



**THURBER** ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
MOOSE CREEK BRIDGE REPLACEMENT  
HIGHWAY 72, KENORA DISTRICT, ONTARIO  
W.P. 473-00-01, SITE #41S-16**

**Geocres Number: 52K-014**

**Report to**

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**PART 1: FACTUAL INFORMATION**

**1 INTRODUCTION**

This report presents the factual findings obtained from a foundation investigation conducted for the proposed replacement of the Moose Creek Bridge on Highway 72, located south of the Town of Sioux Lookout.

The purpose of the investigation was to explore the subsurface conditions at the site, and based on the data obtained, to provide a borehole location plan, record of borehole sheets, a stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained in the course of the investigation.

Archive drawings consisting of “Plan and Elevation” and “General Details” dated March 3, 1942 and “Gabion Retaining Wall and Pile Cap Reinforcement” dated January 1969 provided by MMM were reviewed during preparation of this report.

Thurber carried out the investigation as a sub-consultant to MMM Group Limited, under the Ministry of Transportation Ontario (MTO) Agreement Number 6010-E-0011.

**2 SITE DESCRIPTION**

The bridge site is located on Highway 72 approximately 500 m south of Fireside Road and 15.5 km south of the Town of Sioux Lookout, Ontario.

The Moose Creek at the Highway 72 crossing flows from west to east, discharging into Abram Lake to the east of the highway. The Moose Creek flows through a long broad marsh, which is approximately 150 m wide at the crossing. The land surrounding the valley is gently undulating and heavily treed.

The existing bridge is a three span structure supported on timber bents. The bridge has a total length of 18.3 m and a width of 10.0 m. Each span is approximately 6 m in length. The archive drawings dated March 3, 1942 indicate that each bent is supported on a single row of eleven timber piles. The deck consists of a reinforced concrete slab supported on a laminated timber deck.

Photographs of the bridge and surrounding area are presented in Appendix C. As evident on the photographs, movement of the abutment foundations and settlement of the approaches has been experienced. Remedial work carried out to address the foundation displacement has included reinforcement (widening) of the timber pile caps, installation of wood shims between the timber piles and pile cap, and reinforcement of the exposed part of selected piles. Loss of ground is also apparent adjacent to the abutments.

The archive drawing dated January 1969 shows that in addition to the wood shims and pile cap reinforcement, gabion retaining walls were to be installed behind the abutments, presumably to prevent loss of material between the piles. Rock or cold mix were also specified to retain the shoulder fill. At present, rock fill and localized asphaltic material are evident at the abutments, however the gabion walls are not visible.

Additional bents of timber piles, cut-off above the creek water level, are also present under the bridge, apparently from a former bridge structure.

The site lies within the physiographical area of Canadian Shield, which is characterized by Pre-Cambrian igneous and metamorphic bedrock typically occurring as rounded knobs and ridges where exposed. According to Canadian Geological Survey (CGS) data, the bedrock at this site generally consists of mafic to intermediate meta-volcanic rocks of the Winnipeg River Subprovince. The bedrock is overlain by a discontinuous cover of Pleistocene sand, silt and gravel (glaciofluvial outwash) overlain by silt and clay (glaciolacustrine deposit).

### **3 SITE INVESTIGATION AND FIELD TESTING**

The site investigation and field testing at this site were carried out in two stages. Between April 21 and May 3, 2015, a total of four (4) boreholes designated as Boreholes MCB-01, MCB-03, MCB-04 and MCB-06 were drilled from the highway embankment level. Boreholes MCB-01 and MCB-06 were advanced at each bridge approach to depths of 10.1 m and 9.8 m, respectively, and Boreholes MCB-03 and MCB-04 were drilled at the abutments with sampling to depths of 38.7 m and 35.1 m, from which depth dynamic cone penetration testing (DCPT) was performed to 41.7 m and 38.0 m depth.

In addition, twelve hand-augered probeholes were attempted on both sides of the highway embankment at selected locations to investigate the thickness of peat. As the ground within the Moose Creek Valley was still partially frozen, only six (6) probeholes designated as Probehole P1 to P6 were advanced in the swampy area on both sides of the embankment. The probeholes depths varied from 450 mm to 5.5 m depth.

To supplement the existing subsurface information, the second stage of investigation was carried out between July 15 and July 23, 2015, when a total of eighteen (18) boreholes were drilled. The boreholes were distributed within the stretch of the creek valley to the north and south of the existing bridge. Six boreholes were advanced from the highway embankment level, namely Boreholes

MCB-02, MCB-05 and MCB-22 were located to the south of the existing bridge and Boreholes MCB-07, MCB-08 and MCB-21 were located to the north of the bridge. The remaining boreholes were distributed on both sides of the highway embankment in the adjacent swampy area. The boreholes were advanced to depths ranging from 14.3 m to 16.5 m, except for Boreholes MCB-18, MCB-21 and MCB-22, which were terminated at depths ranging from 1.1 m to 6.7 m. In Borehole MCB-20, dynamic cone penetration testing was carried out from 11.3 m to 15.5 m depth.

Boreholes placed on the highway embankment were advanced using a CME 75 track-mounted drill rig in combination with the NW casing/wash boring method. Boreholes located in the swampy area adjacent to the embankment were drilled from the barge using portable tripod drilling equipment.

Soil samples were obtained from the boreholes at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Field vane shear tests were conducted in peat and cohesive soils for determination of undrained shear strengths using MTO Standard “N” size vane and a calibrated torque wrench.

The drilling and sampling operations were supervised on a full time basis by members of Thurber’s technical staff. The supervisor logged the boreholes and processed the recovered soil and rock samples for transport to Thurber’s laboratory for further examination and testing. Undisturbed silty clay samples (Shelby tube samples) were collected from Boreholes MCB-15 and MCB-22 and submitted to TBT Engineering for further laboratory testing.

Groundwater conditions in the open boreholes were observed during the drilling operations. A standpipe piezometer consisting of 19 mm PVC pipe with a slotted screen was installed in Borehole MCB-03. Following the final water level reading, the piezometer was decommissioned in general accordance with MOE Regulation 903.

The ground surface elevations at the borehole and probehole locations were obtained from the drawings provided by MMM. The approximate locations of the boreholes and probeholes are shown on the attached Borehole Locations and Soil Strata Drawing included in Appendix G.

A summary of the drilling program, including borehole and probehole locations, drilling depths, and completion details, is presented in Table 3.1 below.

**Table 3.1 –Summary of Drilling Program**

<b>Location</b>	<b>Borehole Number</b>	<b>Borehole Depth/Base Elevation (m)</b>	<b>Completion Details</b>
South Approach	MCB-01	10.1 / 349.3	Borehole backfilled with bentonite holeplug and cuttings to 1.0 m, then concrete to surface.
South Embankment	MCB-02	15.8 / 344.0	Borehole backfilled with bentonite holeplug to 1.8 m, concrete to 0.2 m, then asphalt to surface.
South Abutment	MCB-03	41.7 / 317.8	Standpipe piezometer consisting of 19 mm diameter Schedule 40 PVC pipe with a 3 m slotted screen

Location	Borehole Number	Borehole Depth/Base Elevation (m)	Completion Details
			installed.
North Abutment	MCB-04	38.0 / 321.6	Borehole backfilled with bentonite holeplug and cuttings to 1.0 m, then concrete to surface.
South Embankment	MCB-05	15.8 / 343.4	Borehole backfilled with bentonite holeplug to 1.6 m, concrete to 0.2, then asphalt to surface.
North Approach	MCB-06	9.8 / 349.9	Borehole backfilled with bentonite holeplug and cuttings to 0.6 m, then concrete to surface.
North Embankment	MCB-07	15.8 / 343.9	Borehole backfilled with bentonite holeplug to 1.5 m, concrete to 0.2 m, then asphalt to surface.
North Embankment	MCB-08	15.8 / 345.0	Borehole backfilled with bentonite holeplug to 1.5 m, concrete to 0.2 m, then asphalt to surface.
West of South Embankment	MCB-09	15.8 / 342.4	Borehole backfilled with bentonite holeplug to surface.
West of South Embankment	MCB-10	16.5 / 341.1	Borehole backfilled with bentonite holeplug to surface.
West of South Embankment	MCB-11	16.5 / 341.0	Borehole backfilled with bentonite holeplug to surface.
East of South Embankment	MCB-12	15.8 / 342.8	Borehole backfilled with bentonite holeplug to surface.
East of South Embankment	MCB-13	15.8 / 342.4	Borehole backfilled with bentonite holeplug to surface.
East of South Embankment	MCB-14	15.8 / 341.9	Borehole backfilled with bentonite holeplug to surface.
West of North Embankment	MCB-15	15.8 / 341.6	Borehole backfilled with bentonite holeplug to surface.
West of North Embankment	MCB-16	15.8 / 342.5	Borehole backfilled with bentonite holeplug to surface.
West of North Embankment	MCB-17	15.8 / 344.0	Borehole backfilled with bentonite holeplug to surface.
East of North Embankment	MCB-18	1.1 / 355.9	Borehole backfilled with bentonite holeplug to surface.
East of North Embankment	MCB-19	14.3 / 343.4	Borehole backfilled with bentonite holeplug to surface.
East of North Embankment	MCB-20	14.5 / 342.6	Borehole backfilled with bentonite holeplug to surface.
North Embankment	MCB-21	4.3 / 356.5	Borehole backfilled with bentonite holeplug to 1.2 m, concrete to 0.2 m, then asphalt to surface.
South Embankment	MCB-22	6.7 / 352.5	Borehole backfilled with bentonite holeplug to 1.5 m, concrete to 0.2 m, then asphalt to surface.
West of South Embankment	P1	4.0 / 354.1	Borehole backfilled with cuttings to surface.
West of South Embankment	P2	5.2 / 352.6	Borehole backfilled with cuttings to surface.
West of South	P3	5.5 / 352.1	Borehole backfilled with cuttings to surface.

Location	Borehole Number	Borehole Depth/Base Elevation (m)	Completion Details
Embankment			
West of North Embankment	P4	0.5 / 358.8	Borehole backfilled with cuttings to surface.
East of North Embankment	P5	4.6 / 357.1	Borehole backfilled with cuttings to surface.
East of North Embankment	P6	2.9 / 355.1	Borehole backfilled with cuttings to surface.

#### 4 LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. The results of this testing are shown on the Record of Borehole sheets included in Appendix A. Grain size analyses and Atterberg Limits tests were conducted on selected samples and the results of this testing program are summarized on the Record of Borehole sheets in Appendix A and are shown on the figures included in Appendix B.

Oedometer tests were performed on selected undisturbed silty clay samples (Shelby tube samples) in the TBT Engineering laboratory. The results of the testing are enclosed in Appendix B.

#### 5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets and the Summary of Probeholes in Appendix A for details of the encountered soils. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling and observations during drilling; therefore they represent transitions between soil types rather than exact geological boundaries. The subsurface conditions may vary between and beyond the borehole locations. The model of the soil stratigraphy is illustrated on the “Borehole Locations and Soil Strata” drawing and soil profiles enclosed in Appendix G.

The subsurface stratigraphy below the existing embankment fill encountered at the site generally consists of a layer of amorphous peat overlying a deposit of silty clay, which in turn is underlain by glaciofluvial deposits comprising of silt/silty sand and transitioning to sand. Bedrock was not encountered during this investigation.

More detailed descriptions of the individual strata are presented below.

##### 5.1 Asphalt

Asphalt pavement was encountered in Boreholes MCB-01 to MCB-08 and MCB-21 drilled from the roadway. The thickness of the asphalt ranged from 75 mm to 225 mm. The greatest thickness of asphalt was noted in Boreholes MCB-03 and MCB-04 located in proximity to



the existing bridge abutments, which may indicate maintenance works (asphalt padding) due to ongoing embankment settlements.

## 5.2 Fill

Embankment fill was encountered below the asphalt in Boreholes MCB-01 to MCB-08 and MCB-21. A fill material was also found in Borehole MCB-18 drilled near the toe of embankment. The fill thickness where fully penetrated varied from 1.9 m in Borehole MCB-08 to 6.8 m in Borehole MCB-01 with the underside between 2.0 m and 7.0 m depth (Elev. 358.8 and 352.4).

In all roadway boreholes except Boreholes MCB-02 and MCB-03, the upper 0.6 m to 2.2 m of fill consisted of granular material ranging from gravelly sand to sandy gravel forming the road base. Trace to some silt and occasional cobbles were encountered in this fill. The road base was underlain by finer material consisting of sand to sand and silt with localised zones of silt and silty clay to clayey silt. Occasional cobbles were also encountered in this fill. Borehole MCB-18 advanced near the embankment toe encountered 1.1 m of sand fill with some peat content.

In the upper 1.5 to 2.2 m of the fill below the pavement surface, recorded SPT 'N' values ranged from 21 blows for 0.3 m penetration to 50 blows for 0.1 m penetration, indicating a compact to very dense relative density. The higher 'N' values may indicate the presence of cobbles in the fill. Below this level, 'N' values varied from zero (Weight of Rod to Weight of Hammer) to 14 blows for 0.3 m, indicating a very loose to compact condition. Moisture contents of the granular fill typically ranged from 3% to 12%, and the moisture content in the finer fill ranged from 12% to 29%.

The results of grain size analyses conducted on fill samples are provided on the Record of Borehole sheets in Appendix A and are illustrated in Figures B1 to B3 of Appendix B. The results are summarized as follows:

Particles	Gravelly Sand to Sandy Gravel	Sandy Clayey Silt	Silty Sand to Sand and Silt
Gravel	29 to 52%	0%	0 to 14%
Sand	43 to 63%	30%	53 to 76%
Silt & Clay	5 to 20%	-	24%
Silt	-	43%	19 to 39%
Clay	-	27%	5 to 20%

## 5.3 Peat

A layer of peat was encountered below the embankment fill in all boreholes drilled through the roadway except for Borehole MCB-08. Peat was also encountered from the ground

surface in all boreholes drilled adjacent to the embankment, except for Borehole MCB-18 which was terminated in the fill. The peat was described as dark brown, typically fibrous below the embankment fill and amorphous adjacent to the embankment. Trace shell fragments were observed in the lower zone of the deeper peat areas.

The thickness of the peat beneath the embankment fill ranged from 0.1 m to 3.3 m, with the base of the peat at depths ranging from 2.8 m to 9.0 m depth (Elev. 358.0 to 350.4). The peat in the boreholes drilled beyond the embankment toe extended from the ground surface to depths ranging from 1.1 m to 6.1 m, with the base of the deposit between Elev. 357.0 and Elev. 351.4. The greater thickness of the peat was encountered in the southern part of the site both under the embankment and in the area adjacent to the embankment.

SPT 'N' values obtained in the peat under the embankment fill ranged from 1 to 10 blows per 0.3 m of penetration, indicating a very loose to loose condition. 'N' values recorded in the peat adjacent to the embankment varied from zero (Weight of Rod to Weight of Hammer) to 5 blows per 0.3 m of penetration, indicating a very loose to loose condition.

In areas adjacent to the embankment, undrained shear strengths measured by field vane shear tests (VST) carried out in the peat ranged from 12 kPa to 32 kPa, with typical values between 17 kPa and 22 kPa. In the peat layer beneath the embankment fill, higher undrained shear strengths of 25 kPa to 38 kPa were measured, possibly reflecting consolidation of the peat under the weight of the embankment fill. Two higher values of 70 kPa and 80 kPa recorded in Borehole MCB-05 may indicate the presence of roots in the tested peat zone.

Natural moisture contents of the peat samples collected from the boreholes put down adjacent to the embankment ranged from 51% to 792%, with the lower values obtained in samples collected near the ground surface, and the highest values from the central zone of the deposit. The natural moisture content of peat samples collected from beneath the embankment fill varied between 147% and 430%, which may again reflect consolidation of the peat under the embankment fill.

#### **5.4 Silty Clay**

A layer of grey silty clay was encountered below the peat in all boreholes (excluding Borehole MCB-18 terminated in fill). Occasional silt and clayey silt seams and trace to some sand were noted in this deposit, as well as trace of rootlets in the upper zone immediately beneath the peat. Where fully penetrated, the thickness of the layer ranged from 1.4 m to 7.8 m with the lower boundary encountered between 2.7 m and 14.3 m depth (Elev. 344.4 to 356.8). Boreholes MCB-01, MCB-06, MCB-10, MCB-11 and MCB-21 were terminated in the silty clay deposit between 4.3 m and 16.5 m depth (Elev. 356.5 and 341.0), which indicates that the silty clay may extend to greater depths than penetrated in the boreholes.

SPT 'N' values recorded in the silty clay ranged from zero blows (Weight of Rod to Weight of Hammer) to 25 blows per 0.3 m penetration, with typical values from zero to 3 blows per 0.3 m penetration. The higher N values, ranging from 8 to 25 blows per 0.3 m penetration, were generally recorded in the boreholes located close to the south and north boundaries of the valley (Boreholes MCB-09, MCB-12, MCB-16 and MCB-17, where the silty clay layer was relatively thin.

Field vane testing (VST) conducted in the boreholes adjacent to the embankment resulted in undrained shear strengths ranging from 12 kPa to 46 kPa with typical values between 15 kPa and 25 kPa. Similar to the measurements of N-values, higher undrained shear strengths were obtained in the boreholes located at the boundaries of the site. The undrained shear strengths measured in the silty clay encountered below the embankment were somewhat higher and ranged from 17 kPa to 65 kPa with the majority of values ranging from 17 kPa to 45 kPa. One value of 10 kPa was obtained in Borehole MCB-04 in the upper 0.7 m thick zone of silty clay immediately beneath the peat. Based on the SPT and VST data, the consistency of the silty clay varied from very soft to stiff.

The sensitivity of the silty clay, calculated as a ratio of undisturbed strength to remoulded strength, in the majority of the boreholes ranged from 3 to 8, suggesting that the silty clay is normal to sensitive. However, in Borehole MCB-15 and MCB-19, the sensitivity of silty clay was between 5 and 14, indicating sensitive to extra sensitive soil.

The results of grain size analyses conducted on samples of the silty clay are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figures B4 to B8 of Appendix B. The results are summarized as follows:

Particles	Content in %
Gravel	0 to 12
Sand	0 to 21
Silt	31 to 77
Clay	23 to 69

The results of Atterberg Limits tests conducted on samples of the silty clay are provided on the Record of Borehole sheets in Appendix A and illustrated in Figure B15 to B17 of Appendix B. The results indicated that the deposit has plastic limits ranging from 18 to 20% and liquid limits ranging from 32 to 46%. Plasticity indices, the difference between the plastic limit and liquid limit, ranged from 14 to 27%, suggesting low to medium plasticity of the deposit.

Natural moisture contents of the silty clay ranged from 22 to 83% with the typical moisture content values between 35 and 60%.

Oedometer Tests were performed on selected undisturbed samples of silty clay (Shelby tubes samples) collected from Borehole MCB-15 and MCB-22. The testing was performed in the TBT Engineering laboratory. The results of the testing are enclosed in Appendix B and summarized below.

#### Consolidation Test Results

Borehole	Sample Depth (m)	$e_o$	$C_c$	$C_r$	$p_{e'}$ (kPa)	$p_{o'}$ (kPa)	OCR	$c_v$ m <sup>2</sup> /yr
MCB-15	6.1 - 6.7	1.8	0.7	0.07	50	25	2.0	1.6
MCB-22	6.1 - 6.7	1.3	0.3	0.03	80	80	1.0	3.2

### 5.5 Silt

A layer of grey silt was encountered below the silty clay in 15 of the 22 boreholes, namely in Boreholes MCB-02 to MCB-05, MCB-07 to MCB-09, MCB-12 to MCB-17, MCB-19 and MCB-20. The silt contained trace of gravel, trace to some clay, trace to some sand and occasional silty clay/clayey silt and sand seams. Where fully penetrated in Boreholes MCB-03 and MCB-04, the thickness of the silt was 8.1 m and 9.0 m, and the lower boundary was encountered at depths of 21.5 m and 19.2 m (Elev. 338.0 and 340.4). The remaining boreholes were terminated in the silt at depths ranging from 11.3 m (Elev. 346.8) to 15.8 m (Elev. 341.6).

SPT 'N' values recorded in the silt layer ranged from zero to 25 blows per 0.3 m penetration, indicating a very loose to compact relative density. Natural moisture contents of the silt ranged from 18% to 52%, typically 18% to 30%.

The results of grain size analyses conducted on samples of the silt are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figures B9 to B13 of Appendix B. The results are summarized as follows:

Particles	Content in %
Gravel	0 to 7%
Sand	0 to 36%
Silt	61 to 93%
Clay	2 to 24%.

### 5.6 Silty Sand

A layer of grey silty sand with trace clay and occasional silty clay and sand seams was encountered below the silt deposit in Boreholes MCB-03 and MCB-04. The thickness of silty sand measured in these boreholes was 6.0 m and 7.8 m, and the lower boundary was encountered at 27.5 m and 27.0 m depth (Elev. 332.0 and 332.6).

SPT 'N' values recorded in the silty sand ranged from 7 to 14 blows for 0.3 m penetration, indicating a loose to compact relative density. Measured natural moisture contents ranged from 17 to 22%.

Due to low sample recovery, grain size analyses were not conducted on samples of silty sand.

## 5.7 Sand

A deposit of sand was encountered below the silty sand in Boreholes MCB-03 and MCB-04. The sand contains trace to some silt, trace clay and occasional silty clay seams. Boreholes MCB-03 and MCB-04 were advanced with sampling 11.2 m and 8.4 m into the sand to depths of 38.7 m and 35.4 m (Elev. 320.8 and 324.2).

SPT 'N' values recorded in the deposit ranged from 10 to 26 blows per 0.3 m penetration, indicating a compact relative density.

Dynamic cone penetration testing conducted below the sampled depths in these boreholes indicated a gradual increase of N values with depth, which may at least partially reflect increasing friction on the cone and drill rods. The tests were terminated at depths of 41.7 m (Elev. 317.8) in Borehole MCB-03 and 38.0 m (Elev. 321.6) in Borehole MCB-04 when N values of 100 blows per 0.3 m of penetration were obtained.

The results of grain size analyses conducted on samples of the sand are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B14 of Appendix B. The results are summarized as follows:

Particles	Content in %
Gravel	0%
Sand	83 to 89%
Silt and Clay	11 to 17%

Measured natural moisture contents ranged from 15% to 20%.

## 5.8 Water Levels

Water levels in the boreholes were observed during drilling operations and measured upon completion of drilling. However, water was also used during the wash-boring operations to advance boreholes drilled from the highway embankment grade, therefore, the measured water levels on completion of drilling may not reflect prevailing groundwater levels at the site.

A standpipe piezometer was installed in Borehole MCB-03 to monitor groundwater level after drilling. The piezometer was installed in silty sand with the tip at 28.3 m depth.

The water levels measured in the open boreholes upon completion of drilling and in the piezometer are summarized in Table 5.1.

**Table 5.1 - Water Level Measurements**

Borehole Number	Date	Water Level (m)		Comments
		Depth	Elevation	
MCB-01	May 3, 2015	N/A	N/A	N/A
MCB-02	May 16, 2015	2.3	357.5	Upon completion
MCB-03	May 3, 2015	0.7	358.8	Piezometer
MCB-04	May 3, 2015	0.0	359.6	Water level rose to the road surface upon advancing borehole to 38.0 m depth.
MCB-05	July 17, 2015	1.1	358.1	Upon completion
MCB-06	April 23, 2015	N/A	N/A	N/A
MCB-07	July 17, 2015	1.8	357.9	Upon completion
MCB-08	July 15, 2015	1.2	359.6	Upon completion
MCB-09	July 19, 2015	0.1	358.1	Upon completion
MCB-10	July 18, 2015	0.3	357.3	Upon completion
MCB-11	July 19, 2015	0.0	357.5	Upon completion
MCB-12	July 20, 2015	0.1	358.5	Upon completion
MCB-13	July 20, 2015	0.2	358.0	Upon completion
MCB-14	July 21, 2015	0.0	357.7	Upon completion
MCB-15	July 22, 2015	0.0	357.4	Upon completion
MCB-16	July 23, 2015	0.3	358.0	Upon completion
MCB-17	July 23, 2015	0.5	359.3	Upon completion
MCB-18	July 23, 2015	N/A	N/A	N/A
MCB-19	July 21, 2015	0.2	357.5	Upon completion
MCB-20	July 22, 2015	0.2	357.9	Upon completion
MCB-21	July 17, 2015	0.9	359.9	Upon completion
MCB-22	July 23, 2015	N/A	N/A	N/A

In summary, the groundwater level measured in the piezometer was at Elev. 358.8, and the water levels measured in the open boreholes upon completion of drilling ranged from the ground surface to 0.5 m depth (Elev. 357.3 to 359.3) in the boreholes drilled in the swamp and 0.7 m to 2.3 m depth (Elev. 357.5 to 359.9) in the boreholes drilled through the road embankment.

The following water levels in Moose Creek were indicated in the available documents:

Archive drawing (March 1942) - Elev. 358.0 (1174.6 ft) on October 15, 1941

Preliminary General Arrangement drawing (April 2015) - Elev. 356.7 on November 2011

- Elev. 358.9 High Water Level

Preliminary Profile drawing (MMM) - Elev. 358.8 on May 30, 2014.

The water level in the creek and groundwater levels are subject to precipitation patterns and are expected to fluctuate seasonally. Observations made during drilling operations confirmed that the water level in the Moose Creek can change/rise significantly in a short period of time. Therefore, the water levels at any given time may vary from the levels measured during the foundation field investigation.

## 6 MISCELLANEOUS

Eastern Ontario Diamond Drilling of Hawkesbury, Ontario supplied the drill rig and conducted the drilling, sampling and in-situ testing operations. Boreholes placed on the highway embankment were advanced using a CME 75 track-mounted drill rig in combination with the NW casing/wash boring method. A portable tripod drill rig was supplied to carry out the drilling, sampling and in-situ testing operations for boreholes located in the swampy area adjacent to the embankment.

The drilling and sampling operations were supervised in the field by Ms. Eckie Siu and Mr. Matthew Whalen, EIT. Mr. Mark Farrant, P.Eng. directed the field operations.

The report was prepared by Ms. Anna Piascik, P.Eng., and reviewed by Mr. Murray Anderson, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations projects.

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**FOUNDATION INVESTIGATION AND DESIGN REPORT**  
**MOOSE CREEK BRIDGE REPLACEMENT**  
**HIGHWAY 72, KENORA DISTRICT, ONTARIO**  
**W.P. 473-00-01, SITE #41S-16**

**Geocres Number: 52K-014**

**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**7 GENERAL**

This report presents interpretation of the geotechnical data in the factual report and provides geotechnical recommendations to assist the design team in selecting and designing a suitable foundation system for the proposed replacement bridge, as well as recommendations regarding embankment modifications (grade raise and widening) associated with the bridge replacement.

The interpretation and recommendations presented in this Design Report are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purpose or by any other party including the construction or design-build contractor. The contractor must make their own interpretation of the factual data presented in the Investigation Report (Part 1) as to the potential effects on equipment selection, construction methods and scheduling. Where comments are made on construction, they are provided only to highlight those aspects which could affect the design of the project.

