



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
BAYFIELD RIVER BRIDGE REPLACEMENT
HIGHWAY 21, SITE 12-188
BAYFIELD, ONTARIO
GWP 3070-11-00**

GEOCRES NO. 40P12-37

**Latitude : 43.5689
Longitude : - 81.6985**

Report

to

McIntosh Perry

**Date: March 19, 2019
File: 17127**



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PART 1 FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a geotechnical investigation conducted by Thurber Engineering Ltd. (Thurber) for the proposed replacement of the Highway 21 Bayfield River Bridge located over the Bayfield River at the Town of Bayfield, Ontario.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide borehole location and soil strata drawings with stratigraphic profiles and drawings, records of boreholes, laboratory test results and a description of the subsurface conditions. A model of the subsurface conditions was developed for the site based on the data obtained from the present and previous investigations.

Thurber was retained by McIntosh Perry Consulting Engineers (MP) to carry out this foundation investigation under the MTO Assignment Number 3016-E-0002.

During the preparation of this report and in addition to the boreholes drilled, reference has been made to information on subsurface conditions contained in a previous foundation report for the site. The title of this report is listed below:

- Preliminary Foundation Investigation and Design Report, Highway 21/Bayfield River Bridge Replacement, Site Number 12-188, Highways 401, 4 and 21 Structural Replacements, GWP 3070-11-00, Assignment No. 3 (3011-E-0048), prepared for the Ministry of Transportation, Ontario – West Region by Golder Associates Ltd., Geocres No. 40P-12-34, dated October 2016 (Reference 1).

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2 SITE DESCRIPTION

The Bayfield River Bridge is located near the northerly limits of the Town of Bayfield, Ontario.

The existing bridge carries Highway 21 over the Bayfield River. It is approximately 60 m long and 12 m wide, and consists of two spans supported by two abutments and a central pier in the river. Existing design information indicates that the footings are founded at approximate Elevation 173.8m. Highway 21 at the bridge location is a two-lane undivided highway with a sidewalk on one side and a narrow shoulder on the other side.

The Bayfield River flows in a northerly direction into Lake Huron. The northeast and southeast quadrants adjacent to the bridge approaches are moderately to densely vegetated with trees, shrubs and grass. A private and a publicly operated marina occupies the northwest and southwest quadrants, respectively. Selected photographs of the bridge and its immediate surroundings are presented in Appendix C.

From published geological information, the site is situated within the physiographic region known as the Huron Slope, which is characterized by a deposit of clayey silt till. In the vicinity of the river valley, alluvial deposits of gravel, sand and silt as well as glacial outwash deposits of sand and gravel are present. The site is underlain by limestone of the Dundee Formation. Available information indicates that the bedrock surface is in the order of 20 m below highway grade at this site.

3 INVESTIGATION PROCEDURES

The site investigation and field testing for this project were carried out in two phases. Phase 1 was carried out over water on a barge between August 29 and September 14, 2017 during which time five boreholes were advanced to depths ranging from 7.3 m to 11.1 m below the barge deck surface. Boreholes 17-08, 17-09, 17-14 and 17-15 were advanced to address cofferdam design where required, while Borehole 17-04 was drilled to address pier foundation design of the temporary east detour bridge.

Phase 2 was carried out on land between June 26 and July 24, 2018 during which time sixteen boreholes were advanced to depths ranging from 1.9 m to 28.6 m below ground surface. Boreholes 18-01, 18-02 and 18-03 were drilled near the proposed replacement south abutment and approach, while Boreholes 18-05, 18-06 and 18-07 were drilled near the proposed replacement north abutment and approach. Boreholes 18-18 and 18-19 were drilled near the south abutment of the temporary west detour, while Boreholes 18-20 and 18-21 were drilled near



the north abutment of the temporary west detour. Boreholes 18-10 and 18-11 were advanced to address embankment widening and possible retaining walls on the west side of the north approach. The remaining boreholes were advanced to address the east detour abutments and approaches. The approximate locations of all the boreholes are shown on the Borehole Location Plan and Stratigraphic Drawings in Appendix D.

The as-drilled northing and easting co-ordinates of all the boreholes have been established by Thurber in the field using in-house GPS units. For the boreholes on land, the corresponding ground surface elevations were provided by MP based on the project topographic survey database. For the in-water boreholes, the elevations were based on the river water level at the time of the investigation. The precision of the horizontal survey of the boreholes on land is rated at within 1 m, whereas the precision of the elevation is the same as that of the project topographic survey. For the in-water boreholes, the accuracy of the borehole survey data would likely be lesser due to the moving targets.

The in-water boreholes were advanced using a tripod rig mounted on a barge supplied and operated by Forage M3 Drilling of Hawkesbury, Ontario. All on-land boreholes were advanced by using a Diedrich D53 track-mounted drill rig or a tripod rig supplied and operated by Walker Drilling Ltd. of Utopia, Ontario. Hollow stem augers were used in conjunction with the track-mounted drill rig, while wash boring with NW casing were used in conjunction with the tripod rigs. In all boreholes, soil samples were obtained using a 50 mm outside diameter split-spoon sampler driven in conjunction with the Standard Penetration Test (SPT). Bedrock core samples were recovered in selected boreholes using rotary core drilling techniques and NQ size core barrel.

Groundwater conditions were observed in the open boreholes throughout the drilling operations. Standpipe piezometers were installed in selected boreholes to permit monitoring of the groundwater levels at the site. A piezometer consisted of a 25 mm diameter PVC pipe with a slotted screen sealed at a selected depth within the borehole. The boreholes with no piezometer installations were backfilled in general accordance with Ontario Regulation 903 (O.Reg. 903). After obtaining the final water level readings, all piezometer installations were decommissioned in general accordance with O.Reg. 903.

The details of borehole completion and standpipe piezometer installations are summarized in Table 3.1 below.



Table 3.1 Borehole Completion Details

Borehole No.	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Tip Elevation (m)	Completion Details
17-04	11.1* / 166.2	None installed	Borehole backfilled with bentonite holeplug and cuttings to surface.
17-08	7.3* / 170.0	None installed	Borehole backfilled with bentonite holeplug and cuttings to surface.
17-09	9.8* / 167.5	None installed	Borehole backfilled with bentonite holeplug and cuttings to surface.
17-14	7.8* / 169.5	None installed	Borehole backfilled with bentonite holeplug and cuttings to surface.
17-15	7.3* / 170.0	None installed	Borehole backfilled with bentonite holeplug and cuttings to surface.
18-01	11.3 / 174.5	None installed	Borehole backfilled with bentonite holeplug and cuttings to surface.
18-02	25.4 / 160.3	16.8 / 168.9	Backfilled with filter sand from 25.4 to 13.1m, bentonite holeplug from 13.1 to surface.
18-03	24.3 / 161.4	None installed	Borehole backfilled with bentonite holeplug and cuttings to surface.
18-05	28.6 / 157.1	None installed	Borehole backfilled with bentonite holeplug and cuttings to surface.
18-06	25.9 / 159.8	18.2 / 167.5	Backfilled with filter sand from 25.9 to 14.7m, bentonite holeplug from 14.7 to surface.
18-07	11.3 / 174.4	None installed	Borehole backfilled with bentonite holeplug and cuttings to surface.
18-10	10.1 / 168.8	None installed	Borehole backfilled with bentonite holeplug and cuttings to surface.
18-11	6.2 / 172.6	None installed	Borehole backfilled with bentonite holeplug and cuttings to surface.
18-12	5.2 / 176.8	None installed	Borehole backfilled with bentonite holeplug and cuttings to surface.
18-13	1.9 / 179.3	None installed	Borehole backfilled with bentonite holeplug and cuttings to surface.
18-16	8.2 / 172.0	None installed	Borehole backfilled with bentonite holeplug and cuttings to surface.
18-17	16.1 / 168.7	None installed	Borehole backfilled with bentonite holeplug and cuttings to surface.
18-18	10.1 / 170.7	None installed	Borehole backfilled with bentonite holeplug and cuttings to surface.
18-19	15.1 / 164.8	10.6 / 169.3	Backfilled with filter sand from 15.1 to 7.0 m, bentonite holeplug from 7.0 to surface.



Borehole No.	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Tip Elevation (m)	Completion Details
18-20	14.3 / 164.2	10.7 / 167.8	Backfilled with filter sand from 14.3 to 7.0 m, bentonite holeplug from 7.0 to surface.
18-21	8.5 / 169.8	None installed	Borehole backfilled with bentonite holeplug and cuttings to surface.

* Below barge deck surface

The field investigation was supervised on a full-time basis by a member of Thurber's technical staff who marked/staked the boreholes in the field, arranged for the clearance of subsurface utilities, 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.

4 LABORATORY TESTING

Routine laboratory testing was carried out at Thurber's laboratory. The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size analysis and Atterberg Limits testing. Point Load Testing was carried out on selected rock cores for estimating the unconfined compressive strength of intact rock. Unconfined Compression Tests were carried out on four selected intact rock cores. Results of the laboratory testing of the present investigation are summarized on the Record of Borehole sheets and presented on the figures included 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 and on the Borehole Locations and Soil Strata drawings in Appendix D. A general description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions. It must be recognized that soil conditions may vary between and beyond the borehole locations. The following descriptions are based on borehole information obtained during the present investigation.

In general, the subsurface stratigraphy below the sand and gravel or silty clay embankment fill consists of a layer native sand and gravel to sandy gravel overlying clayey silt to silty clay till. Below the river, silt to silty sand sediments overlie the sand and gravel to sandy gravel layer which



is underlain by sandy silt to clayey silt till. The site is underlain by limestone bedrock. More detailed descriptions of the individual stratum are presented below.

5.1 Asphalt

Asphalt was encountered in Boreholes 18-01 to 18-03, and 18-05 to 18-07 with measured thickness of 25 to 75 mm.

5.2 Rock Fill

A 0.8 m thick surficial layer of rock fill was encountered at ground surface in Borehole 18-18.

5.3 Concrete

A 200 mm thick layer of concrete was encountered below the asphalt in Borehole 18-05, which has likely penetrated the existing approach slab at this location.

5.4 Topsoil

Surficial topsoil with thickness varying between 50 and 75 mm was encountered at ground surface in Boreholes 18-13, 18-20 and 18-21.

5.5 River Bed Sediments

River bed sediments comprised of silt was encountered in Boreholes 17-04 and 17-14. The thickness of this deposit varies from 0.7 to 0.8 m. Measured SPT 'N' values in the silt layer ranged from 4 to 9 blows per 0.3 penetration indicating loose conditions. Measured moisture contents were at 42 percent and 62 percent.

5.6 Sand and Gravel to Sandy Gravel Fill

Sand and gravel to sandy gravel fill containing trace to some silt was encountered below the asphalt or concrete in Boreholes 18-01 to 18-03, 18-05 to 18-07, 18-10 and 18-18. The thickness of this cohesionless fill ranged from 1.3 m to 11.6 m. The base of this fill is located at between 1.4 m and 11.7 m depths, or Elevations 184.4 to 173.3 m.

SPT 'N' values varying from 2 blows to 64 per 0.3 m of penetration were recorded in this fill with typical values ranging between 10 blows and 45 blows. These values indicated typical compact to dense conditions with some very loose or very dense zones. Measured moisture contents within this fill varied between 3 percent and 20 percent.



The results of a grain size distribution analysis carried out on samples of this fill are presented on the Record of Borehole Sheets included in Appendix A and on Figure B1 of Appendix B. The results of the grain size distribution analysis are summarized below:

Soil Particle	Percentage (%)
Gravel	59 to 79
Sand	16 to 35
Silt & Clay	5 to 10

5.7 Sandy Silt to Silty Sand Fill

Layers of sandy silt to silty sand fill containing trace to some gravel and trace organics were encountered beneath the sand and gravel fill, topsoil or at ground surface in Boreholes 18-01, 18-10, 18-12 and 18-13. The thickness of this cohesionless fill ranged from 0.8 m to 1.4 m. The base of this fill is located at between 0.8 and 2.2 m depths, or Elevations 183.6 to 177.5 m.

SPT 'N' values ranging from 24 blows per 0.3 m of penetration to greater than 100 blows for less than 0.3 m penetration indicated compact to very dense conditions. The higher 'N' values infer the presence of obstructions such as cobbles or boulders. Measured moisture contents within this fill varied between 5 percent and 14 percent.

5.8 Silty Clay Fill

Silty clay fill containing trace to some sand and trace gravel was encountered within the embankment fill or at ground surface in Boreholes 18-01, 18-02, 18-06, 18-07, 18-10, 18-11, 18-16 to 18-21. The thickness of this cohesive fill ranged from 0.7 m to 8.5 m. The base of this fill is located at between 1.4 m and 9.9 m depths, or Elevations 181.7 to 171.7 m.

SPT 'N' values ranged from 3 blows to 76 blows per 0.3 m of penetration, although typical values varied between 8 blows and 29 blows. These range of values indicated a typical stiff to very stiff consistency with some soft to firm, and hard zones. Measured moisture contents within this fill varied between 8 percent and 21 percent.

The results of grain size distribution analysis carried out on samples of this cohesive fill are presented on the Record of Borehole Sheets included in Appendix A and on Figure B2 of Appendix B. The results of the grain size distribution analysis are summarized below:



Soil Particle	Percentage (%)
Gravel	0 to 3
Sand	13 to 24
Silt	44 to 64
Clay	16 to 38

Results of Atterberg Limits tests conducted on a sample of this cohesive fill are presented in Figure B9 in Appendix B. The results are also summarized below:

Index Property	Percentage (%)
Liquid Limit	28
Plasticity Index	14

The results of the Atterberg Limits testing indicate that the silty clay fill is of low plasticity with a group symbol of CL.

5.9 Sand and Gravel to Sandy Gravel

Native sand and gravel to sandy gravel containing trace to some silt and trace clay was encountered below the fill or clayey silt on land in Boreholes 18-01 to 18-03, 18-05, 18-06, 18-11, 18-16, 18-18 to 18-20. In the river, this deposit was encountered just below river bed or the sediments in Boreholes 17-04, 17-08, 17-14 and 17-15. Where fully penetrated, the thickness of this cohesionless fill ranged from 2.6 m to 5.8 m. The base of this deposit on land is located at between 5.6 m and 14.6 m depths, or Elevations 173.6 to 171.1 m. The base of this deposit below the barge deck surface is located at between 4.3 m and 6.1 m depths, or Elevations 171.2 to 173.0. Boreholes 17-08 and 17-15 were terminated in this sand and gravel layer. Boreholes 18-01, 18-11, 18-16 and 17-08 were terminated in this deposit at 6.2 m to 11.3 m depths, or Elevations 174.5 to 170.0 m.

Most SPT 'N' values recorded in this fill varied from 9 blows to 46 per 0.3 m of penetration indicating typically compact to dense conditions. Higher 'N' values between 50 blows per 0.3 m penetration and greater than 100 blows for less than 0.3 m penetration indicate very dense conditions and possible presence of cobbles or boulders. Measured moisture contents within this fill typically ranged between 7 percent and 30 percent.



The results of a grain size distribution analysis carried out on samples of this deposit are presented on the Record of Borehole Sheets included in Appendix A and on Figures B3 and B4 of Appendix B. The results of the grain size distribution analysis are summarized below:

Soil Particle	Percentage (%)
Gravel	28 to 65
Sand	26 to 53
Silt & Clay	5 to 26

5.10 Sandy Silt to Silty Sand Till

Layers of native sandy silt to silty sand till was encountered in Borehole 18-17, 17-04, 17-08 and 17-09. The till generally contained some clay, trace gravel. In Borehole 18-21, the till has a higher sand content than silt content and can be described as a sand till. Where fully penetrated, the thickness of this till layer ranged from 1.3 m to 1.8 m. This till extended to between 5.6 m and 7.6m depths, or Elevations 172.7 to 169.7 m. Borehole 18-17 was terminated within this till at 16.1 m depth, or Elevation 168.7 m.

SPT 'N' values recorded in this till deposit ranged from 13 blows per 0.3 m penetration to greater than 100 blows for less than 0.3 m of penetration, indicating compact to very dense conditions. The high values could be attributed to the presence of cobbles and boulders in Boreholes 17-04 and 17-09. Measured moisture contents within the till varied between 8 percent and 15 percent.

The results of grain size distribution analyses carried out on samples of the sandy silt to silty sand till 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	5 to 19
Sand	31 to 65
Silt	19 to 50
Clay	6 to 15

It is noted that glacial tills inherently contain cobbles and boulders.

5.11 Sandy Silt, Clayey Silt to Silty Clay

Layers of sandy silt, clayey silt to silty clay were encountered in Boreholes 18-01, 18-12, 18-13, 18-17 and 17-15. Where fully penetrated, the sandy silt, clayey silt to silty clay was 1.3 m to 6 m



thick with the base at 5.6 m to 13.2 m depths, or Elevations 177.4 to 171.6 m. Boreholes 18-12 and 18-13 were terminated within the silty clay.

Most SPT 'N' values measured in the clayey silt to silty clay ranged from 8 blows to 89 blows per 0.3 m of penetration indicating a stiff to hard consistency. In Borehole 18-13, 'N' values of greater than 100 blows for less than 0.3 m penetration inferred the presence of cobbles or boulders. In Borehole 18-17, an 'N' value of 4 blows per 0.3 m penetration indicated a loose condition. Measured moisture contents within this fill varied between 12 percent and 20 percent.

The results of grain size distribution analysis carried out on samples of these soils 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 analysis are summarized below:

Silty Clay

Soil Particle	Percentage (%)
Gravel	0 to 1
Sand	0 to 8
Silt	53 to 62
Clay	38 to 40

Sandy Silt to Clayey Silt

Soil Particle	Percentage (%)
Gravel	0
Sand	9 to 31
Silt	55 to 71
Clay	14 to 20

Results of Atterberg Limits tests conducted on a sample of the silty clay are presented in Figure B10 in Appendix B. The results are also summarized below:

Index Property	Percentage (%)
Liquid Limit	28
Plasticity Index	14

The above results indicate that the silty clay is of low plasticity with a group symbol of CL.



5.12 Clayey Silt to Silty Clay Till

A clayey silt to silty clay till deposit was encountered in Borehole 18-02, 18-03, 18-05, 18-06, 18-10, 18-18, 18-19, 18-20, 18-21, 17-04, 17-09 and 17-14. The till generally contained some sand and trace gravel. Where fully penetrated, the thickness of this till ranged from 2.0 m to 5.7 m. This till extended to between 9.3 m and 19.0 m depths, or Elevations 168.6 to 166.7 m. Boreholes 18-10, 18-18, 18-21 and 17-14 were terminated within this till at 7.8 to 10.1 m depth, or Elevations 170.7 to 168.8 m.

Most SPT 'N' values recorded in the till deposit ranged from 13 blows to 77 blows per 0.3 m of penetration indicating stiff to hard consistency. High 'N' values of greater than 100 blows for less than 0.3 m penetration infer the presence of cobble and boulders in Boreholes 18-02, 18-05, 18-10, 18-19, 18-20 and 17-09. Measured moisture contents within the till varied between 8 percent and 20 percent.

The results of grain size distribution analyses carried out on samples of the clayey silt to silty clay till 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 analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	1 to 12
Sand	10 to 49
Silt	33 to 52
Clay	12 to 37

It is noted that glacial tills inherently contain cobbles and boulders.

Results of Atterberg Limits tests conducted on samples of this cohesive till are presented in Figure B11 in Appendix B. The results are also summarized below:

Index Property	Percentage (%)
Liquid Limit	15 to 21
Plasticity Index	5 to 9

The above results indicate that this till is of slight to low plasticity with group symbols of CL-ML and CL.



5.13 Limestone Bedrock

Limestone bedrock was encountered underlying the clayey silt to silty clay till and proven by coring in Boreholes 18-02, 18-03, 18-05, 18-06, 18-19, 18-20, 17-04 and 17-09. The table below summarizes depths to bedrock and top of bedrock elevations encountered in these boreholes.

Table 5.1 - Top of Bedrock

Foundation Element	Borehole Number	Top of Bedrock	
		Depth below highway grade / adjacent ground (m)	Elevation (m)
Replacement Bridge			
South Abutment	18-02	17.1	168.6
	18-03	18.3	167.4
North Abutment	18-05	19.0	166.7
	18-06	17.9	167.8
West Detour Bridge (Temporary)			
South Abutment	18-19	12.0	167.9
North Abutment	18-20	11.0	167.4
In-Water			
East Detour Bridge Pier (abandoned option)	17-04	9.6* / 7.3	167.7
Cofferdam	17-09	9.3* / 4.1	168.0

* Depth below barge deck

Elsewhere, Boreholes 18-10, 18-17, 18-18 and 18-21 encountered auger refusal between Elevations 168.7 and 170.7 m.

In general, the bedrock is described as slightly weathered, moderately weathered at joints, grey limestone with largely horizontal to sub-horizontal joints, and contains zones of vugs at various locations throughout the cores. There are also fractured or rubble zones at various locations.

Total Core Recovery (TCR) in the majority of core runs ranged from 90 percent to 100 percent, except for occasional values of 63, 83 and 85 percent measured in Boreholes 18-03 and 18-05. The Rock Quality Designation (RQD) values ranged from 8 percent to 98 percent with most values lying between 50 percent and 90 percent, indication typically fair to good rock quality. Lower RQD values ranging between 8 percent and 47 percent indicate poor to very poor rock quality at some locations including the fractured and rubble zones. The Fracture Index (FI) of the rock, expressed



as number of fractures per 0.3 m of core, typically ranged from 1 to 5 except for the fractured and rubble zones where the FI is greater than 10.

The unconfined compressive strength (UCS) of the rock, estimated from the results of a majority of point load and unconfined compression tests, ranged from 34 to 205 MPa indicating medium strong to very strong intact rock cores. Occasional values of 15 and 20 MPa indicate weak zones. Results of these rock strength tests are included on the borehole logs in Appendix A and presented in Appendix B.

5.14 Groundwater Conditions

The water levels in the boreholes were observed during the drilling operations and measured upon completion of drilling. A standpipe piezometer was installed in each of Boreholes 18-02, 18-06, 18-19 and 18-20 to permit longer term monitoring of the groundwater level. Groundwater levels measured in the piezometers and in the open boreholes upon completion, are presented in Table 5.2.

Table 5.2 - Measured Groundwater Levels

Borehole Number	Date	Groundwater Level		Comment
		Depth (m)	Elevation (m)	
18-02	July 6, 2018	9.0	176.7	Piezometer
	July 12, 2018	8.2	177.5	
	October 2, 2018	8.8	176.9	
18-06	July 12, 2018	8.0	177.7	Piezometer
	October 2, 2018	8.0	177.7	
18-19	July 20, 2018	1.3	178.6	Piezometer
	July 24, 2018	1.3	178.6	
	October 2, 2018	1.4	178.5	
18-20	July 20, 2018	0.4	178.1	Piezometer
	July 24, 2018	0.3	178.2	
	October 2, 2018	0.5	178.0	

Water level in the Bayfield River was reported to be at about Elevation 176.8 m in early September 2017. It is anticipated that the groundwater table at this site is governed by the river level.

The above water level measurements are short-term observations and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater and river water levels may be at a higher elevation after periods of significant or prolonged precipitation, or after snowmelt.



6 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling.

Walker Drilling of Utopia, Ontario, supplied and operated track-mounted and tripod drill rigs for the drilling, sampling and in-situ testing operations for the field investigation. The tripod rig has been used both over water in conjunction with a barge, and on land at heavily vegetated areas and sloping grounds.

The field investigation was supervised on a full-time basis by technical staff of Thurber, who logged the boreholes and processed the recovered soil and rock samples for transport to Thurber's laboratory for further examination and testing. Overall supervision of the field program was carried out by Mr. Stephane Loranger, CET, of Thurber.

It is understood that as-drilled borehole elevations have been provided to Thurber by MP, based on co-ordinates established on site.



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**FOUNDATION INVESTIGATION AND DESIGN REPORT
BAYFIELD RIVER BRIDGE REPLACEMENT
HIGHWAY 21, SITE 12-188
BAYFIELD, ONTARIO
GWP 3070-11-00**

GEOCRES NO. 40P12-37

PART 2 ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This section of the report presents interpretation of the geotechnical data in the factual portion of this report and provides foundation recommendations to assist the design team in selecting and designing a suitable foundation system for the proposed Highway 21 Bayfield River replacement bridge and associated works.

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 contractor. The contractor must make their own interpretation based on the factual data in the first part of this 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.

The existing Bayfield River Bridge was constructed in 1949 and is a 60.9 m long two-span deck-truss bridge. It has a reinforced concrete deck of about 11.7 m in width supported on transverse steel floor beams. The foundation consists of two cast-in-place concrete abutments and a cast-in-place concrete pier supported on spread footings. The footings for the existing bridge are founded at about Elevation 174.

Visual observations of conditions above the waterline related to the general geotechnical performance did not reveal obvious signs of settlement or distress at the foundation elements. The approach slopes appeared to be stable with no obvious signs of instability. All slope faces were well vegetated.



Based on two General Arrangement (GA) drawings (Concepts 1 and 2) dated June 2018 provided by MP, the replacement bridge will be single span arch structure with a concrete deck. The spans between abutment bearings will be 85 m with a deck width of approximately 17 m. There will be a structural overhang on the west side of the bridge to support a pedestrian sidewalk. The GA drawings show that the bridge abutments will be supported on deep foundations. It is understood that there will be no grade change behind the north and south abutments.

The discussion and recommendations presented in this report are based on the information provided by MP and on the factual data obtained during the course of this investigation and a previous investigation carried out by others (Reference 1 in Part 1).

8 PERMANENT REPLACEMENT BRIDGE FOUNDATION DESIGN

8.1 Foundation Conditions

In general, the subsurface stratigraphy on land below the embankment fill consists of a typically compact to dense deposit of sand and gravel to sandy gravel overlying compact to very dense sandy silt to silty sand till at some locations. The above soils are underlain by very stiff to hard clayey silt to silty clay till. There are also layers of sandy silt, clayey silt to silty clay. The site is underlain by limestone bedrock. The groundwater table at this site is largely governed by the river level, and the groundwater level at the north and south banks is typically within 1 m above the river level at the time of the present investigation.

Discussions of foundation alternatives are presented in the following sections of this report.

8.2 Structural Classification

In accordance with the currently applicable CHBDC (2014) CSA S6-14, the analysis and design of structures depend on its importance category and consequence classification. Such designations are defined by the Regulatory Authority which, in this case, is the Ministry of Transportation Ontario (MTO).

For the purpose of reporting, this structure has been classified as a Major-Route Bridge with Typical Consequence based on CHBDC S6-14 Sections 4.4.2 and 6.5.2, respectively.

Based on the above classification and Table 6.1 in Section 6.5.2 in the CHBDC, a consequence factor, ψ , of 1.0 has been used for assessing ULS and SLS geotechnical resistances. Should the



consequence classification changes, the geotechnical assessment and recommendations will need to be reviewed and revised as necessary.

8.3 Foundation Alternatives

Given that the proposed structure is a true arch bridge, the magnitude of lateral loadings is anticipated to be relatively high. Accordingly, the foundation support must have sufficient lateral geotechnical resistance to satisfy the design requirements.

Based on the subsurface and site conditions, and project requirements at this site, initial consideration was given to supporting the structure using the following foundation types:

- H-piles driven to the hard glacial till or bedrock
- Augered H-piles socketted into bedrock
- Augered caissons (drilled shafts) socketted into bedrock
- Spread footings

Steel H-piles driven to bedrock is a possible option to provide foundation support to this new bridge provided the base fixity at the pile tips and the pile widths are sufficient to mobilize adequate lateral geotechnical resistance. In order to install a piled foundation, the existing footings would have to be completely removed. Lateral resistance of driven H-piles is lower than what can be provided by augered caissons or augered piles. Moreover, the borehole information indicates that there are risks that some piles could not fully penetrate the very stiff to hard clayey silt to silty clay till ('N' values > 100-blows) to reach bedrock. Should this occur, base fixity and therefore adequate lateral resistance cannot be confirmed. In view of these reasons, no further recommendations are provided for driven piles in this report.

