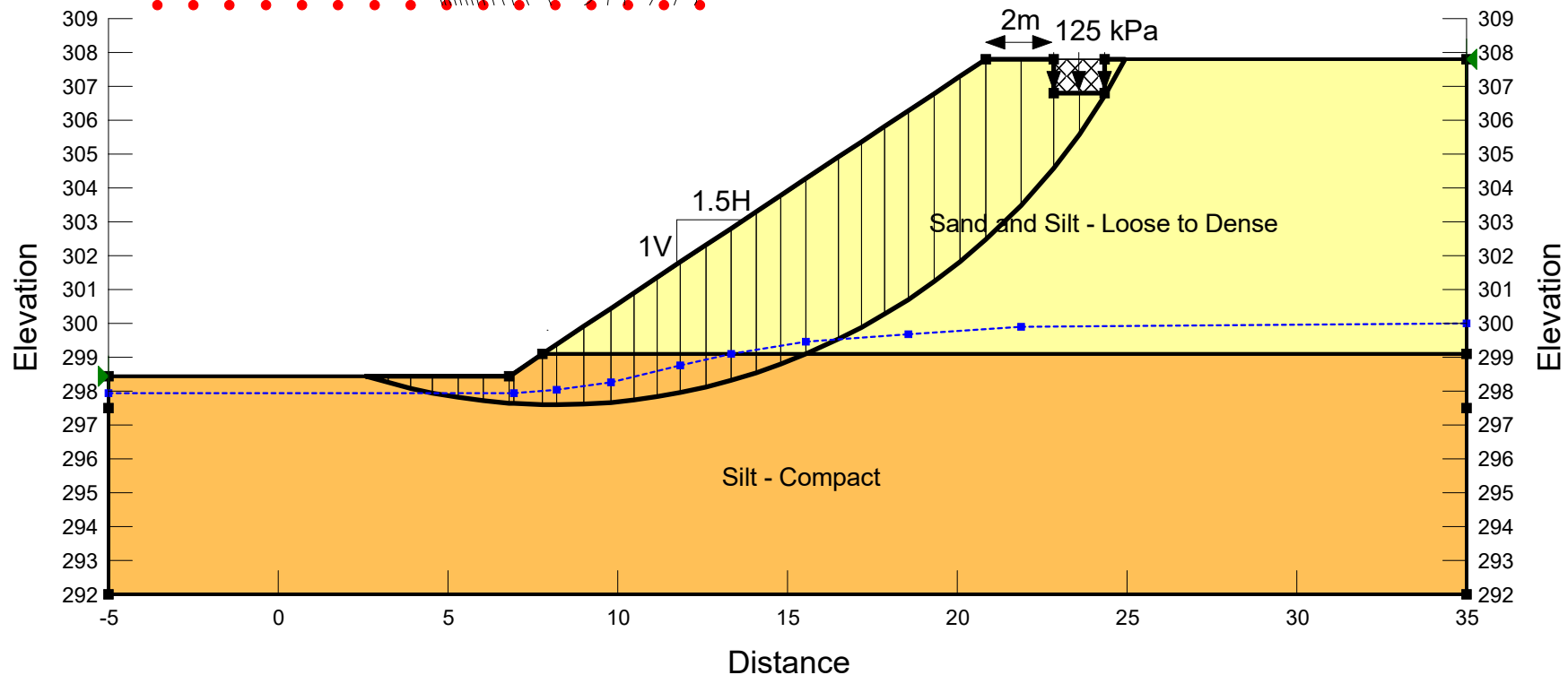


FIGURE 3 - STATIC STABILITY ANALYSIS CAMROAD CREEK CULVERT EXCAVATION - 2H:1V RAISED INVERT & LESS SIDEFILL & PIPE INSTALL /REMOVAL, LONG-TERM CONDITION

File Name: 15595 -Camroad LT 2m setback-2-1-0.8m ftg depth-with pipe removal-revised.gsz
Created By: Geoff Lay
Date: 11/05/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 0.1 m
Seismic: 0

Sand and Silt - Loose to Dense 21 kN/m³ 0 kPa 32 °
Silt - Compact 20 kN/m³ 0 kPa 30 °