At present, Highway 72 crosses the Moose Creek on a three span structure supported on timber bents. The bridge has a total length of 18.3 m and a width of 10.0 m, and each span is approximately 6 m in length. Archive drawings dated March 3, 1942 indicate that each bent is supported on a single row of eleven timber piles. The timber pile cut-off (top of pile) was approximate Elev.359.0, however the pile length and tip elevation are not shown. The deck consists of a reinforced concrete slab supported on a laminated timber deck.

Movement of the abutment foundations and settlement of the approaches has been experienced. Remedial work carried out to address the foundation displacement has included reinforcement (widening) of the timber pile caps, installation of wood shims between the timber piles and pile cap, and reinforcement of the exposed part of selected piles. Loss of ground is also apparent adjacent to the abutments.



The archive drawing dated January 1969 shows that in addition to the wood shims and pile cap reinforcement, gabion retaining walls were to be installed behind the abutments, presumably to prevent loss of material between the piles. Rock or cold mix were also specified to retain the shoulder fill. At present, rock fill and localized asphaltic material are evident at the abutments, however the gabion walls are not visible.

Additional bents of timber piles, cut-off above the creek water level, are also present under the bridge, apparently from a former bridge structure.

The Moose Creek bridge is located within a long broad marsh, which is approximately 150 m wide at the crossing. The bridge approaches and roadway embankment crossing the marsh vary in height from approximately 1.5 to 2.5 m above the swamp level. The existing road grade at the bridge is near Elev. 359.5.

The General Arrangement drawing dated May 2016 indicates that the replacement bridge will be a single span structure with a total length of 22 m and a width of 12.4 m. Each abutment will be supported on a single row of steel H-piles. Sheet pile walls will be installed behind the H-piles to retain the abutment backfill. The new abutments will be positioned in front of the existing abutments and timber piles.

The current design calls for the road grade at each abutment to be raised by approximately 1100 mm. The grade raise along the north approach will be maintained for a distance of approximately 40 m from the north abutment, and then reduce gradually to existing grade some 150 m to the north of the bridge. The grade raise along the south approach will be maintained for a distance of approximately 30 m from the south abutment, and then gradually reduce to meet existing grade some 150 m from the bridge. In conjunction with the grade raise, the approach embankment will be widened by about 2 m on both sides.

The engineering discussion and recommendations presented in this report are based on information provided by MMM Group Limited and on the factual data obtained in the course of this investigation.

## **8 STRUCTURE FOUNDATIONS**

The borehole information indicates that the existing bridge approaches were constructed by placement of sand and silt fill over the existing peat deposits in the marsh. The fill thickness encountered in the boreholes at the abutments and immediate approaches ranged from 4.1 to 7.0 m, and the underlying peat thickness was 2.0 to 2.5 m with a lower boundary at depths of 6.4 to 9.0 m. A peat thickness of 4.4 to 6.1 m was encountered in the adjacent swamp.

The peat is underlain by a soft to firm silty clay, which in turn overlies a loose to compact cohesionless deposit consisting of silt transitioning with depth to silty sand then to sand. The sand extended to depths of at least 38.7 and 35.4 m (the limit of sampling in Boreholes MCB-03 and MCB-04), and DCPT testing performed below these depths obtained N-values of 100 blows for less than 0.3 m of penetration at depths of 41.7 m and 38.0 m.

The water levels measured in the open boreholes and shown for Moose Creek on various documents ranged from Elev. 356.7 to 359.9. The high water level (annual) shown on the preliminary GA drawing is Elev. 358.9. A groundwater level at Elev. 358.8 was measured in the piezometer extended into the silty sand deposit below the clay layer. Water levels in Moose Creek are typically at the ground surface in the swamp and can change significantly in a short period of time.

Foundation options initially considered for this bridge included:

- spread footings placed on native soil or engineered fill,
- driven steel H-piles, and
- augered caissons.

A comparison of the technical advantages and disadvantages of the alternative foundation schemes is presented in Appendix D.

Discussion on the design of the feasible foundation alternatives are presented in the following sections together with the corresponding geotechnical design parameters. A preferred foundation option from a geotechnical perspective is presented.

### **8.1 Spread Footings on Native Soil or Engineered Fill**

Given the low strength and highly compressive nature of the peat and silty clay, and the significant depth to a competent foundation stratum below the water level, spread footings founded at shallow depth or on engineered fill pads to support the abutments are not considered to be a feasible alternative for support of the bridge structure.

### **8.2 Driven H-Pile Foundations**

A system of driven steel H-piles developing resistance primarily through shaft friction could be considered to support the bridge loads.

#### **8.2.1 Axial Resistance**

Given the soft/compressible nature of the soils directly below the existing embankment, friction piles will have to be driven to significant depths into the very loose to compact cohesionless deposits below the very loose peat and soft to firm silty clay to develop adequate resistance. The geotechnical resistances recommended for HP 310x110 piles driven to Elev. 322.0 in the compact sand are presented in Table 8.1.

**Table 8.1 – Geotechnical Resistance and Reaction for Driven HP310x110 Piles**

<b>Foundation Element</b>	<b>Pile Tip Depth/Elevation (m)</b>	<b>Factored Geotechnical Resistance at ULS (kN) per pile</b>	<b>Geotechnical Reaction at SLS (kN) per pile</b>
South Abutment	37.8 / 322.0	550	385
North Abutment			

The pile length was estimated assuming a pile cut-off at Elev. 359.8. The recommended pile tip elevation is considered approximate and the actual tip elevation required to develop the design resistance will need to be confirmed by monitoring during installation.

Oversize materials (e.g. greater than 75 mm nominal diameter) should not be used for any new fill through which the piles will be driven.

### **8.2.2 Pile Installation**

Pile installation should be in accordance with OPSS 903.

Pile driving at both abutments should be controlled in accordance with Standard Drawing SS103-11 (Hiley Formula) and an ultimate pile resistance should be specified by the designer. The Hiley formula need not be used until the piles are within 3.0 m of the design pile tip elevation. The appropriate pile driving note is “Piles to be driven in accordance with Standard SS 103-11 using an ultimate resistance of “R” kN per pile. “R” should have a minimum value of twice the design load at ULS, but should not exceed 1,100 kN.

If the proposed bridge design requires that the deviation at the top of the pile be limited to tight tolerance, a driving template or other means may be required to achieve the specified maximum deviation.

Pile tip protection is not required and should not be used for driven H-piles developing resistance through shaft friction at this site.

The alignment of the H-piles should be carefully selected to avoid the existing timber bents and pile foundations. The peat and silty clay underlying the site are soft and sensitive to disturbance, and therefore it is important that the existing timber piles are left in place. The existing piles may be cut off at the level of the channel base. Suggested wording for an NSSP in this regard is provided in Appendix E.

The groundwater level measured in the deep piezometer installed in Borehole MCB-03 and the water level observed at the road surface during drilling of Borehole MCB-04 indicate that an upward hydraulic gradient exists in the cohesionless deposit underlying the peat and clay layers. It is anticipated that any upward seepage of groundwater along pile shafts extended into the cohesionless deposit will be effectively cut off by adhesion within the soft cohesive clay layer.

### **8.2.3 Pile Lateral Resistance**

The geotechnical lateral resistance acting on a pile in cohesive soils may be calculated using a value for the coefficient of horizontal subgrade reaction ( $k_s$ ) and ultimate lateral resistance ( $p_{ult}$ ) as follows:

$$k_s = 67 S_u / D \quad (\text{kN/m}^3)$$

$$p_{ult} = 9 S_u \quad (\text{kPa})$$

Where  $S_u$  = undrained shear strength of the soil (kPa)

$D$  = pile width or diameter in metres.

The geotechnical lateral resistance acting on a pile in cohesionless soils may be calculated using the following correlations for a value of the coefficient of horizontal subgrade reaction ( $k_s$ ) and ultimate lateral resistance ( $p_{ult}$ ):

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

$$p_{ult} = 3 \gamma' z K_p \quad (\text{kPa})$$

where  $z$  = depth of embedment of pile (m)

$D$  = pile width or diameter (m)

$n_h$  = coefficient related to soil relative density ( $\text{kN/m}^3$ )

$\gamma'$  = effective unit weight ( $\text{kN/m}^3$ )

$K_p$  = passive earth pressure coefficient.

The above equations and recommended parameters summarized in Table 8.2, below, may be used to analyze the interaction between a pile and the surrounding soil. The lateral pressures obtained from the analysis should not exceed the ultimate lateral resistance.

**Table 8.2 – Soil Parameters for Lateral Pile Resistance**

Soil Unit	Elevation (m)		$\gamma'$ (kN/m <sup>3</sup> )	$n_h$ (kN/m <sup>3</sup> )	$K_a$	$K_o$	$K_p$	$S_u$ (kPa)
	Top	Bottom						
South Abutment (Borehole MCB-03)								
Silty Sand Fill	359.3*	357.1	11	1,500*	0.30	0.47	1.3*	-
Clayey Silt Fill	357.1	354.0	9	1,500	0.35	0.52	2.8	-
Peat	354.0	351.5	1	-	0.49	0.66	2.0	15
Silty Clay	351.5	346.1	8	-	0.42	0.59	2.4	17
Silt	346.1	338.0	9	2,000	0.35	0.52	2.9	-
Silty Sand	338.0	332.0	10	2,500	0.33	0.50	3.0	-
Sand	332.0	320.8**	11	4,000	0.31	0.47	3.3	-
North Abutment (Borehole MCB-04)								
Sand/Silt Fill	359.4*	357.5	11	1,500*	0.30	0.47	1.3*	-
Sand/Silt Fill	357.5	355.5	9	1,500	0.35	0.52	2.8	
Peat	355.5	353.2	1	-	0.49	0.66	2.0	15
Silty Clay	353.2	349.4	8	-	0.42	0.59	2.4	20
Silt	349.4	340.4	9	2,000	0.35	0.52	2.9	-

Soil Unit	Elevation (m)		$\gamma'$ (kN/m <sup>3</sup> )	$n_h$ (kN/m <sup>3</sup> )	$K_a$	$K_o$	$K_p$	$S_u$ (kPa)
	Top	Bottom						
Silty Sand	340.4	332.6	10	2,500	0.33	0.50	3.0	-
Sand	332.6	324.2**	11	4,000	0.31	0.47	3.3	-

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

\*\* Pile tip elevations may vary at pile locations.

The spring constant,  $K_s$ , for analysis may be obtained from the expression:

$$K_s = k_s L D \text{ (kN/m)},$$

where  $k_s$  = coefficient of horizontal subgrade reaction (kN/m<sup>3</sup>),

$D$  = pile width (m), and

$L$  = length (m) of the pile segment or element used in the analysis.

The ultimate lateral resistance,  $P_{ult}$ , may be obtained from the expression,  $P_{ult} = p_{ult} L D$ . This represents the ultimate load at which the pile fails and will not support any additional load at greater displacements.

The modulus of subgrade reaction and ultimate lateral resistance may have to be reduced, based on the pile spacing. The reduction factors to be used for a pile group oriented perpendicular or parallel to the direction of loading are provided in Table 8.3. Intermediate values may be obtained by linear interpolation.

**Table 8.3 – Subgrade Reaction Reduction Factors for Pile Spacing**

Condition	Pile Spacing, Centre to Centre	Reduction Factor
Pile group oriented <i>perpendicular</i> to direction of loading	4D	1.0
	1D	0.5
Pile group oriented <i>parallel</i> to direction of loading	8D	1.0
	6D	0.7
	4D	0.4
	3D	0.25

In the case of conventional abutments, i.e. not integral type, horizontal loads may be resisted by means of battered piles.

### 8.3 Downdrag

Placement of additional approach fill behind the abutments to raise the road grade and widen the embankment would result in the development of downdrag along the length of pile embedded within the fill, peat and clay due to consolidation of the peat and silty clay under the weight of the new fill.

We understand however that the proposed embankment design will incorporate expanded polystyrene (EPS) as lightweight fill to compensate for any load increase and thereby prevent

post-construction settlements of the approach fills. Consequently, downdrag of the piles will not be an issue. Further comments regarding EPS design are provided elsewhere in the report.

#### **8.4 Caissons / Drilled Shafts**

A suitable caisson bearing stratum was not identified within reasonable depth during the current investigation. Further, caisson installation would need to extend through peat, soft to firm silty clay and very loose to compact cohesionless soils below the water table to achieve adequate capacity, requiring such means as drilling mud and/or a permanent liner to support the caisson sidewalls and prevent “boiling” at the caisson base. Inspection of the caisson base to confirm the bearing stratum would not be possible in these conditions. The use of caissons is therefore not recommended, and this alternative has not been developed herein.

#### **8.5 Recommended Foundation**

From a geotechnical perspective and based on the subsurface conditions, steel H-piles driven into the compact sand is the preferred foundation option at this site.

#### **8.6 Frost Cover**

The depth of frost penetration at this site is approximately 2.6 m. The base of pile caps, if employed, should be provided with a minimum of 2.6 m of earth cover as protection against frost action.

#### **8.7 Impact on Existing Foundations**

New H-piles will be driven adjacent to the existing bridge abutments to support the replacement bridge. The new foundation units should be positioned strategically to avoid encountering the existing foundations during driving of the new piles.

Information on the existing pile length or tip elevations is not available. In light of the subsurface conditions present at this site, it is probable that the existing timber piles are terminated either in soft to firm silty clay or saturated, loose to compact silt or silty sand. Driving new piles may impact the performance of the existing pile foundations. Therefore, it is recommended that a monitoring program be implemented for the duration of foundation construction to identify any movement of the existing structure. The program should include establishment of adequate benchmarks outside the zone of potential influence and acquirement of baseline readings in advance of construction. Appropriate monitoring points and tolerable levels of movement should be specified by the structural designer. If movements exceed tolerable levels, the Contractor should be prepared to jack and/or level the bridge structure. Suggested wording for an NSSP for monitoring of the existing structure during pile driving has been included in Appendix E.

## 9 SHEET PILE ABUTMENTS

The current design proposes the installation of steel sheet pile walls adjacent to the pile foundations in lieu of conventional abutment walls. The sheet piles will provide containment and resistance to lateral earth pressures from the approach fill. The alignment of the proposed sheet pile walls should be carefully selected to avoid existing timber bents and piles.

Lateral stability of the sheet pile walls should be checked by the wall designer using the parameters presented in Table 9.1. The coefficients of passive earth pressure ( $K_p$ ) are provided for horizontal ground surface in front of the sheet pile wall. For sloping ground in front of the sheet pile wall, the recommended values for the coefficients of passive earth pressure ( $K_p$ ) should be reduced. The possibility of material loss due to creek erosion in front of the sheet piles should also be considered in the check of the lateral earth pressure balance.

**Table 9.1 – Soil Parameters for Sheet Pile Analysis**

Soil Unit/ Borehole Number		Top of Layer Elevation (m)	$\gamma'$ kN/m <sup>3</sup>	$n_h$ (kN/m <sup>3</sup> )	$K_a$	$K_o$	$K_p$	$S_u$ (kPa)
<b>South Abutment</b>								
Silty Sand Fill		359.5**	11	1,500 *	0.30	0.47	1.3 *	-
Clayey Silt Fill		357.0	9	1,500	0.35	0.52	2.8	-
Peat	MCB-03	354.0	1	-	0.49	0.66	2.0	15
	MCB-11	357.5						
	MCB-14	357.7						
Silty Clay		351.5	8	-	0.42	0.59	2.4	17
Silt	MCB-03	346.1	9	2,000	0.35	0.52	2.9	-
	MCB-11	341.0						
	MCB-14	344.4						
Silty Sand		338.0	10	2,500	0.33	0.50	3.0	-
Sand		332.0	11	4,000	0.31	0.47	3.3	-
<b>North Abutment</b>								
Sand/Silt Fill		359.6**	11	1,500 *	0.30	0.47	1.3 *	-
Loose Sand/Silt Fill		357.5	9	1,500	0.35	0.52	2.8	-
Peat	MCB-04	355.5	1	-	0.49	0.66	2.0	15
	MCB-15	357.4						
Silty Clay		353.0	8	-	0.42	0.59	2.4	20
Silt	MCB-04	349.4	9	2,000	0.35	0.52	2.9	-
	MCB-15	345.2						
Silty Sand		340.4	10	2,500	0.33	0.50	3.0	-
Sand		332.6	11	4,000	0.31	0.47	3.3	-

\* Passive resistance coefficient in the upper fill accounts for the 2H:1V front/side slope.

\*\* Top of sheet pile elevation may vary.

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

As outlined in further sections of the report, ultralight (EPS) fill is to be placed behind the abutment sheet piles to compensate for any load increase on the compressible foundation soils and mitigate consolidation settlements. In confined spaces between the sheet pile and EPS where compaction of backfill material cannot be achieved (such as within the sheet pile trough), backfill should comprise 9.5 mm clear stone meeting the requirements of OPSS.PROV 1004.

Cobbles and boulders may be encountered during driving the sheet piles through the existing embankment fill. Any rock fill/erosion protection materials present at the bridge abutments, as well as any visible obstructions along the sides of the embankments should be removed prior to driving the sheet piles.

The sheet pile alignment should be strategically located to avoid encountering existing pile foundations or ancillary structures. Archive drawings indicate that gabion retaining walls may be present at the corners of the existing abutments. The presence and actual locations of the gabion walls should be confirmed prior to driving sheet piling, and if necessary, the gabion walls should be removed prior to driving the piles.

Use of tip protection is not recommended for the sheet piles at this site.

In light of the soft foundation clay and the underlying sensitive silt deposit, vibratory methods should not be used at this site to install the sheet piles. An NSSP to this effect is presented in Appendix E. To reduce the potential for displacing the foundation H-piles during sheet pile installation, the sheet piles should be installed prior to driving of the abutment piles if practical.

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

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

## **10 LATERAL EARTH PRESSURES**

Earth pressures acting on the structure may be assumed to be distributed triangularly and to be governed by the characteristics of the abutment backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are given by the expression:

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

where:  $p_h$  = horizontal pressure on the wall at depth  $h$  (kPa)



$K$  = coefficient of lateral earth pressure

$\gamma$  = unit weight of retained soil

$h$  = depth below top of fill where pressure is computed (m)

$q$  = value of any surcharge (kPa)

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

**Table 10.1 – Coefficients of Lateral Earth Pressure**

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I or Type III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.38*	0.31	0.46*
At-rest (Restrained Wall)	0.43	-	0.47	-
Passive	3.7	-	3.3	-

\* For wing walls.

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

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

In accordance with Clause 6.9.3 of the CHBDC, 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 2.0 m for Granular B Type I or III, or at a depth of 1.7 m for Granular A or Granular B Type II.

## 11 SEISMIC CONSIDERATIONS

The following seismic parameters should be used for design:

- Velocity Related Seismic Zone 0
- Zonal Velocity Ratio 0.00
- Acceleration Related Seismic Zone 0
- Zonal Acceleration Ratio 0.00
- Peak Ground Acceleration 0.04 g

The soil profile type at this site has been classified as Type III. Therefore, according to Table 4.4 of the CHBDC, a Site Coefficient “S” (ground motion amplification factor) of 1.5 should be used in seismic design.

In accordance with Clause 4.6.4 of the CHBDC, retaining structures should be designed using active ( $K_{AE}$ ) and passive ( $K_{PE}$ ) earth pressure coefficients that incorporate the effects of earthquake loading.

For the design of retaining walls under seismic loading, the coefficients of horizontal earth pressure in Table 11.1 may be used:

**Table 11.1 – Earth Pressure Coefficient for Earthquake Loading**

Loading Condition	Earth Pressure Coefficient (K) for Earthquake Loading			
	Granular A or Granular B Type II $\phi = 35^\circ$ ; $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I or Type III or Existing Fill $\phi = 32^\circ$ ; $\gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active ( $K_{AE}$ )*	0.28	0.42	0.32	0.51
Passive ( $K_{PE}$ )	3.6	-	3.2	-
At Rest ( $K_{OE}$ )**	0.47	-	0.52	-

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

\*\* After Woods (1973).

The loose saturated silt layer underlying the silty clay deposit may be susceptible to liquefaction under seismic loading. However, considering the low seismic activity in the area (acceleration related seismic zone of zero), liquefaction of the foundation soils is not a concern.

## 12 EMBANKMENT DESIGN

The preliminary profile information provided by the designer indicates that the existing road grade will be raised by approximately 1100 mm at the abutments. The grade raise along the north approach will be maintained for a distance of approximately 40 m from the north abutment, and then reduce gradually to existing grade some 150 m to the north of the bridge. The grade raise along the south approach will be maintained for a distance of approximately 30 m from the south abutment, and then gradually reduce to meet existing grade some 150 m from the bridge.

Ongoing settlement and deformation of the existing approaches has been experienced in the past as a result of the existing embankment being constructed over the compressible peat and clay deposits, as evidenced by a depression and thicker asphalt layer adjacent to each bridge abutment, pavement cracking and other deficiencies. Placement of additional fill to raise the grade will induce further settlement and deformation of the roadway pavement due to the increased loading on the underlying peat and clay. The increased embankment height may also impact the stability of the embankment slopes constructed over the weak organic deposits and soft clay.

Various alternative methods were assessed to improve the settlement performance and maintain an adequate factor of safety against embankment instability under the increased embankment height. These methods included the following:

- Full and/or partial sub-excavation of the peat and soft cohesive soils, and replacement with granular embankment fill;
- Provision of berms and/or flattening of embankment slopes to improve global stability;
- Ground improvement techniques such as rammed aggregate piers, soil mixing or geosynthetic reinforcement;
- Construction techniques such as preloading/surcharging and wick drain installation to accelerate settlement or staged construction to maintain stability;
- Use of lightweight fill;
- Installation of sheet pile walls along both sides of the embankment to improve stability; and
- Temporary roadway detouring or permanent realignment.

We understand that temporary or permanent rerouting of the highway is not an acceptable alternative. Consequently, full sub-excavation of the peat and clay, as well as preloading/surcharging and wick drain installation are also not feasible at the site. Use of rammed aggregate piers or soil mixing is not recommended due to the thickness of the peat and clay as well as the presence of the underlying loose, cohesionless strata which may be subject to hydraulic uplift.

Discussion of the remaining, feasible construction methodologies for embankment construction including analysis of anticipated settlements and embankment stability are presented in the following sections.

## **12.1 Assessment of Embankment Settlement**

### **12.1.1 Design Criteria**

The criteria for acceptable post construction settlement applicable to embankment design on MTO projects is defined in the MTO Guideline “Embankment Settlement Criteria for Design”. The relevant settlement criteria for transitions to bridge abutments and embankment widening over a 20-year post-construction period (non-freeway) are outlined in the table below:

**Table 12.1 - MTO Guideline - Embankment Settlement Criteria for Design**

Longitudinal		Widening	
Distance from Abutment	Maximum Post-Construction Settlement (mm)	Maximum Post-Construction Settlement (mm)	Differential Settlement Rate
0 m to 20 m	25	75	100:1
20 m to 50 m	50		
50 m to 75 m	100		
>75 m	200		

The above criteria have been used to determine whether mitigation measures are required to limit post-construction settlements of the approach embankments at the Moose Creek site.

### 12.1.2 Selection of Parameters for Design

Information obtained from the field investigation and laboratory testing has been compiled and geotechnical parameters for estimating settlements were selected for the deposits governing the design, namely peat and silty clay. A summary of the parameters are presented in Figures F1 and F2 in Appendix F. The figures include plots of undrained shear strength, preconsolidation stress, water content and consolidation parameters estimated from oedometer testing and from empirical correlation. The parameters selected for use in settlement evaluation are marked on the plots and are summarized in Table 12.2, below.

**Table 12.2 - Engineering Parameters for Estimate of Settlement**

Stratigraphic Unit	$\gamma$ kN/m <sup>3</sup>	$S_u$ kPa	$e_o$	$C_c$	$C_{ca}$	$C_{ra}$	$c_v$ m <sup>2</sup> /y
Peat	11	15	8.5	5.8	0.6	0.06	10
Silty Clay	17	17	1.3	0.7	0.3	0.03	3.5

The compression index ( $C_c$ ) and recompression index ( $C_r$ ) for the peat deposit were evaluated from empirical correlations based on water content and review of available data from technical literature.

For calculating primary consolidation settlements, it was assumed that the silty clay encountered below the embankment is in a normally consolidated state, based on the value of preconsolidation stress,  $\sigma_p'$ , ranging from 70 kPa to 90 kPa estimated from the test results. The compression index ( $C_c$ ) and recompression index ( $C_r$ ) for the silty clay were evaluated from interpretation of the laboratory consolidation test results. The results from the consolidation tests were supplemented with estimates based on the results of water contents and Atterberg Limits tests using empirical correlations available in literature.

Review of laboratory consolidation test data obtained for the silty clay deposit at this site and available test results for similar clay deposits in Northern Ontario suggest that an average

value of the coefficient of consolidation,  $c_v$ , equal to  $3.5 \text{ m}^2/\text{year}$  is appropriate. Similarly, a value of  $10 \text{ m}^2/\text{year}$  was utilized for the peat underlying the embankment fill.

### 12.1.3 Results of Settlement Analysis

The magnitude of the long-term settlements to be anticipated due to consolidation of the peat and clay under the increased loading of an embankment grade raise of up to 1100 mm were carried out using Terzaghi one-dimensional consolidation theory. The estimated settlements due to the grade raise are summarized in the table below.

**Table 12.3 - Estimated Embankment Settlements due to Grade Raise**

Station	Existing Fill Height (m)	Grade Raise (mm)	Estimated Primary Consolidation Settlement (mm)				
			2 months	3 months	6 months	2 years	20 years
17+640	1.7	160	34	35	35	35	35
17+660	1.7	210	38	39	40	40	40
17+680	1.7	370	65	66	68	70	70
17+700	1.6	670	155	175	190	195	200
17+720	1.8	940	125	150	200	280	300
17+740	1.8	1040	110	135	185	285	310
<b>Bridge (17+761 to 17+783)</b>							
17+800	2.2	1100	130	155	205	260	270
17+820	2.2	1050	135	160	195	245	250
17+840	2.1	910	105	125	145	185	190
17+860	2.0	700	85	95	99	100	100
17+880	2.0	470	60	65	69	70	70
17+890	2.0	340	45	48	50	50	50
17+900	2.0	240	35	38	40	40	40
17+910	2.0	160	22	24	25	25	25

The estimated primary consolidation settlement for the majority of the area of grade raise exceeds the post-construction settlement criteria established in the MTO Guidelines for embankment settlement.

The settlement values indicated in the table represent the settlements anticipated below the centreline of the embankment due to the proposed grade raise constructed with granular fill. As additional fill thickness will be placed at the sides of the embankment to widen the approaches, and the thickness of peat remaining under the existing embankment fill may increase towards the outer edges of the embankment, differential settlement should be anticipated across the roadway cross-section. The magnitude of the differential settlement is difficult to estimate, however it is anticipated that it may exceed the MTO criteria for widening of 100:1.