Augered steel H-piles socketted into bedrock may be considered for foundation support to the new bridge. The depth of sockets depends on the structural requirements for base fixity and lateral geotechnical resistance. Temporary steel liners and balancing head of water/slurry will likely be required to provide sidewall support and mitigate risk of basal heave during installation. The space between the pile and the hole should be grouted with structural grade concrete. In addition, information from MP indicates that this option would require removing the entire existing footings which is anticipated to be costly and time consuming. It is noted that battering of augered piles is limited and, therefore, lateral bridge loading will have to be resisted by lateral geotechnical resistance mobilized by the pile shafts and the rock sockets. The feasibility and cost effectiveness of this option should be assessed.



Augered caissons socketted into bedrock are feasible for supporting the bridge structure. The depth of sockets depends on the structural requirements for base fixity and lateral geotechnical resistance. Consideration should be given to using permanent steel liners to provide sidewall support and to be sealed into the limestone. A balancing head of water/slurry inside the liner may be required to mitigate the risk of basal heave during installation. Tremie concrete should then be used to construct the caisson after the rebar cage is in place. This option enhances constructability by providing a partial groundwater cutoff and increases overall lateral resistance of the foundations.

Spread footings, if used, would likely be founded on a deposit of typically compact to dense sand and gravel to sandy gravel which was encountered at and below the proposed underside of the bridge abutments. Dewatered cofferdams will be required for footing construction below the river and groundwater level. In addition, the relatively large lateral bridge loading will need to be resisted by interface friction under the footing and the earth pressure that can be mobilized behind the abutment walls. In addition, information from MP indicates that results of a scour analysis require scour protection to an elevation which is even lower than the likely footing elevations. The overall feasibility and cost effectiveness of the spread footing option should be assessed.

Preferred Foundation Alternative

From a foundations technical and cost effectiveness perspective, it is recommended that the bridge abutments be supported on augered caissons socketted into bedrock.

More detailed comparison of the technical advantages and disadvantages of the alternative foundation schemes is presented in Appendix E.

8.4 Augered Steel H-piles or Pipe Piles

Consideration may be given to supporting the abutments on steel H-piles set within sockets that are drilled into the limestone bedrock. The sockets should be pre-drilled and the socket base should be cleaned of loose and shattered rock. The pile should then be lowered into the socket and the remaining space grouted with minimum 30 MPa concrete. A minimum 2 m of socket depth in bedrock is recommended. However, the rock socket depth should be governed by base fixity, lateral load resistance and any other structural requirements.

Tables 8.1 and 8.2 present the recommended founding depths and elevations for the augered H-piles or pipe piles at each abutment location. It is recommended that a minimum rock socket depth of 2 m be used.

Table 8.1
Founding Depths and Elevations for Augered H-Piles or Pipe Piles

Foundation Element	Borehole	Assumed Design Bedrock Elevation (m)	Minimum Socket Depth (m)	Assumed Founding Elevation (m)
South Abutment	18-02 18-03	167.4	2	165.4
North Abutment	18-05 18-06	166.7	2	164.7

8.4.1 Axial Resistance

For an H-pile or pipe pile grouted within a 600 mm nominal diameter socket of 2 m in bedrock, Table 8.2 below presents geotechnical resistances that may be used for design.

Table 8.2 Design H-Pile Axial Resistances

Foundation Unit	H-Pile Section			
	HP 310 x 110		HP 360 x 132	
	Factored Axial Pile Resistance at ULS (kN)	Axial Pile Resistance at SLS (kN)	Factored Axial Pile Resistance at ULS (kN)	Axial Pile Resistance at SLS (kN)
Both Abutments	2,000	N/A	2,400	N/A

N/A: Not applicable since SLS condition does not govern design of piles in rock

The values of the Factored Axial Pile Resistance at ULS were assessed based on static analysis assuming a Consequence Factor equal to 1 (Typical), and a geotechnical resistance factor equal to 0.4 (Typical degree of understanding of the subsurface conditions), as per CHBDC 2014. The SLS condition does not govern design of piles socketted within bedrock.

The structural resistance of the pile should be reviewed by the structural designer to confirm that the values given above are not exceeded.



8.4.2 Lateral Resistance

Lateral bridge loadings can be geotechnically resisted by the augered steel H-piles or pipe piles through passive pressure developed along the embedded portion of the piles below the abutment stem.

The lateral resistance of a pile may be calculated using values for the coefficient of horizontal subgrade reaction (k_s) and the pressures obtained from the analysis should not exceed the ultimate values given in the following relationships:

Sand and Gravel/Embankment Fill

$$\begin{aligned}
 k_s &= n_h z / D \quad (\text{kN/m}^3) \\
 p_{ult} &= 3 \gamma' z K_p \quad (\text{kPa}) \\
 \text{where } p_{ult} &= \text{ultimate lateral resistance mobilized by a pile, kPa} \\
 z &= \text{pile embedment depth, m} \\
 D &= \text{augered hole diameter, m} \\
 n_h &= \text{coefficient related to soil density, kN/m}^3 \\
 \gamma' &= \text{submerged soil unit weight (below water), kN/m}^3 \\
 K_p &= \text{passive earth pressure coefficient}
 \end{aligned}$$

Clayey Silt to Silty Clay Till

$$\begin{aligned}
 k_s &= 67 C_u / D \quad (\text{kN/m}^3) \\
 p_{ult} &= 9 C_u \quad (\text{kPa}) \\
 \text{where } p_{ult} &= \text{ultimate lateral resistance mobilized by a pile, kPa} \\
 C_u &= \text{undrained shear strength of cohesive soils, kPa} \\
 \gamma &= \text{total unit weight of soil, kN/m}^3 \\
 D &= \text{augered hole diameter, m}
 \end{aligned}$$

For pile lateral resistance design, soil-pile interaction analyses may be carried out using the coefficient of horizontal subgrade reaction values provided in Table 8.4 below.

Table 8.4 Recommended Geotechnical Parameters for Lateral Resistance Design

Location	Ref. Bore -holes	Approx. Elev. (m)	Undrained Shear Strength C_u (kPa)	n_h (kN/m ³)	K_p	Unit Weight γ (kN/m ³)	Ground -water Depth (m)	Soil Conditions
South Abutment	18-02 18-03	185 to 175	-	3,000	3.0	20/10*	7	Embankment Fill



		175 to 172	-	5,500	3.5	11*		Sand and Gravel
		172 to 167	200	-	-	21		Clayey Silt Till
		Below 167	Rock socket – see section below					
North Abutment	18-05 18-06	185 to 175	-	3,000	3.0	20	7	Embankment Fill
		175 to 172	-	4,000	3.2	10*		Sand and GravelImpact
		172 to 167	200	-	-	21		Clayey Silt to Silty Clay TillImpact
		Below 167	Rock socket – see section below					

* Submerged unit weight for cohesionless soils below groundwater level

The spring constant, K , for analysis may be obtained by the expression, $K = k_s \times d_z \times D$ (kN/m), where k_s is the coefficient of horizontal subgrade reaction (kN/m³), D is the augered hole diameter (m), d_z is the length (m) of the pile segment or element used in the analysis. The ultimate lateral resistance on any one segment of pile, P_{ult} , may be obtained from the expression, $P_{ult} = p_{ult} \times d_z \times D$. This represents the ultimate load at the contact between the soil and the pile above which additional load cannot be supported at greater displacements.

For lateral soil-pile group interaction analysis, the values for k_s should be reduced based on pile spacing. The group efficiency factors can be calculated based on side-by-side and line-by-line factors shown in Figures C6.11.3(r), C6.11.3(s), and C6.11.3(t) of the CHBDC 2014, S6.1-14 (Commentary).

The design of laterally loaded augered steel piles must take into account such factors as the relative rigidity of the foundation elements to the surrounding rock, the fixity condition at the head of the rock socket (top of bedrock level), the structural capacity of the foundation elements to withstand bending moments and shear, the rock resistance that can be mobilized and the maximum tolerable lateral deflection at the pile head.

8.4.3 Rock Sockets

Although a minimum 2 m socket depth is recommended, the required depth of rock socket should be determined to satisfy base fixity, lateral load resistance and other structural requirements. This will likely involve an iteration process during detailed design. This report discusses only the geotechnical resistances provided by the rock sockets.



For rock sockets formed within the limestone bedrock, the ultimate passive force that can be mobilized by the embedded portion of a socket is as follows:

$$P_{P(ult)} = (1 + 1.4 z / D) \sigma_{rm} \cdot D \cdot L \quad (\text{kN}) \quad \text{for } z \leq 3D$$

$$P_{P(ult)} = 5 \sigma_{rm} \cdot D \cdot L \quad (\text{kN}) \quad \text{for } z > 3D$$

where z = depth of socket below rock surface (m)
 D = socket diameter (m)
 σ_{rm} = 1.5 MPa (equivalent rock mass strength within rock socket based on Hoek and Brown classification).

The above equations are based on similar equations found in a U.S. Transportation Research Board (TRB) publication titled "Rock-Socketed Shafts for Highway Structure Foundations", NCHRP Synthesis 360 dated 2006.

8.4.4 Downdrag

There will not be any grade raise associated with the new bridge and approaches. The majority of the foundation soils are cohesionless and very stiff to hard clayey till which would undergo elastic compression under the new fill. Some ground settlement associated with placing new fill for the embankment widening for the temporary west detour is anticipated. However, much of this settlement would take place during fill placement and during the minimum one month waiting period (see Section 9 below) prior to paving. Post paving settlement should be considered negligible. Since pile installation would only commence after the traffic is shifted to the detour, downdrag on the piles is not considered to be a design issue.

8.4.5 Augered Pile Installation

Augered pile installation should be in general accordance with clauses for caissons in OPSS.PROV 903. The pre-drilled holes for forming the rock socket should have a nominal diameter of 600 mm.

For each caisson, a temporary steel liner should be available to support the caisson sidewalls and provide partial seepage cut-off where required.

The installation of caissons at this site must consider the following issues:



- Caisson installation equipment must be able to advance through cobbles, boulders and other obstructions within the fill and till deposits.
- Caisson installation equipment with rock drilling / coring capabilities must be used to penetrate the strong to very strong limestone to form the rock sockets.

Selection of the construction methods and equipment employed to address the above issues is the responsibility of the Contractor. The contract documents must contain statements to alert bidders of the above conditions (see suggested NSSP wording in Appendix G).

Although the temporary liner will minimize the ingress of water above the limestone bedrock, it is anticipated that water will accumulate inside the liner due to water seepage from the surrounding soil and discontinuities within the limestone, the caisson base during augering, and leakage of the liner. It is recommended that a balancing head of water or slurry be kept inside the liner to minimize the risk of basal heave during construction. Once the pile is in place inside the rock socket, concrete should be placed using tremie techniques without delay.

8.5 Augered Caissons (Drilled Shafts)

Augered caissons socketted within the limestone bedrock are a feasible foundation option for this bridge. It is recommended that a steel liner (casing) be sealed into the limestone and left in place permanently. A casing sealed in rock will provide a partial water cutoff thus minimizing accumulation of water inside the casing during construction. The rock socket should be formed below the casing. Tremie concrete may be placed inside the casing once the rebar cage is set in place. The permanent casing will also provide additional lateral stiffness to counteract the lateral bridge loading.

The limestone bedrock within the investigated depth is in a slightly weathered state overall with moderately weathered joints. Fractures or rubble zones exist below the top of bedrock. A minimum rock socket depth of 3 m is recommended. The upper 1 m of bedrock has been neglected for providing geotechnical resistance. However, the required depth of rock socket should be determined to satisfy base fixity, lateral load resistance and any other structural requirements. For planning and design purposes, the following founding levels are recommended.

Table 8.5 Caisson Founding Levels at Both Abutments

Foundation Element	Reference Boreholes	Socket Diameter D (m)	Highest Caisson Founding Elevation (m)	
			3 m Socket Depth	4 m Socket Depth
South Abutment	18-02 18-03	0.9	164.4	163.4
		1.2		
		1.5		
North Abutment	18-05 18-06	0.9	163.7	162.7
		1.2		
		1.5		

8.5.1 Axial Resistance

Table 8.6 presents the recommended axial geotechnical resistances for 0.9 m, 1.2 m and 1.5 m diameter caissons with socket lengths of 3 m and 4 m below the bedrock surface. The SLS condition does not govern design of caissons socketted into bedrock.

Table 8.6 Axial Geotechnical Resistances for Caisson Design

Caisson Diameter D (m)	Socket Length in Bedrock (m)	Factored Geotechnical Resistance at ULS (kN)
0.9	3	4,400
	4	6,100
1.2	3	5,500
	4	7,800
1.5	3	6,600
	4	9,500

The minimum spacing between adjacent caissons should be as per the CHBDC 2014. The vertical resistance will not be significantly affected by the caisson spacing for caissons socketted within bedrock.

The discussion on downdrag in Section 8.4.4 is also applicable to augered caissons.

For checking uplift resistance of the caissons, the following values are recommended.

Table 8.7 Axial Geotechnical Resistances for Uplift Design

Caisson Diameter D (m)	Socket Length in Bedrock (m)	Factored Geotechnical Resistance for Uplift at ULS (kN)
0.9	3	1,700
	4	2,600
1.2	3	2,300
	4	3,500
1.5	3	2,900
	4	4,300

The values of the Factored Axial Pile Resistance at ULS were assessed based on static analysis assuming a Consequence Factor equal to 1 (Typical), and a geotechnical resistance factor equal to 0.3 (Typical degree of understanding of the subsurface conditions), as per CHBDC 2014.

8.5.2 Lateral Resistance

Lateral bridge loadings can be geotechnically resisted by the augered caissons through passive pressure developed along the embedded portion of the caissons below the abutment wall.

The design of laterally loaded augered caissons must take into account such factors as the relative rigidity of the foundation elements to the surrounding soil and rock, the fixity of the condition at the head of the foundation elements, the structural capacity of the foundation elements to withstand bending moments and shear, the rock resistance that can be mobilized and the maximum tolerable lateral deflection at the top of caisson.

Lateral resistance design for augered caissons including rock socket design may be carried out as per the recommendations in sub-section 8.4.2 by substituting the augered hole diameter with the caisson diameter.

A set of p-y curves have been developed for the structural designer to carry out the lateral resistance analysis. Numerical data pertinent to these curves is attached in Appendix H.

8.5.3 Caisson Installation

Caisson installation should be in general accordance with relevant clauses in OPSS.PROV 903.



General requirements for caisson installation are similar to those for augered piles in sub-section 8.4.4. It is expected, however, that rock drilling and steel liner advancement for the caissons will require more effort due to the larger diameters. Suggested wording of an NSSP for rock socketted caissons is included in Appendix G.

8.6 Spread Footings

As discussed above, the feasibility and cost effectiveness of spread footings for supporting the anticipated large lateral loading of an arch bridge will need to be assessed. The relatively large horizontal load component and the load eccentricity on the footing should be evaluated. Although horizontal resistance can be developed from lateral earth pressure behind the abutment walls, the magnitude of wall movement that would be required to mobilize earth pressure will need to be determined. In addition, it is considered unlikely that passive earth pressure and interface friction at the underside of the footing can be fully mobilized at the same time.

Based on available subsurface information and the design layout, consideration may be given to supporting the abutments on spread footings founded at or below Elevation 174 m on the typically compact to dense sand and gravel to sandy gravel deposit.

For preliminary design, spread footings founded as outlined above may be designed using a Factored Geotechnical Resistance at ULS of 450 kPa and a Geotechnical Resistance at SLS (up to 25 mm settlement) of 300 kPa. The recommended geotechnical resistances are based on a minimum 2 m wide footing subjected to vertical concentric loading. Where eccentric or inclined loads are applied, the resistance values used in design must be reduced in accordance with the CHBDC (2014) Clause 6.10.3 and Clause 6.10.4.

Resistance to lateral forces / sliding resistance between the cast-in place concrete footings and the compact to dense sand and gravel to sandy gravel should be calculated in accordance with the CHBDC (2014) using an ultimate coefficient of friction of 0.6. A resistance factor of 0.8 should be applied to this value.

Footing excavation in cohesionless soils will extend below the groundwater level. Accordingly, prior dewatering to lower the groundwater level will be essential to prevent base boiling and to construct the footing in the dry.

In cases where the exposed subgrade is disturbed or contains loose materials, sub-excavation followed by backfilling with mass concrete fill of the same class as that of the footing should be used to raise the subgrade to the design footing level.



All footing excavations must be inspected prior to placing concrete to confirm that the base has been adequately cleaned. Construction of the spread footings should be completed in the dry. Dewatered cofferdams would likely be required during construction.

Excavation and backfilling for the footings must be in accordance with OPSS 902.

8.7 Frost Depth

The design depth of frost penetration at this site is 1.4 m with reference to OPSD 3090.101. The base of the pile caps, caisson caps or spread footings must be provided with a minimum 1.4 m earth cover, or its thermal equivalent, for frost protection purposes.

9 TEMPORARY WEST DETOUR

The bridge replacement and road reconstruction project includes a temporary detour route during construction to be located immediately to the west of the existing bridge. The river crossing will be facilitated by a Temporary Modular Bridge (TMB) which is a single span steel truss structure. Consideration was initially given by MP to support the TMB abutments on compacted granular fill pads. Given the requirements for sub-excavation, backfilling and the marginal global stability scenarios at the forward slope areas, consideration was subsequently given to supporting the TMB on driven steel H-piles.

9.1 Driven Steel H-Piles

A drawing titled “Bayfield River Detour Bridge, Temporary Modular Bridge General Arrangement” dated February 2019 indicates that it is proposed to support the TMB on two abutments each to be founded on two rows of vertical driven piles. The TMB is 70.1 m long between the abutments and there will be two 15.3 m long end spans each to be supported on a spread footing founded on a compacted granular pad. A standard HP 310 x 110 pile section, or heavier HP 310 x 132 and HP 360 x 132 sections, driven to practical refusal may be used. The piles should ideally be driven to bedrock although some piles may not be able to fully penetrate the hard clayey silt to silty clay till immediately above bedrock. The pile tips should be fitted with driving shoes such as the Titus Steel Standard H Point or approved equivalent.

For planning and design purposes, the recommended design founding elevations for the H-pile sections quoted above driven to the hard clayey silt to silty clay till (“100-blow” till) or bedrock are as follows:



9.1 – Design Pile Tip Elevations for TMB

Foundation Unit	Reference Borehole	Pile Tip Elevation (m)
North Abutment	18-20	167.5
South Abutment	18-19	168.0

For axial capacity, the following geotechnical resistances per pile driven to practical refusal in the hard clayey silt till just above the bedrock may be used.

Table 9.2 – Design Pile Axial Resistances

Foundation Unit	HP 310 x 110		HP 310 x 132 HP 360 x 132	
	Factored Geotechnical Resistance at ULS (kN)	Geotechnical Resistance at SLS (kN)	Factored Geotechnical Resistance at ULS (kN)	Geotechnical Resistance at SLS (kN)
Abutments	900	700	1,100	900

The SLS values correspond to a maximum pile settlement of 25 mm.

The structural capacity of a pile must not be exceeded and should be confirmed by the structural designer.

Downdrag load on piles is not a design issue for these piles for the TMB.

9.2 Spread Footings on Engineered Fill Pad

The end spans of the pile supported TMB may be founded on concrete footings placed on engineered fill pads, each of which should have a minimum thickness of 1 m. These pads may be placed near the ground surface after surficial vegetation, topsoil, organics and debris are stripped.

The engineered fill should consist of OPSS Granular “A” or Granular B Type II placed in 150 mm lifts and compacted to 100% of its Standard Proctor Maximum Dry Density (SPMDD) at $\pm 2\%$ of the optimum moisture content. The top of the engineered fill pad should be at least 0.5 m wider than the footprint of the spread footing. The subgrade for the engineered fill pad should be inspected and all organics, soft/loose soils, and deleterious materials should be removed from the footprint of the engineered fill excavation. Figure H1 in Appendix H shows a typical MTO abutment on a compacted Granular A pad.



The following recommended geotechnical resistances may be used for design of a spread footing not less than 1.5 m in width and placed on properly compacted engineered fill as noted above:

Factored Geotechnical Resistance at ULS (kPa)	-	140 kPa
Geotechnical Resistance at SLS (kPa)	-	110 kPa

At the footing locations, new fill for the temporary detour may cause settlements up to the order of 25 mm which is anticipated to occur as the fill is placed and compacted.

The values of a Factored Geotechnical Resistance at ULS was assessed assuming a Consequence Factor equal to 1 (Typical), and a Resistance Factor equal to 0.5 (Typical degree of understanding of the subsurface conditions), as per CHBDC 2014. The Geotechnical Resistance at SLS was assessed assuming a factor of 0.8 for typical degree of understanding of the subsurface conditions.

The geotechnical resistances quoted above are for concentric, vertical loads only. In the case of eccentric or inclined loading, the geotechnical resistance should be calculated as illustrated in the CHBDC 2014 Clause 6.10.3 and Clause 6.10.4.

The lateral resistance of the concrete footings founded on engineered fill may be computed using an unfactored friction coefficient of 0.6. This is an “ultimate” value and requires a degree of sliding movement to occur to fully mobilize the resistance. A resistance factor of 0.8 should be applied to this value.

Information from MP indicates that the TMB north abutment will be located approximately 7.5 m behind the existing sheet pile wall. In order to minimize the risk of impacting this wall, care should be taken not to allow heavy construction equipment to work between the temporary abutment and the sheet pile wall.

9.3 Detour Embankment

While there is no permanent grade raise or embankment widening planned for the replacement bridge approaches, there will be a temporary widening of the existing embankments on the west side as part of the temporary west detour during construction. The existing north and south approach slopes at the Bayfield River bridge are typically vegetated with small trees, shrubs, grass and weeds. Cross-sections provided by MP indicate that the existing overall approach slope inclination is typically at approximately 2H : 1V on the west side. The existing approach fills are in the order of 6 m in height. There is an existing sheet pile wall along the river bank on the west side of the north embankment. No detail of the sheet piles is available.



It is understood that the temporary west detour embankments will be widened to form a platform of about 11 m in width to accommodate two lanes of traffic plus shoulders. The new fill will be up to 5 m to 5.5 m in height above existing ground surface. The latest drawings show that a 2H : 1V slope inclination has been proposed for the west detour widening at the south approach without extending beyond the MTO right-of-way (ROW). At the north approach, the MTO ROW precludes a 2H : 1V slope inclination. Therefore, consideration was initially given to constructing a temporary wall to retain the widening fill such that the new fill would not encroach into the adjacent private property. The wall alignment on these drawings are located some 7 m away from the existing sheet pile wall at the river bank. Given the retained height and the depth to competent founding stratum, it is anticipated that the wall would be anchored for maintaining stability and limiting movement. A reinforced earth embankment at inclinations steeper than 2H : 1V are currently being considered at the north approach. The latest design information suggests that a 1H : 1V slope is preferred at this site. For a Retained Soils System (RSS) slope, a proprietary supplier and designer should be contacted for internal stability design and construction supervision.

9.3.1 Detour Embankment South Approach

MTO approved Select Subgrade Material (SSM) or granular materials satisfying OPSS.PROV 1010 requirements may generally be used for constructing the detour embankment at this site. On the south side, the new embankment widening constructed using these materials will be stable at a slope inclination not steeper than 2H : 1V.

9.3.2 Detour Embankment North Approach

SSM and granular materials may be used as temporary widening fill using a 2H : 1V upper slope of about 2 m in height, below which the temporary wall will retain the lower portion of the fill. Global stability of the temporary wall and its retained fill of selected configurations were assessed using the commercially available slope stability program GEO-SLOPE produced by Geo-Studio International Ltd. by employing the Morgenstern-Price method of analysis. Although this is a temporary detour for construction, the construction period could range between 1 to 2 years. As such, stability analyses were carried out for both short term (undrained) and long term (drained) conditions.

In addition, the global stability of a RSS embankment at 1H : 1V inclination has also been analysed.



Based on consideration of the risk involved and past experience with design of highway embankments, factors of safety of 1.3 and 1.5 are considered appropriate to achieve short term and long term stability, respectively.

The geotechnical parameters employed in the analyses were estimated from empirical correlations based on SPT N-values and index properties reported in the boreholes. These parameters are shown on the figures for selected stability analysis results.

Selected results of the slope stability analyses for various scenarios are shown on Figures F1 to F5 in Appendix F. The results are also summarized in Table 9.1 below.

Table 9.1 – Summary of Computed Factors of Safety

Slope Location and Conditions	Detour Fill Height / Top Elevation (m)	Drained or Undrained (Long or Short Term)	Factor of Safety (FOS)	Figure Number (Appendix F)
North Approach – Existing Condition	-	Drained (Long Term)	1.3	F1
North Approach – SSM Fill Retaining Wall (deep foundation)	≈5.5 / ≈184	Undrained (Short Term)	2.1	F2
North Approach – SSM Fill Retaining Wall (deep foundation)	≈5.5 / ≈184	Drained (Long Term)	1.9	F3
North Approach – Gran. B II Fill RSS Slope (1H : 1V)	≈5.5 / ≈184 to 185	Undrained (Short Term)	1.7	F4
North Approach – Gran. B II Fill RSS Slope (1H : 1V)	≈5.5 / ≈184 to 185	Drained (Long Term)	1.7	F5
North Approach – Gran. B II Fill RSS Slope (Seismic)	≈5.5 / ≈184 to 185	Undrained (Short Term)	1.6	F6

Figure F1 indicates that the existing north approach embankment on the west side is stable. Figures F2 to F6 indicate that a temporary wall on deep foundations retaining SSM would yield factors of safety greater than 1.5 which satisfy MTO requirements.

Based on the results discussed above, it is recommended that the temporary wall for the west detour be supported on deep foundations. One option is interlocking sheet piles founded within



the underlying stiff to hard clayey silt to silty clay till. Design of such a wall may be carried out using the geotechnical parameters recommended in section 12. If a stiffer wall is anticipated to limit lateral deflection and the adjacent ground movement, or if wall stability is a concern, additional bracings and/or soil anchors may be used.

9.3.3 Embankment Construction

All west detour embankment fill must be constructed with adequate quality control in accordance with OPSS.PROV 206 and OPSS.PROV 501 requirements. It is recommended that OPSS 1010 Select Subgrade Material (SSM) or granular materials (mandatory for RSS slope) Lateral resistance of driven H-piles is lower than those that can be provided by augered caissons or augered piles. be used as temporary widening fill. Inorganic earth fill, especially those with large proportions of clayey materials or high plastic clays, is not recommended for embankment widening at this site due to potentially greater settlement during construction, difficulties in achieving the specified compaction and potential embankment stability issues. The new fill must be keyed into the existing fill in accordance with the requirements of OPSD 208.010.

It is also recommended that all permanent and temporary slope surfaces be vegetated and seeded in accordance with current MTO practice with reference to OPSS.PROV 804. It is important to note that earth slopes steeper than 2H : 1V may be subject to surficial instability including sloughing and gullying, unless the slope is constructed as an RSS block. Surface runoff and precipitation must be prevented from flowing perpendicularly down any slope surface. Erosion protection measures will have to be taken as necessary to avoid adverse impacts on the highway.

10 RETAINING WALL BACKFILL AND LATERAL EARTH PRESSURES

Backfill to retaining walls should consist of free-draining granular material conforming to Granular A or B Type II specifications (OPSS.PROV 1010).