The majority (around 75%) of the estimated settlement is expected to occur in the peat and occur relatively quickly (6 months). The remainder will occur due to consolidation of the

underlying clay layer and occur at a slower rate. Based on analysis of the time rate of consolidation, approximately 90% of combined settlement due to primary consolidation of both deposits is expected to be completed within a period of about 2 years after construction. Secondary consolidation may continue at a slower rate for many years.

Considering the magnitude of the estimated embankment settlement, the potential for differential settlement across the roadway cross-section, as well as the past performance of the existing embankment, it is recommended that measures to mitigate the settlement be implemented at this site. In view of the site limitations and subsurface conditions, use of lightweight fill (EPS) to compensate for additional fill placement is the preferred method.

## **12.2 Assessment of Embankment Stability**

### **12.2.1 Method of Analysis**

The global stability of the approach embankment was assessed using the commercially available slope stability program GEO-SLOPE and applying the Morgenstern-Price method of analysis. A cross-section at Sta. 17+725 was selected for the analyses as this location was considered to have the least favourable subsurface conditions for stability. Stability analyses were carried out for both short term (undrained) and long term (drained) conditions, for the following cases:

- existing embankment side slope and abutment fore slope (long term condition only);
- existing embankment side slope with a 1100 mm grade raise and widening;
- existing embankment side slope and abutment fore slope (with existing timber pile foundations) subjected to a 20 kPa surcharge load representing piling equipment (drained, with pore pressures);
- finished embankment side slope and abutment fore slope with sheet pile wall containment, grade raise and settlement mitigation (EPS) in place;
- finished embankment side slope and abutment fore slope with sheet pile wall containment, grade raise and settlement mitigation (EPS) in place, subjected to a 20 kPa surcharge representing an undressed crane loading (drained, with pore pressures).

Stability analysis for a fully dressed crane loading during girder lifts was not carried out as imposition of high lifting loads on the EPS is not recommended.

Considering the fluctuating water level in Moose Creek, it is anticipated that a sheet pile enclosure will be required to control water during EPS installation and embankment widening. The stability analyses involving sheet pile walls therefore assumed that the sheet

piles will extend at least 2 m into the clay deposit underlying the peat to minimize inflow of water into the excavation.

Based on consideration of the risk involved and past experience with design/monitoring of highway embankment founded on cohesionless soils, factors of safety of 1.3 and 1.5 are considered appropriate to achieve short and long-term stability for embankments, respectively.

### 12.2.2 Selection of Parameters for Analysis

Soil shear strength parameters used in the stability analyses were evaluated on the basis of undrained shear strength measurements obtained from in-situ vane shear testing, empirical correlations with in-situ SPT results, and experience with similar soil deposits in Northern Ontario.

Profiles of undrained shear strength versus elevation, together with the selected design lines for the peat and clay based on the field and laboratory test data, are presented on Figures F1 and F2 in Appendix F. Where appropriate, undrained shear strength measurements obtained from the in-situ vane shear tests were revised using a correction factor as a function of the plasticity index (after Bjerrum, CFEM 2006). An observed increase of the shear strength of the peat with depth was incorporated in the analyses.

Based on this assessment, the soil parameters utilized in the analyses are summarized in Table 12.4, below.

**Table 12.4 - Engineering Parameters for Slope Stability Analysis**

Soil Type	Unit Weight (kN/m <sup>3</sup> )	Undrained Shear Strength (kPa)	Angle of Internal Friction (degrees)	Effective Cohesion (kPa)	Pore Pressure Coefficient B-bar
New Embankment Fill	22	-	32	-	-
Existing Fill	21	-	30	-	-
Peat	11	15 increasing to 20 with depth	23	-	0.3
Silty Clay	17	17	23	5	0.9
Silt	19	-	29	-	-

The low water level in Moose Creek, Elev. 356.7 indicated on the preliminary general arrangement drawing, was assumed as the critical condition in the slope stability analyses.

The embankment geometry and stratigraphy models used in the analyses are presented in Figures F3A to F9B in Appendix F.

### 12.2.3 Results of Slope Stability Analyses

The results of the slope stability analyses carried out for the various embankment and loading cases outlined above are shown on Figures F3A to F9B in Appendix F. The results are also summarized in Table 12.5.

All computed factors of safety exceed the accepted values of 1.3 for short term conditions and 1.5 for long term conditions, provided the sheet piles for the final embankment configuration are extended at least 2 m into the clay stratum along the embankment sides, and to at least elevation 347.0 along the new abutment face.

**Table 12.5 – Summary of Computed Factors of Safety**

Condition	Analysis * Type	Computed Factor of Safety	Figure Number (Appendix F)
Existing embankment sideslope	ESA	1.54	F3A
Existing abutment foreslope, with timber piles	ESA	1.39	F3B
Embankment sideslope, with 1100 mm grade raise	TSA	1.17	F4A
	ESA	1.29	F4B
Existing embankment sideslope, with 20 kPa surcharge from piling rig on near side	USA	1.29	F5A
Existing embankment sideslope, with 20 kPa surcharge from piling rig on far side	USA	1.45	F5B
Existing abutment foreslope with timber piles, with 20 kPa surcharge from piling rig set back 5m from abutment	USA	1.38	F6
Finished embankment sideslope, with sheet pile walls, EPS and grade raise	TSA	1.54	F7A
	ESA	2.03	F7B
Finished abutment foreslope, with sheet pile walls, EPS and grade raise	TSA	1.71	F8A
	ESA	2.73	F8B
Finished embankment sideslope, with sheet pile walls, EPS and grade raise, with 20 kPa surcharge from undressed lifting crane	USA	1.72	F9A
Finished abutment foreslope, with sheet pile walls, EPS and grade raise, with 20 kPa surcharge from undressed lifting crane	USA	2.17	F9B

\* TSA = Total Stress Analysis (undrained condition, short term)

ESA = Effective Stress Analysis (drained condition, long term)

USA= Undrained Stress Analysis (with excess pore pressures generated by surcharge loading)



Based on the results of the slope stability analyses, it is recommended that the sheet pile walls are driven to or below the levels indicated above assuming the proposed grade raise is constructed using EPS fill. The depth of sheet pile penetration may need to be greater to provide sufficient lateral stability and this requirement should be checked by the structural designer.

### 12.3 Recommended Embankment Design

Based on the results of the settlement and slope stability analyses, and considering the proposed grade raise and site limitations, the recommended embankment design involves installation of sheet pile walls along both sides of the existing embankment, and replacement of an adequate thickness of existing fill material with EPS to compensate for the additional loading that would otherwise result from the grade raise.

Further comments regarding sheet pile design and EPS installation are presented in the following sections.

Consideration was also given to replacement of the peat with rock fill as an alternative to sheet pile installation for embankment widening and grade revision. However, this option is not recommended as complete removal of the peat is not feasible due to staging requirements, the additional weight of the rock fill (with a higher unit weight than peat) would cause consolidation settlement of the underlying silty clay, and the differential settlement across the roadway cross-section resulting from these factors is difficult to predict. Use of EPS in the embankment to compensate for the settlement in this case would not adequately mitigate the settlement, and in view of the variable high water levels at the site, containment of EPS within a sheet pile enclosure is preferred to minimize potential buoyancy issues.

### 12.4 Sheet Pile Design

In general, sheet pile design for the embankment sides should be carried out as previously outlined for the abutment sheet piles. Supplementary design parameters reflecting the varying subsurface stratigraphy along the embankments are presented in Table 12.6.

**Table 12.6 – Soil Parameters for Sheet Pile Analysis**

Soil Unit/ Borehole Number	Top of Layer Elevation (m)	$\gamma'$ kN/m <sup>3</sup>	$n_h$ (kN/m <sup>3</sup> )	$K_a$	$K_o$	$K_p$	$S_u$ (kPa)
<b>South Embankment</b>							
Peat	357.5	1	-	0.49	0.66	2.0	15
Silty Clay	351.5	8	-	0.42	0.59	2.4	17
Silt	344.5	9	2,000	0.35	0.52	2.9	-
Silty Sand	338.0	10	2,500	0.33	0.50	3.0	-
Sand	332.0	11	4,000	0.31	0.47	3.3	-

Soil Unit/ Borehole Number	Top of Layer Elevation (m)	$\gamma'$ kN/m <sup>3</sup>	$n_h$ (kN/m <sup>3</sup> )	$K_a$	$K_o$	$K_p$	$S_u$ (kPa)
<b>North Embankment</b>							
Peat	357.0	1	-	0.49	0.66	2.0	15
Silty Clay	353.0	8	-	0.42	0.59	2.4	20
Silt	349.0	9	2,000	0.35	0.52	2.9	-
Silty Sand	340.4	10	2,500	0.33	0.50	3.0	-
Sand	332.6	11	4,000	0.31	0.47	3.3	-

As noted previously, the sheet pile tip elevation should be no higher than Elev. 349.5 (2 m into the underlying clay deposit) to control water during EPS installation and embankment widening. The depth of sheet pile penetration may need to be greater to provide sufficient lateral stability and this requirement should be checked by the structural designer. If adequate lateral support is not available or deflections exceed tolerable levels, tie-backs connecting the sheet pile walls on opposite sides of the embankment may be required.

### 12.5 Design and Installation of Lightweight (EPS) Fill

Lightweight Expanded Polystyrene (EPS) fill used to mitigate settlements should be designed with a thickness adequate to compensate for the additional weight of granular fill used to raise the road grades on the approaches. If possible subject to water levels, consideration should also be given to increasing the EPS thickness to lighten the existing embankment loading and mitigate the ongoing embankment settlement observed in the past.

A minimum of 1.0 m of granular fill cover (including the pavement structure) should be provided over the EPS.

Selection of the grade of EPS must be appropriate for the pavement and traffic loading. Design of the EPS embankment should be carried out in accordance with Transportation Research Board NCHRP Report 529, "Guideline and Recommended Standard for Geofoam Applications in Highway Embankments".

Given the limited thickness of embankment fill above the water level, buoyancy is a potential concern for the EPS performance. Adequate cover should be provided to resist buoyancy of the EPS for the highest creek water level anticipated during the design life of the bridge with an appropriate factor of safety. The annual high water level noted on the preliminary GA drawings is Elev. 358.9.

Considering the variable water level in Moose Creek and the presence of cohesionless embankment fill and peat deposit adjacent to the embankment, placement of the EPS should be carried out within a permanent sheet pile enclosure to control water inflow into the excavation and ensure that EPS installation is carried out in the dry.

To avoid crushing the EPS, heavy construction equipment (ie., dressed lifting cranes) must not be permitted on the EPS embankment. Structural means will be required to support heavy lifting equipment during installation of the bridge girders.

A Special Provision addressing the supply and installation of the EPS embankment fill should be included in the contract documents. A sample Special Provision is included in Appendix E.

### **13 SCOUR AND EROSION PROTECTION**

Rock protection should be provided along any soil surfaces that may be in contact with the creek flow. In particular, erosion protection should be provided in front of the sheet pile walls to prevent scouring and undermining of the sheet pile walls at the abutments.

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

Detailed scour and erosion protection design should be provided by a hydraulic/hydrological specialist.

### **14 EXCAVATION AND DEWATERING**

Excavation for bridge replacement and EPS fill placement behind the abutments is expected to be limited to the existing approach fill.

The excavation and backfilling for foundations and embankment construction should be carried out in accordance with OPSS 902.

All excavations should be carried out in accordance with the requirements of the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the existing fill may be classified as Type 3 soil above the water table and as Type 4 soil below the water table.

The excavations are expected to extend below the annual high water level. Given that sheet pile enclosure will be constructed to contain the abutment fill, accommodate embankment widening and enable EPS installation in the dry, it is expected that pumping from sumps will be sufficient to maintain a reasonable dry excavation. The sheet piles should be installed at least 2 m into the silty clay layer to cut-off water inflow into excavation.

The selection of the method of excavation and water control is the responsibility of the Contractor and should be based on his equipment, experience and interpretation of the site conditions. Provision should be made for the handling of pavement structure materials, potential obstructions in the fill, and existing foundation components.

Roadway protection systems will be required to facilitate staged construction at this site. The temporary excavation support system should be designed and constructed in accordance with OPSS 539 for Performance Level 2. The use of sheet piles may be considered as one method for roadway

protection. The design of roadway protection is the responsibility of the Contractor and all shoring should be designed by a Professional Engineer experienced in such designs.

## 15 CONSTRUCTION CONCERNS

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

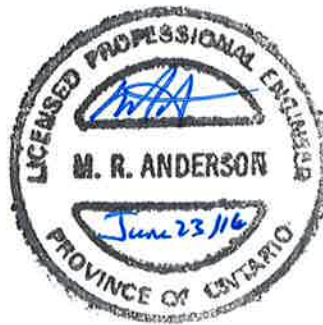
- Driving of H-piles and sheet piles for the replacement bridge may potentially cause settlement of the existing bridge during staged construction. It is recommended that settlement monitoring of the existing bridge be carried out for the duration of pile driving. The Contractor should be prepared with appropriate equipment on site to maintain the grade of the existing bridge within acceptable tolerance.
- Installation of the sheet piles may encounter resistance in the fill due to the presence of cobbles or other obstructions. Erosion protection (cobbles and boulders) is evident on the face of the front slopes at the bridge abutments. Removal of such obstructions by the Contractor will be required.
- Vibratory methods must not be used to install sheet piles at this site.
- The existing piles should be left in place to minimize disturbance to the very loose and very soft soils underlying the site.
- The sequence of H-pile and sheet pile installation should be carefully considered to avoid pile alignment problems.
- The Contractor should be aware of the potentially fluctuating creek water levels and anticipate the possible impacts on construction and dewatering requirements.
- The Contractor's selection of construction equipment and methodology should include assessment of the capability of the subgrade soils to support the proposed construction equipment and any temporary structures or fill (i.e. as a pad for crane support). Site conditions may limit the type of equipment suitable for use. The design and safety of any temporary works is the responsibility of the Contractor. Recommended wording for an NSSP addressing this issue is provided in Appendix E.

## 16 CLOSURE

Engineering analysis and preparation of the foundation design report were carried out by Ms. Anna Piascik, P.Eng. The report was reviewed by Mr. Murray Anderson, P.Eng. and Dr. P. K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

### THURBER ENGINEERING LTD.

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## **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 <sup>(1)</sup> 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

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



### 4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

### 5. LEGEND FOR RECORDS OF BOREHOLES

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

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

 Water Level  
 Shear Strength Determination by Pocket Penetrometer

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

## EXPLANATION OF ROCK LOGGING TERMS


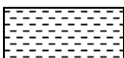



### ROCK WEATHERING CLASSIFICATION

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

### DISCONTINUITY SPACING

<b>Bedding</b>	<b>Bedding Plane Spacing</b>
Very thickly bedded	Greater than 2m
Thickly bedded	0.6 to 2m
Medium bedded	0.2 to 0.6m
Thinly bedded	60mm to 0.2m
Very thinly bedded	20 to 60mm
Laminated	6 to 20mm
Thinly Laminated	Less than 6mm

### SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

### STRENGTH CLASSIFICATION

<b>Rock Strength</b>	<b>Approximate Uniaxial Compressive Strength</b>		<b>Field Estimation of Hardness*</b>
	<b>(MPa)</b>	<b>(psi)</b>	
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

### TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length
Solid Core Recovery:(SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run
Rock Quality Designation:(RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a % of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index:(FI)	Frequency of natural fractures per 0.3m of core run.



# UNIFIED SOILS CLASSIFICATION

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

# RECORD OF BOREHOLE No MCB-01

1 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 441.2 E 372 045.8 ORIGINATED BY MNW  
 HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2015.05.03 - 2015.05.03 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa											
359.4	GROUND SURFACE							20	40	60	80	100							
0.0	ASPHALT:(150mm)							20	40	60	80	100							
0.2	Gravelly <b>SAND</b> , trace to some silt, trace organics Compact to Very Dense Brown Moist (FILL)		1	SS	69		359												
			2	SS	40														
357.9							358												
1.5	Silty <b>SAND</b> , trace clay, trace gravel, occasional cobbles Compact to Dense Greyish Brown Wet (FILL)		3	SS	88														
			4	SS	13		357												
356.7																			
2.7	Clayey <b>SILT</b> , trace sand, trace gravel, occasional lenses of gravelly sand Stiff Grey to Greyish Brown Moist to Wet (FILL)		5	SS	14		356												
355.6																			
3.8	Silty <b>SAND</b> , trace clay, occasional silt lenses Loose to Compact Greyish Brown Wet (FILL)		6	SS	14		355												
							354												
			7	SS	4		353												
352.4																			
7.0	<b>PEAT</b> , fibrous, trace sand Loose Dark Brown Wet		8	SS	5		352												
							351												
350.4	Trace of shell fragments in 300mm zone at 8.7m depth																		
9.0	Silty <b>CLAY</b> , trace sand Very Soft Grey Moist		9	SS	0		350												

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No MCB-01

2 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 441.2 E 372 045.8 ORIGINATED BY MNW  
 HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2015.05.03 - 2015.05.03 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
349.3 10.1	Continued From Previous Page  END OF BOREHOLE AT 10.1m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 1.0m, THEN CONCRETE TO SURFACE.							20 40 60 80 100	20 40 60				kN/m <sup>3</sup>	GR SA SI CL

# RECORD OF BOREHOLE No MCB-02

1 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 381.7 E 372 036.8 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.16 - 2015.07.16 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w <sub>P</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT $\gamma$  kN/m <sup>3</sup>	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 (%)
359.8	GROUND SURFACE														
0.0	ASPHALT:(125mm)														
0.1	Silty <b>SAND</b> , some gravel, trace clay, occasional cobbles Compact to Very Dense Brown Moist (FILL)		1	SS	50/ 0.125										
			2	SS	23										
			3	SS	10										
357.7															
2.1	<b>PEAT</b> , fibrous, trace sand Loose Dark Brown Moist to Wet		4	SS	5										
356.7															
3.1	Silty <b>CLAY</b> , some sand, trace rootlets in the upper zone Soft to Firm Grey Wet		5	SS	6										
			6	SS	3										
353.7															
6.1	<b>SILT</b> , trace to some sand, trace clay, occasional clay seam Very Loose to Loose Grey Wet		7	SS	8										
			8	SS	2										
			9	SS	2										

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No MCB-02

2 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 381.7 E 372 036.8 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.16 - 2015.07.16 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE      LIQUID CONTENT      LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								○ UNCONFINED      + FIELD VANE					W <sub>p</sub> W      W <sub>L</sub>			
								● QUICK TRIAXIAL      × LAB VANE	20   40   60   80   100				20   40   60			
	Continued From Previous Page															
			10	SS	2		349						○		0   0   93   7	
							348									
			11	SS	2								○			
							347									
			12	SS	3		346						○			
							345									
			13	SS	3								○		0   17   81   2	
344.0							344									
15.8	END OF BOREHOLE AT 15.8m. WATER LEVEL AT 2.3m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 1.8m, CONCRETE TO 0.2m, ASPHALT TO SURFACE.															

ONTMT4S 1197.GPJ 2015TEMPLATE(MTO).GDT 11/6/15

# RECORD OF BOREHOLE No MCB-03

1 OF 5

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 459.0 E 372 047.9 ORIGINATED BY MNW  
 HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2015.04.27 - 2015.04.30 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	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 <sub>p</sub> w      w <sub>L</sub>				GR	SA	SI	CL
359.5	GROUND SURFACE							20	40	60	80	100							
0.0	ASPHALT:(225mm)							20	40	60	80	100							
0.2	Silty <b>SAND</b> , some gravel, trace clay, occasional cobbles Dense Brown Moist to Wet (FILL)		1	SS	32		359												
			2	SS	50/ 0.100		358												
357.1																			
2.4	Clayey <b>SILT</b> , some sand to sandy, trace gravel Stiff Grey Moist (FILL)		3	SS	12		357												
			4	SS	8		356												
354.9																			
4.6	<b>SAND</b> , trace silt, trace gravel Loose Greyish Brown Wet (FILL)		5	SS	4		355												
354.0																			
5.5	<b>PEAT</b> , fibrous Very Loose Dark Brown Wet   Trace shell fragments, trace wood fragments in 500mm zone at 7.5m depth		6	SS	2		353												
351.5																			
8.0	Silty <b>CLAY</b> , trace sand, occasional silt lense Soft to Firm Grey Moist to Wet		7	SS	0		350												

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No MCB-03

2 OF 5

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 459.0 E 372 047.9 ORIGINATED BY MNW  
HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
DATUM Geodetic DATE 2015.04.27 - 2015.04.30 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)								
								20   40   60   80   100	○ UNCONFINED      + FIELD VANE	● QUICK TRIAXIAL      × LAB VANE	W <sub>P</sub> W      W <sub>L</sub>								
	Continued From Previous Page							20   40   60   80   100				20   40   60							
346.1																			
13.4	<b>SILT</b> , trace to some clay, trace to some sand, occasional clay seam Loose to Compact Grey Wet																		

Continued Next Page

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

# RECORD OF BOREHOLE No MCB-03

3 OF 5

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 459.0 E 372 047.9 ORIGINATED BY MNW  
 HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2015.04.27 - 2015.04.30 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT $\gamma$  kN/m <sup>3</sup>	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 (%)			GR
	Continued From Previous Page		14	SS	3															
							339													
338.0							338													
21.5	Silty <b>SAND</b> , trace clay Loose Grey Moist						337													
			15	SS	8		336													
							335													
							334													
			16	SS	7		333													
332.0							332													
27.5	<b>SAND</b> , trace to some silt, trace clay, occasional silty clay seam Compact Grey Moist						331													
			17	SS	17		330													

Continued Next Page

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



# RECORD OF BOREHOLE No MCB-03

4 OF 5

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 459.0 E 372 047.9 ORIGINATED BY MNW  
 HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2015.04.27 - 2015.04.30 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
	Continued From Previous Page													
			18	SS	15									
			19	SS	14									
			20	SS	26									
320.8 38.7	End of sampling at 38.7m. Start DCPT at 38.0m													

Continued Next Page

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

RECORD OF BOREHOLE No MCB-03

5 OF 5

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 459.0 E 372 047.9 ORIGINATED BY MNW  
HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
DATUM Geodetic DATE 2015.04.27 - 2015.04.30 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
	Continued From Previous Page							20	40	60	80	100				
317.8							319									
318																
41.7	<p>END OF BOREHOLE AT 41.7m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.</p> <p>WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) May 03/15 0.7 358.8</p>															

# RECORD OF BOREHOLE No MCB-04

1 OF 4

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 482.1 E 372 042.6 ORIGINATED BY MNW  
 HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2015.05.01 - 2015.05.03 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
359.6	GROUND SURFACE							20 40 60 80 100					
0.0	ASPHALT:(200mm)							20 40 60 80 100					
0.2	Sandy GRAVEL (FILL)							20 40 60 80 100					
358.8							359						
0.8	Silty SAND to SAND and SILT, trace clay, trace gravel, occasional cobble Very Loose to Very Dense Light Brown to Grey Moist (FILL)		1	SS	31								2 58 35 5
			2	SS	70								
			3	SS	0								
	Very loose zone between 2.2m and 2.7m depth		4	SS	3								0 76 19 5
355.5													
4.1	PEAT, fibrous, trace to some sand Very Loose Dark Brown Wet		5	SS	1								
							354						
	Trace of shell fragments in 100mm zone at 6.3m depth		6	SS	0								
353.2													
6.4	Silty CLAY, trace sand, trace peat in the upper 1.0m zone, occasional seams of silt and sand Very Soft to Soft Dark Grey Moist												
			7	SS	2								
			8	SS	1								
													0 0 58 42
							350						

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity




20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No MCB-04

2 OF 4

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 482.1 E 372 042.6 ORIGINATED BY MNW  
 HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2015.05.01 - 2015.05.03 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED    + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE										
	Continued From Previous Page																	
349.4								20 40 60 80 100										
10.2	<b>SILT</b> , trace clay, trace to some sand, occasional silty clay and sand seams Very Loose to Compact Grey Wet							20 40 60 80 100										
			9	SS	10		349											
							348											
			10	SS	14		347											
							346											
			11	SS	7									0 6 85 9				
							345											
			12	SS	3		344											
							343											
			13	SS	13													
							342											
			14	SS	11		341							0 19 75 6				
340.4																		
19.2	Silty <b>SAND</b> , trace clay, occasional silty clay and sand seams Loose to Compact Grey Wet						340											

Continued Next Page

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

# RECORD OF BOREHOLE No MCB-04

3 OF 4

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 482.1 E 372 042.6 ORIGINATED BY MNW  
 HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2015.05.01 - 2015.05.03 CHECKED BY AMP


SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)							
								20    40    60    80    100				W <sub>p</sub> W                      W <sub>L</sub>							
							○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE												
	Continued From Previous Page		15	SS	14														
							339												
							338												
							337												
			16	SS	11														
							336												
							335												
							334												
			17	SS	7														
							333												
332.6	SAND, trace to some silt, trace clay, occasional silty clay seam Compact Grey Moist						332												
27.0							331												
				18	SS	12													
								330											

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

## METRIC

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

[illegible]

ONTMT4S 1197.GPJ 2015TEMPLATE(MTO).GDT 11/6/15

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No MCB-05

1 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 412.0 E 372 035.8 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.17 - 2015.07.17 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
359.2	GROUND SURFACE						<div><div>20406080100</div><div>SHEAR STRENGTH kPa</div><div>○ UNCONFINED    + FIELD VANE</div><div>● QUICK TRIAXIAL    × LAB VANE</div></div> <div><div>20406080100</div><div>WATER CONTENT (%)</div><div>W P                          W                          W L</div></div>						
0.0	ASPHALT:(125mm)												
0.1	SAND and GRAVEL, trace silt Very Dense to Dense Brown Moist (FILL)		1	SS	69								37   54   9 (SI+CL)
			2	SS	46								
357.9													
1.3	SAND and SILT, trace gravel, trace clay Loose to Compact Grey Moist (FILL)		3	SS	21								1   53   39   7
			4	SS	12								
			5	SS	7								
355.2													
4.0	PEAT, amorphous, trace sand, trace roots and rootlets Loose to Compact Dark Brown Moist		6	SS	10								
			7	SS	4								
351.9													
7.3	Silty CLAY, trace sand, occasional silt and sand seams Soft to Firm Grey Wet		8	SS	0							0   0   45   55	
			9	SS	5								

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No MCB-05

2 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 412.0 E 372 035.8 ORIGINATED BY ES  
HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
DATUM Geodetic DATE 2015.07.17 - 2015.07.17 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)		
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE											
	Continued From Previous Page						20 40 60 80 100												
			10	SS	0														
							4.0 + 2.7 +												
			11	SS	0														
							4.0 + 4.0 +												
			12	SS	1														
344.9																			
14.3	SILT, some clay, trace sand Very Loose Grey Wet																		
							5.0 + 3.0 +												
343.4			13	SS	1														
15.8	END OF BOREHOLE AT 15.8m. WATER LEVEL AT 1.1m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 1.6m, CONCRETE TO 0.2m, ASPHALT TO SURFACE.																		