Heavy compaction equipment should not be used adjacent to the abutment walls. Compaction should be carried out in accordance with OPSS.PROV 501.

Earth pressures acting on the structure may be assumed to be triangular and governed by the characteristics of the abutment backfill. For a fully-drained condition, 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 10.1)
γ	=	unit weight of retained soil (see Table 10.1)
h	=	depth below top of fill where pressure is computed (m)
q	=	value of any surcharge (kPa).

In accordance with Clause 6.12.3 of the CHBDC (2014), a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 1.7 m for Granular B Type I, or 2.0 m for Granular A or Granular B Type II. Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS.PROV 501.

Earth pressure coefficients for backfill to the abutment walls are dependent on the material used as backfill. Typical values are shown in Table 10.1.

Table 10.1 – Earth Pressure Coefficients

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

If the structure allows yielding of the wall (unrestrained system), active horizontal earth pressure may be used in the geotechnical design of the structure. If the structure does not allow yielding (restrained system), at-rest horizontal earth pressures should be used.

In conventional design, the use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) might be preferred as it results in lower earth pressures acting on the wall.



The factors in Table 10.1 are “ultimate” values and require certain movements for the respective conditions to be mobilized. The values to be used in design can be estimated from Figure C6.16 in the Commentary to the CHBDC (2014).

It is recommended that perforated sub-drains and/or weep holes be installed, where applicable for walls other than RSS walls, to provide positive drainage of the granular backfill behind the abutment walls. Reference may be made to OPSD 3102.100 where appropriate.

11 EXCAVATION

Excavation for foundation construction at the abutments will extend below the pavement structure and embankment fill into the native, compact to dense sand and gravel deposit.

All excavations at this site must be carried out in accordance with the Occupational Health and Safety Act (OHSA). The excavation and backfilling for foundations must be carried out in accordance with OPSS.PROV 902. For the purposes of the OHSA, the embankment fill and the native soils at this site may be classified as Type 3 soils above the water level, and Type 4 soils below the water level.

Where space permits, it is anticipated that open cuts with sideslopes of 1H : 1V or flatter may be used. Temporary protection (shoring) systems, where required, should be designed by a Professional Engineer experienced in such designs (see section 11).

Excavation for foundation construction may encounter obstructions including cobbles, boulders and other debris that should be taken into consideration.

Where pile caps or spread footings are to be constructed, dewatered cofferdams will be required to permit construction in the dry. Geotechnical recommendations and comments for cofferdam design are provided in sections 11 and 12. Design of the cofferdams and associated dewatering will be the responsibility of the Contractor.

The selection of the method of excavation is the responsibility of the contractor and must be based on his equipment, experience and interpretation of the site conditions. Excavations should be inspected regularly for evidence of instability if they have been left open for extended periods of time and following periods of heavy rain or thawing. If required, remedial actions must be taken to ensure the stability of the excavation and the safety of workers. Exposed soil slopes should be covered with plastic sheeting to protect against precipitation and surface runoff.



12 TEMPORARY PROTECTION

Temporary protection (shoring) will be required during demolition and removal of the existing structure, and construction of the replacement bridge. An item titled "Temporary Protection" as per OPSS.PROV 539 should be included in the contract documents. It is recommended that Performance Level 2 as per Clause 539.04.01.01 and the alignment of the roadway protection be specified on the contract drawings. Cofferdams may also be required during construction.

The design of roadway protection or cofferdams is the responsibility of the Contractor. However, interlocking steel sheetpiles may be considered for use at this site. It is anticipated that the protection system will extend predominantly through the existing sand and gravel to silty clay embankment fill into the underlying compact to dense sand and gravel to sandy gravel overlying very stiff to hard clayey silt to silty clay till to develop the required toe resistance. Installation of the temporary protection or cofferdam should consider that the existing embankment fill may contain obstructions. It is anticipated that the shoring system may be stiffened by cross bracings, where applicable. At the northwest quadrant, the temporary retaining wall may be in the form of an anchored sheet pile wall.

An interlocking sheetpile wall may be designed using the parameters given below:

Soil Bulk Unit Weight	γ	=	20 kN/m ³
Soil Submerged Unit Weight (below gwl)	γ'	=	10 kN/m ³
Coefficient of Active Pressure	K_a	=	0.33 (embankment fill)
		=	0.28 (sand and gravel)
		=	0.31 (clayey silt to silty clay till)
Coefficient of Passive Pressure	K_p	=	3.0 (embankment fill)
		=	3.5 (sand and gravel)
		=	3.2 (clayey silt to silty clay till)

It is recommended that lateral earth pressures acting on the wall be computed in accordance with the CHBDC 2014. The surcharge should include soil loadings above the retained soil and other loadings adjacent to the wall. A sheetpile wall will need to be designed for a river water level that is anticipated to prevail at the time of construction. The actual pressure distribution acting on the protection system is a function of the construction sequence and the relative flexibility of the wall, and these factors must be considered during design of these systems.

The designer of the temporary protection or cofferdam should check whether the depth of the soldier piles is sufficient to provide base fixity.

All temporary protection systems and cofferdams should be designed by a Professional Engineer experienced in such designs.



13 GROUNDWATER AND SURFACE WATER CONTROL

The piezometric readings measured near the abutments indicate that the groundwater level is up to approximate Elevation 178.5 which is slightly higher than the river water level of approximate Elevation 177 m in September 2017.

The design of the dewatering systems is the responsibility of the Contractor. The Contract Documents must alert the Contractor of this responsibility and the need to engage a dewatering specialist. Possible control measures are discussed in the following sections.

Demolition of the existing structure (bottom portion of footings below water to remain) and construction of the new abutments will be carried out adjacent to the river flow channel. Construction excavations may extend below the river level. It is recommended that this phase of the works be carried out during the dry seasons. Regardless, it will be necessary for the Contractor to construct a cofferdam (enclosure) capable of excluding the river flow and supporting the saturated cohesionless fill and native soils through which the excavation must be formed. One type of cofferdam that might be considered consists of interlocking steel sheet piles extending to the underlying clayey silt to silty clay till to form a partial water cutoff.

It is understood that consideration is being given to leaving in place the existing footings below river water level as much as practicable in order to avoid extensive dewatering during demolition.

Responsibility for design of the cofferdam and dewatering system must remain the responsibility of the contractor, who should retain a dewatering specialist/consultant to undertake the design and implementation. Reference should be made to OPSS.PROV 517 and SP FOUND003, which amends OPSS 902. A preconstruction condition survey is not recommended, thus Designer Fill-In ** in this SP should be NA. Recommended wording for an NSSP amending SP FOUND003 to include the requirement that the design Engineer and design-checking Engineer of the dewatering system have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work has been provided in Appendix G.

The design of cofferdams must take into account the maximum river level that will likely be reached during construction. It is recommended that the Contract Documents identify a river level against which the cofferdam must provide protection and prevent flooding of the work area. The appropriate river level should be determined by a river (fluvial) hydrologist, and should probably incorporate the level that can be reached due to a storm of an appropriate return period.

A steel sheetpile cofferdam design at this site may consist of walers and bracings. The geotechnical parameters recommended in Section 12 may be used to design temporary cofferdams (sheet pile enclosures).



14 EROSION AND SCOUR PROTECTION

Erosion and scour protection should be provided along the river banks at and adjacent to the abutment locations, and over all surfaces that may be in contact with the river flow. The sands and silts at this site have a high erodibility rating. Erosion protection must be provided to prevent undermining of the abutment pile or caisson caps, or spread footings where used.

Erosion and scour protection measures should be designed by a qualified and experienced river (open channel) and/or hydraulic engineering specialist. Reference should be made to OPSS 511 for selection of rock protection materials and construction. It is envisaged that this protection may be in the form of armour stones or rip-rap.

A vegetation cover should be established on any other exposed earth surfaces to protect against surficial erosion, in general accordance with OPSS.PROV 804.

15 SEISMIC CONSIDERATIONS

According to Clause 4.4.4 of the CHBDC 2014, an earthquake with a 2475-year return period or 2% probability of exceedance in 50 years should be used for seismic design.

In accordance with the CHBDC (2014), the selection of the seismic site classification is based on the conditions encountered in the upper 30 m of the stratigraphy, which predominantly consists of embankment fill and compact to dense sand and gravel overlying very stiff to hard clayey silt to silty clay till. The site is underlain by limestone bedrock.

The seismic site classification for this site is based on the N_{60} criteria, which corresponds to a Seismic Site Class D in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC (2014). The peak ground acceleration, PGA, for a 2% in 50-year probability of exceedance at this site is 0.068 g as per the National Building Code of Canada (NBCC). The above PGA value should be assigned a site coefficient of 0.62 based on Table 4.8 of the CHBDC (2014).

Below the embankment fill, the site is underlain by compact to dense sand and gravel overlying very stiff to hard clayey silt to silty clay till which is underlain by bedrock. Therefore, soil liquefaction is not considered to be a concern at this site.

16 ADJACENT STRUCTURES AND BURIED UTILITIES

It is recommended that the exact locations and elevations of any utilities present in the vicinity of the site be established by the designer, and compared with the extent of the potential work zones related to the proposed demolition and new construction works. These utilities must not be



damaged and, if necessary, should be relocated and/or otherwise protected. The settlement and displacement/rotation tolerances of the utilities should also be established.

17 CONSTRUCTION CONCERNS

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

1. Foundation Construction adjacent to the River

Construction and demolition works related to this bridge replacement project will be carried out adjacent to the river. Effective cofferdam enclosure and dewatering systems may need to be implemented to facilitate a reasonably dry condition for construction. If caissons with casings are used as foundation support, effective means will be required to seal the casing within the upper portion of the bedrock and to pump the water inside the casing where feasible. The Contractor shall facilitate the equipment, design and operate such systems for the full duration of construction.

2. Obstructions

Boulders, cobbles, loose rocks or other debris may be present in the embankment fill and near the river. Till deposits inherently contain cobbles and boulders. These obstructions may affect installation of the foundations. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions, and extend the foundation elements to the design founding stratum.

3. Rock Sockets

Formation of rock sockets will likely be required during deep foundation construction. The Contractor shall be equipped to drill and clean these rock sockets below the groundwater level prior to placing concrete using the tremie method.

4. River zone excavation and sediments

Excavation for demolition and new pier construction in the river will require removal of the excavated materials. The river should be protected from excess sediment loading at all times.



18 CLOSURE

Engineering analysis and preparation of this foundation design report was carried out by Dr. Sydney Pang, P.Eng.

Dr. .K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects, reviewed the report.



THURBER ENGINEERING LTD.



Sydney Pang, P.Eng.
Associate, Senior Foundations Engineer



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



Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT ⁽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

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


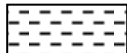



 Water Level
 Shear Strength Determination by Pocket Penetrometer

- (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				
Very thinly bedded	20 to 60mm	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Laminated	6 to 20mm				
Thinly Laminated	Less than 6mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
		Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
		Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
		Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

<u>TERMS</u>	
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a 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 18-01

1 OF 2

METRIC

GWP# 3070-11-00 LOCATION South Approach, MTM NAD 83 Zone11: N 4 825 723.0 E 369 585.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.06.26 - 2018.06.26 LATITUDE 43.568624 LONGITUDE -81.697978 CHECKED BY RD

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		
185.8	GROUND SURFACE																					
0.0 0.1	ASPHALT (75mm)																					
	SAND and GRAVEL, some silt Very Dense Brown Moist (FILL)			GS																		
			1	SS	57																	
184.4																						
1.4	Sandy SILT, trace gravel and clay Compact Brown Moist (FILL)		2	SS	24																	
183.6																						
2.2	Silty CLAY, trace to some sand, trace gravel Stiff to Very stiff Brown Moist (FILL)		3	SS	9													0	16	52	32	
			4	SS	11																	
			5	SS	22																	
180.2																						
5.6	Clayey SILT, trace sand Very Stiff Grey Moist		6	SS	22																	
			7	SS	18														0	9	71	20
177.4																						
8.4	Gravelly SAND, some silt, trace clay Compact Grey Moist																					
			8	SS	24														34	40	20	6
								</														

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-01

2 OF 2

METRIC

GWP# 3070-11-00 LOCATION South Approach, MTM NAD 83 Zone11: N 4 825 723.0 E 369 585.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.06.26 - 2018.06.26 LATITUDE 43.568624 LONGITUDE -81.697978 CHECKED BY RD

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																
174.5	SAND and GRAVEL, some silt, trace clay Compact Grey Moist		9	SS	20		175										
11.3	END OF BOREHOLE AT 7.8m. WATER LEVEL AT 9.2m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																

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

RECORD OF BOREHOLE No 18-02

1 OF 3

METRIC

GWP# 3070-11-00 LOCATION South Approach, MTM NAD 83 Zone11: N 4 825 727.0 E 369 575.0 ORIGINATED BY AF
DIST 21 HWY BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
DATUM Geodetic DATE 2018.07.05 - 2018.07.05 LATITUDE 43.568661 LONGITUDE -81.698101 CHECKED BY RD

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		
185.7	GROUND SURFACE							20	40	60	80	100									
0.0 0.1	ASPHALT (75mm)							20	40	60	80	100									
	SAND and GRAVEL, some silt Compact Brown Moist (FILL)		1	SS	27		185						○								
184.2																					
1.5	Silty CLAY, some sand, some gravel Stiff to Firm Brown Moist (FILL)		2	SS	12		184						○								
			3	SS	14		183						○					3	17	64	16
			4	SS	6		182						○								
181.4																					
4.3	SAND and GRAVEL, some silt Compact to Dense Brown Wet (FILL)		5	SS	12		181														
							180														
			6	SS	40		179						○								
	GRAVEL, some sand		7	SS	36		178												74	19	7 (SI+CL)
177.3																					
8.4	SAND and GRAVEL, trace silt Compact to Dense Brown to Grey Wet		8	SS	30		177						○								
							176														

Continued Next Page

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

RECORD OF BOREHOLE No 18-02

2 OF 3

METRIC

GWP# 3070-11-00 LOCATION South Approach, MTM NAD 83 Zone11: N 4 825 727.0 E 369 575.0 ORIGINATED BY AF
DIST 21 HWY BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
DATUM Geodetic DATE 2018.07.05 - 2018.07.05 LATITUDE 43.568661 LONGITUDE -81.698101 CHECKED BY RD

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						20	40	60	80	100					
	SAND and GRAVEL , trace silt Compact to Dense Grey Wet		9	SS	24											
			10	SS	37											
172.4																
13.3	Clayey SILT , with sand, trace gravel Hard Grey Moist (TILL)		11	SS	44											6 35 44 15
			12	SS	100/ 0.250											
			13	SS	100/ 0.100											
168.6																
17.1	LIMESTONE slightly weathered and moderately weathered at joints, strong to very strong, occasional vugs, grey sub horizontal fracture (25mm) at 17.1m, (50mm) at 17.2m, 17.3m sub vertical fracture (175mm) at 17.3m and (50mm) at 17.7m horizontal fracture at 18.4m horizontal fracture at 18.7m, 19.0m and 19.9m vuggy zone at 19.3m sub vertical fracture (75mm) at 19.4m highly broken zone (325mm) at 19.4m		1	RUN											FI 4 1 1 2 1 1 1	

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-02

3 OF 3

METRIC

GWP# 3070-11-00 LOCATION South Approach, MTM NAD 83 Zone11: N 4 825 727.0 E 369 575.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.07.05 - 2018.07.05 LATITUDE 43.568661 LONGITUDE -81.698101 CHECKED BY RD

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									
	Continued From Previous Page							20	40	60	80	100					
								○ UNCONFINED	+	FIELD VANE							
								● QUICK TRIAXIAL	×	LAB VANE							
								WATER CONTENT (%)									
								20	40	60	80	100					

ONTMT4S2 MTO-17127.GPJ 2017TEMPLATE(MTO).GDT 3/19/19

RECORD OF BOREHOLE No 18-03

1 OF 3

METRIC

GWP# 3070-11-00 LOCATION South Approach, MTM NAD 83 Zone11: N 4 825 736.0 E 369 571.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.06.27 - 2018.06.27 LATITUDE 43.568743 LONGITUDE -81.698150 CHECKED BY RD

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				W _P W W _L WATER CONTENT (%)				GR	SA	SI	CL
185.7	GROUND SURFACE							20	40	60	80	100							
0.0	ASPHALT (75mm)							20	40	60	80	100							
0.1	SAND and GRAVEL, trace silt Loose to Compact Brown Wet (FILL)																		
			1	SS	5									○					
			2	SS	10									○					
			3	SS	8									○					
			4	SS	12									○					
			5	SS	8									○					
			6	SS	14									○					

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC

[illegible]

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 17-04

1 OF 2

METRIC

GWP# 3070-11-00 LOCATION MTM NAD 83 Zone11: N 4 825 764.0 E 369 551.1 ORIGINATED BY AHF
DIST 21 HWY BOREHOLE TYPE Tripod/NQ Coring COMPILED BY MP
DATUM Geodetic DATE 2017.09.10 - 2017.09.13 LATITUDE 43.568996 LONGITUDE -81.698393 CHECKED BY SKP

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					
177.3	Barge deck surface												
0.0													
176.8							177						
0.5	WATER												
175.0							176						
2.3	SILT , some sand, trace gravel Loose Grey Wet		1	SS	9		175						
174.3													
3.0	Sandy GRAVEL , some silt Compact to Very Dense Brown Wet		2	SS	18		174						
			3	SS	69		173						
			4	SS									
							172						
171.2													
6.1	Sandy SILT , some clay, trace gravel Very Dense Brown Moist (TILL)		5	SS	60/ 075		171						
169.7							170						
7.6	Clayey SILT , with sand, some gravel Hard Brown Moist (TILL)		6	SS	57		169						
167.7							168						
9.6	LIMESTONE weathered, grey horizontal fracture at 9.8m		1	RUN									

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-05

1 OF 3

METRIC

GWP# 3070-11-00 LOCATION North Approach, MTM NAD 83 Zone11: N 4 825 783.0 E 369 519.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.07.03 - 2018.07.04 LATITUDE 43.569170 LONGITUDE -81.698788 CHECKED BY RD

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 (%)				
							20	40	60	80	100	W _p	W	W _L		
185.7	GROUND SURFACE															
0.0	ASPHALT (75mm)															
185.4	CONCRETE (200mm)															
0.3	SAND and GRAVEL, trace silt Compact to Loose Brown Moist (FILL)		1	SS	19											
			2	SS	13											
			3	SS	17											
	GRAVEL some sand		4	SS	34											
			5	SS	8											
			6	SS	13											
			7	SS	13											
			8	SS	7											
175.8																

Continued Next Page

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

RECORD OF BOREHOLE No 18-05

2 OF 3

METRIC

GWP# 3070-11-00 LOCATION North Approach, MTM NAD 83 Zone11: N 4 825 783.0 E 369 519.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.07.03 - 2018.07.04 LATITUDE 43.569170 LONGITUDE -81.698788 CHECKED BY RD

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					
	Continued From Previous Page						20 40 60 80 100						
9.9	SAND and GRAVEL , trace silt Compact to Dense Grey Wet		9	SS	19		175						
							174						
							173						
	Sandy GRAVEL		10	SS	31		172						
							171						
172.4													
13.3	Clayey SILT , trace sand and gravel Hard Grey Moist (TILL)		11	SS	100/ 0.250		170						
							169						
							168						
							167						
							166						
			12	SS	100/ 0.200								
			13	SS	51								
			14	SS	36								
166.7													
19.0	LIMESTONE slightly weathered and moderately weathered at joints, strong to very strong, occasional vugs, grey												

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RUN #1

RECORD OF BOREHOLE No 18-05

3 OF 3

METRIC

GWP# 3070-11-00 LOCATION North Approach, MTM NAD 83 Zone11: N 4 825 783.0 E 369 519.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.07.03 - 2018.07.04 LATITUDE 43.569170 LONGITUDE -81.698788 CHECKED BY RD

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											
								20	40	60	80	100							
	Continued From Previous Page																		
<div><div></div><div>157.1</div><div>28.6</div></div>	horizontal fracture at 20.2m and 20.8m		1	RUN		165									FI	TCR=83% SCR=74% RQD=67% UCS = 115 to 118 MPa			
	vuggy zone at 20.4m and (50mm) at 20.7m														0				
	rubble zone (125mm) at 20.8m														1				
	sub horizontal fracture (50mm) at 21.0m														>10				
				2	RUN		164									0	RUN #2 TCR=100% SCR=95% RQD=97% UCS = 55 to 74 MPa		
	vuggy zone (325mm) at 22.4m														0				
	horizontal fracture at 22.7m														0				
	sub horizontal fracture at 21.8m and (75mm) at 22.8m														1				
		sub vertical fracture (75mm) at 23.2m, 24.0m		3	RUN		163										1	RUN #3 TCR=100% SCR=63% RQD=69% UCS = 72 to 92 MPa	
																			1
																			4
																			0
				4	RUN		162										2	RUN #4 TCR=100% SCR=63% RQD=63% UCS = 92 to 156 MPa	
		horizontal fracture at 24.4m and 25.4m																	7
		sub horizontal fracture (75mm) at 25.1m and (25mm) at 25.4m																	1
		dolomite interbed (50mm) at 25.4m, 25.7m																	0
				5	RUN		161										1	RUN #5 TCR=63% SCR=35% RQD=30% UCS = 52 to 105 MPa	
		rubble zone (300mm) at 25.5m																	5
		limestone breccia (300mm) at 25.5m																	>10
		horizontal fracture at 25.9m, 26.1m and 26.4m																	2
		vuggy at 25.9m		6	RUN		160										>10	RUN #6 TCR=100% SCR=77% RQD=73% UCS = 70 to 116 MPa	
		dolostone interbed (175mm) at 25.9m																	2
		rubble zone (350mm) at 26.1m																	
	horizontal fracture at 27.4m, 27.5m, 27.8m, 28.1m, 28.2m and 28.3m					159										3			
	vugs zone (50mm) at 27.5m, (125mm) at 27.8m, (25mm) at 28.1m and 28.2m																1		
																	2		
	sub horizontal fracture (75mm) at 28.0m																4		
	dolostone interbed (50mm) at 27.5m																		
	sub vertical fracture (125mm) at 28.3m																		
	END OF BOREHOLE AT 28.6m. WATER LEVEL AT 8.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																		

ONTMT4S2 MTO-17127.GPJ 2017TEMPLATE(MTO).GDT 3/19/19

RECORD OF BOREHOLE No 18-06

1 OF 3

METRIC

GWP# 3070-11-00 LOCATION North Approach, MTM NAD 83 Zone11: N 4 825 786.0 E 369 511.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.07.04 - 2018.07.05 LATITUDE 43.569198 LONGITUDE -81.698886 CHECKED BY RD

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										
185.7	GROUND SURFACE							20	40	60	80	100						
0.0 0.1	ASPHALT (25mm)																	
	SAND and GRAVEL, some silt Dense Brown Moist (FILL)		1	SS	31		185											
184.0																		
1.7	Silty CLAY, some sand, trace gravel Soft to Firm Brown Moist (FILL)		2	SS	3		184											
			3	SS	6		183											
			4	SS	4		182											
181.7																		
4.0	SAND and GRAVEL, trace silt Dense to Compact Brown Wet (FILL)		5	SS	45		181											
	Sandy GRAVEL						180											
179.8			6	SS	8		179											
5.9	Loose																	
178.7			7	SS	31		178											
7.0			8	SS	13		177											
175.8							176											

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-06

3 OF 3

METRIC

GWP# 3070-11-00 LOCATION North Approach, MTM NAD 83 Zone11: N 4 825 786.0 E 369 511.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.07.04 - 2018.07.05 LATITUDE 43.569198 LONGITUDE -81.698886 CHECKED BY RD

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										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE												
								● QUICK TRIAXIAL × LAB VANE												
	Continued From Previous Page							20	40	60	80	100					GR	SA	SI	CL
159.8 																				

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

METRIC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	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					WATER CONTENT (%)				
							<div><div></div><div></div><div></div><div></div><div></div></div> <div>○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE</div>					<div>PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT</div> <div>w_p w w_L</div>				
185.7	GROUND SURFACE					▽	ELEVATION SCALE	20 40 60 80 100					20 40 60			0 14 51 35
0.0	ASPHALT (75mm)							185								
0.1	SAND and GRAVEL, some silt Compact Brown Moist (FILL)		1	GS												
			1	SS	12											
184.3								184								
1.4	Silty CLAY, trace sand and gravel Firm to Stiff Brown Moist (FILL)		2	SS	6											
			3	SS	11											
			4	SS	10											
								182								
			5	SS	12											
								180								
			6	SS	11											
								179								
			7	SS	15											
								178								
			8	SS	10											
175.8						176										

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-07

2 OF 2

METRIC

GWP# 3070-11-00 LOCATION North Approach, MTM NAD 83 Zone11: N 4 825 795.0 E 369 506.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.06.26 - 2018.06.26 LATITUDE 43.569279 LONGITUDE -81.698947 CHECKED BY RD



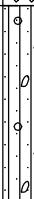

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
9.9	Continued From Previous Page Sandy SILT , some clay, trace gravel Compact Grey Wet		9	SS	25		175										4 58 25 13
174.4																	
11.3	END OF BOREHOLE AT 11.3m. WATER LEVEL AT 9.8m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																

RECORD OF BOREHOLE No 17-08

1 OF 1

METRIC

GWP# 3070-11-00 LOCATION MTM NAD 83 Zone11: N 4 825 721.2 E 369 544.1 ORIGINATED BY AHF
DIST 21 HWY BOREHOLE TYPE Casing/Coring NW COMPILED BY MP
DATUM Geodetic DATE 2017.08.29 - 2017.08.29 LATITUDE 43.568612 LONGITUDE -81.698484 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							PLASTIC LIMIT w _P NATURAL MOISTURE CONTENT w LIQUID LIMIT w _L WATER CONTENT (%)			
177.3	Barge deck surface							20	40	60	80	100						
0.0							177											
176.8																		
0.5	WATER						176											
175.3																		
2.0	SAND and GRAVEL , trace silt Compact to Loose Grey Wet		1	SS	13		175							○				
			2	SS	4		174							○				
			3	SS	32		173							○				
			4	SS	43									○				
172.2							172							○				18 32 39 11
5.1	Sandy SILT , some clay, some gravel Compact to Very Dense Brown Wet (TILL)		5	SS	21		171							○				
170.9														○				38 36 26 (SI+CL)
6.4	SAND and GRAVEL , some silt and clay Very Dense Brown Wet		6	SS	79		170											
170.0																		
7.3	END OF BOREHOLE AT 7.3m. BOREHOLE BACKFILLED WITH BENTONITE BOREPLUG AND CUTTINGS TO SURFACE.																	

ONTMT4S2 MTO-17127.GPJ 2017TEMPLATE(MTO).GDT 3/19/19

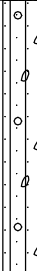


+³, ×³: Numbers refer to Sensitivity 20 15 10 5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-09

1 OF 2

METRIC

GWP# 3070-11-00 LOCATION MTM NAD 83 Zone11: N 4 825 741.1 E 369 524.7 ORIGINATED BY AHF
 DIST 21 HWY BOREHOLE TYPE Tripod/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2017.09.05 - 2017.09.05 LATITUDE 43.568792 LONGITUDE -81.698722 CHECKED BY SKP

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												
177.3	Barge deck surface							20	40	60	80	100								
0.0							177													
176.8							176													
0.5	WATER						175													
							174													
							173													
172.1							172													
5.2	Silty SAND , some gravel, trace to some clay Very Dense Grey Wet (TILL) pieces of cobble/boulder Brown		1	SS	70		171													
			2	SS	100/ .100															
170.3			3	SS	100/ .100															
7.0	Clayey SILT , with sand, trace gravel Hard Brown Moist (TILL)		4	SS	34		170													
			5	SS	59/ 125		169													
168.0							168													
9.3	LIMESTONE weathered, grey																			
167.5																				
9.8	END OF BOREHOLE AT 9.8m.																			