ONTMT4S 1197.GPJ 2015TEMPLATE(MTO).GDT 11/6/15



## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No MCB-06

2 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 500.0 E 372 044.7 ORIGINATED BY MNW  
 HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2015.04.21 - 2015.04.23 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	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	20 40 60						
	Continued From Previous Page BOREHOLE BACKFILLED WITH CUTTINGS AND BENTONITE HOLEPLUG TO 0.6m, CONCRETE TO SURFACE.																

# RECORD OF BOREHOLE No MCB-07

1 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 528.9 E 372 054.3 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.17 - 2015.07.17 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	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 <sub>P</sub> w      w <sub>L</sub>				GR	SA	SI	CL
359.7	GROUND SURFACE					▽	359												
0.0	ASPHALT:(100mm)																		
0.1	Sandy <b>GRAVEL</b> , trace silt Very Dense Brown Moist (FILL)		1	SS	76									○					52   43   5 (SI+CL)
														○					
358.4			2	SS	45									○					
1.3	<b>SAND</b> , some silt, trace gravel Dense Brown Moist (FILL)																		
358.0																			
1.7	Silty <b>SAND</b> , some clay Loose to Compact Grey Moist (FILL)		3	SS	30									○					
														○					
			4	SS	11												0   57   23   20		
			5	SS	9														
355.4																			
4.3	<b>PEAT</b> , amorphous, trace roots, trace sand Loose Dark Brown Wet		6	SS	5														
353.9																			
5.8	Silty <b>CLAY</b> , trace sand, occasional silt layer Soft to Firm Grey Wet		7	SS	4								○						
													○						
			8	SS	3									○			0   0   54   46		

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10


(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No MCB-07

2 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 528.9 E 372 054.3 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.17 - 2015.07.17 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)					
								20   40   60   80   100			w <sub>P</sub> w                      w <sub>L</sub>					
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE								
	Continued From Previous Page															
349.5																
10.2	<b>SILT</b> , trace sand, trace clay Loose to Compact Grey Wet															
			10	SS	10		349									
							348									
			11	SS	5		347							0   3   91   6		
			12	SS	4		346									
							345									
			13	SS	4		344							0   3   93   4		
343.9																
15.8	END OF BOREHOLE AT 15.8m. WATER LEVEL AT 1.8m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 1.5m, CONCRETE TO 0.2m, ASPHALT TO SURFACE.															

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

# RECORD OF BOREHOLE No MCB-08

1 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 559.2 E 372 053.3 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.15 - 2015.07.15 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
360.8	GROUND SURFACE							20 40 60 80 100		PLASTIC LIMIT w <sub>P</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	
0.0	ASPHALT:(75mm)		1	SS	50/			20 40 60 80 100					
0.1	Gravelly <b>SAND</b> , some silt, occasional asphalt fragments, occasional cobble Very Dense Dark Brown Moist (FILL)		2	SS	85/ 0.275		360						30 50 20 (SI+CL)
359.5													
1.3	<b>SAND</b> , some silt, trace gravel, trace peat Compact Brown Moist (FILL)		3	SS	13		359						
358.8													
2.0	Silty <b>CLAY</b> , some sand, some gravel, trace peat in the upper 0.5m zone Stiff Grey Moist		4	SS	9		358						
			5	SS	4								12 11 35 42
							357						
356.2													
4.6	<b>SILT</b> , trace to some sand, trace clay Very Loose to Loose Grey Wet		6	SS	7		356						
			7	SS	6		355						
							354						
			8	SS	3		353						0 2 92 6
							352						
			9	SS	3								
							351						

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No MCB-08

2 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 559.2 E 372 053.3 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.15 - 2015.07.15 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								20 40 60 80 100					
	Continued From Previous Page							○ UNCONFINED + FIELD VANE					
	<b>SILT</b> , trace to some sand, trace clay Very Loose to Loose Grey Wet							● QUICK TRIAXIAL × LAB VANE					
								WATER CONTENT (%)					
								20 40 60					
								PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT					
								w <sub>p</sub> w w <sub>L</sub>					
</													

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# RECORD OF BOREHOLE No MCB-09

1 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 375.5 E 372 021.0 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE Tripod COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.19 - 2015.07.19 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								20 40 60 80 100	PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w			LIQUID LIMIT w <sub>L</sub>
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE			WATER CONTENT (%)				
358.2	GROUND SURFACE						20 40 60 80 100					GR SA SI CL	
0.0	<b>PEAT</b> , amorphous, trace roots Loose Dark Brown Wet		1	SS	3						248	0 0 56 44	
							2.5						
							3.3						
			2	SS	5						250		
355.7													
2.5	Silty <b>CLAY</b> , trace sand Stiff Grey Moist		3	SS	15		3.7						
							3.3						
354.3													
3.9	<b>SILT</b> , trace sand, some clay Loose to Compact Grey Wet		4	SS	23							0 0 87 13	
			5	SS	6								
			6	SS	8								
			7	SS	7								

Continued Next Page

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

RECORD OF BOREHOLE No MCB-09

2 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 375.5 E 372 021.0 ORIGINATED BY ES  
HWY 72 BOREHOLE TYPE Tripod COMPILED BY AN  
DATUM Geodetic DATE 2015.07.19 - 2015.07.19 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)							
								20    40    60    80    100				w <sub>P</sub> w                      w <sub>L</sub>							
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE											
Continued From Previous Page																			
345.0			8	SS	6		348										0   16   45   39		
13.2			Silty <b>CLAY</b> , some sand Stiff Grey Wet	10	SS		10	345											
343.5			<b>SILT</b> , trace sand, trace to some clay Very Loose Grey Wet	11	SS		3	343											
14.7																			
342.4	END OF BOREHOLE AT 15.8m. WATER LEVEL AT 0.1m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.																		
15.8																			

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE



# RECORD OF BOREHOLE No MCB-10

1 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 418.6 E 372 023.0 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE Tripod COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.18 - 2015.07.18 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	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											
357.6	GROUND SURFACE							20	40	60	80	100	20	40	60					
0.0	<b>PEAT</b> , amorphous, trace roots and rootlets Very Loose Dark Brown Wet		1	SS	1															
			2	SS	3															
			3	SS	2															
								2.5												
								2.2												
			4	SS	0															
								2.0												
								2.7												
			5	SS	0															
	Becoming fibrous with trace shell fragments, trace clay below 5.1m depth							2.0												
								2.0												
351.5																				
6.1	Silty <b>CLAY</b> , trace sand, occasional silt seams Soft Grey Wet		6	SS	0															
										3.5										
										4.0										
					7	SS	1													
								3.0												
								3.0												
			8	SS	0															

Continued Next Page

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

# RECORD OF BOREHOLE No MCB-10

2 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 418.6 E 372 023.0 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE Tripod COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.18 - 2015.07.18 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)						
								○ UNCONFINED + FIELD VANE					w P w w L						
								● QUICK TRIAXIAL × LAB VANE											
	Continued From Previous Page												GR SA SI CL						
			9	SS	0		347						0 0 42 58						
			10	SS	0		346												
			11	SS	0		344						0 0 33 67						
			12	SS	1		342												
341.1																			
16.5	END OF BOREHOLE AT 16.5m. WATER LEVEL AT 0.3m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.																		

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

## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

## METRIC








+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No MCB-12

1 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 370.4 E 372 046.9 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE Tripod COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.20 - 2015.07.20 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
358.6	GROUND SURFACE							20 40 60 80 100					
0.0	<b>PEAT</b> , amorphous, trace roots Very Loose Dark Brown Wet		1	SS	2		358					156	
													
357.0							357						
1.6	Silty <b>CLAY</b> , trace sand Firm to Very Stiff Grey Wet to Moist		2	SS	5								
							356						
			3	SS	25		355						0 6 54 40
354.5													
4.1	<b>SILT</b> , trace to some sand, some clay Very Loose to Compact Grey Wet to Moist		4	SS	10		354						
							353						
			5	SS	7		352						
							351						
			6	SS	11		350						
			7	SS	12		349						0 2 88 10

Continued Next Page

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

# RECORD OF BOREHOLE No MCB-12

2 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 370.4 E 372 046.9 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE Tripod COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.20 - 2015.07.20 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL LIQUID LIMIT			UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								20 40 60 80 100	○ UNCONFINED + FIELD VANE	W P W W L						
	Continued From Previous Page							● QUICK TRIAXIAL × LAB VANE	20 40 60 80 100					kN/m <sup>3</sup>	GR SA SI CL	
			8	SS	15		348						○			
							347									
			9	SS	9		346						○			
			10	SS	14		345						○			
							344									
			11	SS	3		343						○		0 13 69 18	
342.8																
15.8	END OF BOREHOLE AT 15.8m. WATER LEVEL AT 0.1m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.															

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# RECORD OF BOREHOLE No MCB-13

1 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 405.6 E 372 049.0 ORIGINATED BY ES  
HWY 72 BOREHOLE TYPE Tripod COMPILED BY AN  
DATUM Geodetic DATE 2015.07.20 - 2015.07.20 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	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										
358.2	GROUND SURFACE							20   40   60   80   100	W <sub>p</sub>	W	W <sub>L</sub>								
0.0	<b>PEAT</b> , amorphous. trace roots, trace sand Very Loose Dark Brown Wet		1	SS	1														
			2	SS	1														
			3	SS	1														
353.9																			
4.3	Silty <b>CLAY</b> , trace sand Soft to Firm Grey Wet		4	SS	13										0	0	60	40	
			5	SS	2														
			6	SS	0											0	0	65	35
			7	SS	0														

Continued Next Page

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

# RECORD OF BOREHOLE No MCB-13

2 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 405.6 E 372 049.0 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE Tripod COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.20 - 2015.07.20 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)		
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE											
	Continued From Previous Page							20	40	60	80	100	20	40	60				
348.0							348												
10.2	<b>SILT</b> , trace to some sand, some clay to clayey, trace gravel Very Loose to Loose Grey Wet		8	SS	2		347						○						
							346						○			0 10 66 24			
			9	SS	9		345												
			10	SS	6		344						○			7 13 61 19			
							343						○						
342.4			11	SS	9														
15.8	END OF BOREHOLE AT 15.8m. WATER LEVEL AT 0.2m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.																		

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



# RECORD OF BOREHOLE No MCB-14

1 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 444.9 E 372 055.8 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE Tripod COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.21 - 2015.07.21 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	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 <sub>p</sub> w      w <sub>L</sub>				GR	SA	SI	CL	
357.7	GROUND SURFACE							20	40	60	80	100							
0.0	<b>PEAT</b> , amorphous, trace to some rootlets Very Loose Dark Brown Wet		1	SS	0														592
351.6																			
6.1	Silty <b>CLAY</b> , trace sand, occasional silt seam Soft to Stiff Grey Wet		5	SS	0														
	</																		

Continued Next Page

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

## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No MCB-15

1 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 491.4 E 372 030.5 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE Tripod COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.22 - 2015.07.22 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS ▽*	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)								
								20   40   60   80   100	○ UNCONFINED      + FIELD VANE	W <sub>P</sub> W      W <sub>L</sub>										
							● QUICK TRIAXIAL      × LAB VANE	20   40   60   80   100												
357.4	GROUND SURFACE																			
0.0	<b>PEAT</b> , trace sand, trace gravel Very Loose Dark Brown Wet		1	SS	1		357													
								3.0 +												
							356		2.0 +											
				2	SS	0									761 ○					
							355		2.3 +											
								2.5 +												
			3	SS	0		354								607 ○					
								2.7 +												
							353		3.0 +											
353.0																				
4.4	Silty <b>CLAY</b> , trace sand, occasional silt seam Soft to Firm Grey Wet		4	SS	0		352													
								7.0 +												
								4.7 +												
				1	TW		351													
							350		12.0 +											
									7.0 +											
				5	SS	0														
							349		14.0 +											
									6.0 +											
			6	SS	0		348													

Continued Next Page

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

RECORD OF BOREHOLE No MCB-15

2 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 491.4 E 372 030.5 ORIGINATED BY ES  
HWY 72 BOREHOLE TYPE Tripod COMPILED BY AN  
DATUM Geodetic DATE 2015.07.22 - 2015.07.22 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER • CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	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		
345.2			7	SS	0		347							0 0 57 43
12.2	<b>SILT</b> , trace sand, trace clay Loose to Compact Grey Wet		8	SS	4		345							
							344							
			9	SS	17		343							
							342							0 2 91 7
341.6			10	SS	14									
15.8	END OF BOREHOLE AT 15.8m. WATER LEVEL AT SURFACE UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.													

ONTMT4S 1197.GPJ 2015TEMPLATE(MTO).GDT 11/6/15

## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

RECORD OF BOREHOLE No MCB-16

2 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 525.6 E 372 039.8 ORIGINATED BY ES  
HWY 72 BOREHOLE TYPE Tripod COMPILED BY AN  
DATUM Geodetic DATE 2015.07.23 - 2015.07.23 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE      LIQUID CONTENT      LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)						
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE				w <sub>p</sub> w      w <sub>L</sub>						
	Continued From Previous Page							20	40	60	80	100						
342.5 15.8							348											
			8	SS	16													
			9	SS	12													0   0   92   8
			10	SS	17													
							345											
							344											
							343											
			11	SS	20												0   4   89   7	
	END OF BOREHOLE AT 15.8m. WATER LEVEL AT 0.3m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.																	

ONTMT4S 1197.GPJ 2015TEMPLATE(MTO).GDT 11/6/15

# RECORD OF BOREHOLE No MCB-17

1 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 570.3 E 372 044.7 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE Tripod COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.23 - 2015.07.23 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	
359.8	GROUND SURFACE											
0.0	PEAT, amorphous, trace to some rootlets Very Loose Dark Brown Wet		1	SS	2		359	2.0				
358.7												
1.1	Silty CLAY, trace sand Very Stiff Brown Moist		2	SS	17		358					0 0 76 24
			3	SS	18		357					
356.8												
3.0	SILT, trace sand, trace clay Loose to Compact Grey Wet		4	SS	24		356					
			5	SS	16		355					
							354					
			6	SS	21		353					0 3 89 8
			7	SS	5		352					
							351					
			8	SS	13							
							350					

Continued Next Page

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

# RECORD OF BOREHOLE No MCB-17

2 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 570.3 E 372 044.7 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE Tripod COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.23 - 2015.07.23 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL LIQUID MOISTURE CONTENT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	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					w <sub>p</sub> w w <sub>L</sub>					
								20 40 60 80 100				20 40 60						
	Continued From Previous Page																	
	Becoming sand and silt between 12.0mm and 13.5m depth		9	SS	17		349							○				
							348											
			10	SS	15		347							○		0 36 61 3		
							346							○				
							345											
			12	SS	23									○		0 11 83 6		
344.0							344											
15.8	END OF BOREHOLE AT 15.8m. WATER LEVEL AT 0.5m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.																	

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



# RECORD OF BOREHOLE No MCB-18

1 OF 1

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 488.7 E 372 053.5 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE Probe with Vane COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.23 - 2015.07.23 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT								PLASTIC LIMIT  w <sub>p</sub>	NATURAL MOISTURE CONTENT  w	LIQUID LIMIT  w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa												
								20 40 60 80 100												
357.0	GROUND SURFACE																			
0.0	<b>SAND</b> , some peat, trace gravel Dark Brown/Grey Wet (FILL)		1	GS																
355.9			2	GS			356													
1.1	END OF BOREHOLE AT 1.1m.																			
</																				

# RECORD OF BOREHOLE No MCB-19

1 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 532.0 E 372 070.2 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE Tripod COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.21 - 2015.07.21 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	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 <sub>p</sub> w   w <sub>L</sub>				GR	SA	SI	CL
357.7	GROUND SURFACE							20	40	60	80	100						
0.0	<b>PEAT</b> , amorphous, trace to some rootlets Very Loose Dark Brown Wet		1	SS	0		357	2.6										
								2.5										
			2	SS	0		356											
								2.3										
							355	2.0										
			3	SS	0		354											
								2.5										
353.4							353	2.0										
4.3	Silty <b>CLAY</b> , some sand, becoming sandy Soft to Stiff Grey Moist		4	SS	3												0	21
							352	5.0										
								4.7										
			5	SS	11		351											
350.5							350											
7.2	Silty <b>CLAY</b> , trace sand Soft to Firm Grey Wet		6	SS	0												0	0
							349	5.0										
								6.0										
	Occasional silt seam		7	SS	0		348											

Continued Next Page

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

RECORD OF BOREHOLE No MCB-19

2 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 532.0 E 372 070.2 ORIGINATED BY ES  
HWY 72 BOREHOLE TYPE Tripod COMPILED BY AN  
DATUM Geodetic DATE 2015.07.21 - 2015.07.21 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w <sub>P</sub> NATURAL MOISTURE CONTENT w LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	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						
347.0							347	5.3 +						
10.7	<b>SILT</b> , trace sand, trace clay, occasional silty clay seam Compact Grey Wet		8	SS	15			10.0 +						
							346							
			9	SS	5		345							
	Silty clay seam at 14.0m depth		10	SS	10		344							
343.4														0 0 67 33
14.3	END OF BOREHOLE AT 14.3m. WATER LEVEL AT 0.2m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.													



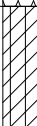

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No MCB-20

1 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 567.2 E 372 071.3 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE Tripod/DCPT COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.22 - 2015.07.22 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	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 <sub>P</sub> w      w <sub>L</sub>				GR	SA	SI	CL	
358.1	GROUND SURFACE							20   40   60   80   100										
0.0	<b>PEAT</b> , amorphous Very Loose Dark Brown Wet		1	SS	1		358											
357.0								2.7 +										
1.1	Silty <b>CLAY</b> , some sand, trace peat Soft to Firm Dark Brown/Grey Moist		2	SS	5		357	6.0 +										
							356											
355.4								3.1 +										
2.7	<b>SILT</b> , trace to some sand, trace to some clay Very Loose to Compact Grey Wet		3	SS	18		355								0	3	81	16
							354											
			4	SS	15		353											
							352								0	7	86	7
							351											
			6	SS	1		350											
			7	SS	6		349								0	18	77	5

Continued Next Page

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

RECORD OF BOREHOLE No MCB-20

2 OF 2

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 567.2 E 372 071.3 ORIGINATED BY ES  
HWY 72 BOREHOLE TYPE Tripod/DCPT COMPILED BY AN  
DATUM Geodetic DATE 2015.07.22 - 2015.07.22 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	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																
346.8			8	SS	12		348										
11.3	End of sampling and start DCPT						347										
							346										
							345										
							344										
							343										
342.6																	
15.5	END OF DCPT AT 15.5m. WATER LEVEL AT 0.2m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.																

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

# RECORD OF BOREHOLE No MCB-21

1 OF 1

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 558.7 E 372 057.8 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.17 - 2015.07.17 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$  kN/m <sup>3</sup>	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									
360.8	GROUND SURFACE							20	40	60	80	100					
0.0	ASPHALT:(100mm)																
0.1	SAND and GRAVEL, trace to some silt, occasional cobble Compact to Very Dense Brown Moist (FILL)		1	SS	53												42 50 8 (SI+CL)
			2	SS	36												
			3	SS	28												
358.5																	
2.3	Silty SAND, trace gravel, trace clay Loose Dark Brown		4	SS	6												7 69 24 (SI+CL)
358.0	Wet (FILL)																
2.8	100mm peat layer at 2.7m depth																
	Silty CLAY, trace to some sand Stiff Dark Grey to Grey Moist		5	SS	6												
356.5																	
4.3	END OF BOREHOLE AT 4.3m. WATER LEVEL AT 0.9m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 1.2m, CONCRETE TO 0.2m, ASPHALT TO SURFACE.																

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No MCB-22

1 OF 1

METRIC

WP# 473-00-01 LOCATION Moose Creek Bridge N 5 542 451.8 E 372 040.5 ORIGINATED BY ES  
 HWY 72 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2015.07.23 - 2015.07.23 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT  W <sub>P</sub>	NATURAL MOISTURE CONTENT  W	LIQUID LIMIT  W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	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 (%)	
359.2	GROUND SURFACE							20	40	60	80	100						
0.0	Unsampled borehole advanced to collect shelly tube sample						359											
							358											
							357											
							356											
							355											
							354											
			1	SS	TW		353									Oedometer Test		
352.5	END OF BOREHOLE AT 6.7m.																	
6.7																		

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**Summary of Subsurface Conditions in Probeholes**

<b>Probehole Number</b>	<b>Subsurface Conditions</b>
P1	0 - 3.8 m Peat 3.8 - 4.0 m Silty Clay
P2	0 – 5.0 m Peat 5.0 – 5.2 m Silty Clay
P3	0 – 4.9 m Peat 4.9 – 5.5 m Peat with trace of shell fragments
P4	0 – 150 mm Topsoil 150 – 450 Sand Fill
P5	0 – 3.5 m Peat 3.5 – 4.3 m Peat with trace of shell fragments 4.3 – 4.6 m Silty Clay
P6	0 – 2.6 m Peat 2.6 – 2.9 m Peat with trace of shell fragments 2.9 – 3.0 m Silty Clay

Note: Probehole locations are shown on the Borehole Location and Soil Strata drawing in Appendix G.



**Appendix B**

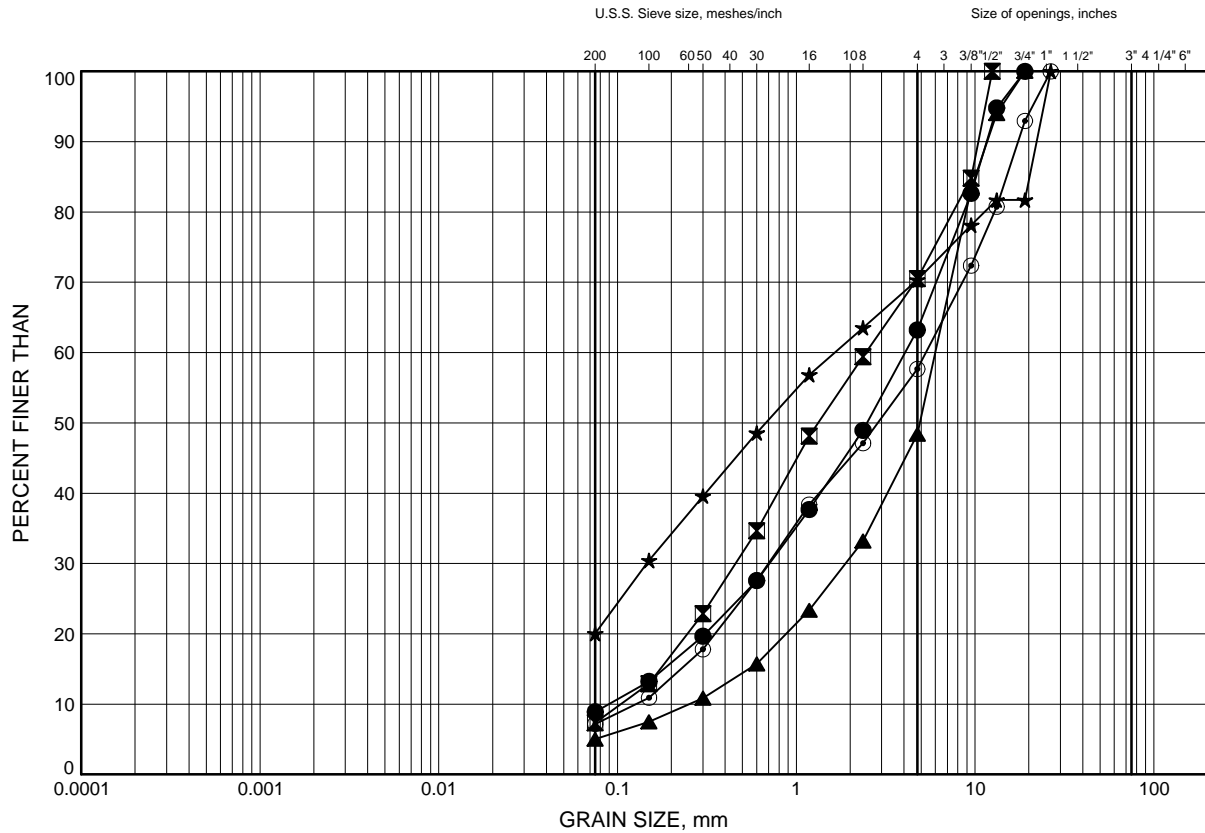
**Laboratory Test Results**

# Moose Creek Bridge

## GRAIN SIZE DISTRIBUTION

FIGURE B1

### GRAVELLY SAND to SANDY GRAVEL (FILL)



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MCB-05	0.35	358.85
⊠	MCB-06	0.38	359.32
▲	MCB-07	0.33	359.37
★	MCB-08	0.98	359.82
⊙	MCB-21	0.41	360.39

Date August 2015  
 WP# 473-00-01



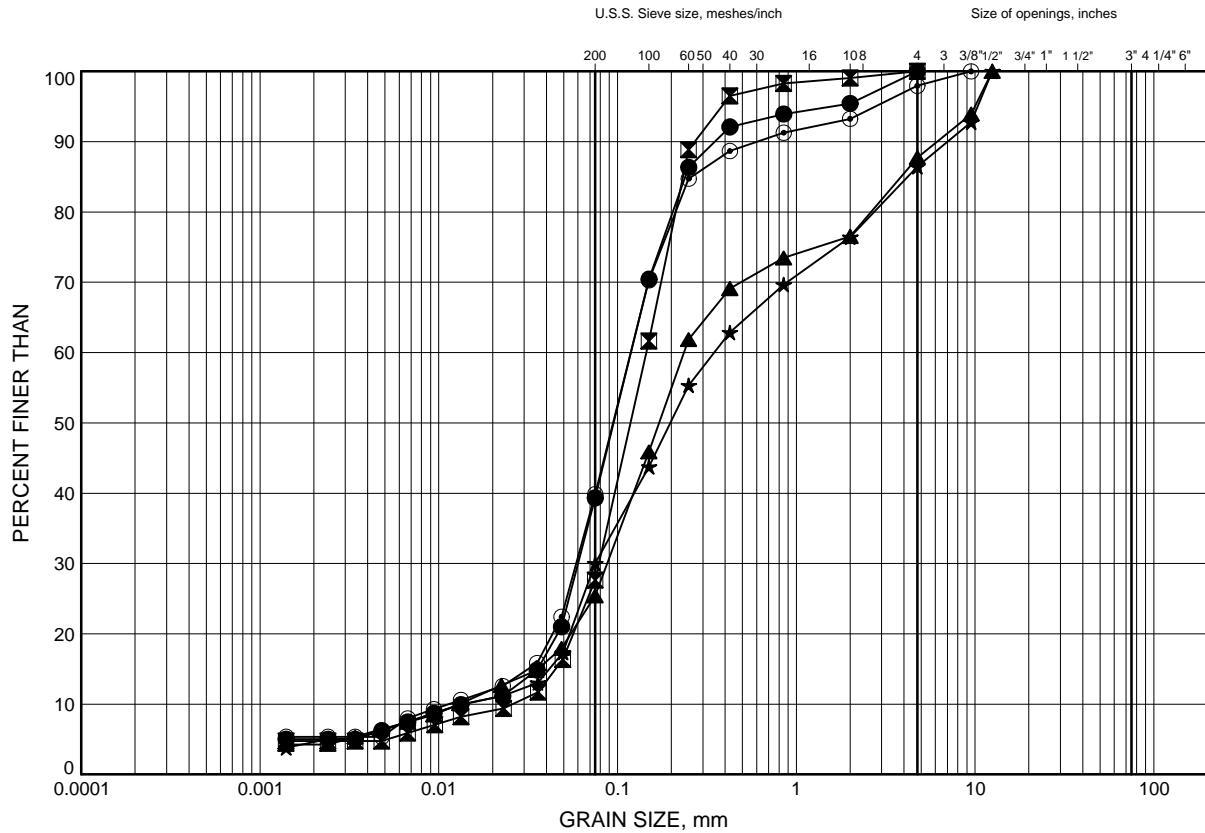
Prep'd AN  
 Chkd. AMP

# Moose Creek Bridge

## GRAIN SIZE DISTRIBUTION

FIGURE B2

### SILTY SAND (FILL)



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MCB-01	1.83	357.57
⊠	MCB-01	6.40	353.00
▲	MCB-02	1.07	358.73
★	MCB-03	1.83	357.67
⊙	MCB-04	1.07	358.53

Date August 2015  
WP# 473-00-01



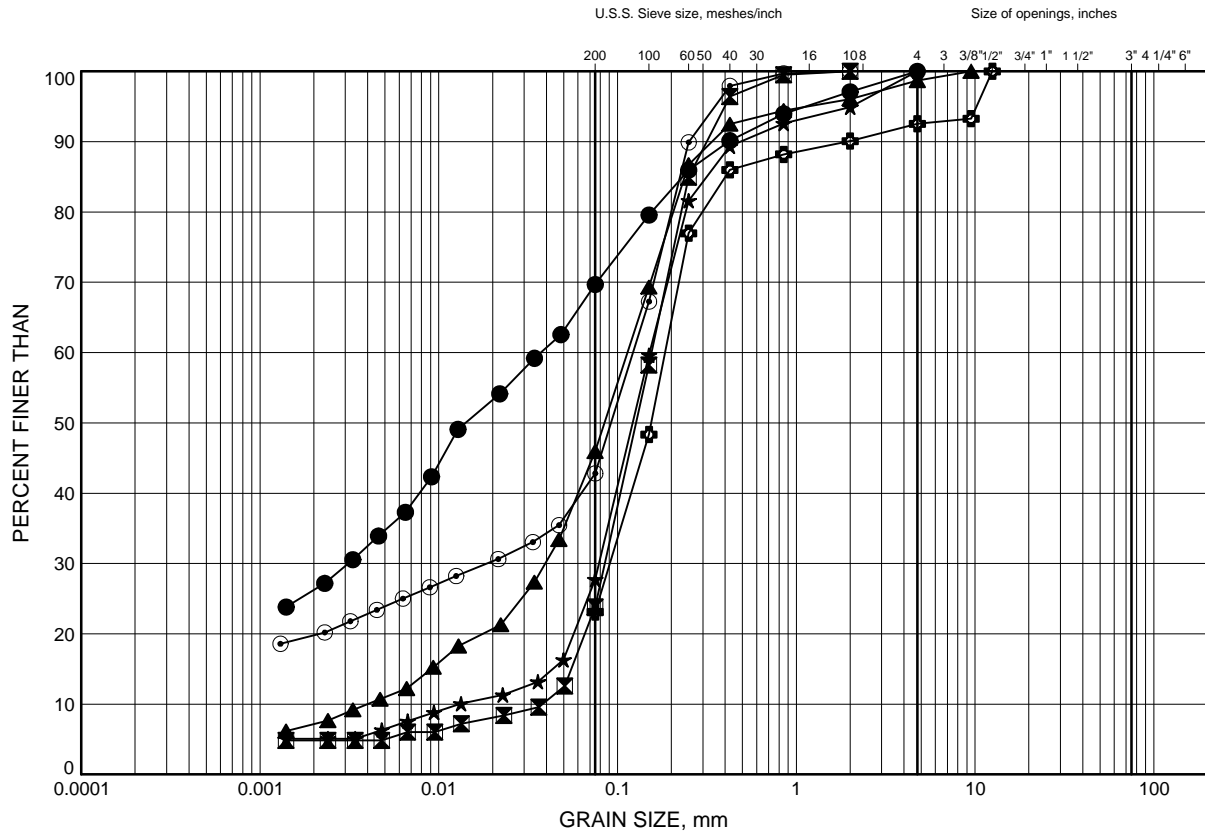
Prep'd AN  
Chkd. AMP

# Moose Creek Bridge

## GRAIN SIZE DISTRIBUTION

FIGURE B3

### SILTY SAND TO CLAYEY SILT (FILL)



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MCB-03	3.35	356.15
⊠	MCB-04	3.35	356.25
▲	MCB-05	1.83	357.37
★	MCB-06	1.83	357.87
⊙	MCB-07	2.59	357.11
⊕	MCB-21	2.59	358.21

Date November 2015

WP# 473-00-01



Prep'd AN

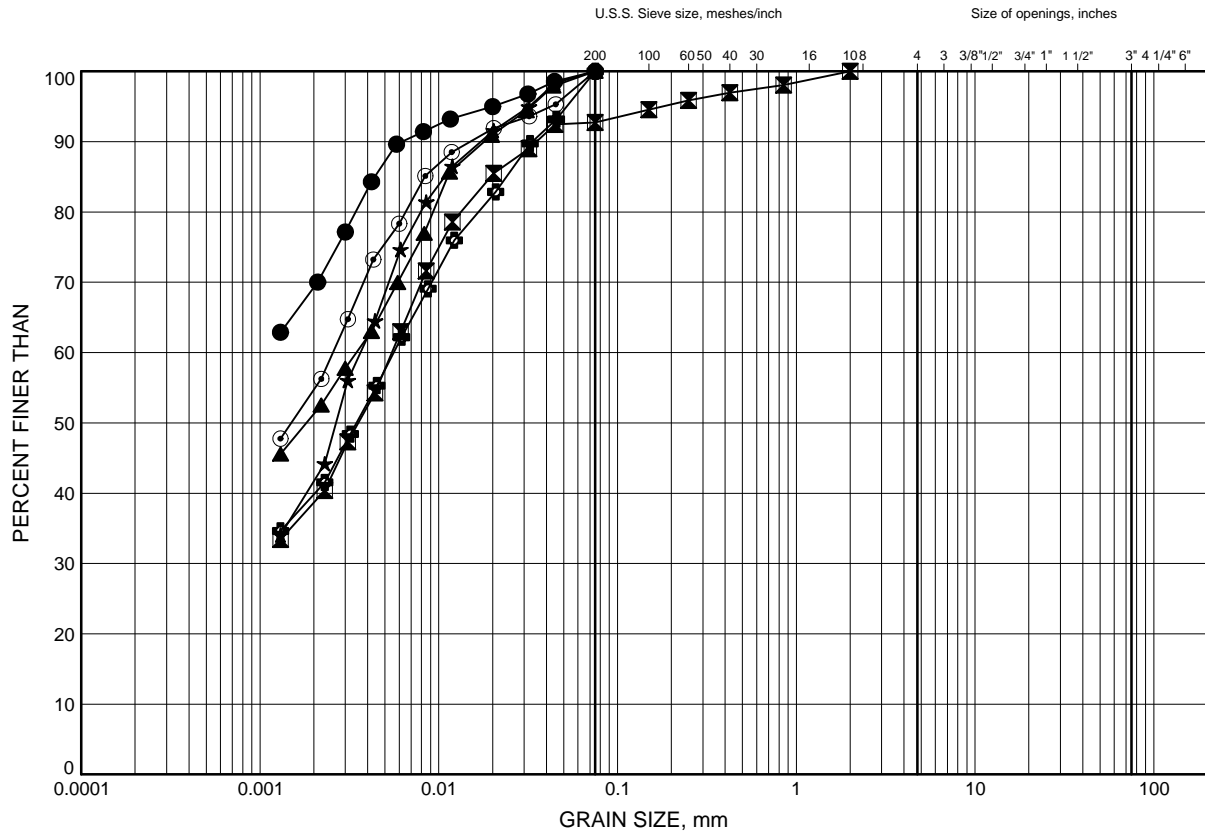
Chkd. AMP

# Moose Creek Bridge

## GRAIN SIZE DISTRIBUTION

FIGURE B4

### SILTY CLAY



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MCB-01	9.45	349.95
⊠	MCB-03	9.45	350.05
▲	MCB-03	10.97	348.53
★	MCB-04	9.45	350.15
⊙	MCB-05	7.92	351.28
⊕	MCB-05	14.02	345.18

Date November 2015

WP# 473-00-01



Prep'd AN

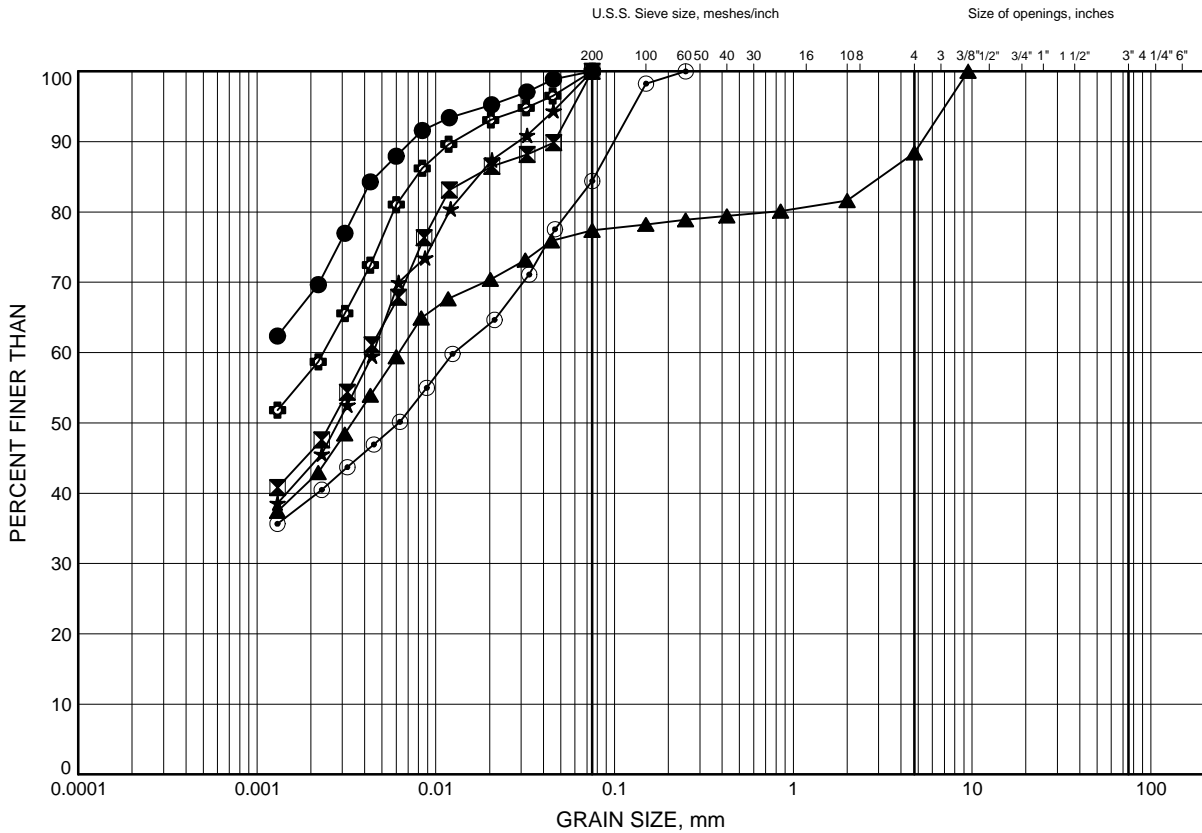
Chkd. AMP

# Moose Creek Bridge

## GRAIN SIZE DISTRIBUTION

FIGURE B5

### SILTY CLAY



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MCB-06	9.45	350.25
⊠	MCB-07	7.92	351.78
▲	MCB-08	3.35	357.45
★	MCB-09	3.35	354.85
⊙	MCB-09	14.02	344.18
⊕	MCB-10	6.40	351.20

Date November 2015

WP# 473-00-01



Prep'd AN

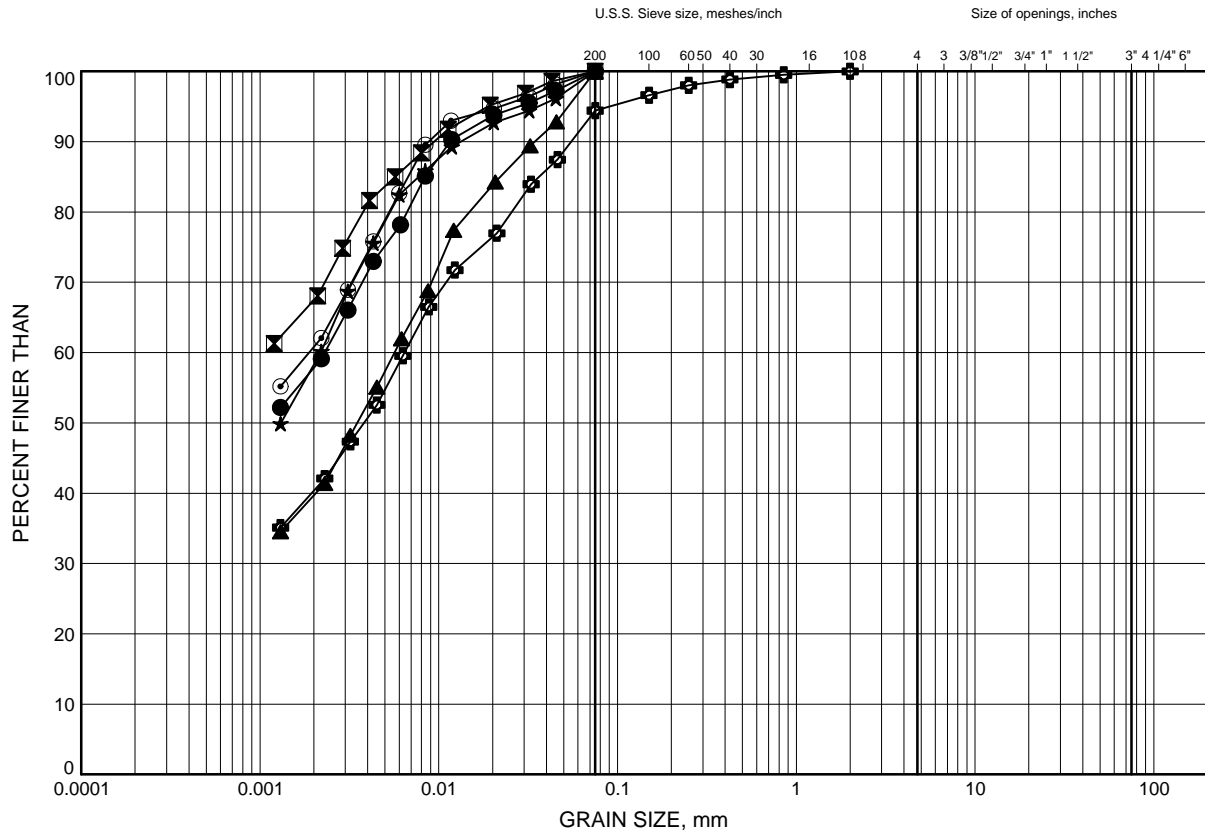
Chkd. AMP

# Moose Creek Bridge

## GRAIN SIZE DISTRIBUTION

FIGURE B6

### SILTY CLAY



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MCB-10	10.97	346.63
⊠	MCB-10	14.02	343.58
▲	MCB-11	6.40	351.10
★	MCB-11	7.92	349.58
⊙	MCB-11	15.54	341.96
⊕	MCB-12	3.35	355.25

Date November 2015

WP# 473-00-01



Prep'd AN

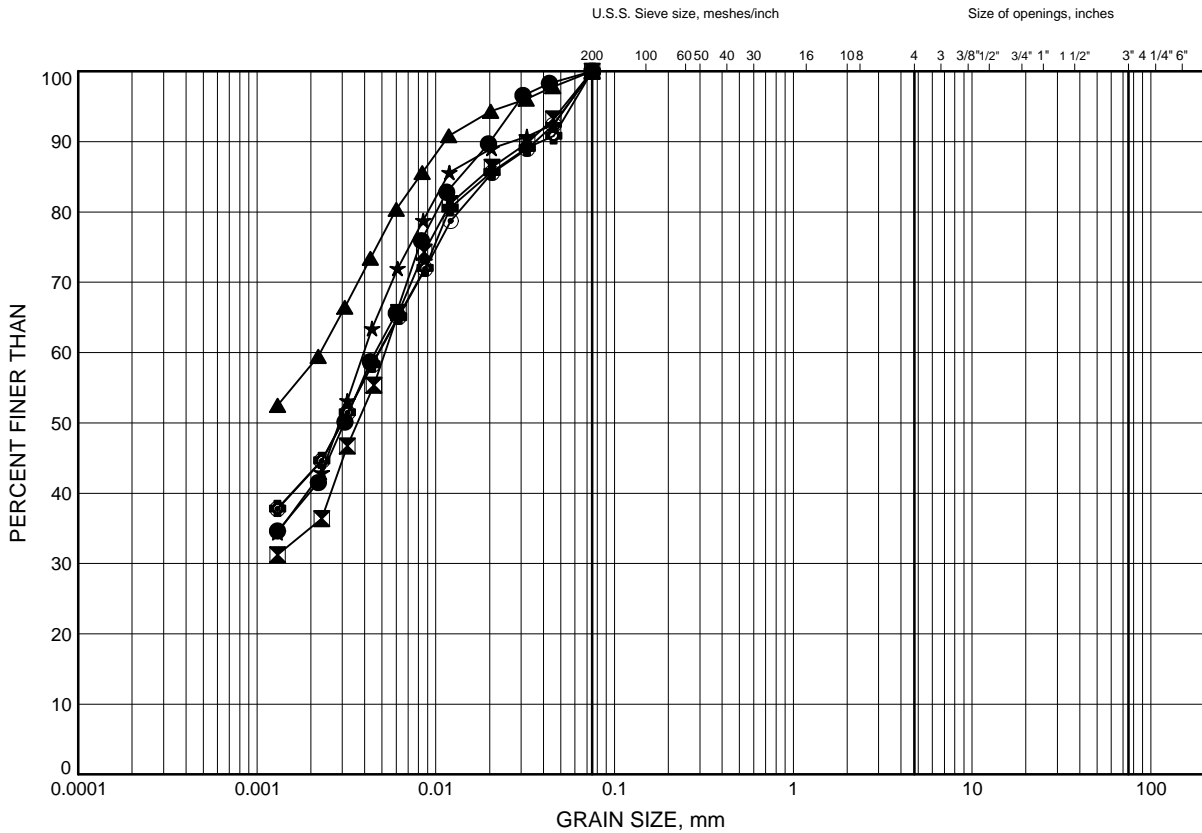
Chkd. AMP

# Moose Creek Bridge

## GRAIN SIZE DISTRIBUTION

FIGURE B7

### SILTY CLAY



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MCB-13	4.88	353.32
⊠	MCB-13	7.92	350.28
▲	MCB-14	7.92	349.78
★	MCB-14	10.97	346.73
⊙	MCB-15	4.88	352.52
⊕	MCB-15	10.97	346.43

Date November 2015  
 WP# 473-00-01



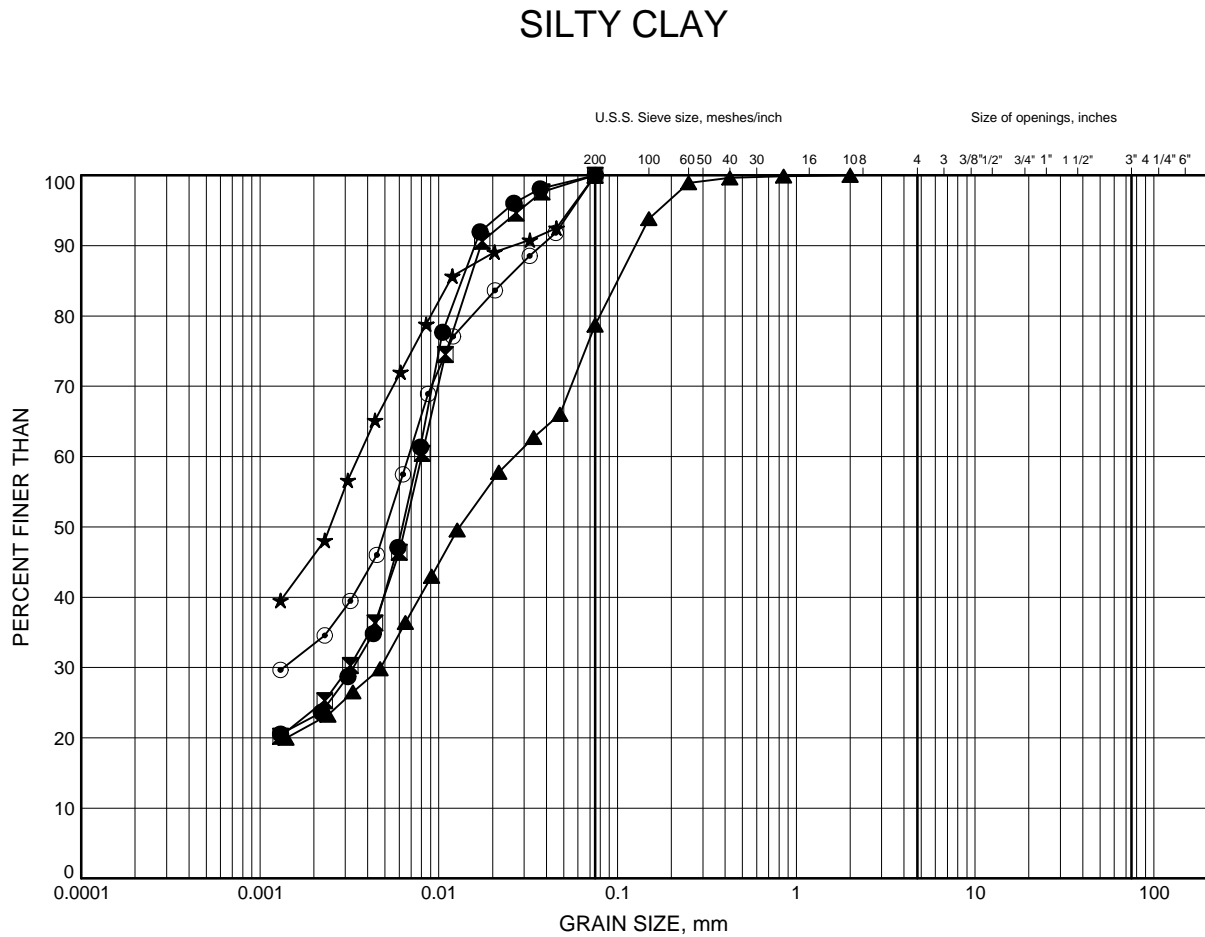
Prep'd AN  
 Chkd. AMP



# Moose Creek Bridge

## GRAIN SIZE DISTRIBUTION

FIGURE B8



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MCB-16	6.40	351.90
⊠	MCB-17	1.83	357.97
▲	MCB-19	4.88	352.82
★	MCB-19	7.92	349.78
⊙	MCB-19	14.02	343.68

Date November 2015

WP# 473-00-01



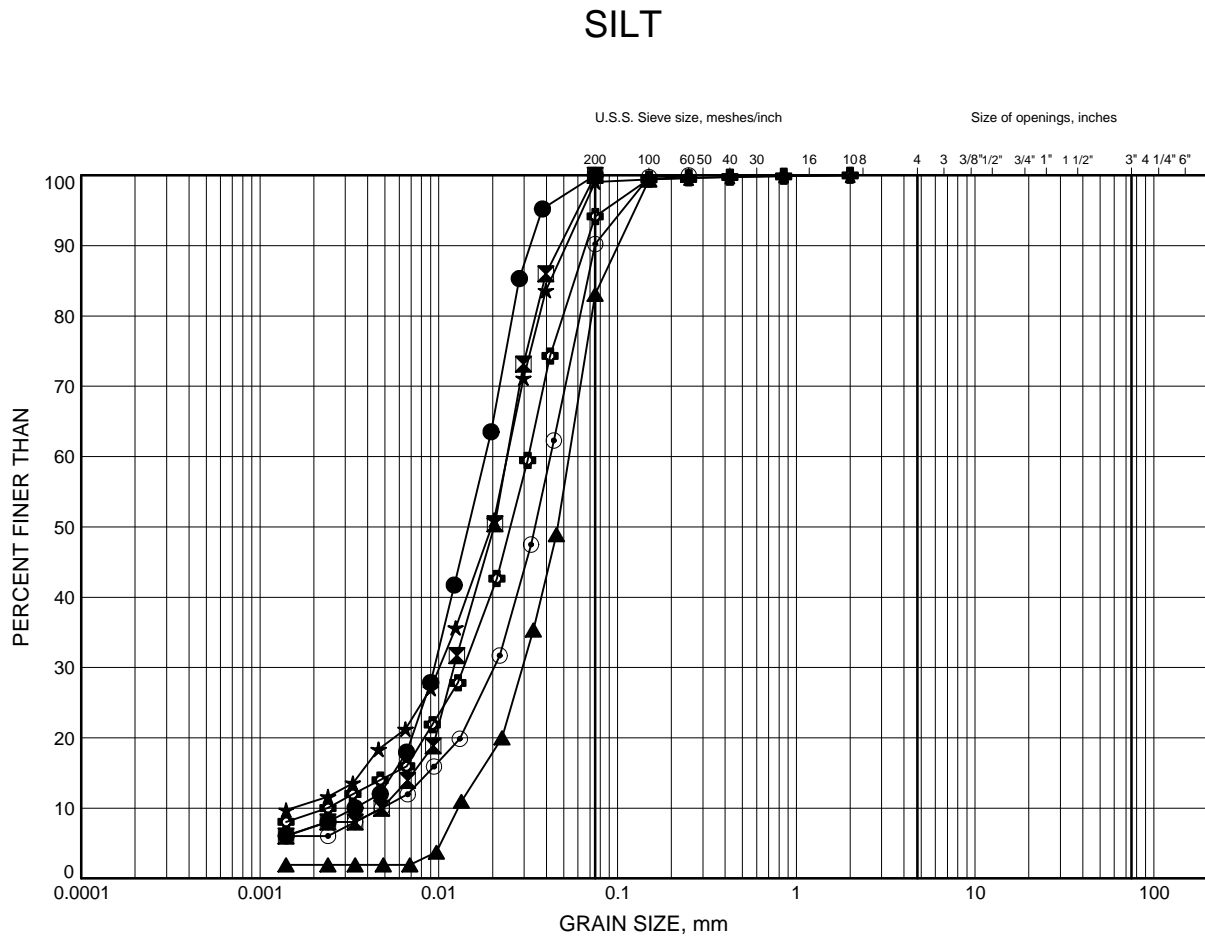
Prep'd AN

Chkd. AMP

# Moose Creek Bridge

## GRAIN SIZE DISTRIBUTION

FIGURE B9



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MCB-02	6.40	353.40
⊠	MCB-02	10.97	348.83
▲	MCB-02	15.54	344.26
★	MCB-03	14.02	345.48
⊙	MCB-03	20.12	339.38
⊕	MCB-04	14.02	345.58