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+³, ×³: Numbers refer to
Sensitivity

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15
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(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-09

2 OF 2

METRIC

GWP# 3070-11-00 LOCATION MTM NAD 83 Zone11: N 4 825 741.1 E 369 524.7 ORIGINATED BY AHF
 DIST 21 HWY BOREHOLE TYPE Tripod/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2017.09.05 - 2017.09.05 LATITUDE 43.568792 LONGITUDE -81.698722 CHECKED BY SKP

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

RECORD OF BOREHOLE No 18-10

1 OF 2

METRIC

GWP# 3070-11-00 LOCATION MTM NAD 83 Zone11: N 4 825 775.0 E 369 494.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.07.11 - 2018.07.11 LATITUDE 43.569100 LONGITUDE -81.699098 CHECKED BY RD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)					
178.9	GROUND SURFACE							20 40 60 80 100									
0.0	Silty SAND , trace gravel Very Dense Brown Moist (FILL)		1	SS	100/ 0.250		178										
177.5																	
1.4	Silty CLAY , some sand, trace gravel Stiff to Firm Brown Moist (FILL)		2	SS	10		177										
			3	SS	5												
			4	SS	3		176										
174.8							175										
4.1	SAND and GRAVEL Loose Brown Wet (FILL)		5	SS	8		174										
173.3																	
5.6	Silty CLAY , trace sand and gravel Firm Brown Moist (FILL)		6	SS	5	173											
						172											
171.7																	
7.2	Silty CLAY , trace sand, trace gravel Hard Grey Moist (TILL)		7	SS	55	171											
							170										
				8	SS	30											
						169											

Continued Next Page

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

RECORD OF BOREHOLE No 18-10

2 OF 2

METRIC

GWP# 3070-11-00 LOCATION MTM NAD 83 Zone11: N 4 825 775.0 E 369 494.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.07.11 - 2018.07.11 LATITUDE 43.569100 LONGITUDE -81.699098 CHECKED BY RD

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				
168.8	Continued From Previous Page		9	SS	100/												
10.1	END OF BOREHOLE AT 10.1m UPON AUGER REFUSAL. WATER LEVEL AT 2.8m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.				0.075												

RECORD OF BOREHOLE No 18-11

1 OF 1

METRIC

GWP# 3070-11-00 LOCATION MTM NAD 83 Zone11: N 4 825 770.0 E 369 506.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Tripod COMPILED BY MP
 DATUM Geodetic DATE 2018.07.19 - 2018.07.19 LATITUDE 43.569053 LONGITUDE -81.698948 CHECKED BY RD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)									
								○ UNCONFINED + FIELD VANE	● QUICK TRIAXIAL × LAB VANE												
178.8	GROUND SURFACE							20	40	60	80	100		20	40	60	kN/m ³	GR	SA	SI	CL
0.0	Silty CLAY , with sand, trace gravel, trace rootlets Hard Brown Moist (FILL)		1	SS	76									○							
			2	SS	48									○							
			3	SS	47									○							
			4	SS	75									○							
173.8														○							
5.0	SAND and GRAVEL , trace silt Very Dense Grey Wet																				
172.6			5	SS	100/																
6.2	END OF BOREHOLE AT 6.2m UPON CASING REFUSAL. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.				0.100									○							



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

RECORD OF BOREHOLE No 18-12

1 OF 1

METRIC

GWP# 3070-11-00 LOCATION MTM NAD 83 Zone11: N 4 825 733.0 E 369 592.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Tripod COMPILED BY MP
 DATUM Geodetic DATE 2018.07.17 - 2018.07.17 LATITUDE 43.568714 LONGITUDE -81.697890 CHECKED BY RD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							WATER CONTENT (%) W _P W W _L			
182.0	GROUND SURFACE							20	40	60	80	100						
0.0	Silty SAND , trace gravel, trace rootlets Dense Brown Moist (FILL)		1	SS	34										○			
			2	SS	43		181								○			
180.6																		
1.4	Silty CLAY , trace sand and gravel Hard Brown Moist		3	SS	52		180								○			
			4	SS	89		179											
															○			
							178											
			5	SS	87		177								○			
176.8																		
5.2	END OF BOREHOLE AT 5.2m UPON CASING REFUSAL. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																	

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

RECORD OF BOREHOLE No 18-13

1 OF 1

METRIC

GWP# 3070-11-00 LOCATION MTM NAD 83 Zone11: N 4 825 741.0 E 369 585.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Tripod COMPILED BY MP
 DATUM Geodetic DATE 2018.07.16 - 2018.07.16 LATITUDE 43.568786 LONGITUDE -81.697976 CHECKED BY RD



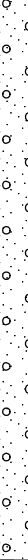

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
181.2	GROUND SURFACE							20	40	60	80	100			
0.0	TOPSOIL: (50mm)														
0.1	Silty SAND , some garvel, trace organics, trace rootlets Very Dense Brown Moist (FILL)		1	SS	64		181								
180.4															
0.8			2	SS	58		180								
	Silty CLAY , some sand, trace gravel, trace rootlets Hard Brown Moist		3	SS	100/										
179.3			4	SS	0.150										
1.9	END OF BOREHOLE AT 1.9m UPON CASING REFUSAL. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.				100/ 0.100										

RECORD OF BOREHOLE No 17-14

1 OF 1

METRIC

GWP# 3070-11-00 LOCATION MTM NAD 83 Zone11: N 4 825 752.7 E 369 587.1 ORIGINATED BY AHF
DIST 21 HWY BOREHOLE TYPE Tripod/NQ Coring COMPILED BY MP
DATUM Geodetic DATE 2017.09.14 - 2017.09.14 LATITUDE 43.568891 LONGITUDE -81.697948 CHECKED BY SKP

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 (%)				
177.3	Barge deck surface															
0.0							177									
176.8																
0.5	WATER						176									
175.7																
1.6	SILT , some clay, trace sand and gravel Loose Grey Wet		1	SS	4		175									
174.9																
2.4	SAND and GRAVEL , trace to some silt, occasional cobbles and boulder fragments Dense Brown Wet		2	SS	30		174									
							173									
			3	SS	79		172									
171.2																
6.1	Clayey SILT , with sand, some gravel Hard Brown Wet (TILL)		4	SS	64		171									
			5	SS	46		170									
169.5																
7.8	END OF BOREHOLE AT 7.8m. BOREHOLE BACKFILLED WITH BENTONITE BOREPLUG AND CUTTINGS TO SURFACE.															

ONTMT4S2 MTO-17127.GPJ 2017TEMPLATE(MTO).GDT 3/19/19

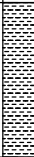



+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-15

1 OF 1

METRIC

GWP# 3070-11-00 LOCATION MTM NAD 83 Zone11: N 4 825 778.8 E 369 558.9 ORIGINATED BY AHF
DIST 21 HWY BOREHOLE TYPE Tripod/NQ Coring COMPILED BY MP
DATUM Geodetic DATE 2017.09.09 - 2017.09.09 LATITUDE 43.569129 LONGITUDE -81.698294 CHECKED BY SKP

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			20 40 60 80 100	20 40 60 80 100	W _P W W _L						
177.3	Barge deck surface															
0.0																
176.8																
0.5	WATER															
175.8																
1.5	SAND and GRAVEL Loose to Dense Grey Wet		1	SS	4								○			
			2	SS	12								○			
			3	SS	37								○			
			4	SS	35								○			
173.0																
4.3	Silty CLAY , trace sand Very Stiff Brown Wet															
			5	SS	16								●	—	0 0 62 38	
171.7																
5.6	SAND and GRAVEL , trace silt Very Dense Brown Wet															
			6	SS	61								○		47 44 9 (SI+CL)	
170.0																
7.3	END OF BOREHOLE AT 7.3m. BOREHOLE BACKFILLED WITH BENTONITE BOREPLUG AND CUTTINGS TO SURFACE.															

ONTMT452 MTO-17127.GPJ 2017TEMPLATE(MTO).GDT 3/19/19


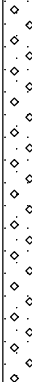
+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-16

1 OF 1

METRIC

GWP# 3070-11-00 LOCATION MTM NAD 83 Zone11: N 4 825 794.0 E 369 525.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Tripod COMPILED BY MP
 DATUM Geodetic DATE 2018.07.24 - 2018.07.24 LATITUDE 43.569269 LONGITUDE -81.698712 CHECKED BY RD

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	
								<div><div></div><div></div><div></div><div></div><div></div></div> <div>20 40 60 80 100</div> <div>○ UNCONFINED + FIELD VANE</div> <div>● QUICK TRIAXIAL × LAB VANE</div>					<div><div></div><div></div><div></div></div> <div>w_P w w_L</div>								
180.2	GROUND SURFACE																				
0.0	Silty CLAY , some sand, trace gravel Stiff to Hard Brown Moist (FILL)		1	SS	12		180							○							
							179														
			2	SS	60		178							○							
			3	SS	29		177							○							
							176														
			4	SS	41		175							○							
174.6																					
5.6	Sandy GRAVEL , trace silt Very Dense Grey Wet		5	SS	59		174							○							
							173														
			6	SS	82									○							
172.0							172														
8.2	END OF BOREHOLE AT 8.2m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																				

ONTMT452 MTO-17127.GPJ 2017TEMPLATE(MTO).GDT 3/19/19

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

RECORD OF BOREHOLE No 18-17

1 OF 2

METRIC

GWP# 3070-11-00 LOCATION MTM NAD 83 Zone11: N 4 825 819.0 E 369 497.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.07.12 - 2018.07.12 LATITUDE 43.569496 LONGITUDE -81.699056 CHECKED BY RD

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	W _P	W	W _L					
184.8	GROUND SURFACE							20	40	60	80	100							
0.0	Silty CLAY , some sand, trace gravel, trace rootlets Stiff to Firm Brown Moist (FILL)						184							○					
			1	SS	13														
			2	SS	9		183							○					
			3	SS	6		182							○				0 17 45 38	
			4	SS	6									○					
							181												
			5	SS	11		180							○					
							179												
			6	SS	7									○					
							178												
177.6																			
7.2	Sandy SILT , some clay, trace rootlets Loose Grey Wet						177							○				0 31 55 14	
			7	SS	4														
176.0							176												
8.8	Silty CLAY , trace sand and gravel Hard Greyish Brown Moist													○					
			8	SS	30		175												

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

METRIC

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 (%)											
						○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL			x LAB VANE	20	40	60	80	100	w _P		w	w _L	GR	SA
	Continued From Previous Page																					
171.6	Silty CLAY , trace sand and gravel Hard to Stiff Grey Moist		9	SS	68											○			0	0	60	40
173																						
172			10	SS	8											○						
171																						
170																						
169																						
13.2	Silty SAND , trace gravel, some clay Very Dense Grey Moist (TILL)		11	SS	51											○			5	45	35	15
16.1	END OF BOREHOLE AT 16.1m UPON AUGER REFUSAL. WATER LEVEL AT 7.4m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																					

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-18

1 OF 2

METRIC

GWP# 3070-11-00 LOCATION South Approach, MTM NAD 83 Zone11: N 4 825 703.0 E 369 580.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.07.09 - 2018.07.09 LATITUDE 43.568445 LONGITUDE -81.698042 CHECKED BY RD

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						PLASTIC LIMIT w _p NATURAL MOISTURE CONTENT w LIQUID LIMIT w _L WATER CONTENT (%)								
180.8	GROUND SURFACE							20	40	60	80	100										
0.0	ROCK FILL							20	40	60	80	100										
180.0																						
0.8	Silty CLAY , trace sand and gravel, trace rootlets Firm Brown Moist (FILL)		1	SS	8		180															
			2	SS	6		179															
178.6																						
2.2	SAND and GRAVEL Loose Brown Wet (FILL)		3	SS	8		178															
			4	SS	2																	
							177															
176.7																						
4.1	SAND and GRAVEL , trace silt and clay Dense Grey Wet		5	SS	34		176												47	43	10 (SI+CL)	
			6	SS	41		175															
							174															
173.6																						
7.2	Clayey SILT , with sand, trace gravel Hard Grey Moist (TILL)		7	SS	49		173												5	42	37	16
			8	SS	100/ 0.275		172															
							171															

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-18

2 OF 2

METRIC

GWP# 3070-11-00 LOCATION South Approach, MTM NAD 83 Zone11: N 4 825 703.0 E 369 580.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.07.09 - 2018.07.09 LATITUDE 43.568445 LONGITUDE -81.698042 CHECKED BY RD

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				
170.7	Continued From Previous Page	11.4															
10.1	END OF BOREHOLE AT 10.1m UPON AUGER REFUSAL. WATER LEVEL AT 2.3m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																

RECORD OF BOREHOLE No 18-19

1 OF 2

METRIC

GWP# 3070-11-00 LOCATION South Approach, MTM NAD 83 Zone11: N 4 825 718.0 E 369 561.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.06.28 - 2018.06.29 LATITUDE 43.568581 LONGITUDE -81.698276 CHECKED BY RD

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									
179.9	GROUND SURFACE							20	40	60	80	100					GR SA SI CL
0.0	Silty CLAY , some sand, trace gravel Stiff Brown Moist (FILL)		1	SS	10		179										
178.5																	
1.4	SAND and GRAVEL , trace silt and clay Compact Brown Moist to Wet		2	SS	22		178										
			3	SS	23		177										
			4	SS	16		176										
			5	SS	22		175										
			6	SS	100/ 0.150		174										
172.7							173										
7.2	Clayey SILT , with sand, some gravel Hard Grey Moist (TILL)		7	SS	57		172										
			8	SS	74		171										
							170										

Continued Next Page

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

METRIC

SOIL PROFILE						SAMPLES							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	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 (%)
	Continued From Previous Page							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				kN/m ³	GR SA SI CL
167.9	Clayey SILT, some sand, some gravel Hard Grey Moist (TILL)		9	SS	100/ 0.250		169						
12.0	LIMESTONE slightly weathered and moderately weathered at joints, medium to very strong, occasional vugs, grey occasional vugs throughout highly broken zone (325mm) at 12.0m horizontal fracture at 12.4m, 13.1m, 13.2m, 13.3m, 13.5m and 13.6m limestone breccia at 12.7m and 13.3m vuggy zone (100mm) at 12.7m sub horizontal fracture (50mm) at 13.8m, 14.3m horizontal fracture at 14.0m, 14.1m and 14.9m vuggy zone (25mm) at 14.0m and (100mm) at 15.0m		1	RUN			168					FI >10	RUN #1 TCR=90% SCR=52% RQD=45% UCS = 20 to 112 MPa
164.8			2	RUN			167					2	RUN #2 TCR=100% SCR=90% RQD=90% UCS = 39 to 108 MPa
15.1	END OF BOREHOLE AT 15.1m. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.						166					2	
	WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2018.07.20 1.3 178.6 2018.07.24 1.3 178.6						165					1	

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-20

1 OF 2

METRIC

GWP# 3070-11-00 LOCATION North Approach, MTM NAD 83 Zone11: N 4 825 768.0 E 369 499.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.07.10 - 2018.07.10 LATITUDE 43.569037 LONGITUDE -81.699037 CHECKED BY RD

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										
178.5	GROUND SURFACE																		
0.0	TOPSOIL: (50mm) Silty CLAY , trace sand and garvel, trace rootlets Firm to Stiff Brown Moist (FILL)		1	SS	6														
			2	SS	9														
			3	SS	5														
175.5	Gravelly SAND , some silt, trace clay Compact to Loose Grey Wet		4	SS	14														
3.0			5	SS	9														
172.9	Silty CLAY , trace sand and gravel Stiff to Hard Brown Moist (TILL)		6	SS	13														
5.6			7	SS	50														
			8	SS	77														
									</										

Continued Next Page

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

RECORD OF BOREHOLE No 18-20

2 OF 2

METRIC

GWP# 3070-11-00 LOCATION North Approach, MTM NAD 83 Zone11: N 4 825 768.0 E 369 499.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.07.10 - 2018.07.10 LATITUDE 43.569037 LONGITUDE -81.699037 CHECKED BY RD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								20	40	60	80					
	Continued From Previous Page															
167.5	Silty CLAY , trace sand and gravel Stiff to Hard Brown Moist (TILL)		9	SS	100/ 0.200		168									
11.0	LIMESTONE slightly weathered and moderately weathered at joints, medium to very strong, occasional vugs, grey horizontal fracture at 11.4m, 11.5m, 11.6m, 11.7m, 12.2m, 12.3m, 12.4m, 12.5m, 12.6m and 12.8m vuggy zone (25mm) at 11.6m, 12.8m highly broken zone (375mm) at 11.8m vertical fracture (125mm) at 12.4m highly broken zone (175mm) at 12.8m horizontal fracture at 13.0m, 13.1m, 13.2m, 13.3m, 13.5m, 13.6m, 13.8m, 13.9m and 14.0 vuggy zone (200mm) at 13.4m		1	RUN			167									
							166									
							165									
164.2	sub vertical fracture (75mm) at 14.1m		2	RUN												
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) 2018.07.20 0.4 178.1 2018.07.24 0.3 178.2															

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

RECORD OF BOREHOLE No 18-21

1 OF 1

METRIC

GWP# 3070-11-00 LOCATION North Approach, MTM NAD 83 Zone11: N 4 825 782.0 E 369 478.0 ORIGINATED BY AF
 DIST 21 HWY BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.07.11 - 2018.07.11 LATITUDE 43.569165 LONGITUDE -81.699295 CHECKED BY RD

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						PLASTIC LIMIT w _P NATURAL MOISTURE CONTENT w LIQUID LIMIT w _L WATER CONTENT (%)				
178.3	GROUND SURFACE							20	40	60	80	100						
0.0 0.1	TOPSOIL: (75mm)																	
	SAND, some silt, trace gravel Compact Brown Moist (FILL)		1	SS	14		178											
							177											
176.6																		
1.7	Silty CLAY, some sand, trace gravel Stiff Brown Moist (FILL)		2	SS	14													
							176											
175.9																		
2.4	SAND, some silt, trace gravel Loose to Compact Brown Moist (FILL)		3	SS	4		175											
			4	SS	11													
174.2							174											
4.1	SAND, some silt and gravel, trace clay Compact Grey Wet (TILL)		5	SS	13		173											
172.7																		
5.6	Silty CLAY, some sand, trace gravel Firm to Hard Grey Wet (TILL)		6	SS	6		172											
							171											
			7	SS	46													
							170											
169.8																		
8.5	END OF BOREHOLE AT 8.5m UPON AUGER REFUSAL. WATER LEVEL AT 2.4m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																	

ONTMT4S2 MTO-17127.GPJ 2017TEMPLATE(MTO).GDT 3/19/19

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 806

1 OF 2

METRIC

PROJECT 12-1132-0076

W.P. 3070-11-00

LOCATION N 4825783.7, E 369508.0

ORIGINATED BY MA

DIST HWY 21

BOREHOLE TYPE POWER AUGER, HOLLOW STEM, TRICONE

COMPILED BY WDF

DATUM GEODETIC

DATE September 30 - October 2, 2014

CHECKED BY

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 (%)
								○ UNCONFINED	+ FIELD VANE						
								● QUICK TRIAXIAL	x LAB VANE						
185.80	PAVEMENT SURFACE														
0.00	CONCRETE														
0.15	FILL, sand and gravel, crushed, trace silt, with pieces of concrete Loose Brown		1	SS	9									33 55 (12)	
			2	SS	5										
			3	SS	10										
182.90															
2.90	FILL, clayey silt, some sand, some gravel, with pieces of wood Firm Brown		4	SS	8										
182.14															
3.66	FILL, sand and gravel, crushed, trace silt Compact to very dense Brown		5	SS	38									56 32 (12)	
			6	SS	52										
			7	SS	23										
180.01															
5.79	FILL, clayey silt, some sand, trace gravel Very stiff Brown		8	SS	20									2 14 56 28	
			9	SS	28										
			10	SS	28										
			11	SS	25										
177.27															
8.53	FILL, silty topsoil, some clay, with roots and organics, some sand, trace gravel Compact Brown and black		12	SS	13										
176.75			13	SS	14										
9.05	FILL, sand, fine, some silt Compact Brown														
176.05			14	SS	20									72 23 (5)	
9.75	SAND AND GRAVEL, trace silt Compact to dense Grey		15	SS	38										
			16	SS	37										
173.30															
12.50	CLAYEY SILT TILL, some sand, trace gravel Very stiff Grey		17	SS	18										
171.93															
13.87	SILTY CLAY TILL, trace sand, with sandy silt pockets Hard Grey		18	SS	38									0 4 47 49	

LDN_MTO_06 12-1132-0076-3001-R01.GPJ LDN_MTO.GDT 21/07/15

Continued Next Page

+ 3, X 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 806

2 OF 2

METRIC

PROJECT 12-1132-0076

W.P. 3070-11-00

LOCATION N 4825783.7 , E 369508.0

ORIGINATED BY MA

DIST HWY 21

BOREHOLE TYPE POWER AUGER, HOLLOW STEM, TRICONE

COMPILED BY WDF

DATUM GEODETIC

DATE September 30 - October 2, 2014

CHECKED BY

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						
								20 40 60 80 100						
								○ UNCONFINED + FIELD VANE						
								● QUICK TRIAXIAL x LAB VANE						
								20 40 60 80 100						

LDN_MTO_06_12-1132-0076-3001-R01.GPJ LDN_MTO.GDT 21/07/15

[illegible]

RECORD OF BOREHOLE No 807

2 OF 2

METRIC

PROJECT 12-1132-0076
W.P. 3070-11-00 LOCATION N 4825729.6, E 369567.9 ORIGINATED BY DJM
DIST HWY 21 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY WDF
DATUM GEODETIC DATE December 19, 2014 CHECKED BY

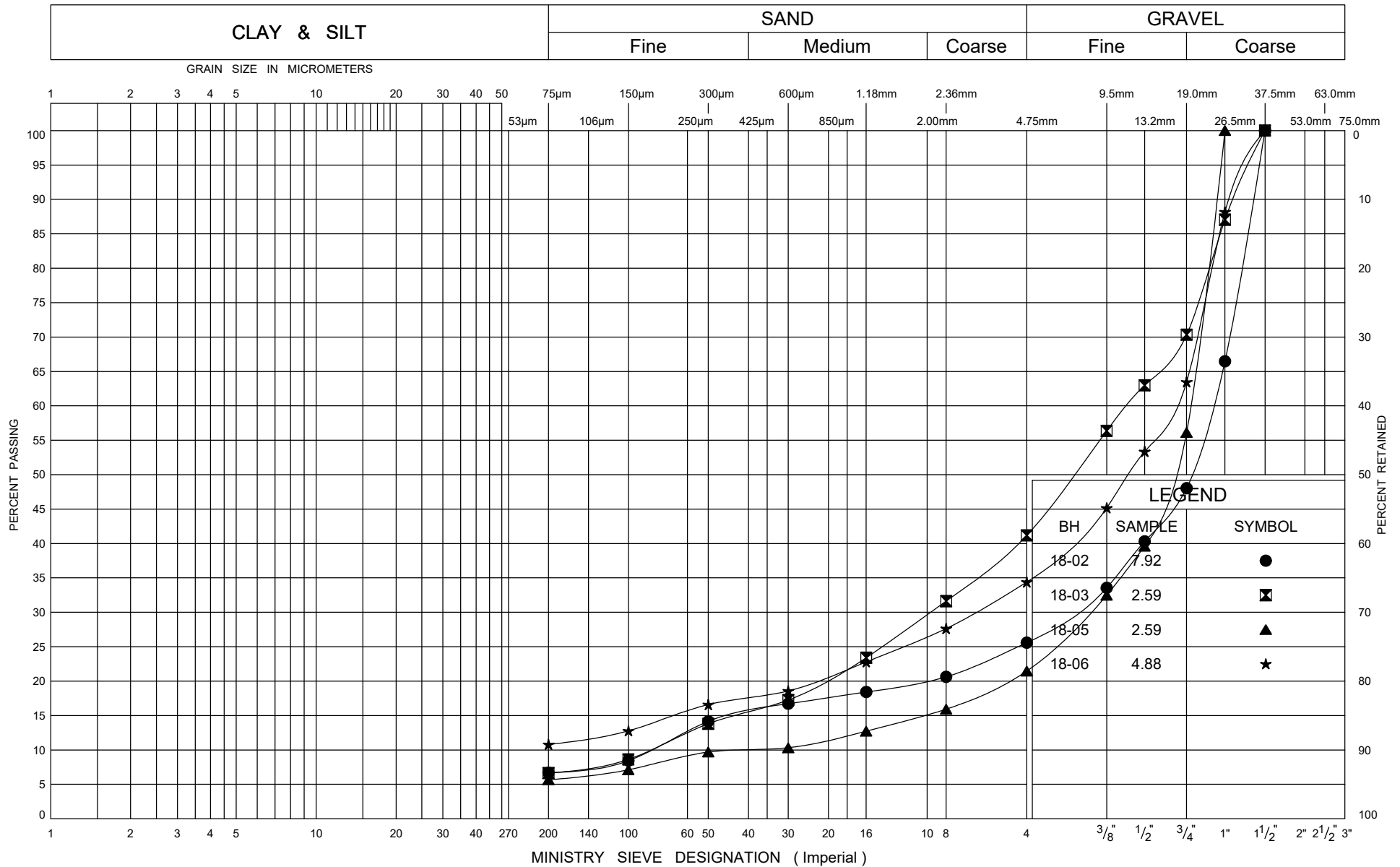
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ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _p W W _L				WATER CONTENT (%)
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE					
							20 40 60 80 100							
170.32			13	SS	59									
15.54	SAND, fine to medium, trace silt Very dense Grey						170							
169.71														
16.15	CLAYEY SILT TILL, sandy, trace gravel Hard Grey		14	SS	51		169							
							168							
			15	SS	45		167							
166.66														
19.20	SANDY SILT TILL, some gravel, with cobbles Very dense Grey		16	SS	100/100mm		166							
165.96														
19.90	END OF BOREHOLE													
	Groundwater encountered at about elev. 175.2m during drilling on Dec. 19, 2014.													