Date August 2015  
WP# 473-00-01

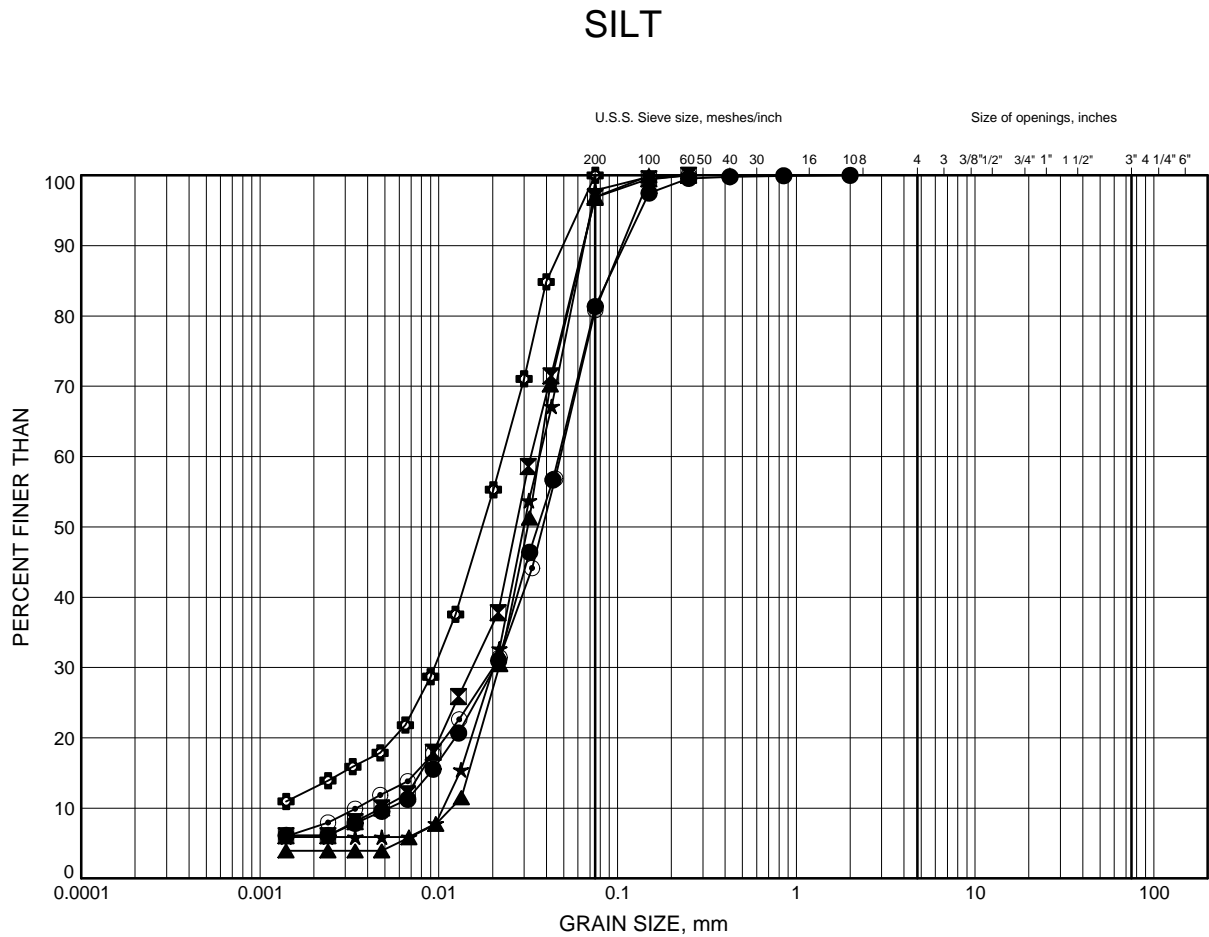


Prep'd AN  
Chkd. AMP

# Moose Creek Bridge

## GRAIN SIZE DISTRIBUTION

FIGURE B10



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MCB-04	18.59	341.01
⊠	MCB-07	12.50	347.20
▲	MCB-07	15.54	344.16
★	MCB-08	7.92	352.88
⊙	MCB-08	12.50	348.30
⊕	MCB-09	7.92	350.28

Date August 2015  
 WP# 473-00-01

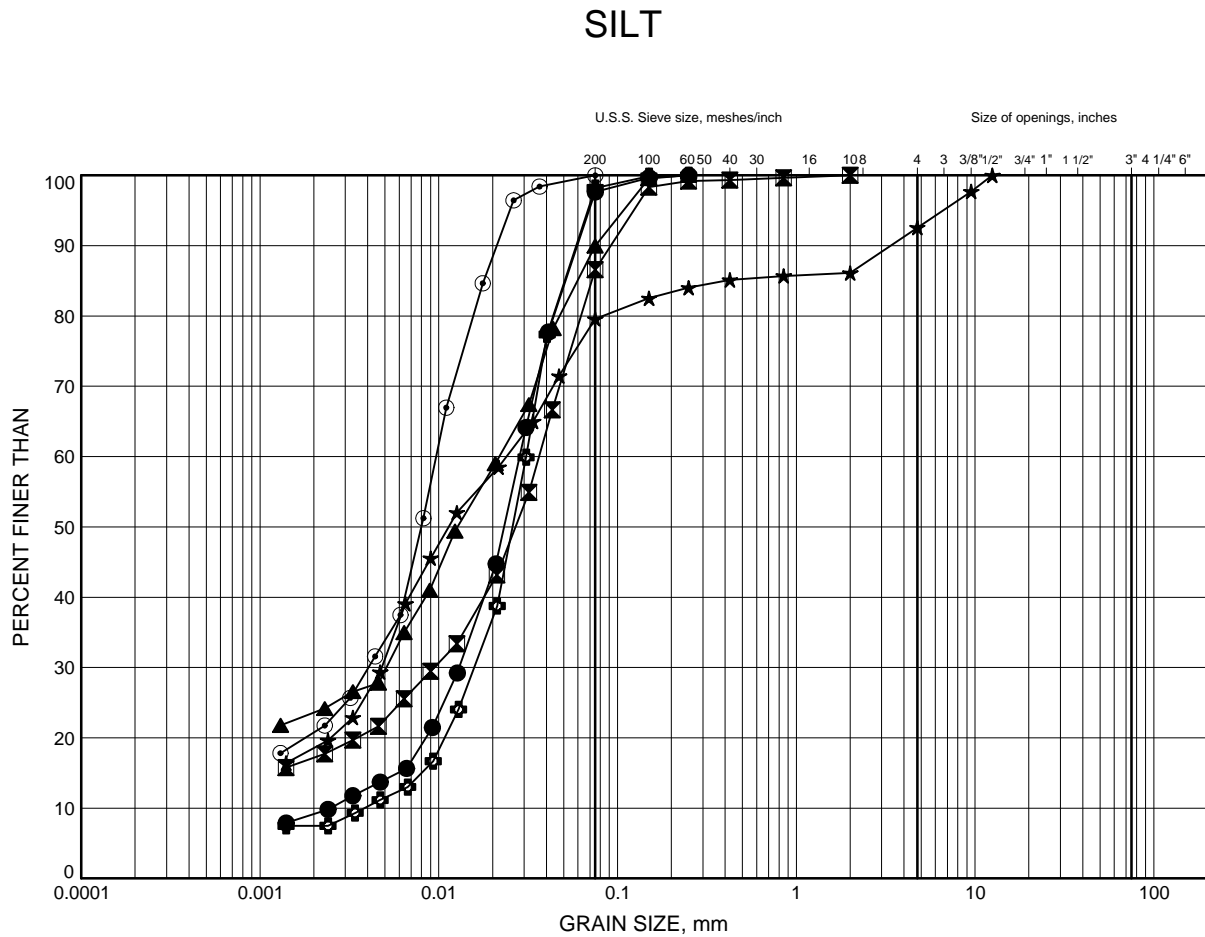


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# Moose Creek Bridge

## GRAIN SIZE DISTRIBUTION

FIGURE B11



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MCB-12	9.45	349.15
⊠	MCB-12	15.54	343.06
▲	MCB-13	12.50	345.70
★	MCB-13	14.02	344.18
⊙	MCB-14	15.54	342.16
⊕	MCB-15	15.54	341.86

Date November 2015

WP# 473-00-01



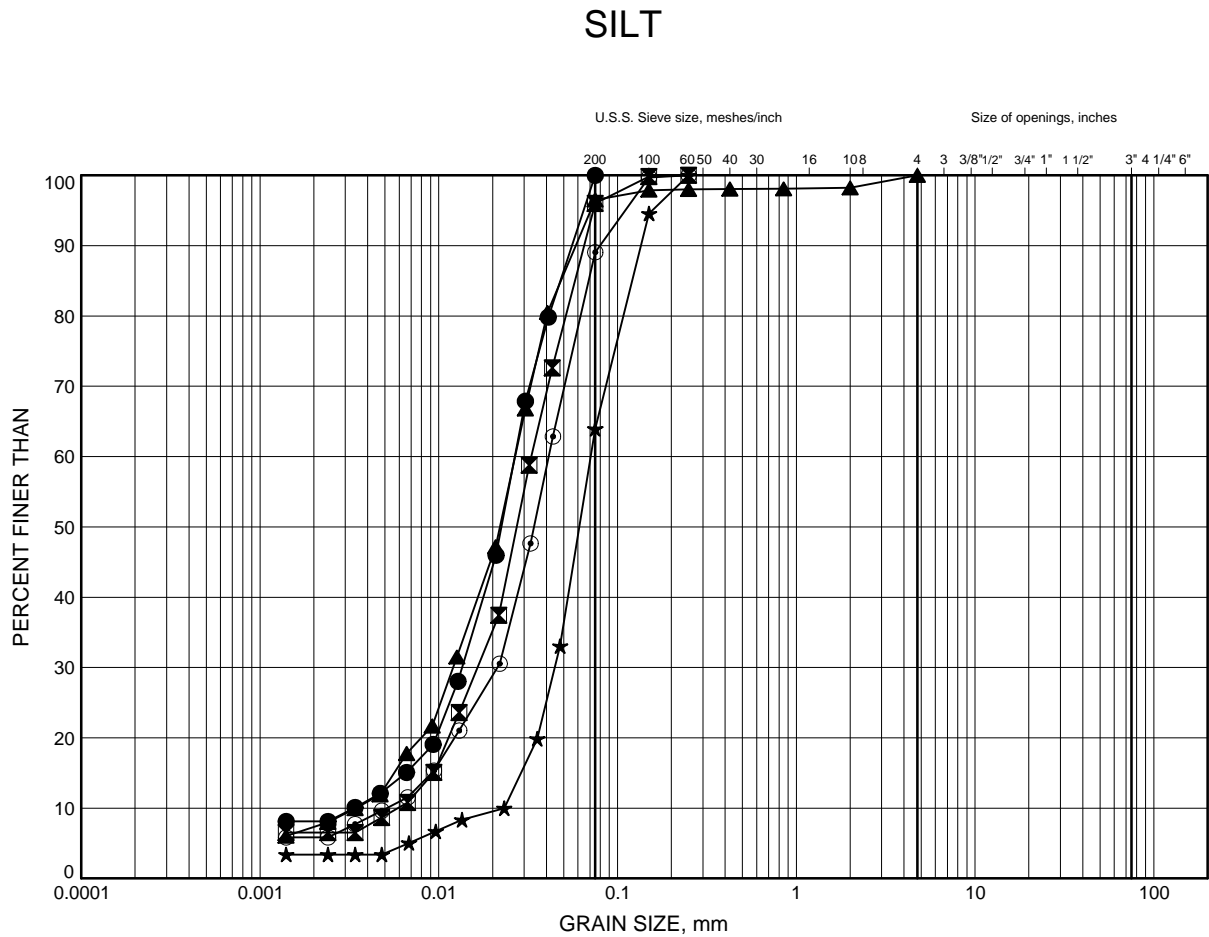
Prep'd AN

Chkd. AMP

# Moose Creek Bridge

## GRAIN SIZE DISTRIBUTION

FIGURE B12



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MCB-16	12.50	345.80
⊠	MCB-16	15.54	342.76
▲	MCB-17	6.40	353.40
★	MCB-17	12.50	347.30
⊙	MCB-17	15.54	344.26

Date August 2015  
WP# 473-00-01

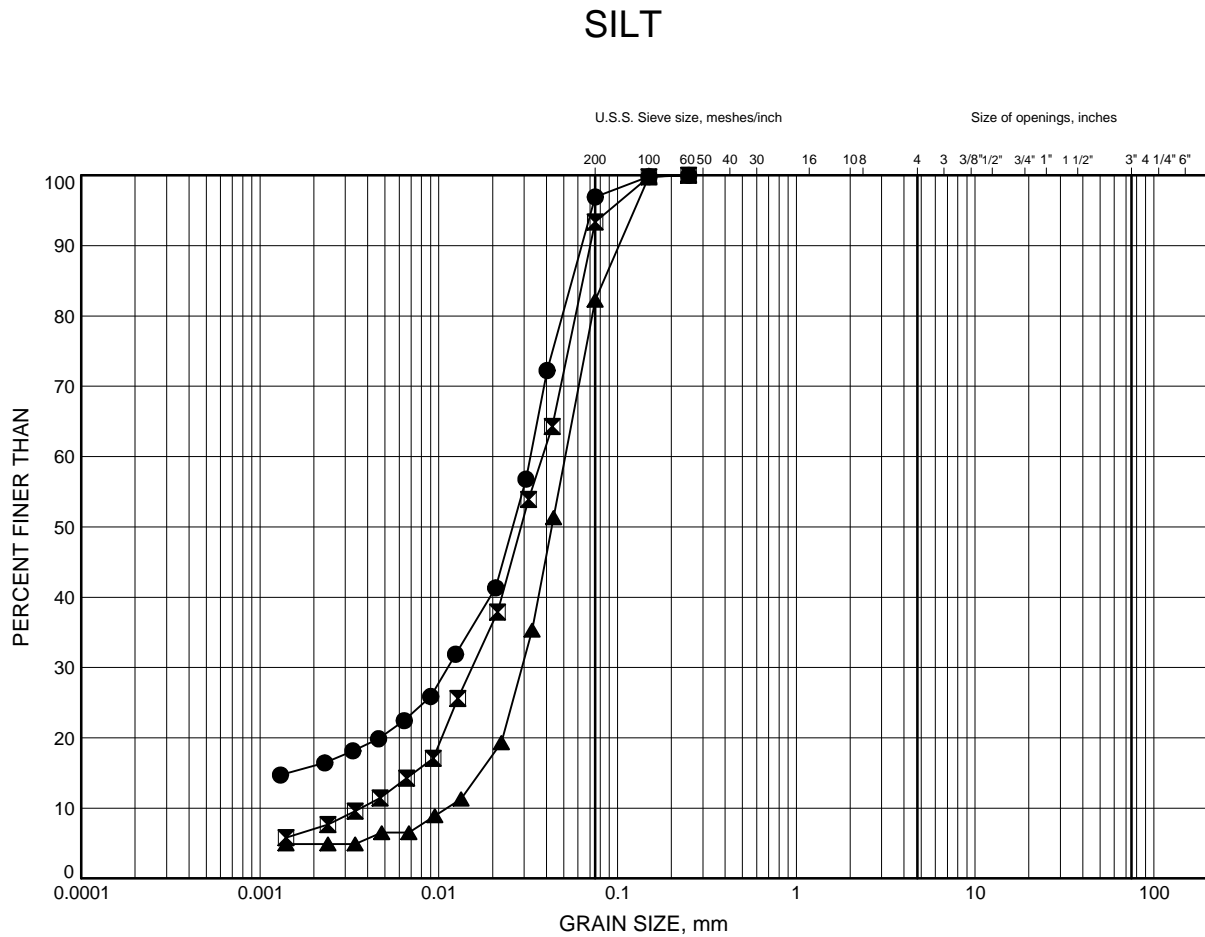


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Chkd. AMP

# Moose Creek Bridge

## GRAIN SIZE DISTRIBUTION

FIGURE B13



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MCB-20	3.35	354.75
⊠	MCB-20	6.40	351.70
▲	MCB-20	9.45	348.65

Date August 2015  
 WP# 473-00-01

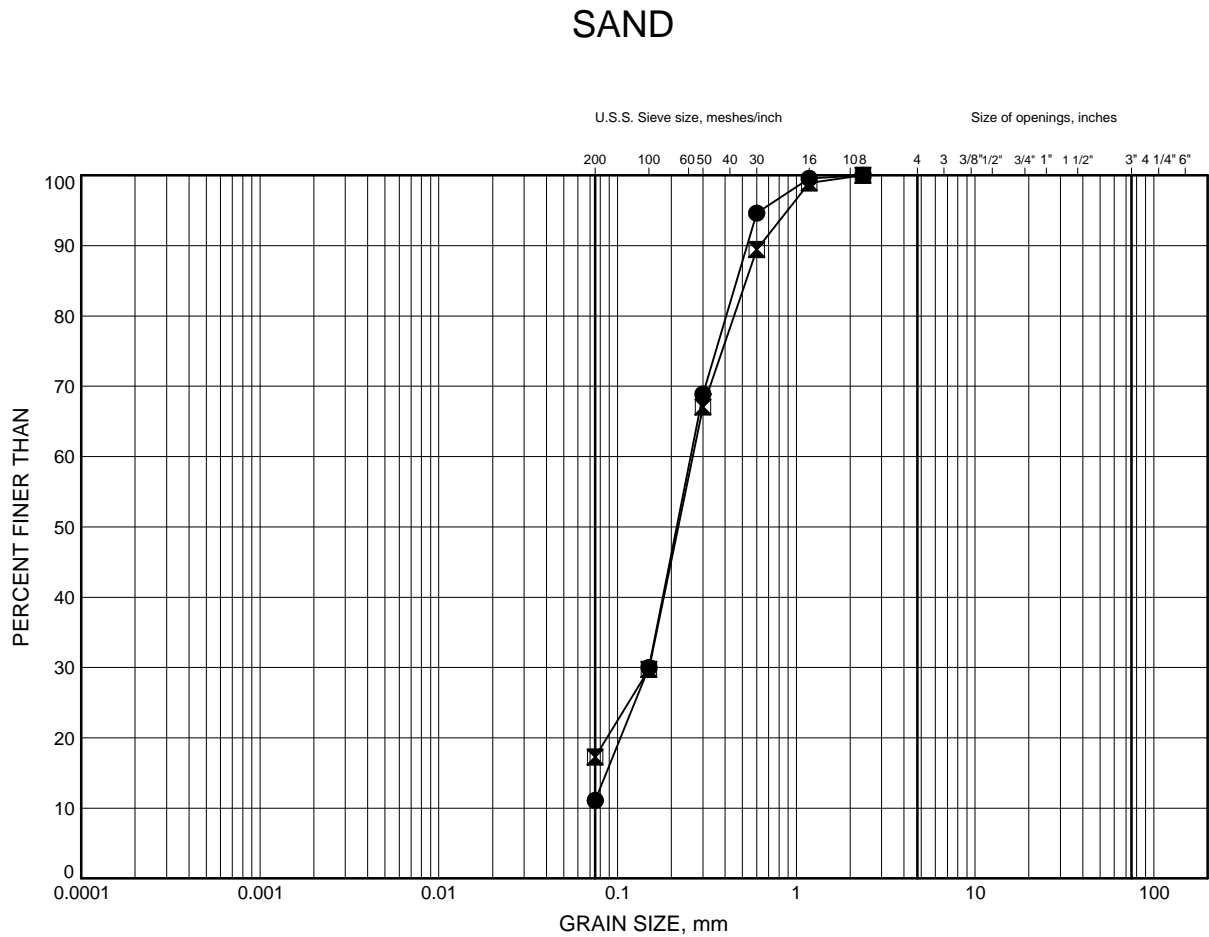


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 Chkd. AMP

# Moose Creek Bridge

## GRAIN SIZE DISTRIBUTION

FIGURE B14



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MCB-03	38.40	321.10
■	MCB-04	32.00	327.60

Date August 2015  
 WP# 473-00-01

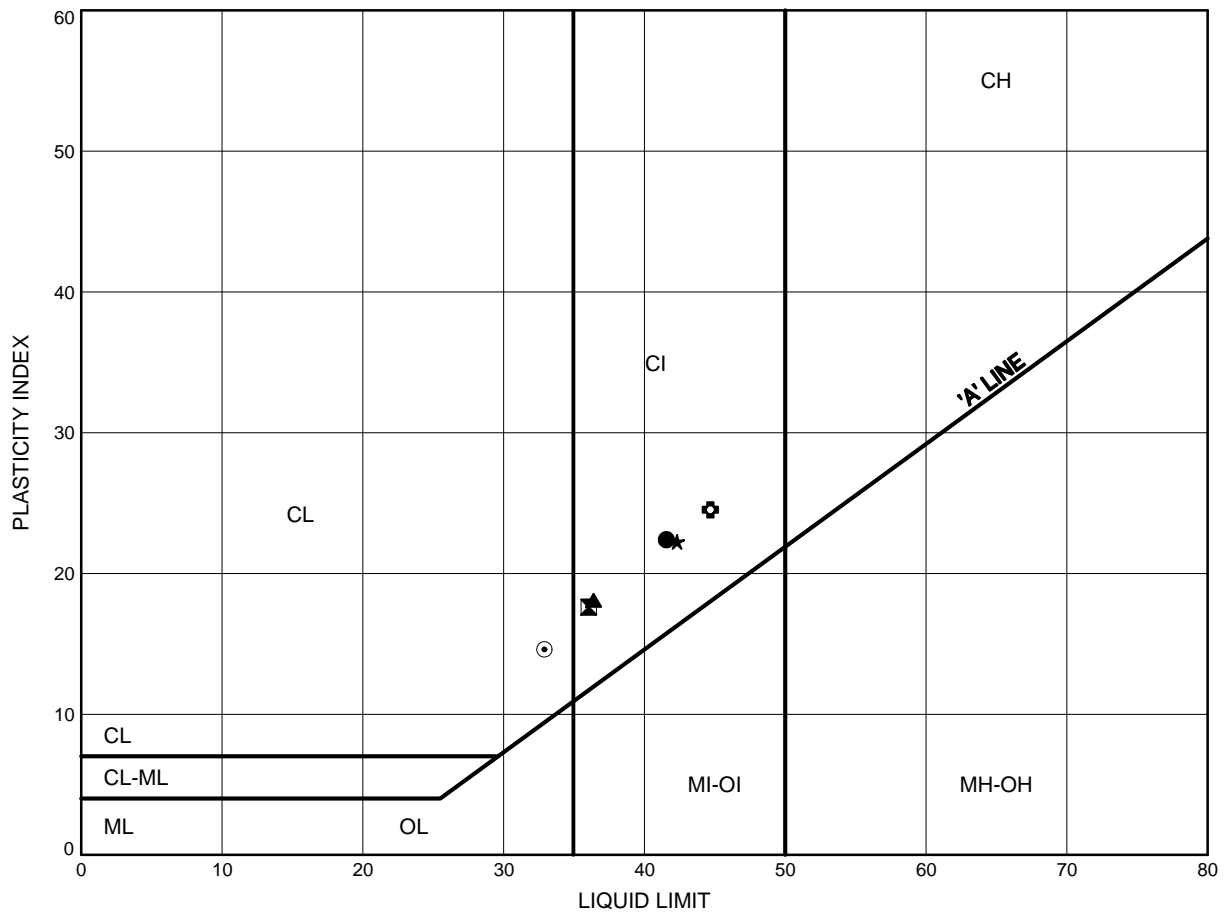


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Moose Creek Bridge  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B15

**SILTY CLAY**



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MCB-01	9.45	349.95
⊠	MCB-03	10.97	348.53
▲	MCB-05	7.92	351.28
★	MCB-06	9.45	350.25
⊙	MCB-07	7.92	351.78
⊕	MCB-08	3.35	357.45

Date August 2015  
 WP# 473-00-01



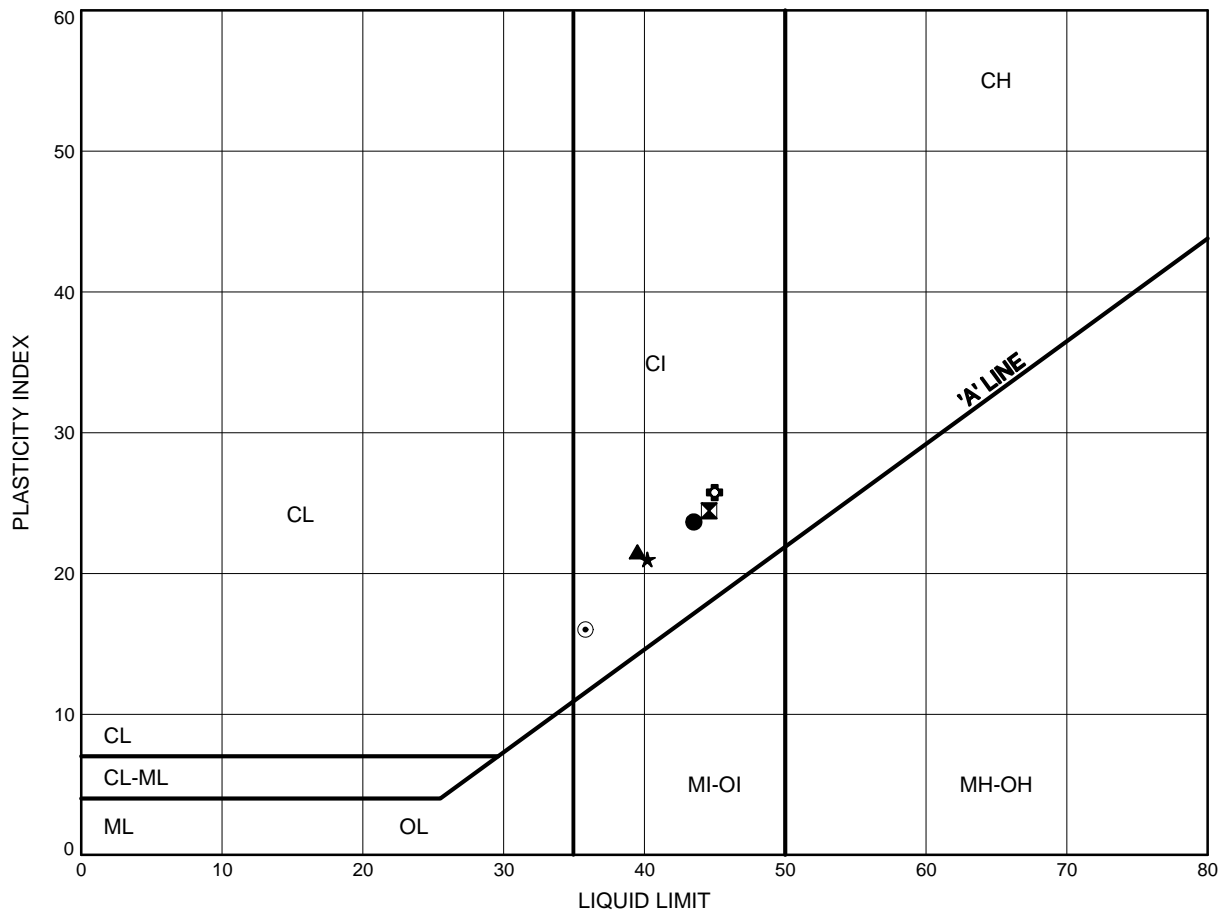
Prep'd AN  
 Chkd. AMP



Moose Creek Bridge  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B16

**SILTY CLAY**



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MCB-10	10.97	346.63
⊠	MCB-10	14.02	343.58
▲	MCB-11	7.92	349.58
★	MCB-11	15.54	341.96
⊙	MCB-13	4.88	353.32
⊕	MCB-14	7.92	349.78