LDN_MTO_06 12-1132-0076-3001-R01.GPJ LDN_MTO.GDT 21/07/15



Appendix B

Laboratory Test Results



Ministry of
Transportation

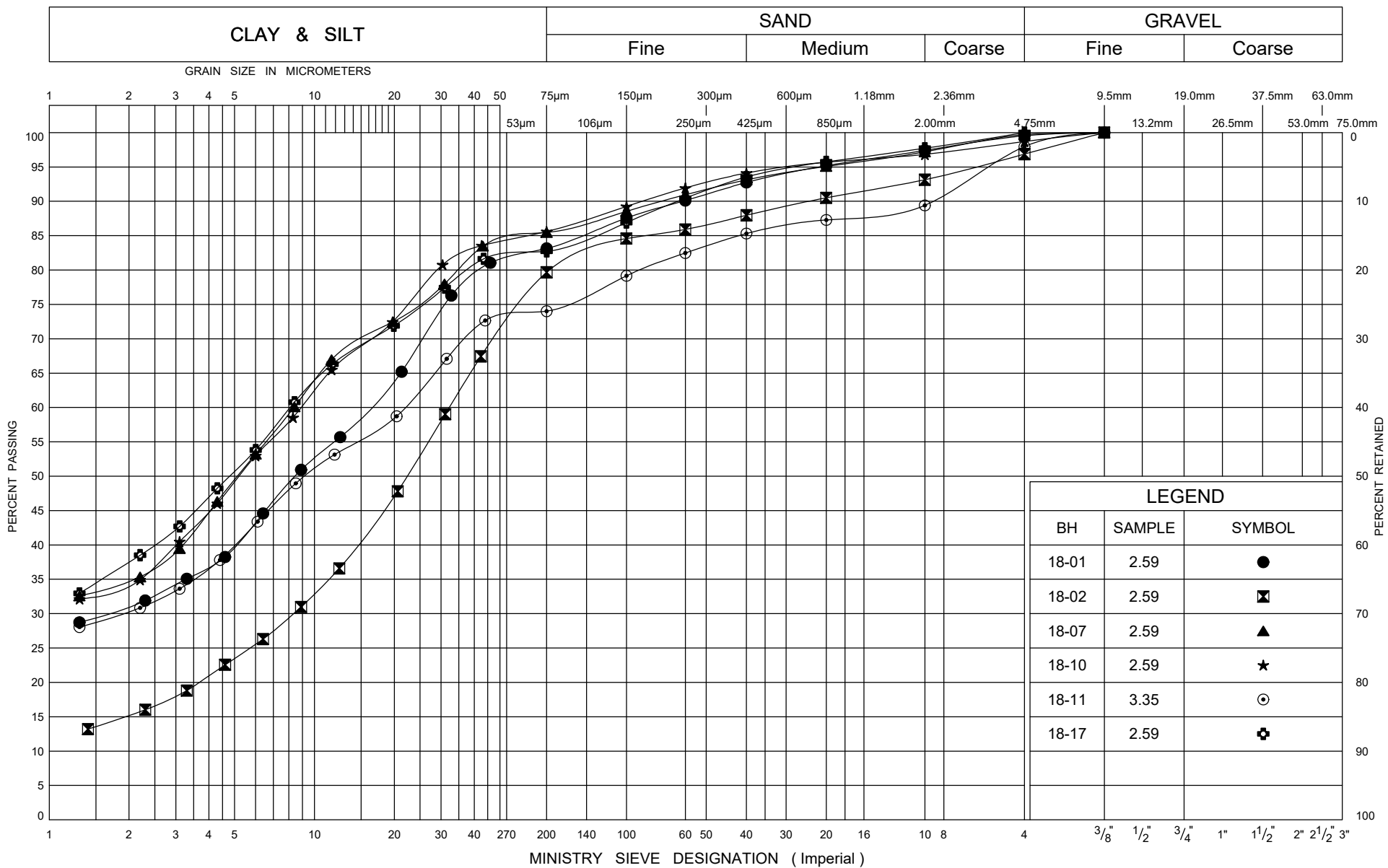
GRAIN SIZE DISTRIBUTION

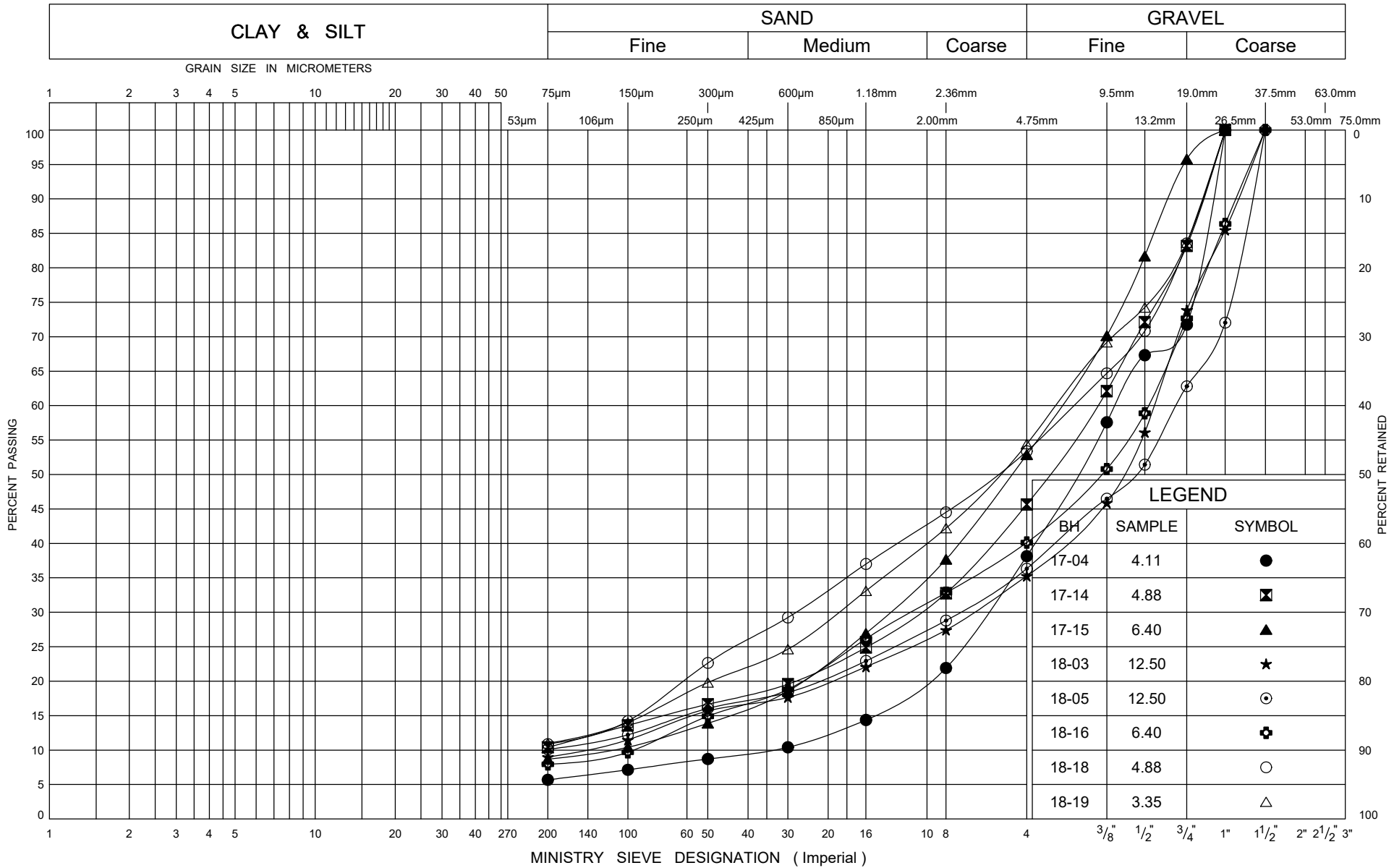
SAND and GRAVEL to Sandy GRAVEL FILL

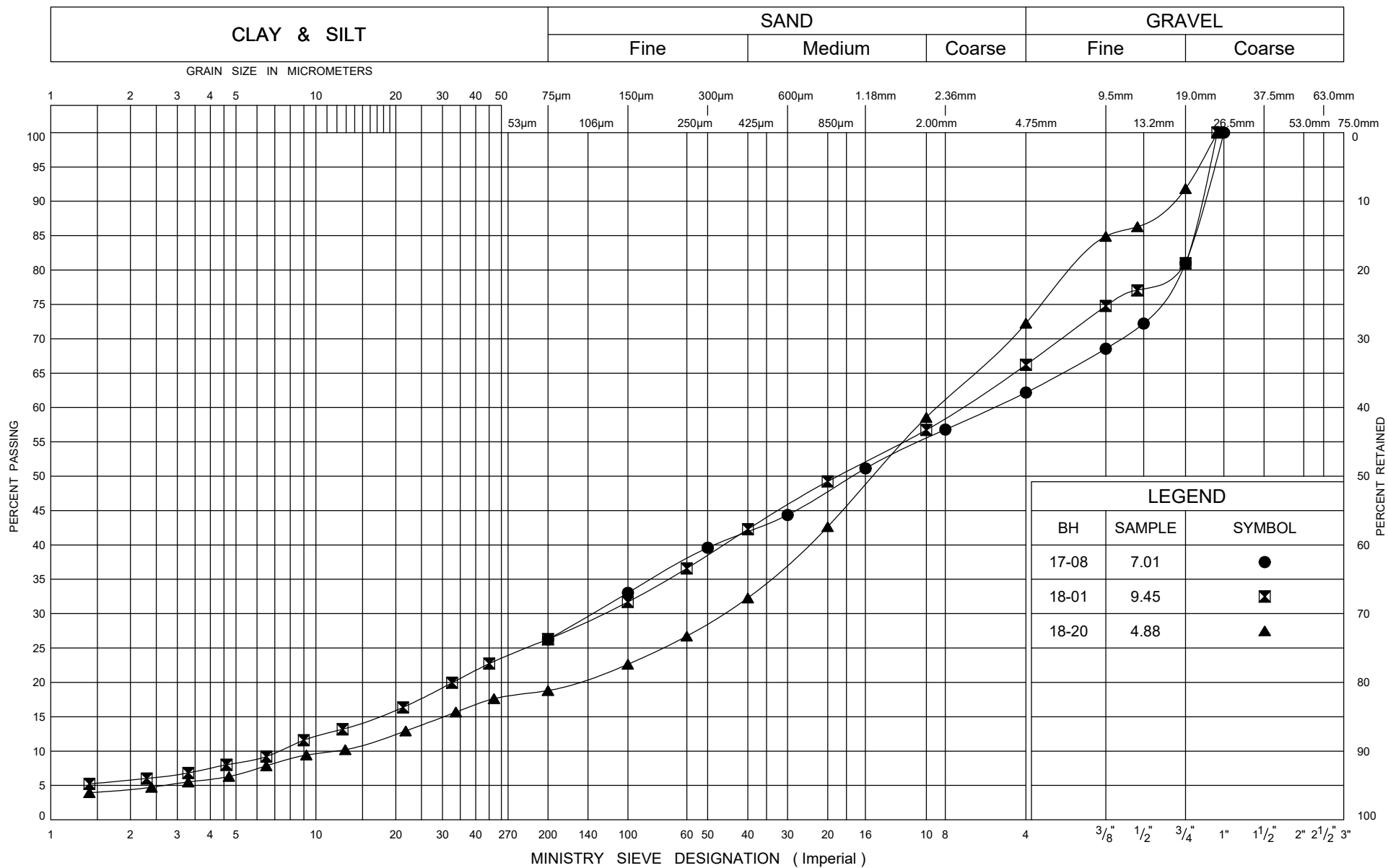
FIG No B1

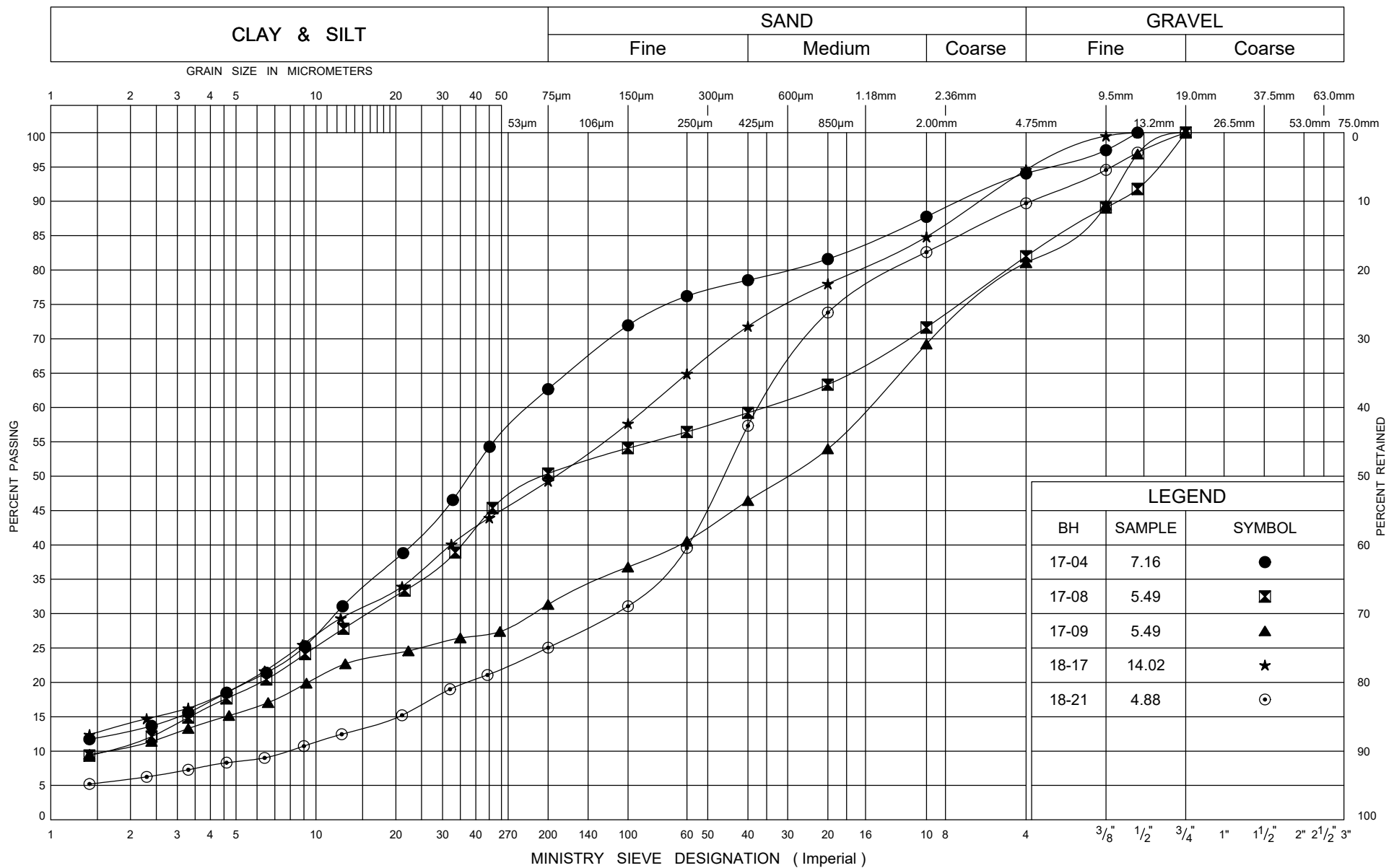
W P 3070-11-00

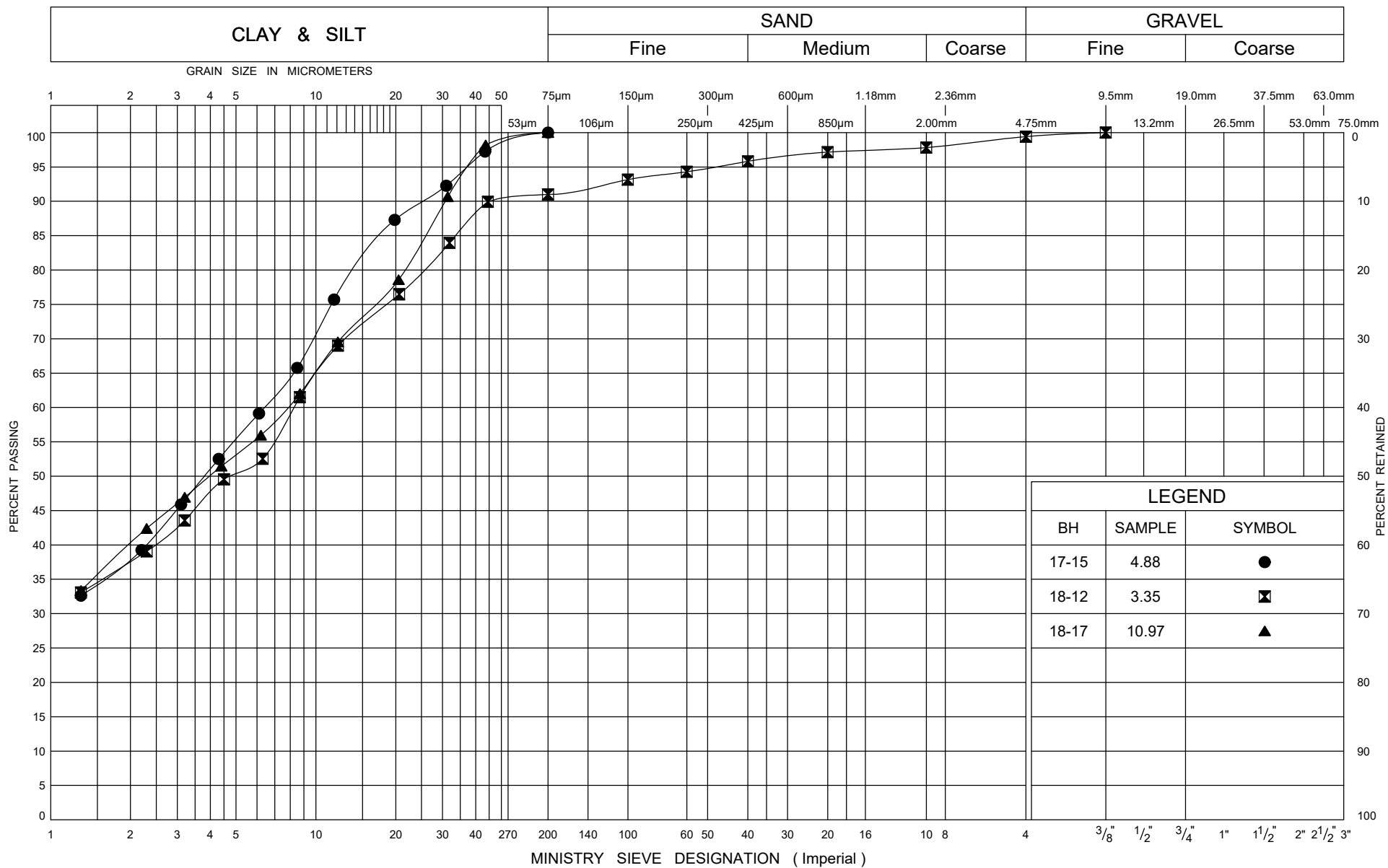
Bayfield River Bridge

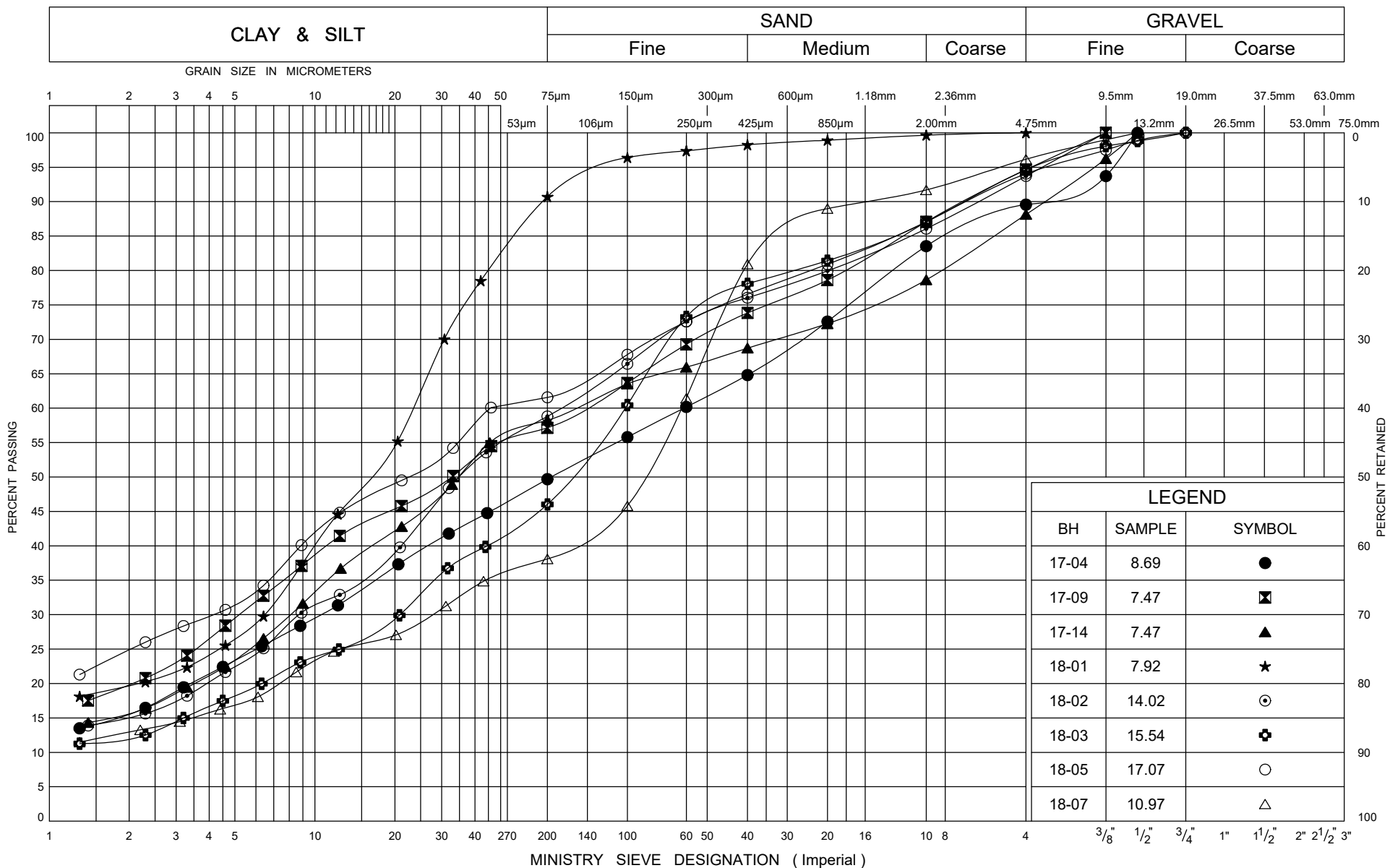


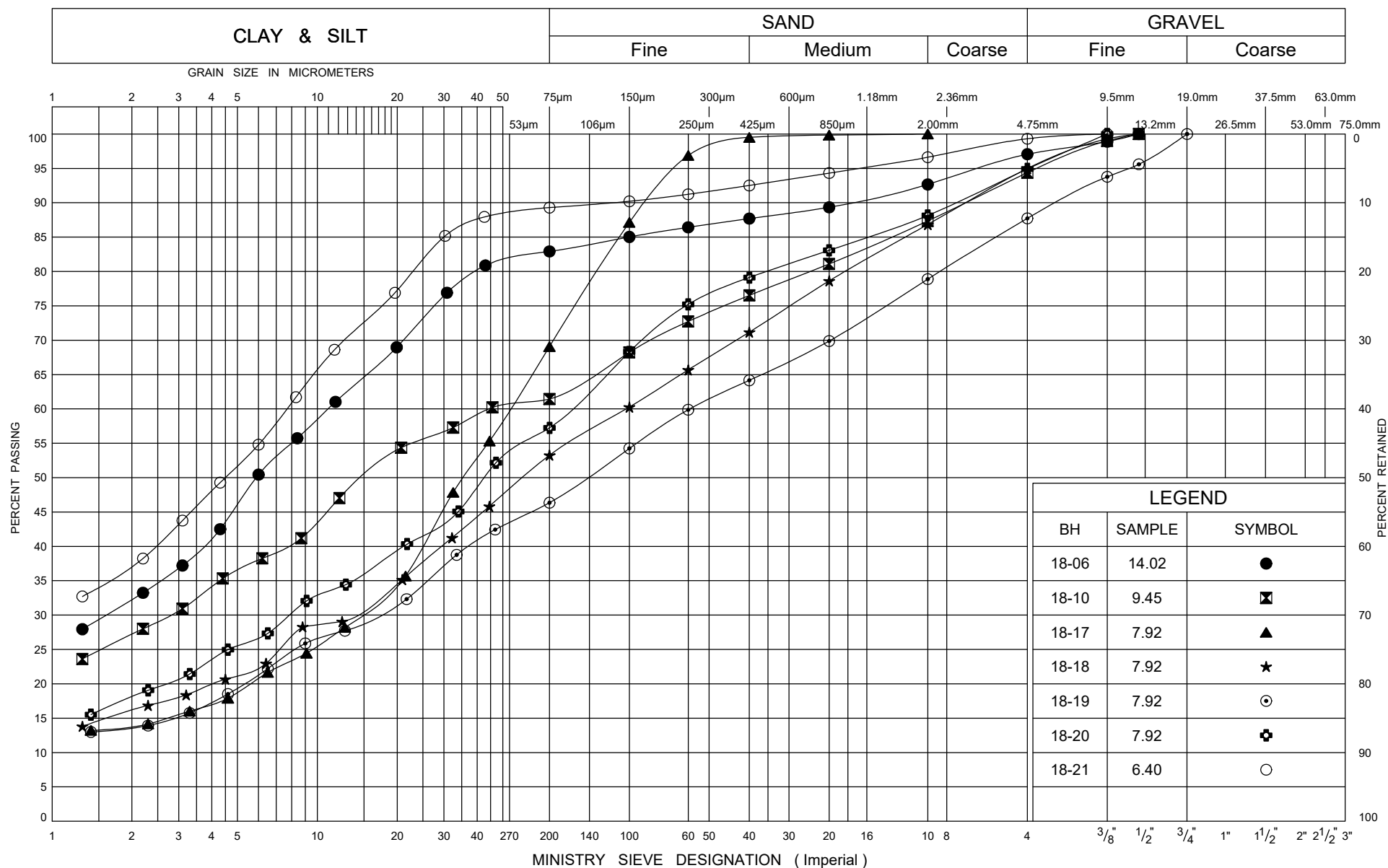












Ministry of
Transportation

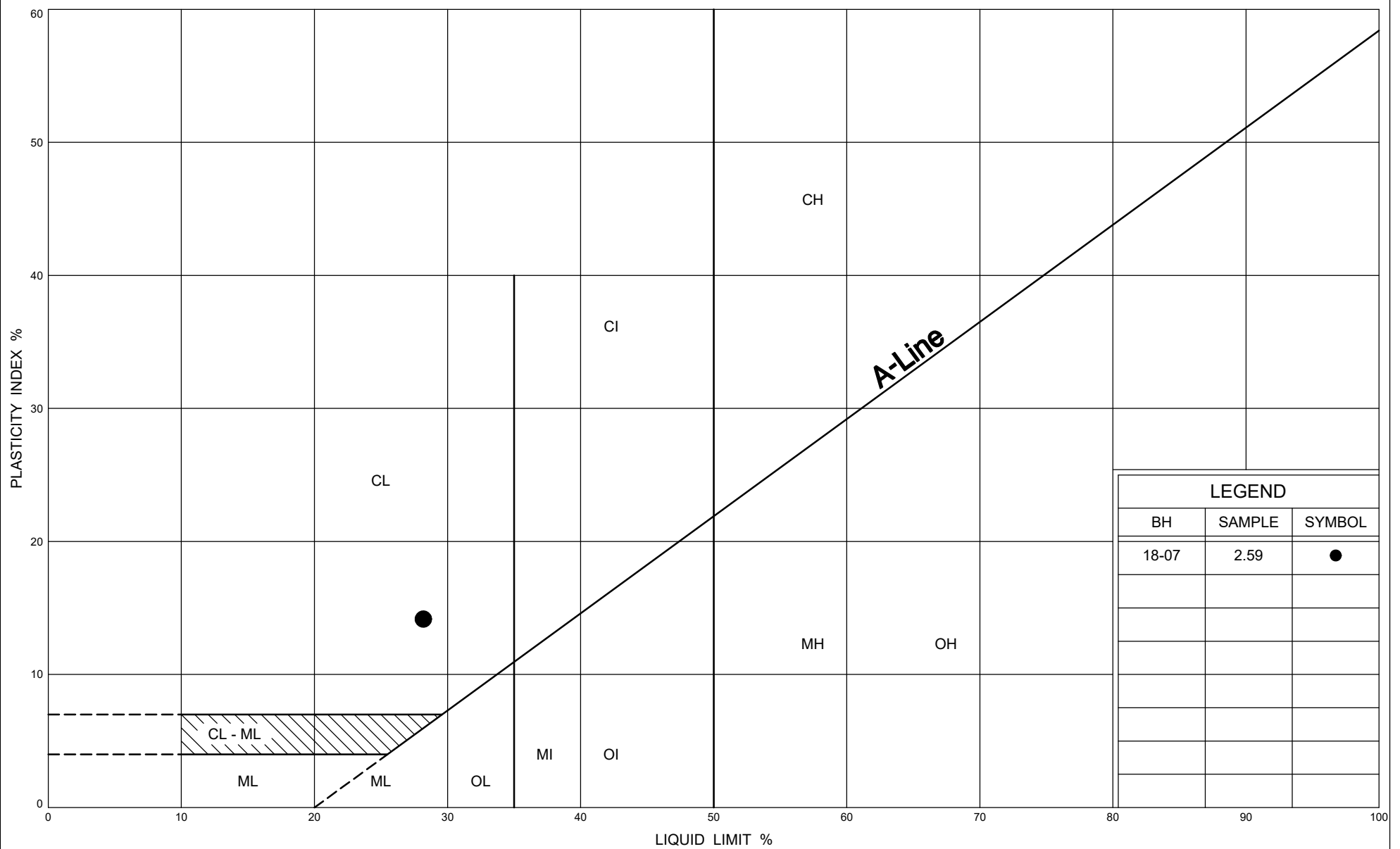
GRAIN SIZE DISTRIBUTION

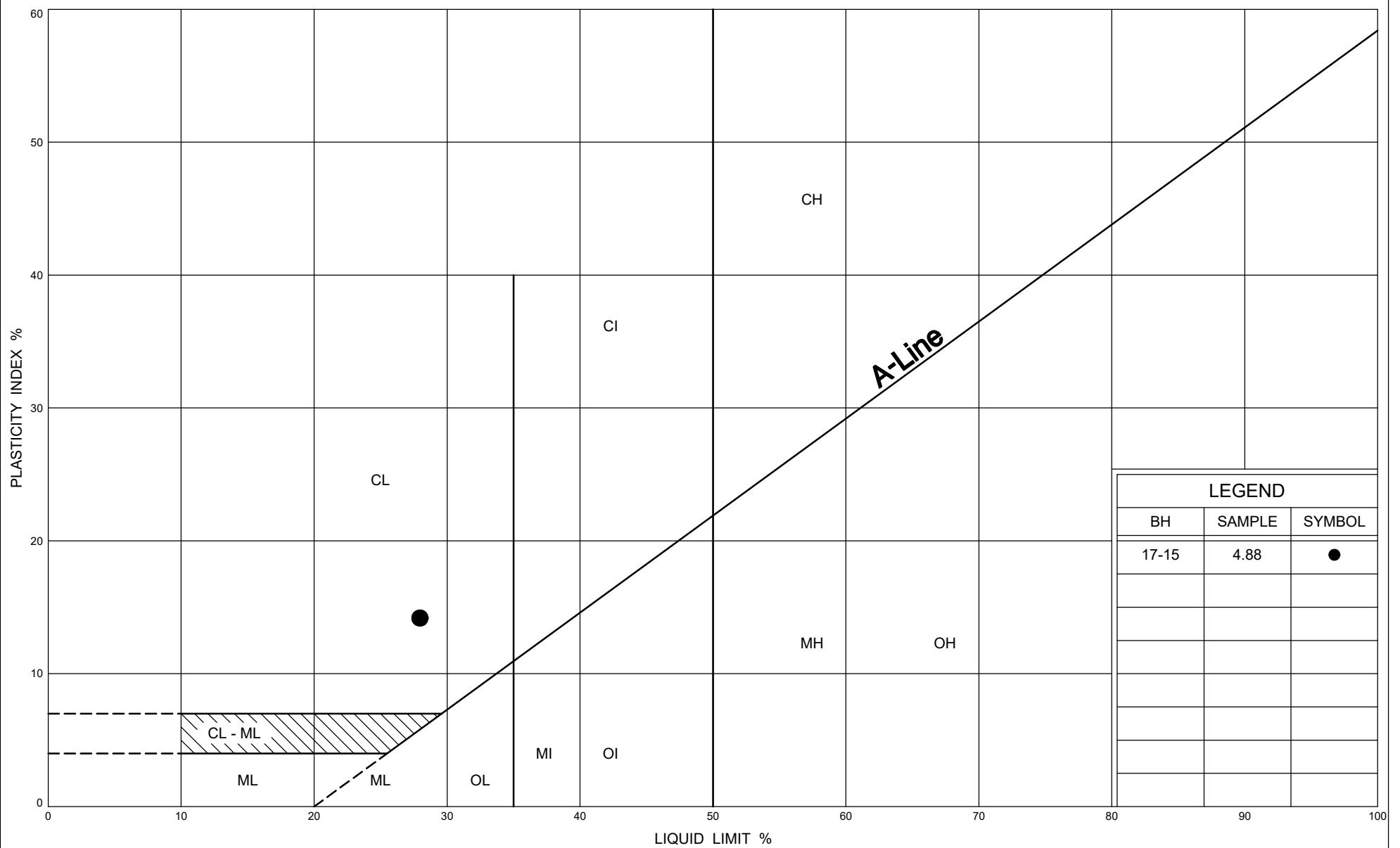
Clayey SILT to Silty CLAY TILL

FIG No B8

W P 3070-11-00

Bayfield River Bridge





Ministry of
Transportation

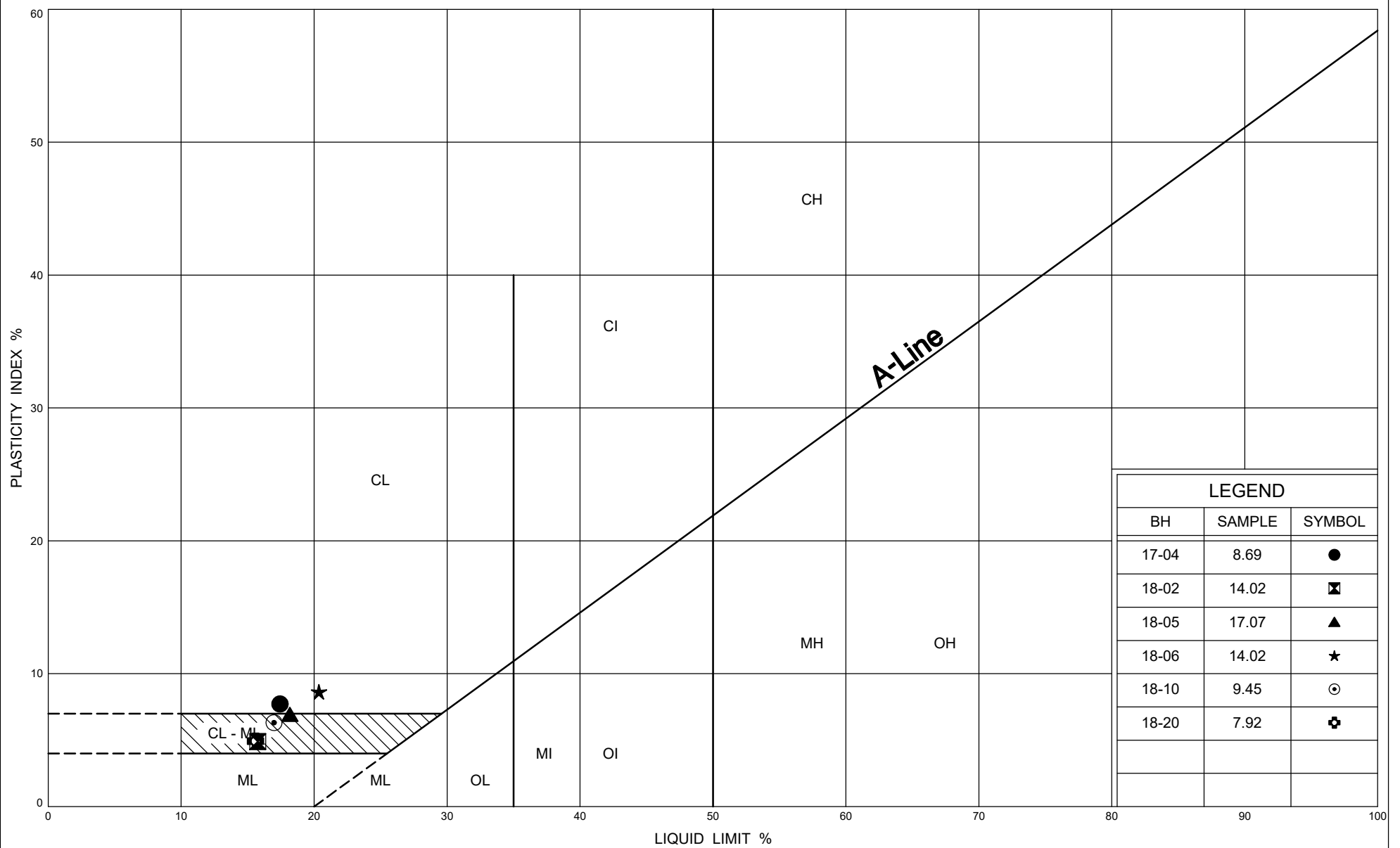
PLASTICITY CHART

Silty CLAY

FIG No B10

W P 3070-11-00

Bayfield River Bridge



Ministry of
Transportation

PLASTICITY CHART

Clayey SILT to Silty CLAY TILL

FIG No B11

W P 3070-11-00

Bayfield River Bridge



ASTM D5731-08

Date Drilled:	Sep 13/17
Date Tested:	Sep 20/17
Tester:	KF
Reviewed by:	WM

- * It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1
- Long pieces of core can be tested diametrically to produce suitable lengths for axial testing
- * Diametral Test should have $0.7 \times D$ on either side of test point.
- * Correlation factor to obtain UCS values is 24.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 17127

Client: McIntosh Perry Consulting Engineers

0 Hwy 21 Bayfield River Bridge 3016-E-0002

Core Size: NQ **BH No :** 18-02

Date Drilled: 05-Jul-18

Date Tested: 09-Jul-18

Tester: _____ MP

Reviewed by: _____ RD

[illegible]

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

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

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

* Correlation factor to obtain UCS values is 24.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 17127

Client: McIntosh Perry Consulting Engineers

0 Hwy 21 Bayfield River Bridge 3016-E-0002

Core Size: NQ **BH No :** 18-03

Date Drilled: 27-Jun-18

Date Tested: 05-Jul-18

Tester: RMT

Reviewed by: _____ RD

[illegible]

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

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

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

* Correlation factor to obtain UCS values is 24.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 17127

Client: McIntosh Perry Consulting Engineers

0 Hwy 21 Bayfield River Bridge 3016-E-0002

Core Size: NQ **BH No :** 18-05

Date Drilled: 04-Jul-18

Date Tested: 10-Jul-18

Tester: _____ MP

Reviewed by: _____ RD

[illegible]

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

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

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

* Correlation factor to obtain UCS values is 24.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 17127

Client: McIntosh Perry Consulting Engineers

0 Hwy 21 Bayfield River Bridge 3016-E-0002

Core Size: NQ **BH No :** 18-06

Date Drilled: 05-Jul-18

Date Tested: 10-Jul-18

Tester: _____ MP

Reviewed by: _____ RD

[illegible]

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

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

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

* Correlation factor to obtain UCS values is 24.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 17127

Client: McIntosh Perry Consulting Engineers

0 Hwy 21 Bayfield River Bridge 3016-E-0002

Core Size: NQ **BH No :** 18-19