Date August 2015  
 WP# 473-00-01

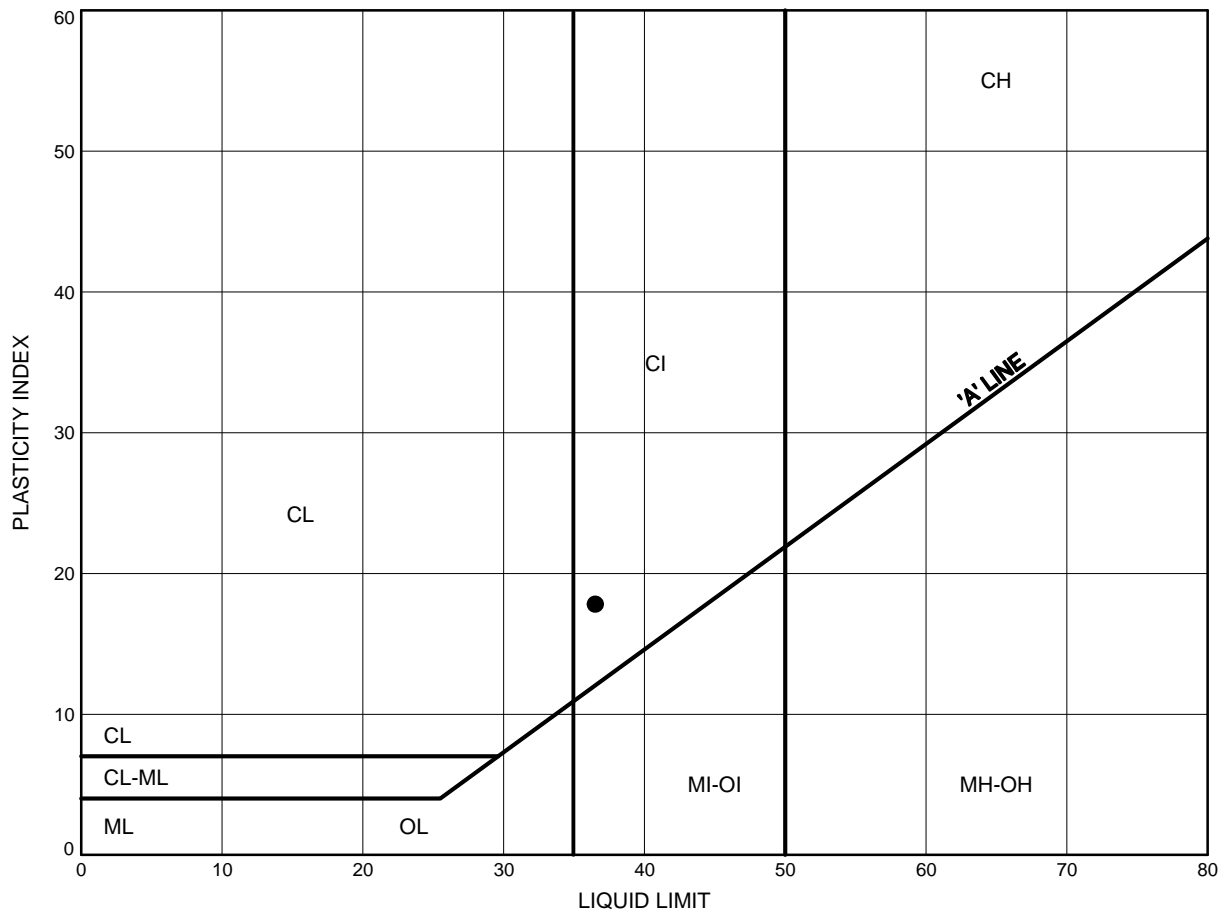


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 Chkd. AMP

Moose Creek Bridge  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B17

**SILTY CLAY**



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MCB-19	7.92	349.78

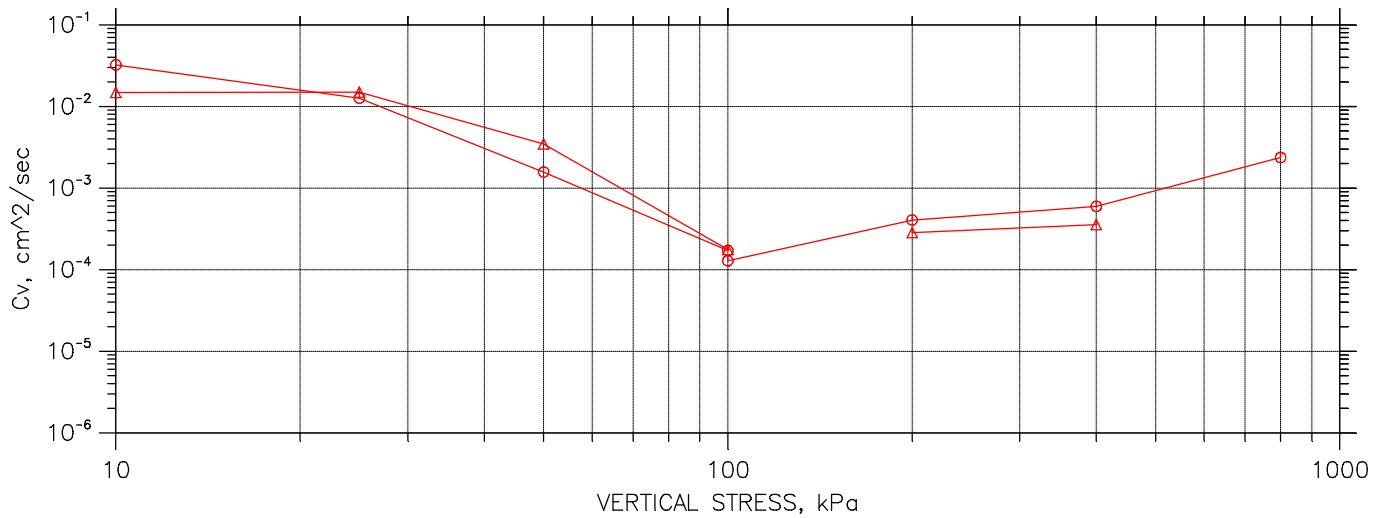
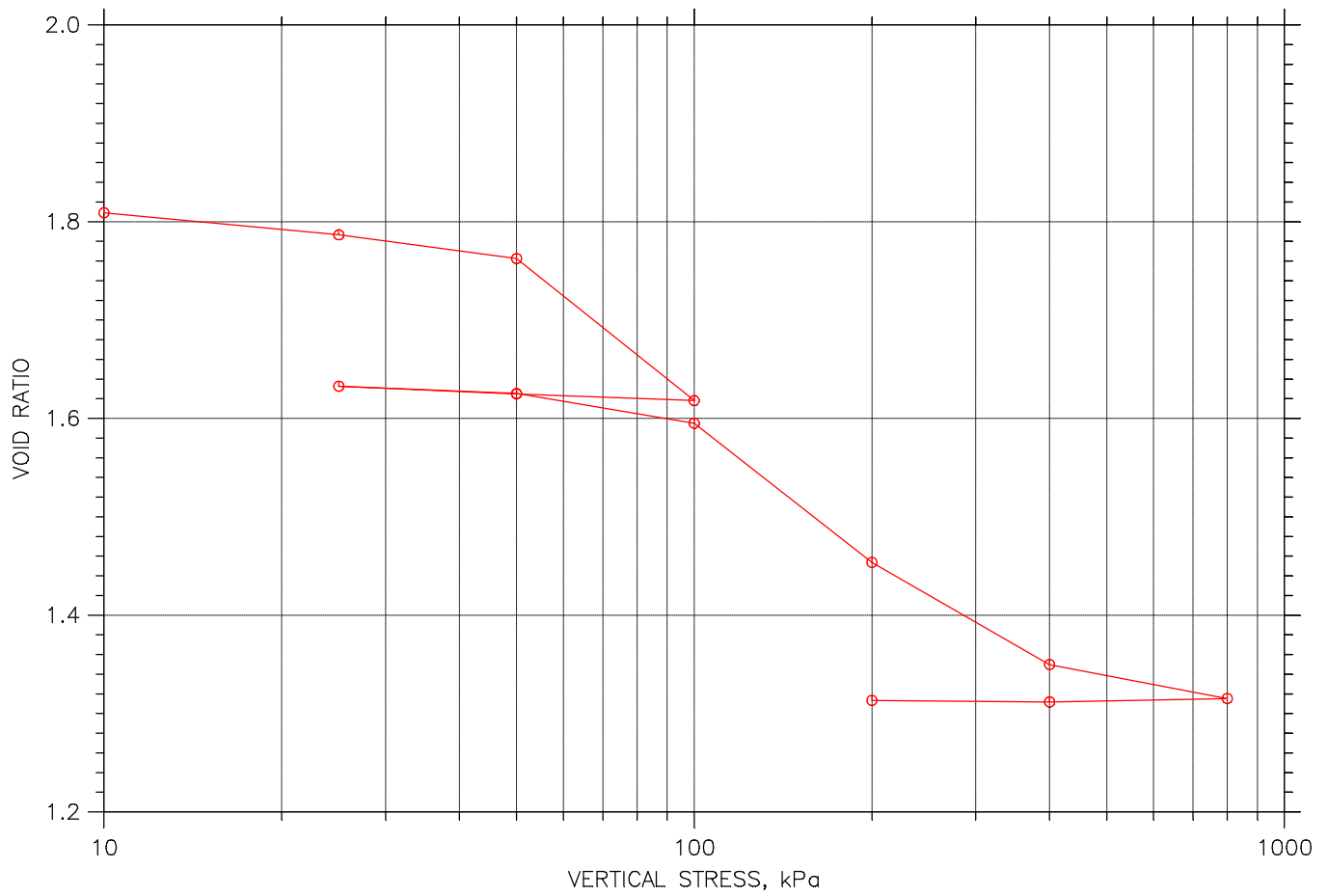
Date August 2015  
 WP# 473-00-01




Prep'd AN  
 Chkd. AMP

# CONSOLIDATION TEST DATA

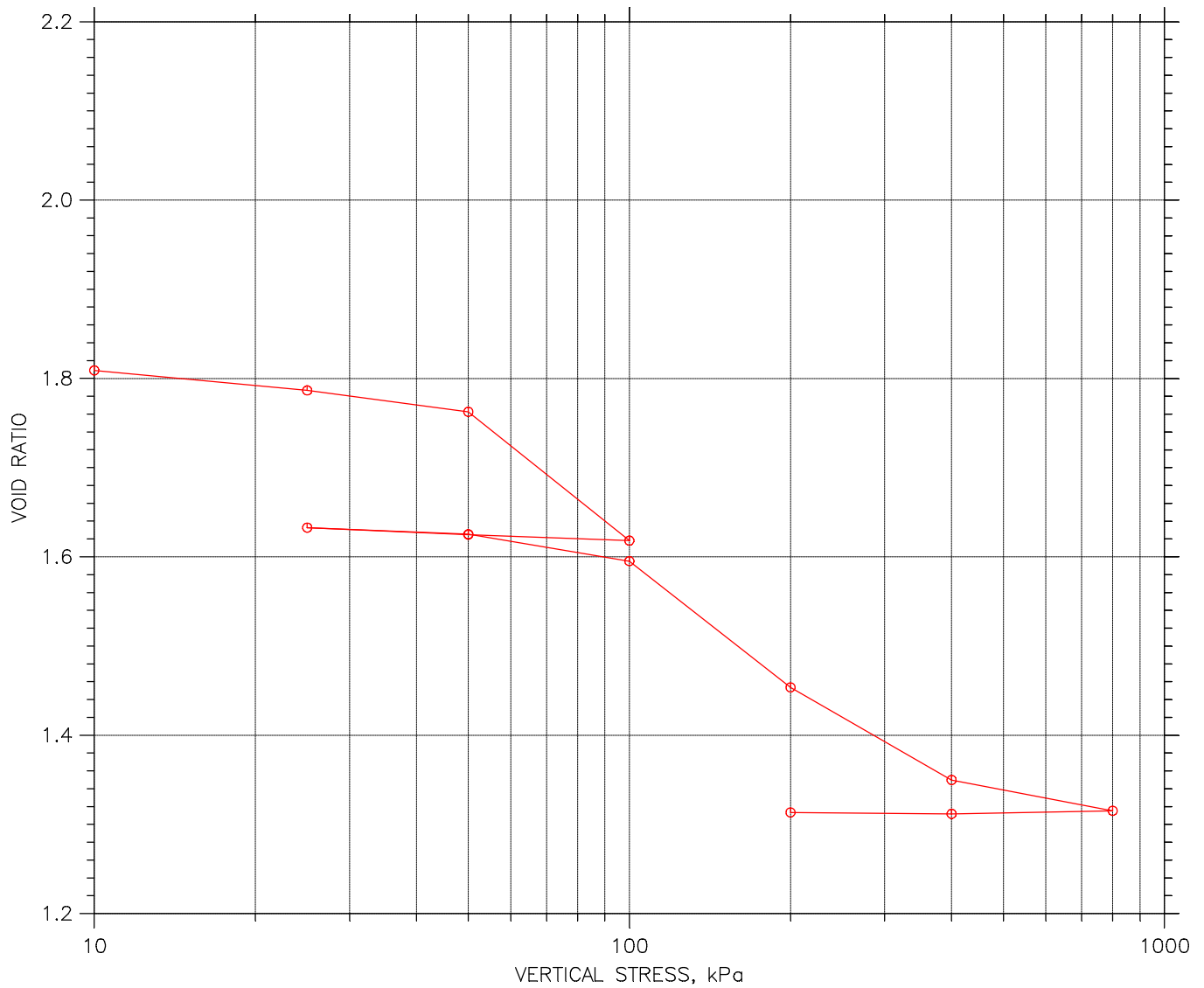
## SUMMARY REPORT




	Project: Moose Creek Bridge	Location: Hwy 72 Sioux Lookout	Project No.: 19-1351-197
	Boring No.: MCB-15	Tested By: TF	Checked By: GM
	Sample No.: TW 1	Test Date: Aug 20/15	Depth: 20'-22'
	Test No.: 1	Sample Type: TW	Elevation: 1
	Description: Grey Clay		
	Remarks:		

# CONSOLIDATION TEST DATA

## SUMMARY REPORT

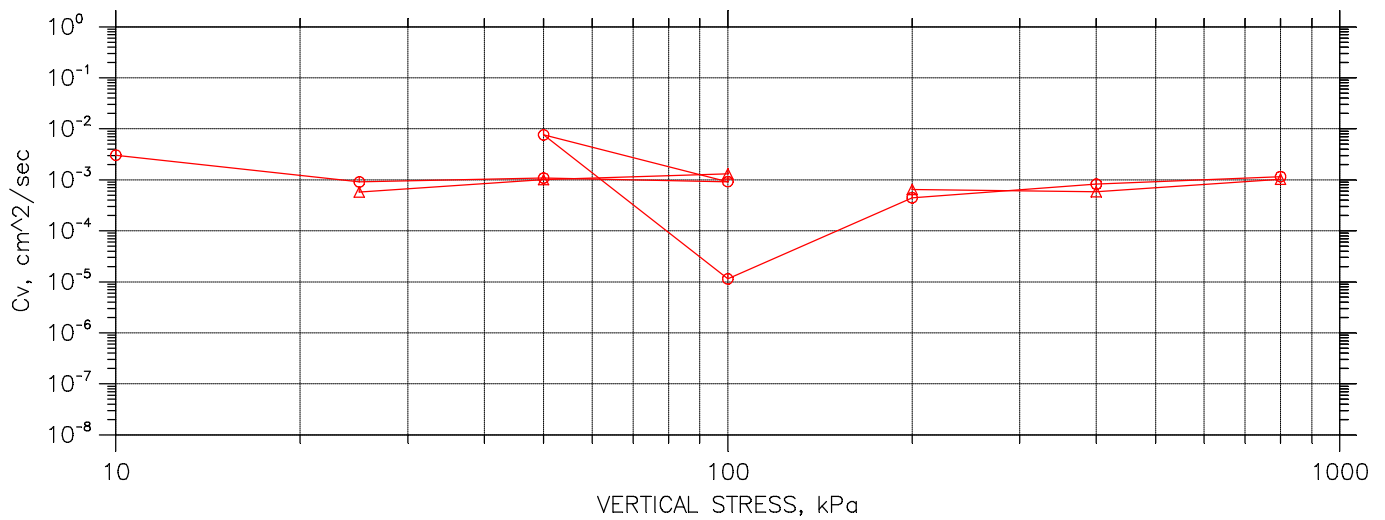
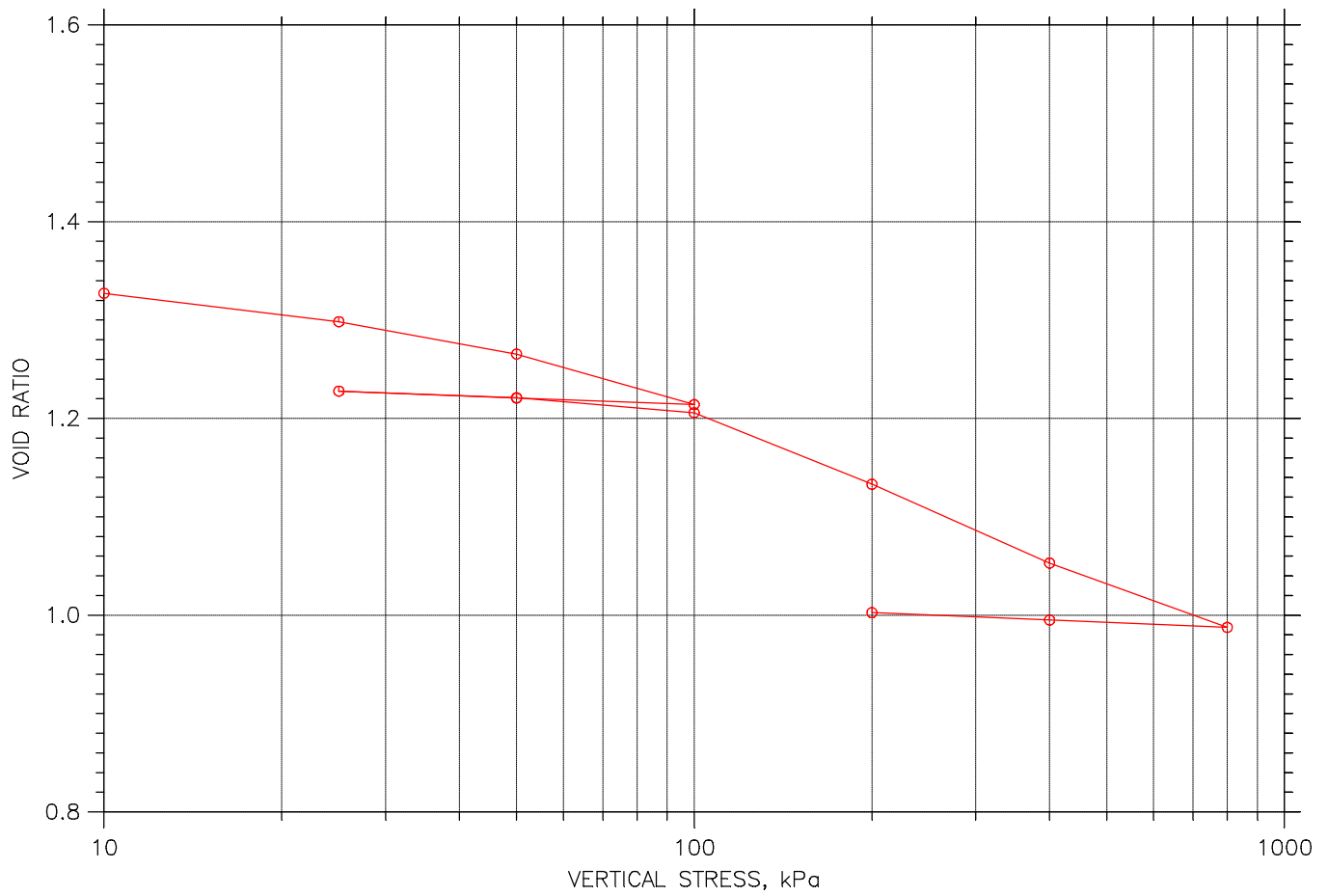



				Before Test	After Test
Overburden Pressure: 0 kPa		Water Content, %		64.42	37.59
Preconsolidation Pressure: 0 kPa		Dry Unit Weight, N/m <sup>3</sup>		9337	11450
Compression Index: 0		Saturation, %		94.73	77.29
Diameter: 50.15 mm	Height: 19.23 mm		Void Ratio	1.84	1.31
LL: 54	PL: 20	PI: 34	GS: 2.70		

	Project: Moose Creek Bridge	Location: Hwy 72 Sioux Lookout	Project No.: 19-1351-197
	Boring No.: MCB-15	Tested By: TF	Checked By: GM
	Sample No.: TW 1	Test Date: Aug 20/15	Depth: 20'-22'
	Test No.: 1	Sample Type: TW	Elevation: 1
	Description: Grey Clay		
	Remarks:		

# CONSOLIDATION TEST DATA

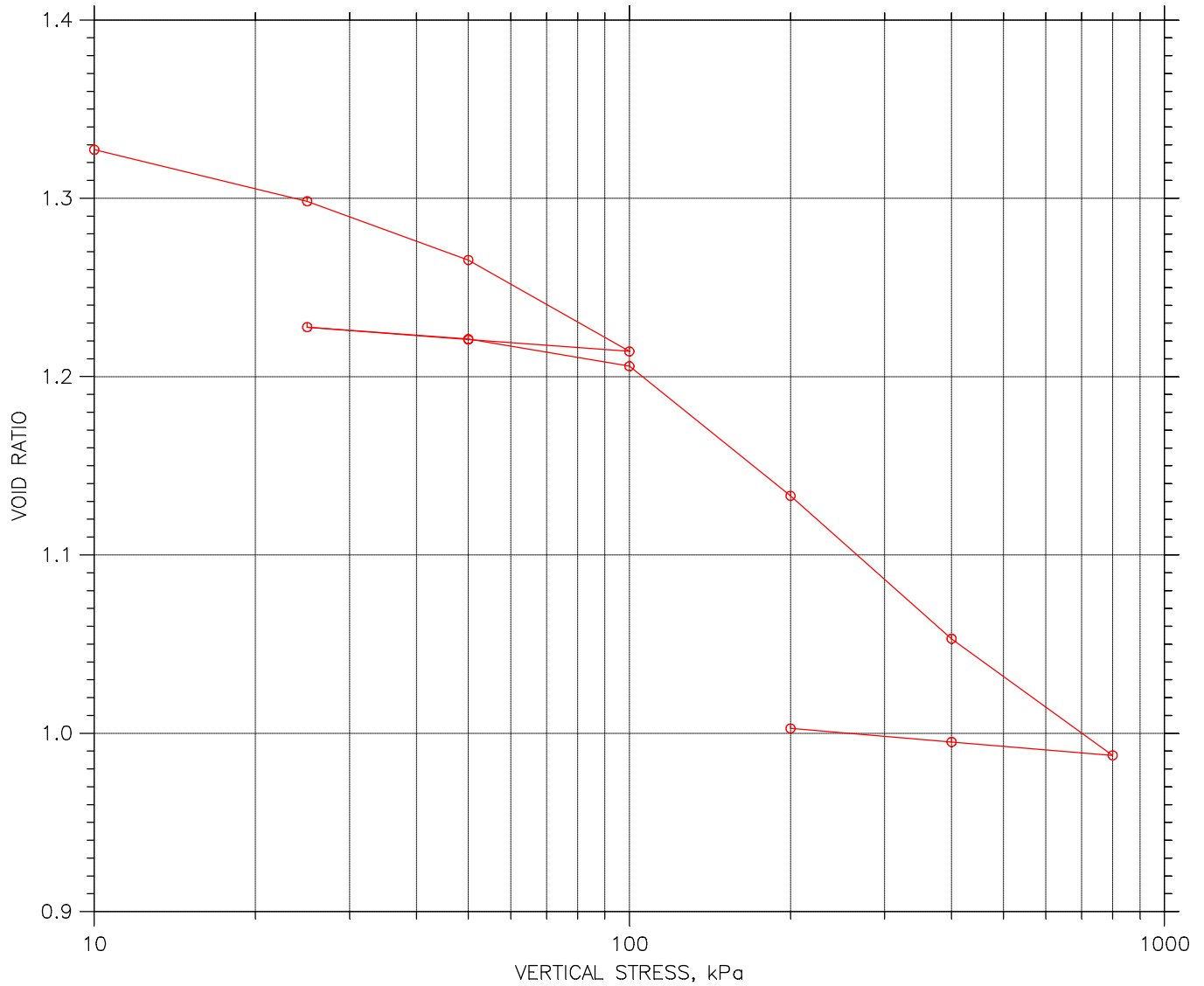
## SUMMARY REPORT




	Project: Moose Creek Bridge	Location: Hwy 72 Sioux Lookout	Project No.: 19-1351-197
	Boring No.: MCB-22	Tested By: TF	Checked By: GM
	Sample No.: TW 1	Test Date: Sept 3/15	Depth: 20'-22'
	Test No.: 1	Sample Type: TW	Elevation: 1
	Description: Grey Clay		
	Remarks:		

# CONSOLIDATION TEST DATA

## SUMMARY REPORT



				Before Test	After Test	
Overburden Pressure: 0 kPa				Water Content, %	52.39	34.26
Preconsolidation Pressure: 0 kPa				Dry Unit Weight, N/m^3	10920	12910
Compression Index: 0				Saturation, %	100.93	90.11
Diameter: 50.15 mm		Height: 18.64 mm		Void Ratio	1.37	1.00
LL: 30	PL: 18	PI: 12	GS: 2.64			

	Project: Moose Creek Bridge	Location: Hwy 72 Sioux Lookout	Project No.: 19-1351-197
	Boring No.: MCB-22	Tested By: TF	Checked By: GM
	Sample No.: TW 1	Test Date: Sept 3/15	Depth: 20'-22'
	Test No.: 1	Sample Type: TW	Elevation: 1
	Description: Grey Clay		
	Remarks:		

## **Appendix C**

### **Site Photographs**



**Photo 1 - Highway 72 - Looking North from South Approach**



**Photo 2 - Looking South at the West Bridge Elevation**





**Photo 3 – Looking South from North East Corner of North Abutment**



**Photo 4 - Looking North from South East Corner of North Abutment**





**Photo 5 - Looking Northeast from South Abutment**



**Photo 6 - Looking West from North Abutment**





**Photo 7 - South Abutment Piles – Looking West**



**Photo 8 - North Abutment Piles – Looking East**





**Photo 9 - North Abutment –Front Slope and Existing Cut-off Piles**



**Photo 10 - South Abutment - Front Slope and existing cut-off piles**





**Photo 11 - Looking South under the Bridge from front slope at North Abutment**



**Photo 12 - Looking North from SE corner – Noticeable Highway 72 Embankment Sag**





**Photo 13 - Looking north along west side of highway embankment; Probehole P3 marked at 20 m distance south of the bridge**



**Photo 14 - Looking south along east side of highway embankment; Probehole P5 marked at 20 m distance north of the bridge.**

## **Appendix D**

### **Comparison of Foundation Alternatives**

**COMPARISON OF FOUNDATION ALTERNATIVES**

Footings on Native Soil	Footings on Engineered Fill	Driven Piles	Caissons
<p><b>Advantages</b></p> <ul style="list-style-type: none"> <li>i. Ease of construction.</li> <li>ii. Lower cost than deep foundations.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Low geotechnical resistance is available in native soils.</li> <li>ii. Deep excavation required to reach founding stratum.</li> <li>iii. Potential for significant consolidation settlement in silty clay.</li> <li>iv. Extensive dewatering required, depending on depth of excavation.</li> </ul> <p><b>NOT RECOMMENDED</b></p>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Generally less costly construction than deep foundation elements.</li> <li>ii. Allows use of perched abutments.</li> <li>iii. Higher geotechnical resistance than on native soil.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Cost of engineered fill placement.</li> <li>ii. Not feasible for abutments in river.</li> <li>iii. Potential for consolidation settlement in silty clay.</li> <li>iv. Dewatering may be required, depending on depth of excavation.</li> </ul> <p><b>NOT RECOMMENDED</b></p>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Piles will develop high geotechnical resistance</li> <li>ii. Piles can be installed into riverbed/in wet.</li> <li>iii. Installation of piles could continue in freezing weather.</li> <li>iv. Allows integral abutment design.</li> <li>v. Requires less excavation than footings.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Higher unit costs than for spread footings.</li> <li>ii. Possibility that cobbles and/or boulders may be encountered in the fill and native deposits.</li> </ul> <p><b>RECOMMENDED</b></p>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Higher resistance is available for caissons than for piles.</li> <li>ii. Construction of caissons could continue in freezing weather.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Caisson will have to be founded in the sand encountered at significant depth.</li> <li>ii. Liners will be required to install caissons in cohesionless soils below the river and groundwater levels.</li> <li>iii. Difficulty in cleaning and inspecting bases.</li> <li>iv. Possibility of cobbles and boulders being encountered during augering and liner installation.</li> </ul> <p><b>NOT RECOMMENDED</b></p>



## **Appendix E**

### **List of Standard Specifications and Special Provisions**

**1) List of Standard Specifications and Special Provisions referenced in this report:**

OPSS 501

OPSS 539

OPSS 804

OPSS 902

OPSS 903

OPSS.PROV 1004

OPSS.PROV 1010

SS103-11 (Hiley Formula)

**2) Recommended wording for “NSSP – Existing Timber Pile Foundations”**

The Contractor shall not extract the existing timber piles on this site. The peat, soft silty clay and loose silt underlying the site are sensitive to disturbance, and extraction of the piles may result in unacceptable ground movements. The below-grade portion of the timber piles must be left in place and the above-grade portion is to be removed as per the Contract Drawings.