Date Drilled: 27-Jun-18

Date Tested: 05-Jul-18

Tester: _____ MP

Reviewed by: _____ RD

[illegible]

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

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

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

* Correlation factor to obtain UCS values is 24.



ASTM D5731-08

Date Drilled:	09-Jul-18
Date Tested:	17-Jul-18
Tester:	MP
Reviewed by:	RD

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

* Correlation factor to obtain UCS values is 24.



Appendix C

Site Photographs



Photo 1: North Abutment Area (looking north)



Photo 2: Southeast Abutment Area (looking north)



Appendix D

Borehole Locations and Soil Strata Drawings



CONT No
GWP No 3070-11-00

HIGHWAY 21
BAYFIELD RIVER BRIDGE
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

McINTOSH PERRY



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

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

NO	ELEVATION	NORTHING	EASTING
18-11	178.8	4 825 769.9	369 506.2
18-12	182.0	4 825 733.0	369 592.0
18-13	181.2	4 825 741.0	369 585.0
18-16	180.2	4 825 794.0	369 525.0
18-17	184.8	4 825 819.0	369 497.0
18-18	180.8	4 825 703.0	369 580.0
18-19	179.9	4 825 718.0	369 561.0
18-20	178.5	4 825 768.0	369 499.0
18-21	178.3	4 825 782.0	369 478.0
805	185.7	4 825 793.9	369 497.5
806	185.8	4 825 783.7	369 508.0
807	185.9	4 825 729.6	369 567.9
808	185.8	4 825 710.5	369 589.3
17-04	177.3*	4 825 764.0	369 551.1
17-08	177.3*	4 825 721.2	369 544.1
17-09	177.3*	4 825 741.1	369 524.7
17-14	177.3*	4 825 752.7	369 587.1
17-15	177.3*	4 825 778.8	369 558.9
18-01	185.8	4 825 723.0	369 585.0
18-02	185.7	4 825 727.0	369 575.0
18-03	185.7	4 825 736.0	369 571.0
18-05	185.7	4 825 783.0	369 519.0
18-06	185.7	4 825 786.0	369 511.0
18-07	185.7	4 825 795.0	369 506.0
18-10	178.9	4 825 775.0	369 494.0

*Barage deck surface

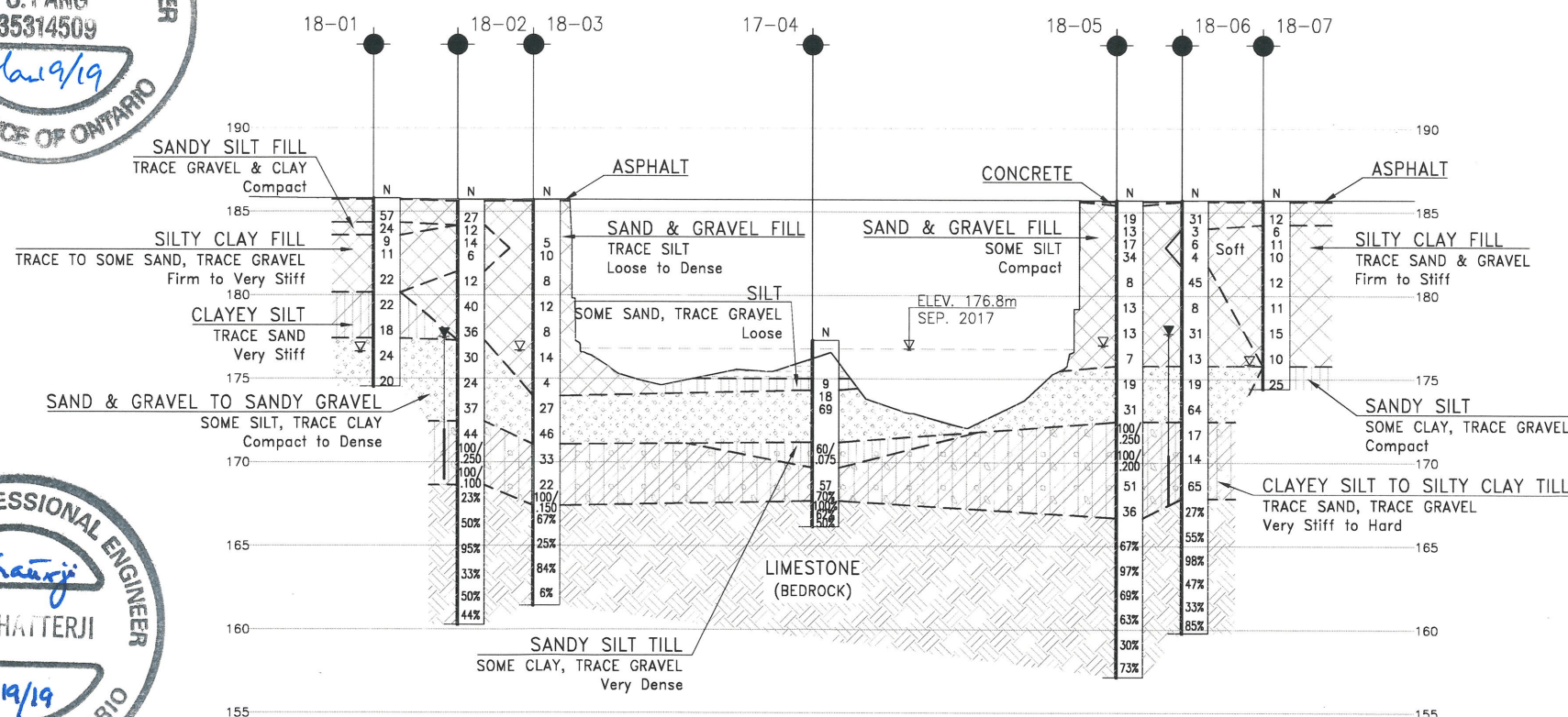
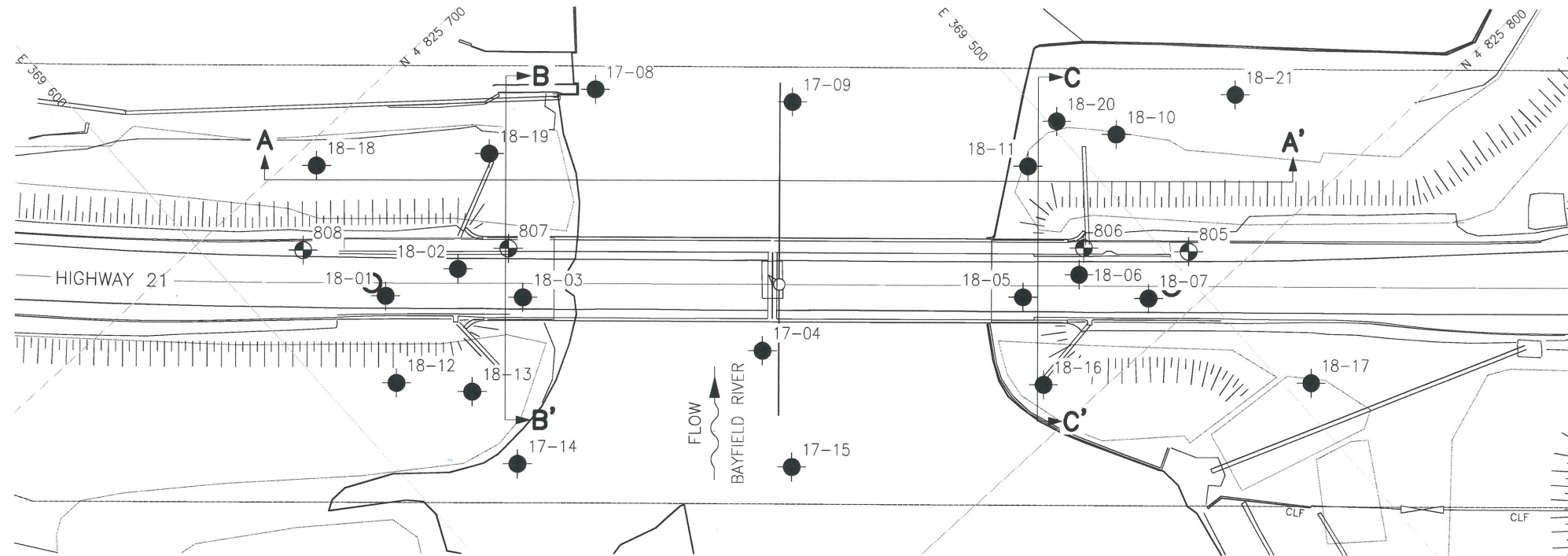
-NOTES-

- 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 11.

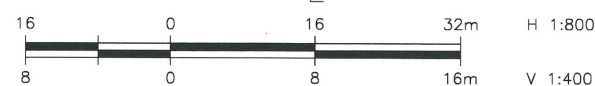
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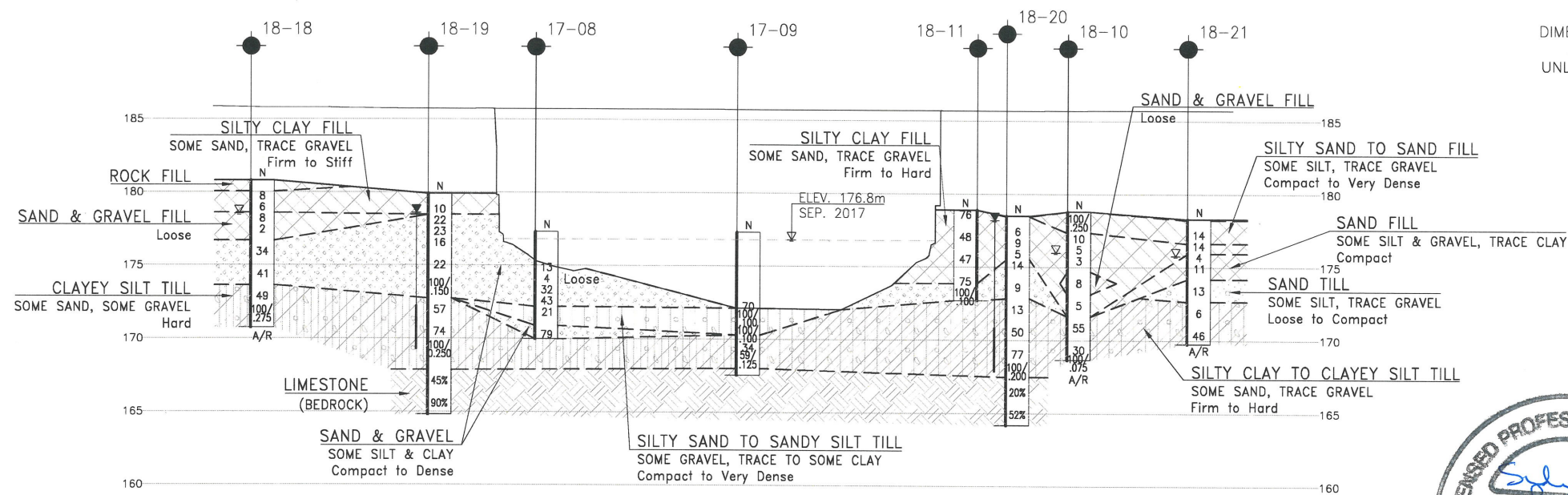
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DRAWN	AN	CHK	RD
		CODE	LOAD
		SITE	STRUCT
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			DATE JAN 2019

FILENAME: H:\Working\7000\17127\ED-17127-PR-BF.dwg
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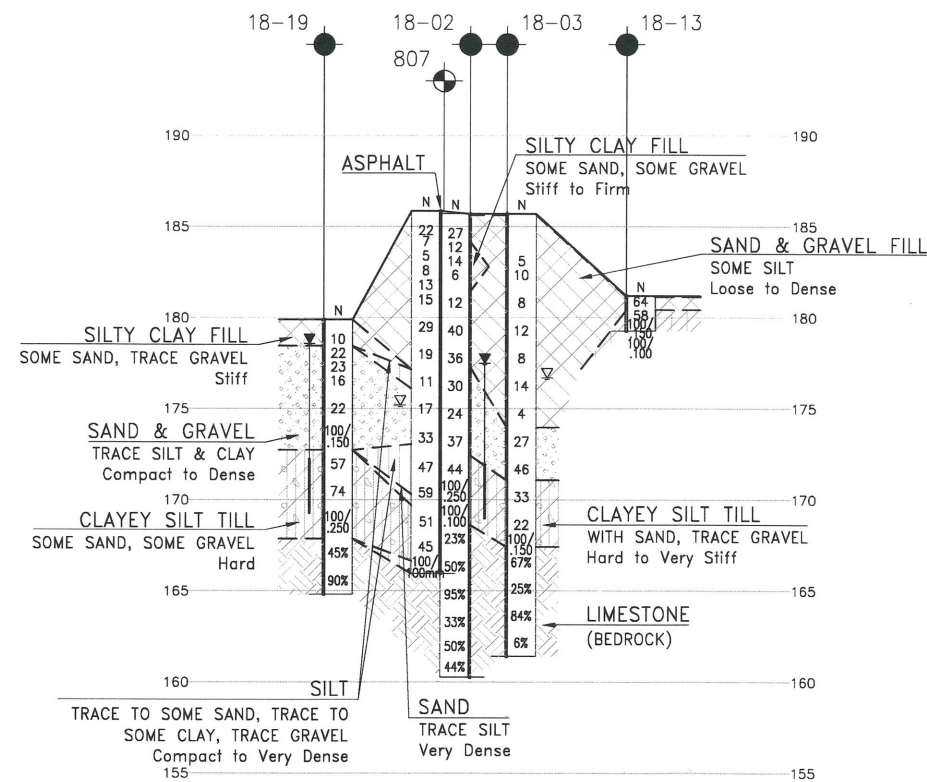
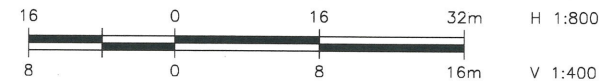


PROFILE ALONG C HWY 21

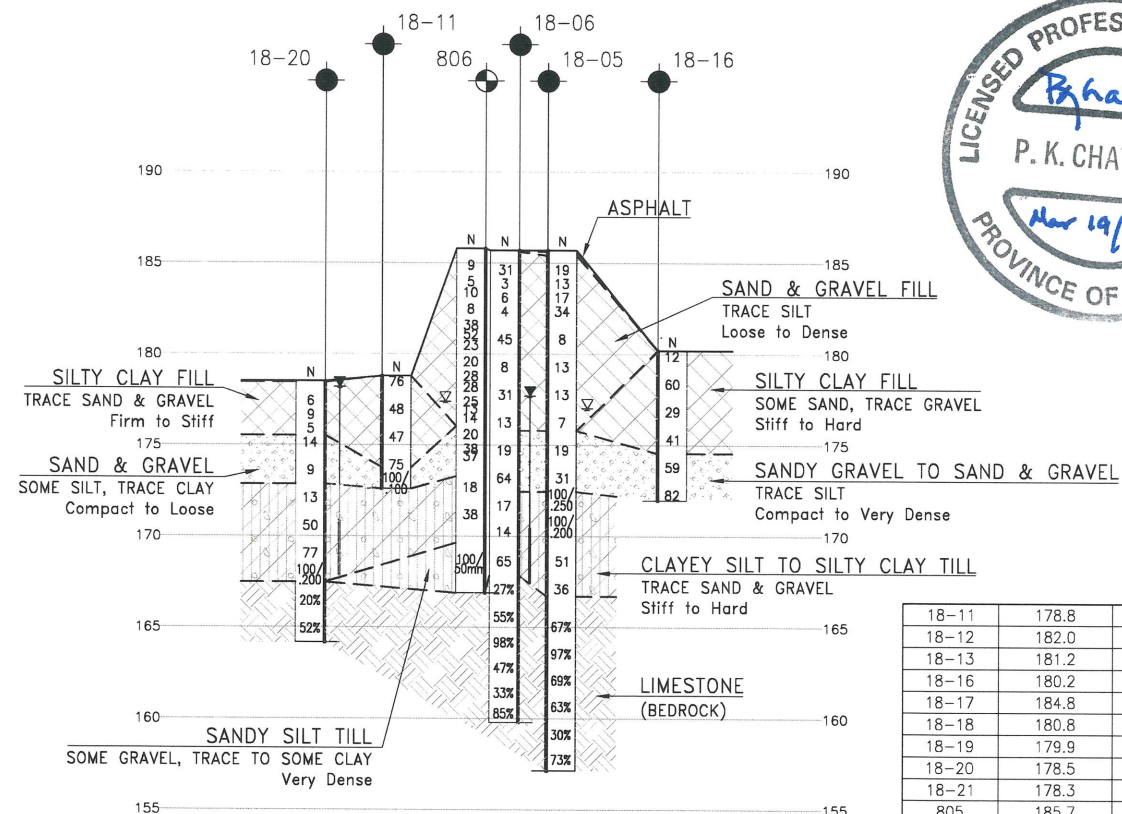
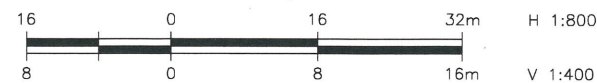




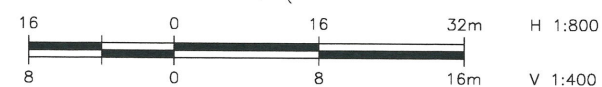
SECTION ALONG A-A' (WEST DETOUR)



SECTION ALONG B-B' (SOUTH ABUTMENT)



SECTION ALONG C-C' (NORTH ABUTMENT)



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

CONT No
GWP No 3070-11-00

HIGHWAY 21
BAYFIELD RIVER BRIDGE
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

McINTOSH PERRY







THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

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

NO	ELEVATION	NORTHING	EASTING
17-04	177.3*	4 825 764.0	369 551.1
17-08	177.3 *	4 825 721.2	369 544.1
17-09	177.3 *	4 825 741.1	369 524.7
17-14	177.3*	4 825 752.7	369 587.1
17-15	177.3 *	4 825 778.8	369 558.9
18-01	185.8	4 825 723.0	369 585.0
18-02	185.7	4 825 727.0	369 575.0
18-03	185.7	4 825 736.0	369 571.0
18-05	185.7	4 825 783.0	369 519.0
18-06	185.7	4 825 786.0	369 511.0
18-07	185.7	4 825 795.0	369 506.0
18-10	178.9	4 825 775.0	369 494.0

-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 11.

GEOCRES No. 40P12-37

18-11	178.8	4 825 769.9	369 506.2
18-12	182.0	4 825 733.0	369 592.0
18-13	181.2	4 825 741.0	369 585.0
18-16	180.2	4 825 794.0	369 525.0
18-17	184.8	4 825 819.0	369 497.0
18-18	180.8	4 825 703.0	369 580.0
18-19	179.9	4 825 718.0	369 561.0
18-20	178.5	4 825 768.0	369 499.0
18-21	178.3	4 825 782.0	369 478.0
805	185.7	4 825 793.9	369 497.5
806	185.8	4 825 783.7	369 508.0
807	185.9	4 825 729.6	369 567.9
808	185.8	4 825 710.5	369 589.3

* Barage deck surface

[illegible]



Appendix E

Foundation Comparison



COMPARISON OF FOUNDATION ALTERNATIVES HIGHWAY 21 BAYFIELD RIVER BRIDGE REPLACEMENT

Spread Footings on Native Soils	Driven Steel H-Piles into Native Glacial Till/Bedrock	Rock Socketted Augered Caissons or H-Piles into Native Glacial Till/Bedrock
<p>Advantages:</p> <ul style="list-style-type: none"> i. Does not involve construction in rock. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Existing footings impose restrictions on new footings. ii. Cofferdam and extensive dewatering will be required during construction. iii. Reliance on friction at the footing/subgrade interface and lateral earth pressure to withstand lateral bridge loading. iv. Subject to uplift under extreme circumstances. v. Scour protection issues adjacent to the river. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Relative ease of construction. ii. Higher vertical resistance than spread footings. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Cobbles and boulders may be encountered in glacially derived soils that could impede pile penetration. ii. Some driven piles may not reach bedrock to provide higher lateral geotechnical resistance. iii. Lower lateral geotechnical resistance comparing with caissons. iv. Cofferdam and dewatering will be required for pile cap construction. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Higher lateral resistance is available due to larger diameter. ii. Lesser number of caissons or augered piles is required for each abutment so that the existing footings do not need to be removed. iii. Adequate uplift resistance. iv. Steel casings/liners used during construction may be left in place permanently to increase lateral stiffness of the foundation element. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Temporary steel casings/liners will be required to minimize sidewall sloughing and water seepage during installation. ii. Tremie concrete will need to be used.
RELATIVE COSTS		
MEDIUM	MEDIUM	MEDIUM
RELATIVE RISKS		
HIGH	MEDIUM	LOW
NOT RECOMMENDED	FEASIBLE IF LATERAL RESISTANCE IS ADEQUATE	<p>ROCK SOCKETTED CAISSONS (RECOMMENDED)</p> <p>ROCK SOCKETTED H-PILES (TECHNICALLY FEASIBLE)</p>



Appendix F

Selected Stability Analysis Results

FIGURE F1

STATIC STABILITY ANALYSIS NORTH OF TEMPORARY MODULAR BRIDGE EXISTING SLOPE - LONG-TERM CONDITION

File Name: 17127 North Approach - Existing Condition.gsz
Created By: Geoff Lay
Date: 9/24/2018

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

Embankment Fill	20 kN/m ³	0 kPa	30 °
Silty Clay Fill - Firm to Stiff	18 kN/m ³	0 kPa	30 °
Sand and Gravel - Loose to Very Dense	22 kN/m ³	0 kPa	35 °
Clayey Silt to Silty Clay Till - Stiff to Hard	21 kN/m ³	0 kPa	32 °

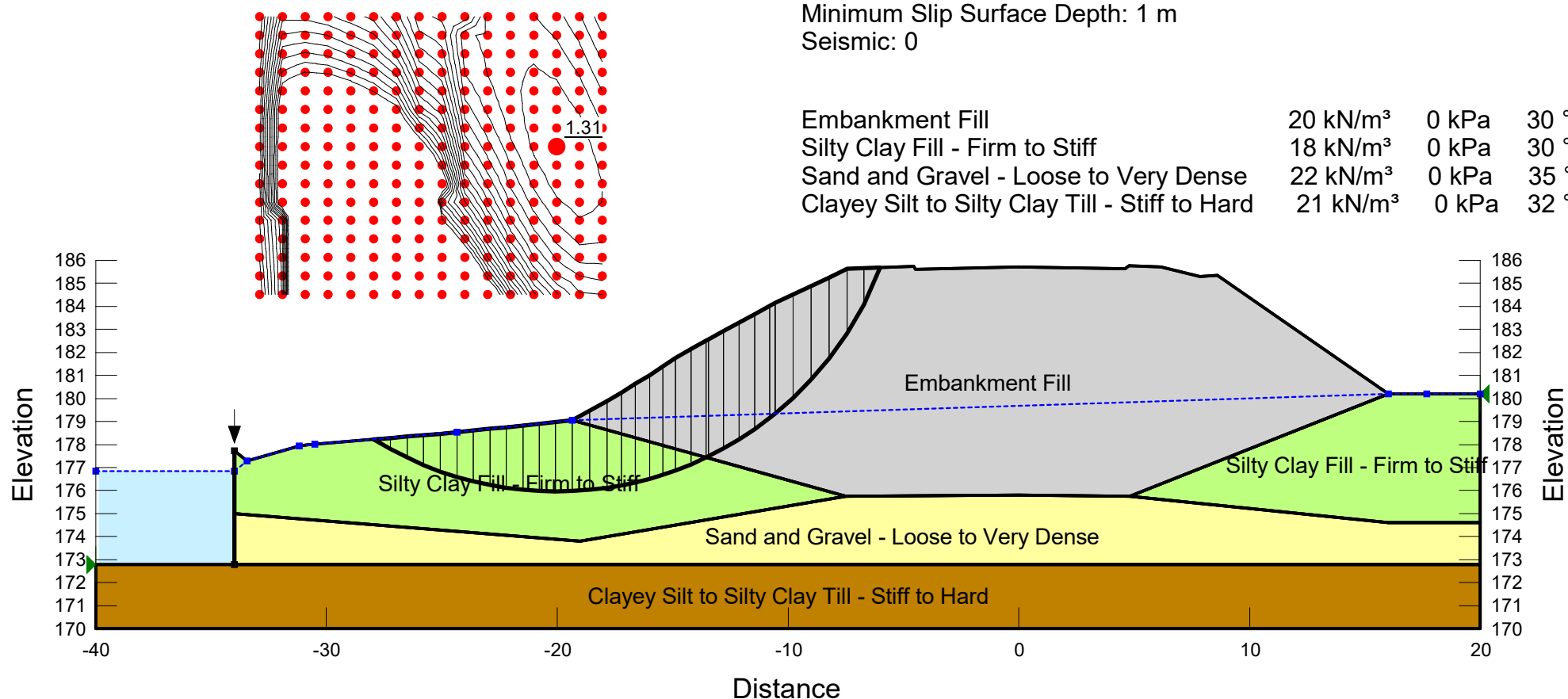


FIGURE F2

STATIC STABILITY ANALYSIS NORTH OF TEMPORARY MODULAR BRIDGE DEEP RETAINING WALL - SHORT-TERM CONDITION

File Name: 17127 North Approach - ST Condition (2) deep.gsz
Created By: Geoff Lay
Date: 10/15/2018

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

Embankment Fill	20 kN/m ³	0 kPa	30 °
Granular Fill (SSM)	21 kN/m ³	0 kPa	30 °
Silty Clay Fill - Firm to Stiff	18 kN/m ³	50 kPa	0 °
Sand and Gravel - Compact to Very Dense	22 kN/m ³	0 kPa	34 °
Clayey Silt to Silty Clay Till - Stiff to Hard	21 kN/m ³	100 kPa	0 °

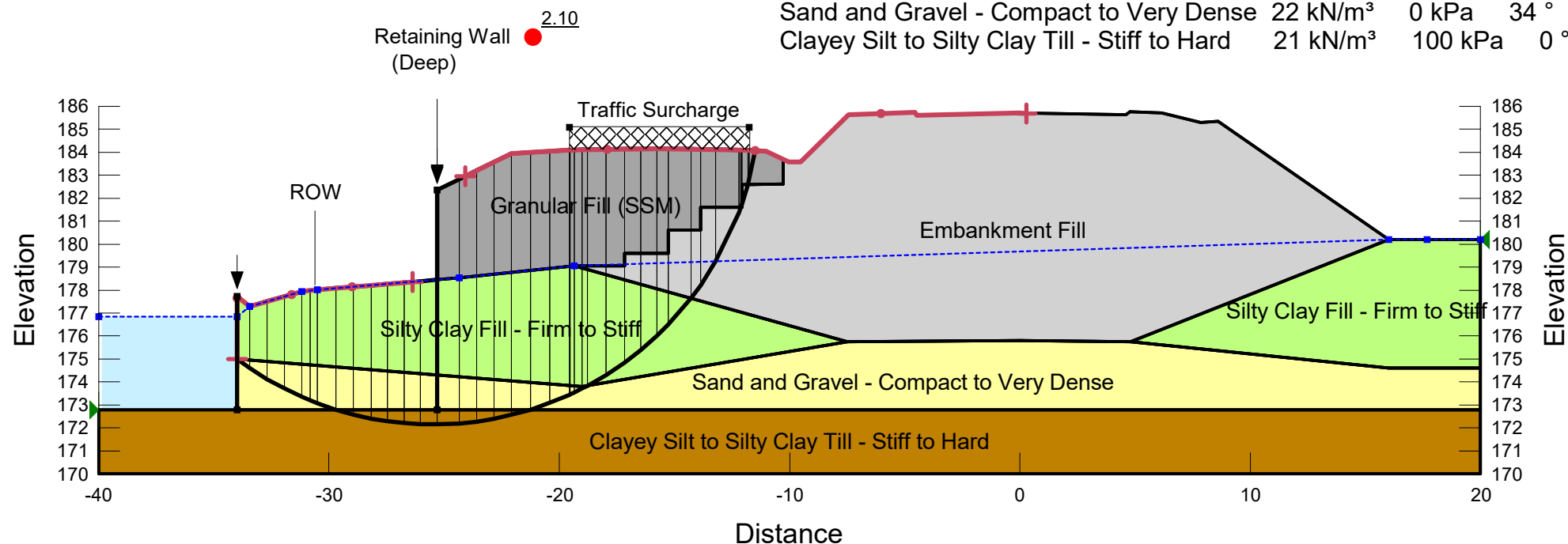


FIGURE F3

STATIC STABILITY ANALYSIS NORTH OF TEMPORARY MODULAR BRIDGE DEEP RETAINING WALL - LONG-TERM CONDITION

File Name: 17127 North Approach - LT Condition (2) deep.gsz
Created By: Geoff Lay
Date: 10/15/2018

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

Embankment Fill	20 kN/m ³	0 kPa	30 °
Granular Fill (SSM)	21 kN/m ³	0 kPa	30 °
Silty Clay Fill - Firm to Stiff	18 kN/m ³	0 kPa	30 °
Sand and Gravel - Compact to Very Dense	22 kN/m ³	0 kPa	34 °
Clayey Silt to Silty Clay Till - Stiff to Hard	21 kN/m ³	0 kPa	32 °

Retaining Wall (Deep) 1.88

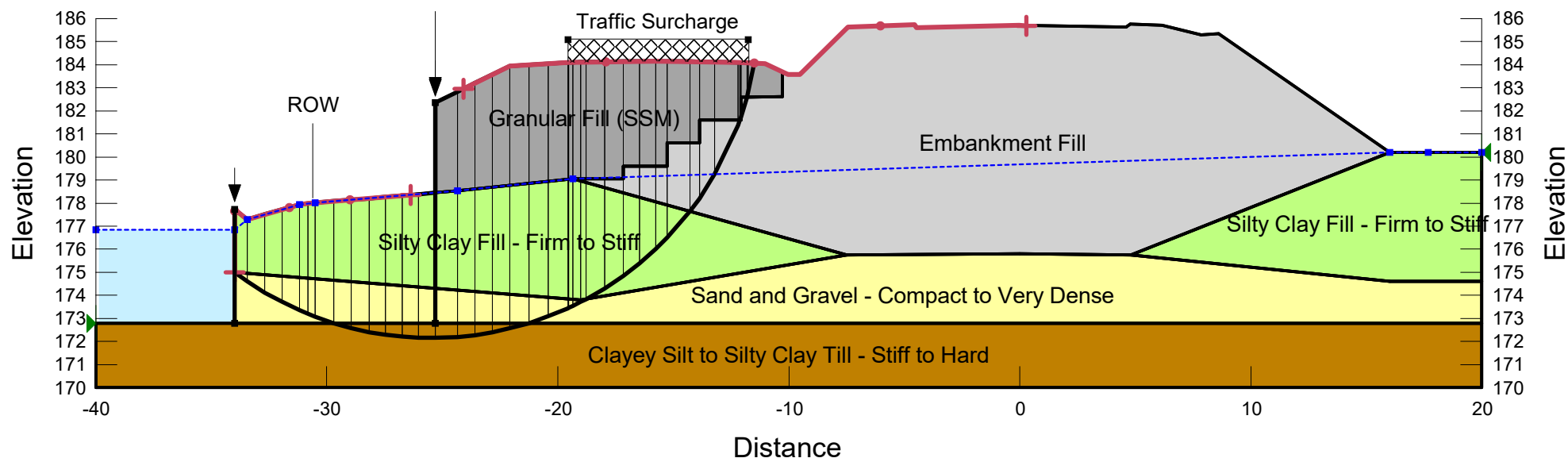


FIGURE F4

STATIC STABILITY ANALYSIS NORTH OF TEMPORARY MODULAR BRIDGE 1H:1V REINFORCED EARTH SLOPE - SHORT-TERM CONDITION

File Name: 17127 North Approach - ST Condition - 1H-1V RSS.gsz

Created By: Geoff Lay

Date: 2/25/2019

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Seismic: 0

Embankment Fill	20 kN/m ³	0 kPa	30 °
RSS	22 kN/m ³	200 kPa	34 °
Granular Fill (B Type II)	22.8 kN/m ³	0 kPa	35 °
Silty Clay Fill - Firm to Stiff	18 kN/m ³	50 kPa	0 °
Sand and Gravel - Compact to Very Dense	22 kN/m ³	0 kPa	34 °
Clayey Silt to Silty Clay Till - Stiff to Hard	21 kN/m ³	100 kPa	0 °

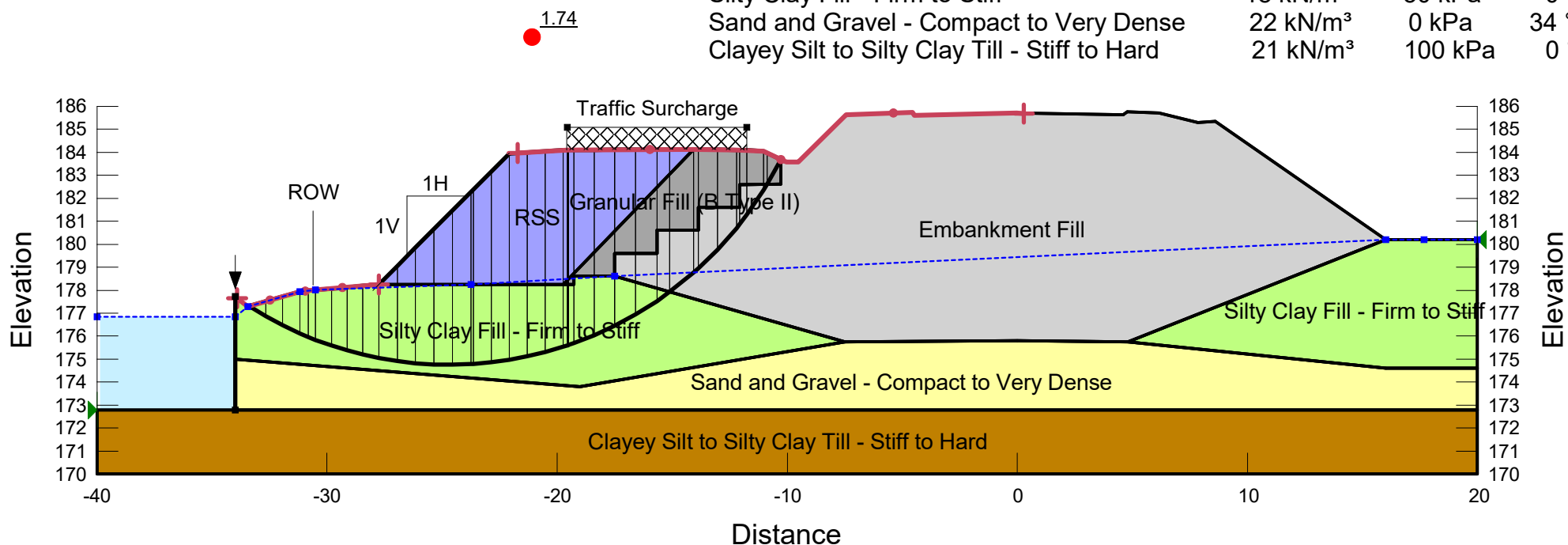


FIGURE F5

STATIC STABILITY ANALYSIS NORTH OF TEMPORARY MODULAR BRIDGE 1H:1V REINFORCED EARTH SLOPE - LONG-TERM CONDITION

File Name: 17127 North Approach - LT Condition - 1H-1V RSS.gsz
Created By: Geoff Lay
Date: 2/25/2019

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

Embankment Fill	20 kN/m ³	0 kPa	30 °
RSS	22 kN/m ³	200 kPa	34 °
Granular Fill (B Type II)	22.8 kN/m ³	0 kPa	35 °
Silty Clay Fill - Firm to Stiff	18 kN/m ³	0 kPa	30 °
Sand and Gravel - Compact to Very Dense	22 kN/m ³	0 kPa	34 °
Clayey Silt to Silty Clay Till - Stiff to Hard	21 kN/m ³	0 kPa	32 °

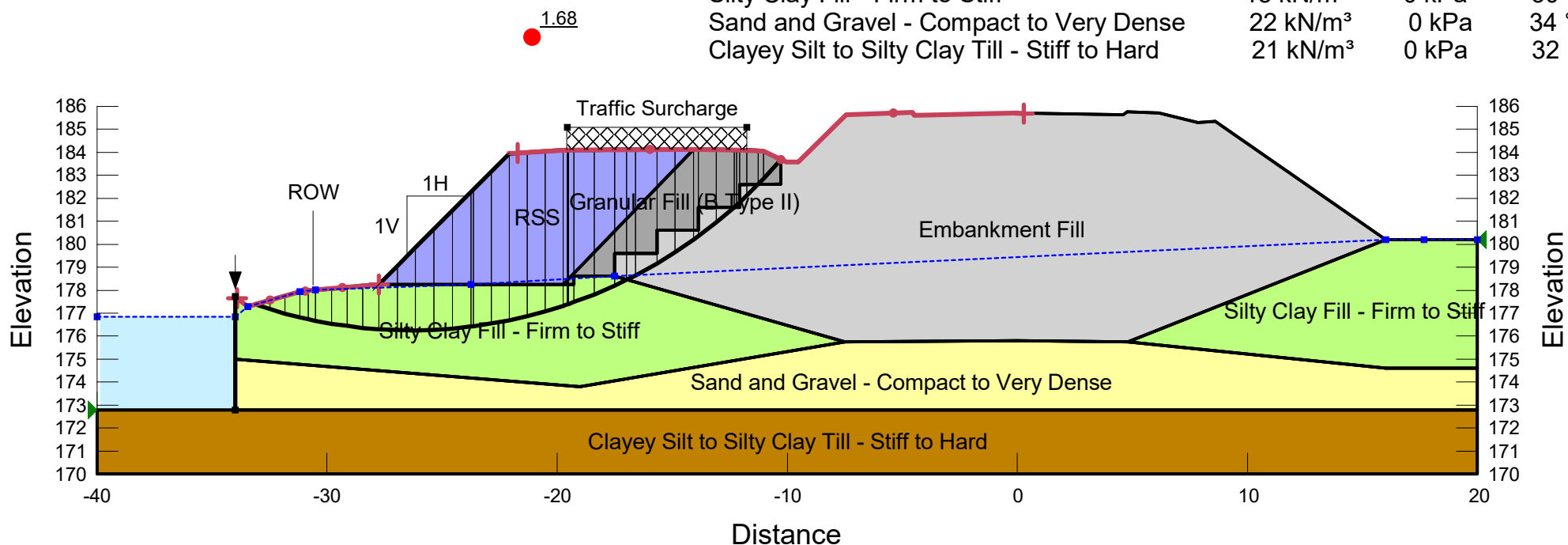


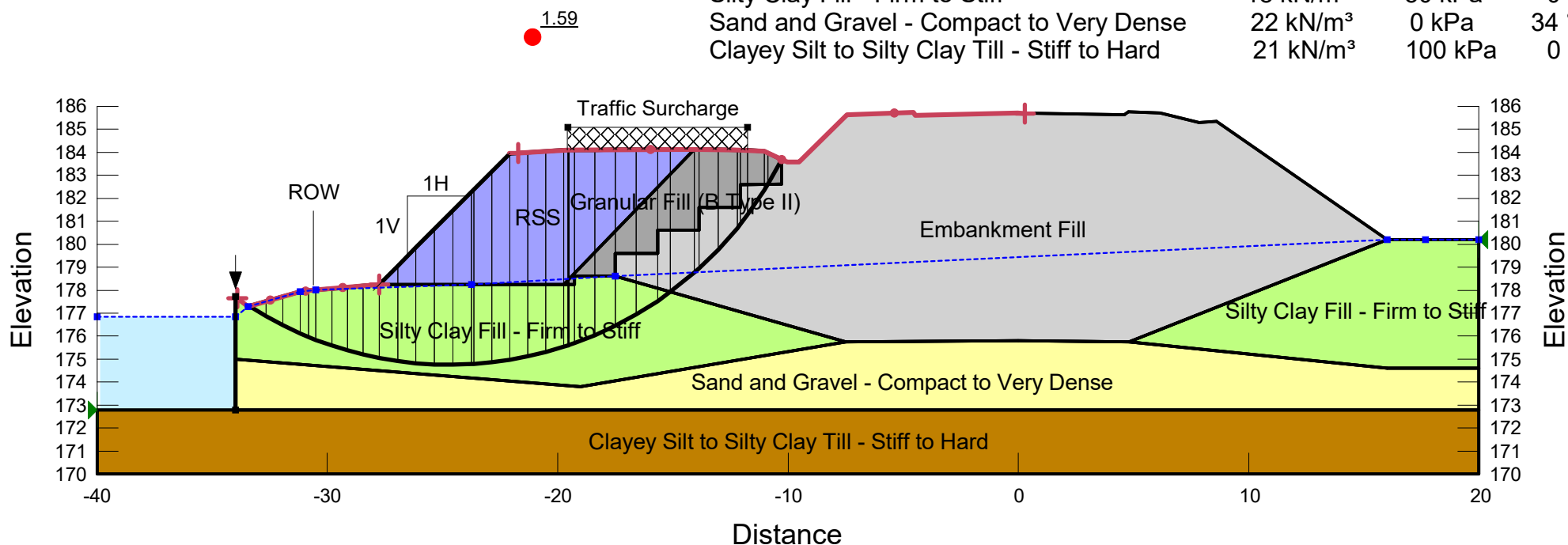
FIGURE F6

STATIC STABILITY ANALYSIS NORTH OF TEMPORARY MODULAR BRIDGE 1H:1V REINFORCED EARTH SLOPE - SEISMIC CONDITION

File Name: 17127 North Approach - ST Condition - 1H-1V RSS seismic.gsz
Created By: Geoff Lay
Date: 2/25/2019

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0.034g

Embankment Fill	20 kN/m ³	0 kPa	30 °
RSS	22 kN/m ³	200 kPa	34 °
Granular Fill (B Type II)	22.8 kN/m ³	0 kPa	35 °
Silty Clay Fill - Firm to Stiff	18 kN/m ³	50 kPa	0 °
Sand and Gravel - Compact to Very Dense	22 kN/m ³	0 kPa	34 °
Clayey Silt to Silty Clay Till - Stiff to Hard	21 kN/m ³	100 kPa	0 °





Appendix G

OPS Used in Report and Suggested NSSP Wordings

The following Special Provisions documents are referenced in this report:

- OPSS.PROV 903
- OPSS.PROV 902
- OPSS.PROV 804
- OPSS.PROV 501
- OPSS.PROV 539
- OPSS.PROV 206
- OPSS.PROV 1010
- OPSD 208.010

1. Suggested Text for NSSP on “Construction of Rock Socketted Caissons and Piles”

Caisson and augered pile installation shall be in accordance with OPSS.PROV 903 and the following.

Rock socketted caisson and augered pile installation at this site will require excavation through cohesionless sands and gravel, and tills below the groundwater table and construction of sockets in the underlying bedrock. The Contractor is advised of the following:

- The cohesionless soils above the bedrock is susceptible to disturbance under conditions of unbalanced hydrostatic head, and measures such as a balancing head of water or slurry inside the liner/casing must be employed to maintain sidewall and basal stability in the caisson excavation, and prevent collapse/washing of cohesionless soils into the rock socket. Selection of the methods and equipment employed to achieve this is the responsibility of the Contractor.
- Where permanent casing is used, the casing must be sealed into the bedrock and the rock socket is to be formed below the casing. A balancing head of water or slurry must be maintained inside the casing.
- Caisson and augered pile installation may encounter cobbles, boulders and/or large rock fragments in the soils overlying the bedrock. The installation methods and equipment must be capable of dislodging, removing or otherwise penetrating such obstructions.
- The bedrock consists of strong to very strong limestone. The strength and hardness of this rock must be taken into account when selecting equipment to advance the caisson into rock. Equipment supplied to construct the rock socket must be capable of excavating the bedrock to the specified socket dimensions without disturbing or fracturing the bedrock forming the sidewalls and base of the socket. Blasting to facilitate the removal of bedrock is not permitted.
- The rock socket must be formed entirely within the bedrock below the level of any cobbles and boulders. Any length of caisson above the bedrock surface will not be considered part of the specified length of rock socket.

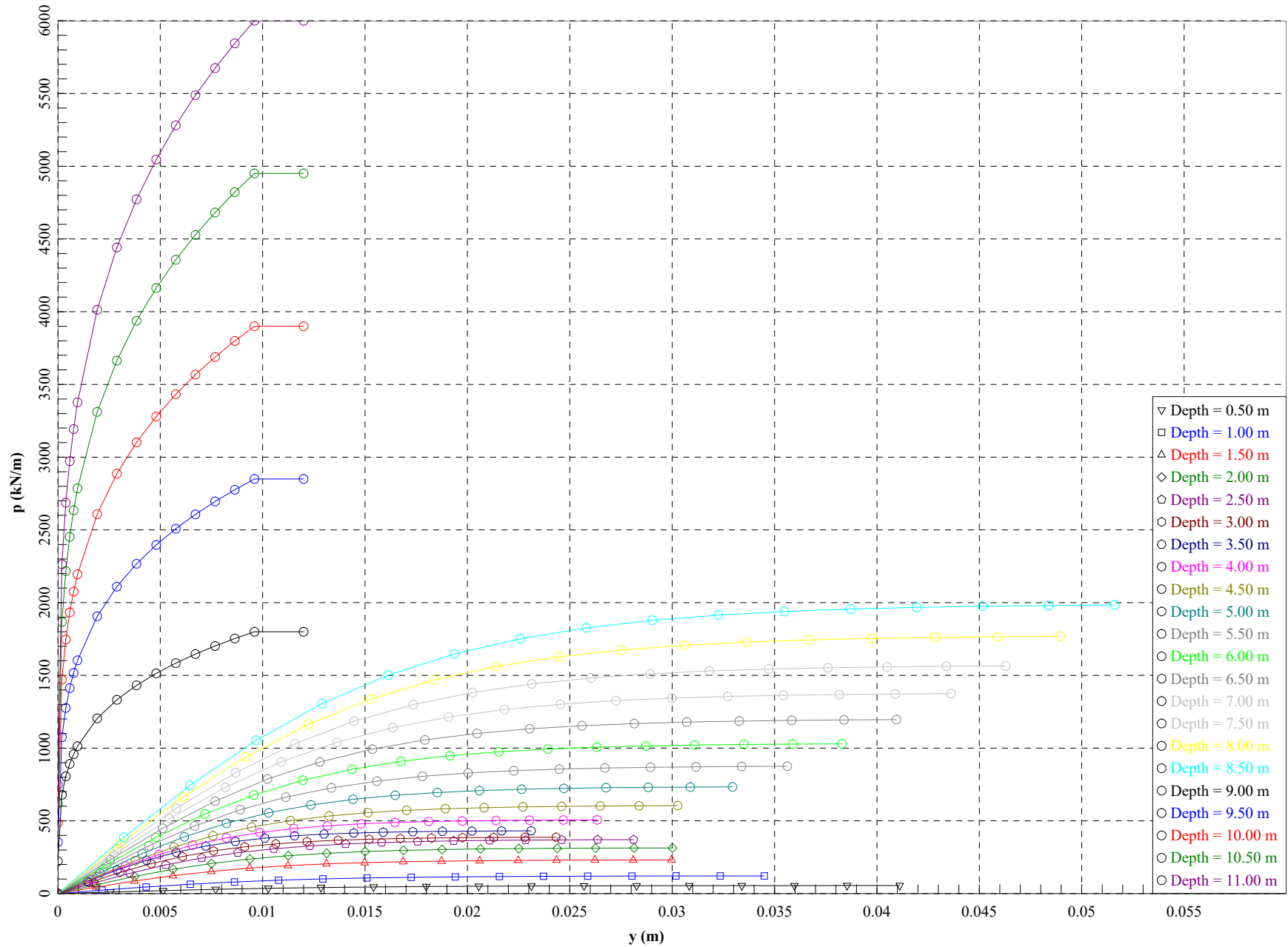


Appendix H

p-y Curves Data for Lateral Caisson Analyses

Figure H1 Abutment on Compacted Fill Showing Granular 'A' Core

17127 Bayfield River Bridge-North Abutment-P-Y Curves-1.2 m Dia. Caisson



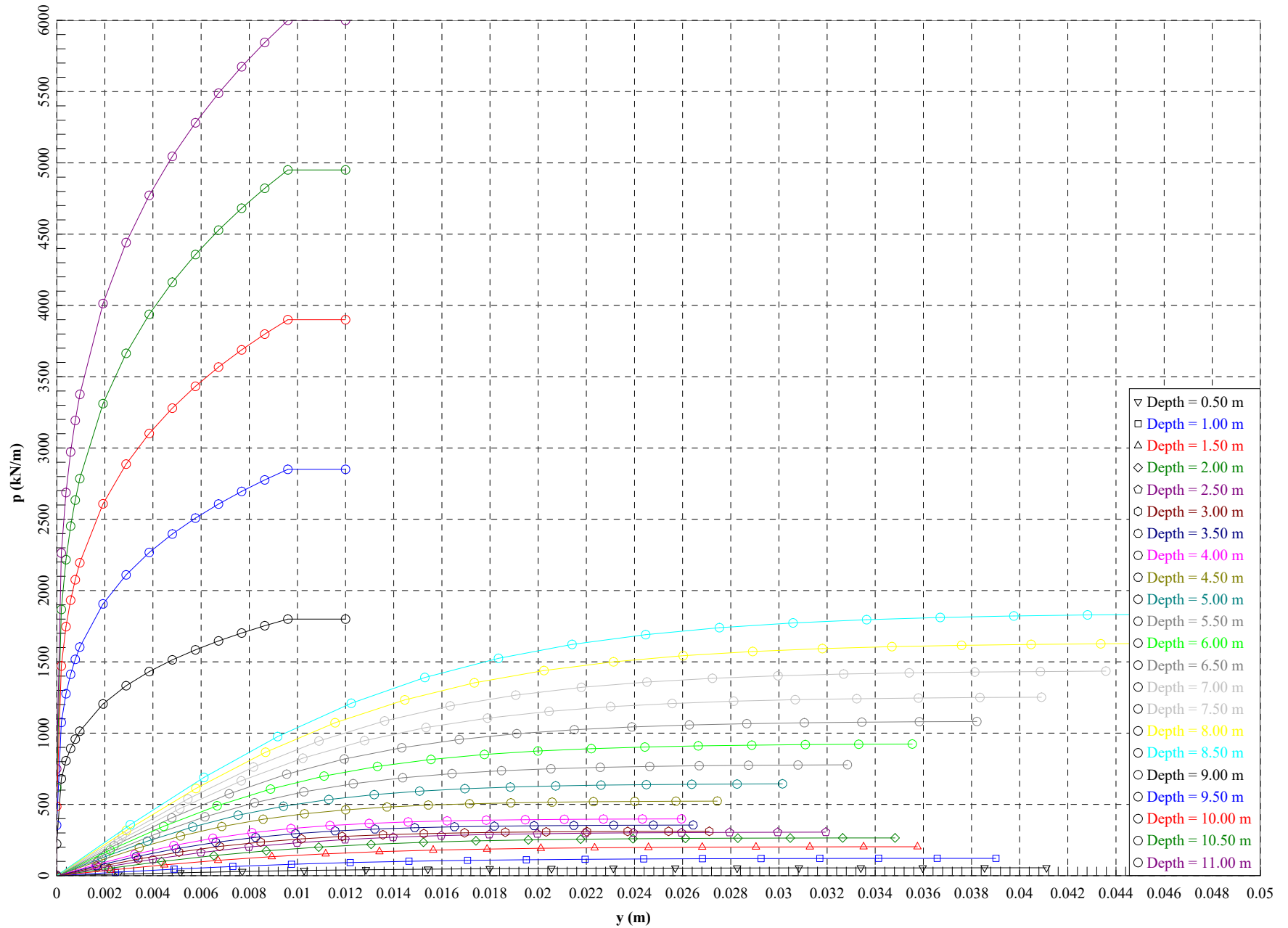


Project # 17127
Project: HWY 21 Bayfield River Bridge
Date: November 13, 2018
Revision: 0

Table 1: South Abutment - P-Y Curves - 1.2 m Diameter Caisson

S T A T I C	Depth Below Elevation of 76 m																					
	0.5		1		1.5		2		2.5		3		3.5		4		4.5		5		5.5	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.003	10.742	0.002	23.650	0.002	44.987	0.002	61.053	0.002	72.164	0.002	75.412	0.001	83.959	0.002	98.518	0.002	117.589	0.002	142.784	0.002	170.370
	0.005	20.706	0.004	45.586	0.004	86.715	0.004	117.684	0.004	139.101	0.003	145.361	0.003	161.836	0.003	189.898	0.004	226.659	0.004	275.224	0.004	328.397
	0.008	29.324	0.006	64.559	0.006	122.805	0.006	166.664	0.005	196.994	0.005	205.860	0.004	229.191	0.005	268.933	0.006	320.994	0.006	389.771	0.007	465.075
	0.010	36.338	0.009	80.002	0.007	152.179	0.008	206.528	0.007	244.113	0.006	255.100	0.006	284.012	0.007	333.260	0.008	397.773	0.008	483.001	0.009	576.318
	0.013	41.770	0.011	91.960	0.009	174.927	0.009	237.400	0.009	280.603	0.008	293.232	0.007	326.466	0.008	383.075	0.009	457.232	0.010	555.200	0.011	662.465
	0.015	45.817	0.013	100.869	0.011	191.873	0.011	260.399	0.011	307.788	0.009	321.640	0.009	358.094	0.010	420.187	0.011	501.528	0.012	608.987	0.013	726.644
	0.018	48.745	0.015	107.316	0.013	204.138	0.013	277.043	0.012	327.461	0.011	342.199	0.010	380.982	0.012	447.044	0.013	533.585	0.014	647.912	0.016	773.089
	0.021	50.821	0.017	111.885	0.015	212.828	0.015	288.837	0.014	341.402	0.012	356.767	0.012	397.202	0.013	466.076	0.015	556.301	0.016	675.495	0.018	806.001
	0.023	52.269	0.019	115.074	0.017	218.895	0.017	297.071	0.016	351.133	0.014	366.936	0.013	408.524	0.015	479.361	0.017	572.158	0.019	694.750	0.020	828.976
	0.026	53.270	0.022	117.278	0.019	223.086	0.019	302.758	0.018	357.856	0.015	373.962	0.014	416.345	0.016	488.539	0.019	583.112	0.021	708.051	0.022	844.848
	0.028	53.956	0.024	118.789	0.021	225.960	0.021	306.659	0.019	362.466	0.017	378.780	0.016	421.709	0.018	494.833	0.021	590.625	0.023	717.173	0.024	855.732
	0.031	54.425	0.026	119.820	0.022	227.921	0.023	309.321	0.021	365.613	0.018	382.067	0.017	425.370	0.020	499.128	0.023	595.751	0.025	723.398	0.027	863.160
	0.033	54.743	0.028	120.521	0.024	229.255	0.024	311.131	0.023	367.752	0.020	384.303	0.019	427.859	0.021	502.049	0.025	599.238	0.027	727.632	0.029	868.212
	0.036	54.959	0.030	120.997	0.026	230.160	0.026	312.359	0.025	369.204	0.021	385.821	0.020	429.548	0.023	504.031	0.026	601.604	0.029	730.505	0.031	871.639
	0.039	55.106	0.032	121.319	0.028	230.773	0.028	313.191	0.026	370.188	0.023	386.848	0.022	430.693	0.025	505.374	0.028	603.206	0.031	732.451	0.033	873.961
	0.041	55.205	0.034	121.537	0.030	231.188	0.030	313.755	0.028	370.853	0.024	387.544	0.023	431.467	0.026	506.283	0.030	604.291	0.033	733.768	0.036	875.533
	Depth Below Elevation of 76 m																					
	6		6.5		7		7.5		8		8.5		9		9.5		10		10.5		11	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.002	200.347	0.003	232.715	0.003	267.474	0.003	304.624	0.003	344.165	0.003	386.096	0.000	222.140	0.000	353.802	0.000	485.487	0.000	617.181	0.000	748.879
	0.005	386.180	0.005	448.571	0.005	515.571	0.006	587.180	0.006	663.397	0.006	744.222	0.000	678.824	0.000	1074.877	0.000	1470.931	0.000	1866.985	0.000	2263.040
	0.007	546.907	0.008	635.265	0.008	730.150	0.009	831.562	0.009	939.500	0.010	1053.965	0.000	806.103	0.000	1276.371	0.000	1746.641	0.000	2216.910	0.000	2687.180
	0.010	677.722	0.010	787.215	0.011	904.796	0.012	1030.465	0.012	1164.221	0.013	1306.065	0.001	891.670	0.001	1411.841	0.001	1932.013	0.001	2452.186	0.001	2972.358
	0.012	779.028	0.013	904.887	0.014	1040.044	0.014	1184.498	0.015	1338.248	0.016	1501.294	0.001	957.931	0.001	1516.748	0.001	2075.566	0.001	2634.384	0.001	3193.202
	0.014	854.499	0.015	992.552	0.016	1140.802	0.017	1299.250	0.018	1467.895	0.019	1646.738	0.001	1012.742	0.001	1603.529	0.001	2194.315	0.001	2785.102	0.001	3375.889
	0.017	909.117	0.018	1055.994	0.019	1213.720	0.020	1382.296	0.021	1561.721	0.023	1751.995	0.002	1204.012	0.002	1906.362	0.002	2608.713	0.002	3311.064	0.002	4013.415
	0.019	947.820	0.020	1100.950	0.022	1265.391	0.023	1441.143	0.024	1628.206	0.026	1826.581	0.003	1332.329	0.003	2109.528	0.003	2886.727	0.003	3663.926	0.003	4441.125
	0.022	974.837	0.023	1132.332	0.025	1301.461	0.026	1482.223	0.028	1674.618	0.029	1878.647	0.004	1431.612	0.004	2266.723	0.004	3101.835	0.004	3936.947	0.004	4772.059
	0.024	993.501	0.026	1154.011	0.027	1326.378	0.029	1510.601	0.031	1706.680	0.032	1914.615	0.005	1513.701	0.005	2396.697	0.005	3279.693	0.005	4162.689	0.005	5045.685
	0.026	1006.301	0.028	1168.879	0.030	1343.467	0.032	1530.063	0.034	1728.668	0.035	1939.282	0.006	1584.262	0.006	2508.418	0.006	3432.573	0.006	4356.729	0.006	5280.884
	0.029	1015.036	0.031	1179.025	0.033	1355.128	0.035	1543.344	0.037	1743.673	0.039	1956.115	0.007	1646.485	0.007	2606.936	0.007	3567.388	0.007	4527.839	0.007	5488.290
	0.031	1020.976	0.033	1185.925	0.035	1363.058	0.038	1552.376	0.040	1753.877	0.042	1967.563	0.008	1702.360	0.008	2695.404	0.008	3688.448	0.008	4681.492	0.008	5674.536
	0.033	1025.007	0.036	1190.607	0.038	1368.440	0.040	1558.505	0.043	1760.801	0.045	1975.330	0.009	1753.218	0.009	2775.929	0.009	3798.640	0.009	4821.351	0.009	5844.062
	0.036	1027.737	0.038	1193.779	0.041	1372.085	0.043	1562.656	0.046	1765.492	0.048	1980.593	0.010	1800.000	0.010	2850.000	0.010	3900.000	0.010	4950.000	0.010	6000.000
	0.038	1029.585	0.041	1195.925	0.044	1374.552	0.046	1565.466	0.049	1768.667	0.052	1984.154	0.012	1800.000	0.012	2850.000	0.012	3900.000	0.012	4950.000	0.012	6000.000

17127 Bayfield River Bridge-North Abutment-P-Y Curves-1.2 m Dia. Caisson

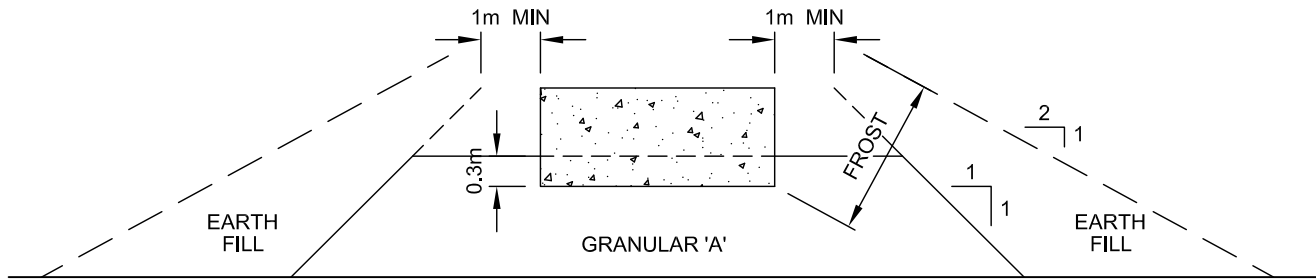




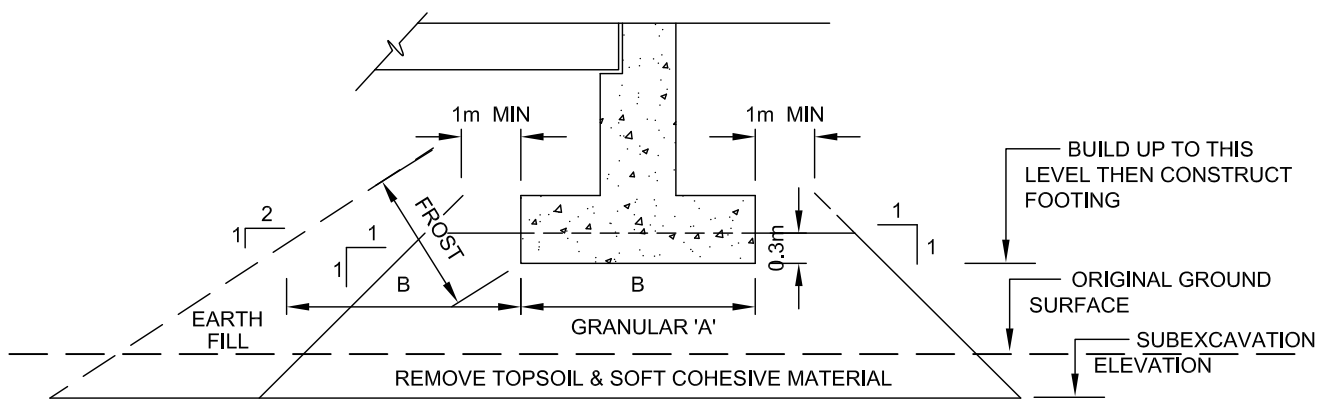
Project # 17127
Project: HWY 21 Bayfield River Bridge
Date: November 13, 2018
Revision: 0

Table 2: North Abutment - P-Y Curves - 1.2 m Diameter Caisson

S T A T I C	Depth Below Elevation of 76 m																					
	0.5		1		1.5		2		2.5		3		3.5		4		4.5		5		5.5	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
	0.003	10.742	0.002	23.652	0.002	39.461	0.002	51.577	0.002	59.363	0.002	60.607	0.002	69.086	0.002	77.501	0.002	101.725	0.002	125.313	0.002	151.295
	0.005	20.706	0.005	45.590	0.004	76.063	0.004	99.418	0.004	114.426	0.003	116.823	0.003	133.168	0.003	149.388	0.003	196.081	0.004	241.549	0.004	291.630
	0.008	29.324	0.007	64.565	0.007	107.720	0.007	140.796	0.006	162.049	0.005	165.444	0.005	188.592	0.005	211.562	0.005	277.690	0.006	342.080	0.006	413.006
	0.010	36.338	0.010	80.008	0.009	133.486	0.009	174.473	0.008	200.810	0.007	205.017	0.007	233.701	0.006	262.166	0.007	344.111	0.008	423.903	0.008	511.793
	0.013	41.770	0.012	91.967	0.011	153.440	0.011	200.553	0.010	230.827	0.008	235.662	0.008	268.635	0.008	301.354	0.009	395.548	0.009	487.268	0.010	588.295
	0.015	45.817	0.015	100.877	0.013	168.305	0.013	219.983	0.012	253.189	0.010	258.493	0.010	294.660	0.010	330.549	0.010	433.868	0.011	534.474	0.012	645.289
	0.018	48.745	0.017	107.325	0.016	179.062	0.015	234.044	0.014	269.373	0.012	275.016	0.012	313.494	0.011	351.677	0.012	461.600	0.013	568.637	0.014	686.535
	0.021	50.821	0.020	111.894	0.018	186.685	0.017	244.007	0.016	280.841	0.014	286.724	0.013	326.840	0.013	366.649	0.014	481.252	0.015	592.845	0.016	715.762
	0.023	52.269	0.022	115.083	0.020	192.007	0.020	250.963	0.018	288.846	0.015	294.897	0.015	336.157	0.015	377.100	0.015	494.970	0.017	609.744	0.018	736.164
	0.026	53.270	0.024	117.287	0.022	195.683	0.022	255.768	0.020	294.376	0.017	300.543	0.017	342.593	0.016	384.320	0.017	504.446	0.019	621.417	0.021	750.259
	0.028	53.956	0.027	118.798	0.025	198.204	0.024	259.063	0.022	298.169	0.019	304.415	0.018	347.006	0.018	389.271	0.019	510.945	0.021	629.423	0.023	759.925
	0.031	54.425	0.029	119.829	0.027	199.925	0.026	261.311	0.024	300.757	0.020	307.057	0.020	350.018	0.019	392.650	0.021	515.380	0.023	634.887	0.025	766.521
	0.033	54.743	0.032	120.530	0.029	201.095	0.028	262.841	0.026	302.517	0.022	308.854	0.021	352.067	0.021	394.948	0.022	518.397	0.024	638.602	0.027	771.007
	0.036	54.959	0.034	121.006	0.031	201.888	0.030	263.878	0.028	303.711	0.024	310.073	0.023	353.457	0.023	396.507	0.024	520.443	0.026	641.124	0.029	774.051
	0.039	55.106	0.037	121.328	0.034	202.426	0.033	264.581	0.030	304.520	0.025	310.899	0.025	354.398	0.024	397.564	0.026	521.830	0.028	642.831	0.031	776.113
	0.041	55.205	0.039	121.547	0.036	202.790	0.035	265.057	0.032	305.068	0.027	311.458	0.026	355.036	0.026	398.278	0.027	522.768	0.030	643.987	0.033	777.508
	Depth Below Elevation of 76 m																					
	6		6.5		7		7.5		8		8.5		9		9.5		10		10.5		11	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
	0.002	179.670	0.002	210.437	0.003	243.597	0.003	279.148	0.003	317.091	0.003	357.425	0.000	222.140	0.000	353.802	0.000	485.487	0.000	617.181	0.000	748.879
	0.004	346.324	0.005	405.630	0.005	469.546	0.005	538.073	0.006	611.210	0.006	688.956	0.000	678.824	0.000	1074.877	0.000	1470.931	0.000	1866.985	0.000	2263.040
	0.007	490.463	0.007	574.451	0.008	664.970	0.008	762.017	0.009	865.593	0.009	975.697	0.000	806.103	0.000	1276.371	0.000	1746.641	0.000	2216.910	0.000	2687.180
	0.009	607.778	0.010	711.856	0.010	824.025	0.011	944.285	0.012	1072.636	0.012	1209.077	0.001	891.670	0.001	1411.841	0.001	1932.013	0.001	2452.186	0.001	2972.358
	0.011	698.628	0.012	818.263	0.013	947.199	0.014	1085.436	0.014	1232.972	0.015	1389.808	0.001	957.931	0.001	1516.748	0.001	2075.566	0.001	2634.384	0.001	3193.202
	0.013	766.310	0.014	897.535	0.015	1038.963	0.016	1190.592	0.017	1352.421	0.018	1524.450	0.001	1012.742	0.001	1603.529	0.001	2194.315	0.001	2785.102	0.001	3375.889
	0.016	815.291	0.017	954.904	0.018	1105.372	0.019	1266.692	0.020	1438.866	0.021	1621.891	0.002	1204.012	0.002	1906.362	0.002	2608.713	0.002	3311.064	0.002	4013.415
	0.018	850.000	0.019	995.556	0.020	1152.429	0.022	1320.618	0.023	1500.121	0.024	1690.938	0.003	1332.329	0.003	2109.528	0.003	2886.727	0.003	3663.926	0.003	4441.125
	0.020	874.229	0.021	1023.935	0.023	1185.279	0.025	1358.262	0.026	1542.882	0.028	1739.138	0.004	1431.612	0.004	2266.723	0.004	3101.835	0.004	3936.947	0.004	4772.059
	0.022	890.967	0.024	1043.538	0.026	1207.972	0.027	1384.267	0.029	1572.421	0.031	1772.435	0.005	1513.701	0.005	2396.697	0.005	3279.693	0.005	4162.689	0.005	5045.685
	0.024	902.445	0.026	1056.983	0.028	1223.535	0.030	1402.101	0.032	1592.680	0.034	1795.270	0.006	1584.262	0.006	2508.418	0.006	3432.573	0.006	4356.729	0.006	5280.884
	0.027	910.279	0.029	1066.157	0.031	1234.155	0.033	1414.271	0.035	1606.504	0.037	1810.853	0.007	1646.485	0.007	2606.936	0.007	3567.388	0.007	4527.839	0.007	5488.290
	0.029	915.606	0.031	1072.397	0.033	1241.378	0.035	1422.548	0.038	1615.906	0.040	1821.451	0.008	1702.360	0.008	2695.404	0.008	3688.448	0.008	4681.492	0.008	5674.536
	0.031	919.220	0.033	1076.631	0.036	1246.279	0.038	1428.164	0.040	1622.285	0.043	1828.642	0.009	1753.218	0.009	2775.929	0.009	3798.640	0.009	4821.351	0.009	5844.062
	0.033	921.669	0.036	1079.499	0.038	1249.599	0.041	1431.969	0.043	1626.607	0.046	1833.513	0.010	1800.000	0.010	2850.000	0.010	3900.000	0.010	4950.000	0.010	6000.000
	0.036	923.326	0.038	1081.440	0.041	1251.846	0.044	1434.543	0.046	1629.532	0.049	1836.810	0.012	1800.000	0.012	2850.000	0.012	3900.000	0.012	4950.000	0.012	6000.000



CROSS-SECTION



LONGITUDINAL SECTION

NOTES:

1. REMOVE TOPSOIL AND OR SOFT SUBSOIL UNDER AREA OF COMPACTED GRANULAR 'A' AND EARTH FILL.
2. PLACE GRANULAR 'A' AND EARTH FILL TO BOTTOM OF FOOTING LEVEL, COMPACTED ACCORDING TO O.P.S.S. 501.
3. CONSTRUCT CONCRETE FOOTING.
4. PLACE REMAINDER OF GRANULAR 'A' AND EARTH FILL AS REQUIRED.
5. SOURCE M.T.C. 1982.

ABUTMENT ON COMPACTED FILL
SHOWING GRANULAR 'A' CORE



THURBER ENGINEERING LTD.

ENGINEER:	DRAWN:	APPROVED:
SKP	AN	SKP
DATE:	SCALE:	DRAWING No.
MARCH 2019	N.T.S.	FIGURE H1