**3) Recommended wording for “NSSP – Monitoring of Existing Structure”**

The Contractor shall ensure that the existing structure remains stable while in use during construction.

A monitoring program is required to confirm that any movements of the existing structure remain within tolerable levels. As a minimum, the monitoring program should require the Contractor to establish reference points over each abutment of the existing structure and to monitor movement of these points relative to known, fixed reference points on a regular basis. The suggested frequency is:

- Three readings on separate days prior to construction to establish a baseline;
- Twice daily while any foundation construction or other subsurface construction is in progress;
- Daily for one week after completion of foundation construction.

The vertical and horizontal accuracy of readings should be  $\pm 2$  mm. All readings should be reported to the Contract Administrator within 24 hours and immediately if any movement exceeds limits set by the structural designer.

The Contract Administrator should be advised of the importance of monitoring and be required to advise the Ministry immediately if the vertical and horizontal movements exceed the specified limits.

**4) Recommended wording for “NSSP – Use of Vibratory Equipment”**

The use of vibratory equipment for the installation of temporary and permanent sheet piles and H-piles is prohibited.

**5) Recommended wording for “NSSP – Use of Heavy Construction Equipment”**

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

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

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

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

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

Furthermore, heavy construction equipment such as dressed lifting cranes must not be permitted on the EPS embankments, in order to avoid crushing or otherwise damaging the EPS blocks.

**6) Sample Special Provision for Rigid Expanded Polystyrene Embankment Fill**

**RIGID EXPANDED POLYSTYRENE EMBANKMENT FILL - Item No.**

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Special Provision

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**1.0 SCOPE**

This special provision covers the requirements for the supply and construction of the rigid expanded polystyrene (EPS) embankment fill and associated works as shown on the contract drawings.

As part of the work of the above noted tender item the Contractor shall supply and install Geomembrane and Polyethylene Sheeting as detailed elsewhere in the contract.

**2.0 REFERENCES**

This special provision refers to the following standards, specifications or publications.

National Standards of Canada

CAN/ULC – S102.2-10

CAN/ULC – S701-11

NCHRP

Report 529      Guideline and Recommended Standard for Geofoam Applications in Highway Embankments

ASTM

ASTM D1621    Test Method for Compressive Properties of Rigid Cellular Plastics

ASTM C203     Test Method for Breaking Load and Flexural Properties of Block Type Thermal Insulation

ASTM C177     Test Method for Steady State Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat Flow Apparatus

ASTM D2842    Test Method for Water Absorption by Rigid Cellular Plastics

ASTM D2863    Test Method for Measuring the Minimum Oxygen Content

ASTM D2126    Test Method for Response of Rigid Cellular Plastics to Thermal and Humid Aging

ASTM D6817    Standard Specification for Rigid Cellular Polystyrene Geofoam

OPSS - Ontario Provincial Standard Specification

OPSS 212	Borrow
OPSS 501	Compaction
OPSS 517	Dewatering
OPSS 1010	Aggregates – Granular A, B, M, and Selected Subgrade Material
OPSS 1860	Geotextiles

#### Subsurface Conditions

The subsurface conditions at the site are described in the Foundation Investigation Report for this Contract.

### **3.0 DEFINITIONS**

For the purpose of this special provision, the following definitions apply:

**Rigid Expanded Polystyrene:** Molded rigid blocks produced by a process of pre-expansion, aging and forming of petroleum based raw material.

**Rigid Extruded Expanded Polystyrene:** Rigid boards made by extrusion of expanded polystyrene beads.

**Production Lot:** The quantity of rigid polystyrene blocks produced in a continuous period of manufacturing the same grade and thickness of product within the same production day.

**Quality Verification Engineer:** An Engineer with a minimum of five (5) years experience related to the design and/or construction of expanded polystyrene systems of similar scope to that in the Contract, or alternatively has demonstrated expertise by providing satisfactory quality verification services for the work at a minimum of two (2) projects of similar scope to the Contract. The Quality Verification Engineer shall be retained by the Contractor to ensure conformance with the contract documents and issue of certificate(s) of conformance.

### **4.0 DESIGN AND SUBMISSION REQUIREMENTS**

#### **4.01 Submission of Shop Drawings**

At least three weeks before the commencement of work, the Contractor shall submit to the Contract Administrator six copies of the shop drawings and method statement signed and sealed by the Quality Verification Engineer that provides full details of materials and construction procedure.

#### **4.02 Delivery, Storage, Handling and Protection**

The Contractor shall submit the method of delivery, storage, handling and protection from damage by weather, traffic, construction staging and other causes as per the rigid expanded polystyrene manufacturer's requirement.

#### **4.03 Construction**

The contractor shall submit full details of the following;

- a) The method of foundation excavation and preparation.
- b) Construction of levelling pad.
- c) The method of placement of expanded polystyrene blocks including temporary ballasting and protection of blocks during installation. The shop drawings shall indicate laying pattern and block dimensions on a layer by layer basis.
- d) The method and limits of placement of polyethylene geomembrane and/or sheeting.
- e) The method of placement of reinforced concrete slab (or equivalent, where applicable).
- f) The method of placement of subbase material.
- g) The method of placement of side slope cover.

#### **5.0 MATERIALS**

##### **5.01 Granular Levelling Pad**

The levelling pad shall consist of a Granular “A” or Granular “B” material with gradation and physical requirements as specified in OPSS 1010.

##### **5.02 Polyethylene geomembrane**

The EPS shall be encapsulated with a polyethylene geomembrane with two coextruded textured surfaces such as [GSE HDT 30A000] or approved equivalent. A minimum 10mil smooth [black] polyethylene sheeting may be used on the sides only.

Polyethylene geomembrane shall be flexible and, by its own weight, shall cover and conform closely to 90 degree edges and corners of EPS blocks without additional heating of the Polyethylene geomembrane.

Polyethylene geomembrane shall be free from pin holes, tears, and any defects.

##### **5.03 Rigid Expanded Polystyrene**

###### **5.03.01 General**

###### **5.03.01.01 The Contractor shall submit:**

- 1. A general statement as to the type, composition, and method of production of the material.
- 2. The manufacturer’s name, address, phone number, identification of a contact person and description of experience background in the manufacturing of the rigid expanded

polystyrene.

3. Certification of compliance of physical and mechanical properties.
4. An identification of a laboratory accredited by the Standards Council of Canada to conduct the testing of the physical and mechanical properties of the rigid expanded polystyrene.
5. The physical and mechanical properties of the rigid expanded polystyrene including:
  - 1) Geometry
  - 2) Nominal Density
  - 3) Compressive Strength
  - 4) Flexural Strength
  - 5) Thermal Resistance
  - 6) Dimensional Stability
  - 7) Flammability
  - 8) Water Absorption
6. Aging and durability characteristics of the polystyrene including the chemical, biological and ultra-violet degradation resistance of the rigid polystyrene.
7. A sample of the expanded polystyrene material to the Quality Verification Engineer for review.
8. To the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer a minimum of one week prior to commencement of work under this item. The Certificate shall state that the expanded polystyrene material is in conformance with the requirements and specifications of the contract documents.

Each block of the same production lot shall be stamped with the same production code showing plant identification, type and date of production. The polystyrene shall be free from defects affecting serviceability.

EPS blocks shall meet ASTM D6817 Standard Specification for rigid cellular polystyrene geofoam

#### **5.03.02 Detail Requirements**

Requirements shall be as shown in Table 1 and as described below.

**Table 1 – Material Properties**

PROPERTY	UNIT	REQUIREMENTS	TEST PROCEDURE
Geometry - Linear - Flatness - Squareness - Thickness	mm	1200 × 600 × 300 with tolerances ± 1% 10mm in 3m ± 0.5% -3, +5	
Compressive Strength	kPa (min.) @ 1% Deformation	50 (EPS Type 22) 65 (EPS Type 24) 75 (EPS Type 29) 103 (EPS Type 39)	ASTM D1621 (Procedure A)
Compressive Strength	kPa (min.) @ 5% Deformation	110 (EPS Type 22) 140 (EPS Type 24) 170 (EPS Type 29) 241 (EPS Type 39)	ASTM D1621 (Procedure A)
Flexural Strength	kPa (min.)	240 (EPS Type 22) 276 (EPS Type 24) 345 (EPS Type 29) 414 (EPS Type 39)	ASTM C203 (Procedure B)
Dimensional Stability	% linear change (max.)	1.5	ASTM D2126
Thermal Resistance	m <sup>2</sup> .°C/W (min. for 25mm thickness)	0.7	ASTM C177 or C518
Flammability	Limiting Oxygen Index (min.)	24	ASTM D2863
Water Absorption	% by Volume (max.)	4 (EPS Type 22) 3 (EPS Type 24) 2 (EPS Type 29) 2 (EPS Type 39)	ASTM D2842

#### **5.03.02.01 Geometry**

The expanded polystyrene shall be supplied in the form of rectangular parallel blocks of minimum acceptable dimensions of 1200 mm x 600 mm x 250 mm.

The maximum deviation from the specified linear dimensions shall be ± 1%. The flatness of the lock faces shall be within ± 10 mm of a line formed by a 3 m straight edge.

The maximum difference in corner to corner dimensions (squareness) shall be 0.5%. The thickness shall be within -3 to +5 mm.

#### **5.03.02.02 Compressive Strength**



At no time shall the vertical stress on the EPS exceed the 1% strain limit. A Factor of Safety of 1.2 shall be applied to all loads, in accordance with NCHRP 529.

The minimum compressive strength, measured in accordance with ASTM D1621, Procedure A, shall be 110 kPa for EPS Type 22 at a strain of not more than 5%. The maximum permissible permanent stress level should not exceed 30% of the compressive strength of the material at 5% strain. The compressive strength for other grades of EPS are listed in Table 1.

#### **5.03.02.03 Flexural Strength**

The minimum flexural strength of the polystyrene shall be 240 kPa for EPS Type 22. The flexural strength shall be determined in accordance with ASTM C203, method 1, Procedure B. The flexural strength for other grades of EPS are listed in Table 1.

#### **5.03.02.04 Dimensional Stability**

Dimensional Stability shall be determined in accordance with ASTM D2126, Procedure G. A tolerance of 1.5% shall be satisfied.

#### **5.03.02.05 Thermal Resistance**

The thermal resistance shall be  $0.7 \text{ m}^2 \cdot ^\circ\text{C} / \text{W}$  for a 25mm thickness using the following equation and using the average value from three specimens:

$$R_{25mm} = \frac{R_{measured}}{\text{Thickness (mm)}} \times 25$$

The thermal resistance shall be measured in accordance with ASTM C177 or C518.

#### **5.03.02.06 Flammability**

The expanded polystyrene shall be classified as to surface burning characteristics in accordance with CAN/ULC - S102.2-10 having a flame spread rating less than 500. The expanded polystyrene shall have a minimum limiting oxygen index measured in accordance with ASTM D2863.

#### **5.03.02.07 Water Absorption**

The water absorption as measured by ASTM D2842 shall be limited to 4% for EPS Type 22 by volume. The water absorption for other grades of EPS are listed in Table 1.

#### **5.03.02.08 Chemical Resistance**

The expanded polystyrene shall be resistant to common inorganic acids and alkalis. A table identifying the chemical resistance as resistant, limited or not resistant shall be submitted.

#### **5.03.02.09 Biological Resistance**

The expanded polystyrene shall be resistant to biological degradation caused by organisms or

enzymes.

#### **5.03.02.10 Environmental**

The expanded polystyrene shall be inert, non-nutritive and highly stable and shall not produce undesirable gases or leachate.

### **6.0 EQUIPMENT**

All cutting of polystyrene materials shall be by electric equipment or by hand.

Heavy equipment shall be limited in weight and size and restricted in operation to avoid damaging the expanded polystyrene as per the manufacturer's requirement.

### **7.0 CONSTRUCTION**

#### **7.01 Qualification**

The Contractor shall have on site at the commencement of the work, a representative of the supplier of the rigid expanded polystyrene to advise on recommended construction procedure.

The Contractor shall maintain liaison with the supplier throughout the construction of the embankment for advice and guidance as required. Periodic site visits by the supplier should be coordinated as required.

#### **7.02 Delivery, Storage and Handling**

The product shall be suitably marked to identify its type, number and the manufacturer's name or trademark.

The Contractor shall protect the expanded polystyrene from exposure to sunlight to avoid ultraviolet degradation as per manufacturer's recommendation.

Protection of materials and works from damage by weather, traffic, construction staging, fire or vandalism and other causes shall be the responsibility of the Contractor.

EPS blocks shall be stored for a minimum 72 hours at ambient room temperature (20 to 25 degrees Celsius) after an EPS block is released from the mould.

EPS blocks shall be stored above ground. EPS blocks shall be protected from moisture and sunlight in accordance with manufacturer's recommendations.

EPS shall not be exposed to open flame or other ignition source. The constructor shall protect the EPS blocks from petroleum based products such as gasoline and diesel fuel and organic solvents such as acetone, benzene and paint thinner.

#### **7.03 Foundation Excavation**

Foundation excavation shall be carried out to the design elevations shown on the drawings. Any softened, loosened or deleterious materials at the foundation footing elevation shall be subexcavated

and replaced with Granular 'A' or Granular 'B' material.

Any unsuitable area as determined by the Engineer, shall be excavated and replaced with suitable compacted backfill. The native soil foundation and/or embankment subgrade shall be free from deleterious, loose, or otherwise unsuitable soils.

#### **7.04 Levelling Pad**

Clear and grub site and remove any subgrade material unsuitable for EPS block placement as determined by the Engineer.

Dewater as required. There shall be no standing water or accumulated snow or ice on the subgrade within the area where the EPS blocks are placed. EPS blocks shall not be placed on a frozen subgrade.

Place, level and compact to 95% standard Proctor density, a 150mm layer of Granular 'A' or Granular 'B' material in accordance with OPSS 501 to within  $\pm 30$  mm of the design elevation. The levelling pad shall not deviate by more than 10 mm at any place on a 3 m straight edge over the limits of the bottom course of blocks. The levelling pad shall not be placed on frozen ground.

EPS shall not be founded directly on existing asphalt pavement. The constructor shall remove existing pavement in addition to any material containing hydrocarbons and replace with clean granular material. Where an EPS embankment is founded above a pre-existing subsurface pavement layer there shall be 200mm (min.) of free draining levelling course below EPS blocks.

#### **7.05 Installation of Blocks**

- (1) The individually marked blocks shall be placed on the prepared levelling pad. The top surface of the first layer of blocks is to be set plane and level. Local trimming of the blocks may be necessary.
- (2) Subsequent successive layers shall be oriented with the long axis of blocks positioned at 90° to the previous layer in order to avoid continuous joints. Block joints shall be offset and staggered between layers.

A continuous check shall be kept to ensure the evenness of the blocks is satisfactory in each layer. Blocks shall be laid with joints with maximum opening of 10 mm between blocks. Differences in heights between adjacent blocks in the same layer should not exceed 5 mm.

- (3) Sloping end adjustments at the abutments shall be accomplished by levelling terraces in the subsoil in accordance with the block thickness.
- (4) Top surface of EPS blocks shall be stepped (or cut on a slope) to match [superelevation or crossfall] and/or grading.
- (5) Temporary ballast shall be provided as necessary to prevent movement of expanded polystyrene both in storage and as placed due to windy conditions. Timber fasteners or equivalent shall be used as necessary.

- (6) The expanded polystyrene embankment shall be protected from accidental ignition due to welding, smoking, grinding or cutting tools, etc. The Contractor shall take all necessary precautions to prevent ignition of the expanded polystyrene.
- (7) The expanded polystyrene shall be protected from organic solvents and other aggressive, harmful chemicals during construction. The proposed method of protection during construction shall be submitted to the Contractor's Quality Verification Engineer for review and to the Contract Administrator for information purposes.
- (8) Exposed blocks shall be covered immediately to avoid possible burrowing by animals.
- (9) Individually marked blocks shall be fabricated and placed to ensure the top surface matches the elevation and crossfall shown on the drawings.
- (10) The top surface and side surfaces of the expanded polystyrene shall be covered with a polyethylene geomembrane and/or 10 mil polyethylene sheeting extending onto adjacent work at the longitudinal ends of the embankment. All joints shall be lapped a minimum of 300 mm to provide a fully sealed enclosure.
- (11) No construction equipment shall be permitted to drive directly on the polyethylene geomembrane. Damage to the geomembrane resulting from construction activities, equipment, or operations shall be repaired by the constructor as per manufacturer's recommendations.
- (12) The side slope of the rigid expanded polystyrene embankment shall be covered with clean sand salvaged from earth excavation operations. Alternatively, Granular B Type 1 to be used.
- (13) The Contractor shall submit details of the sequence and method of installation to the Quality Verification Engineer for review. The submittals shall satisfy the specifications and at a minimum include a detailed description of proposed installation procedures. The details shall be submitted at least three weeks prior to the installation of the rigid expanded polystyrene embankments the Contractor shall also submit to the Contract Administrator, for information purposes, details of the sequence and method of installation. The submittals shall satisfy the specifications and at a minimum contain the above information as provided to the Contractor's Quality Verification Engineer.
- (14) The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer a minimum of one week prior to commencement of work under this item. The Certificate shall state that the installation procedures are in conformance with the requirements and specifications of the contract documents. Quality test certificates for each production lot supplied, showing compliance with all requirements of this special provision shall be obtained by the Contractor and submitted to the Contract Administrator prior to installation. Upon completion of the Expanded Polystyrene Embankment the Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer stating that the Expanded Polystyrene Embankment has been constructed

in conformance with the installation procedures and specifications of the contract documents.

#### **7.06 Drainage**

Sub-drains (where specified on the design drawings) shall be 150 mm diameter perforated PVC drain pipe c/w 19mm clear crush 150mm all around wrapped in a non-woven geotextile.

#### **7.07 Construction Loading**

The pavement system includes all material placed above the EPS blocks within the limits of the roadway (including shoulders) unless noted otherwise. The pavement system shall be constructed above the EPS blocks as shown on the design drawings.

No vehicles or construction equipment shall drive directly on the EPS blocks or the geomembrane. Bedding sand and crushed base course for the pavement system shall be pushed onto the embankment using appropriate light weight equipment. Vibratory equipment (e.g. vibrating drum roller) shall not be used to compact the first 300mm of granular material.

The bearing pressures at the surface of the EPS blocks due to construction loads (including any granular material) shall not exceed the 1% deformation compressive resistance values listed in Table 1. A factor of 1.2 shall be applied to all construction loads.

For the purposes of calculating EPS bearing pressures due to construction loads, use a load dispersion angle of 1H:1V through compacted material and 1H:2V through uncompacted material.

### **8.0 QUALITY ASSURANCE**

#### **8.01 Sampling and Testing**

##### **8.01.01 General**

The Contract Administrator may undertake an independent testing program of the expanded polystyrene. Sampling and testing will be carried out in conformance with the relevant test procedure. The physical and thermal property testing identified in Table 1 will be conducted. The testing shall be conducted by a recognized testing laboratory accredited by the Standards Council of Canada.

##### **8.01.02 Sampling Frequency**

Sufficient sample material shall be obtained from blocks randomly selected by the Contract Administrator from each production lot as soon as the material arrives on site. As a minimum, three blocks shall be tested.

For each EPS grade produced by the block supplier, a minimum of one sample shall be tested per 500 m<sup>3</sup> for the first 2000 m<sup>3</sup>. A minimum of one sample per 2000 m<sup>3</sup> shall be tested thereafter.

##### **8.01.03 Acceptance / Rejection**

Failure of any one of the sample blocks to comply with any requirements of this special provision shall be cause for rejection of the production lot from which it was taken. Replacement of the blocks shall

be at the Contractor's expense.

**9.0 MEASUREMENT FOR PAYMENT**

Measurement will be by volume in cubic metres measured in its original position and based on cross-sections.

**10.0 BASIS OF PAYMENT**

Payment at the Contract price for the above tender item shall be full compensation for all labour, Equipment, and Material to do the work.

## **Appendix F**

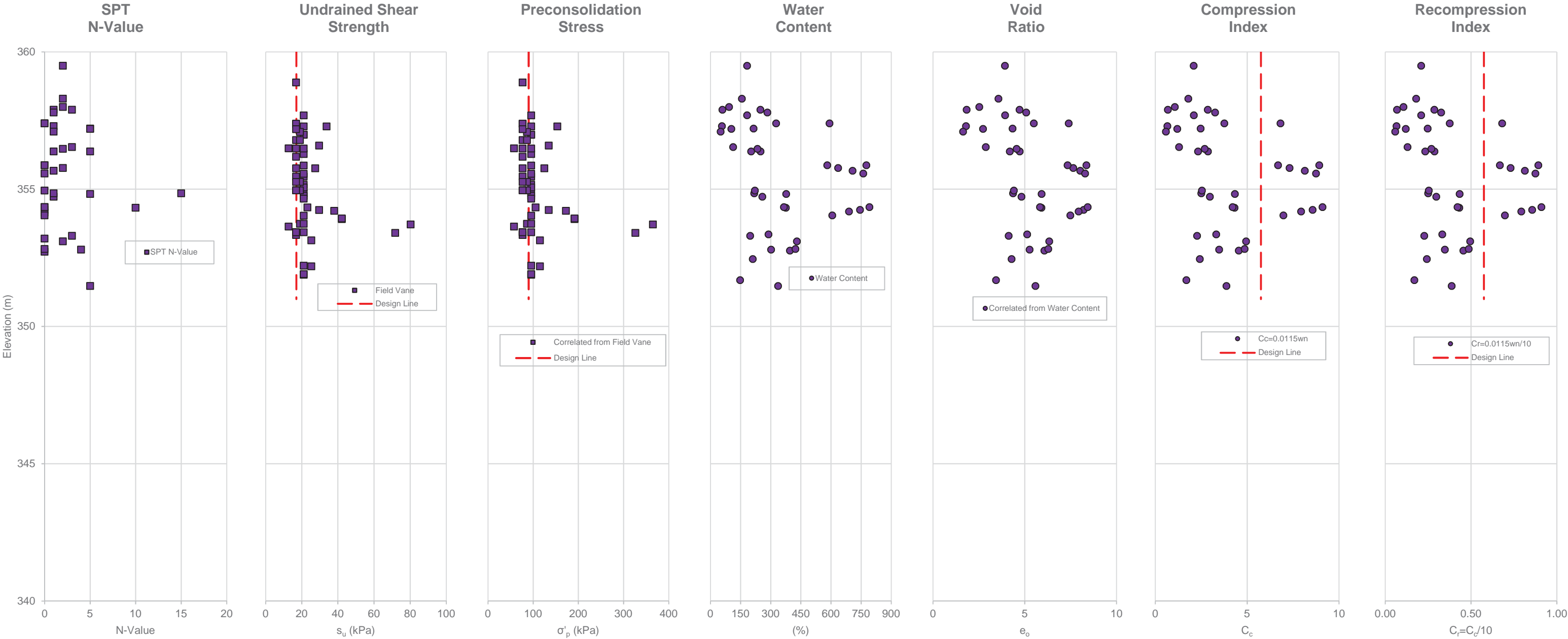
### **Slope Stability Analyses**

**Figures F1 and F2: Parameters Used in Analyses**

**Figures F3A to F9B: Results of Analyses**

SUMMARY OF ENGINEERING PARAMETERS FOR PEAT  
MOOSE CREEK BRIDGE REPLACEMENT

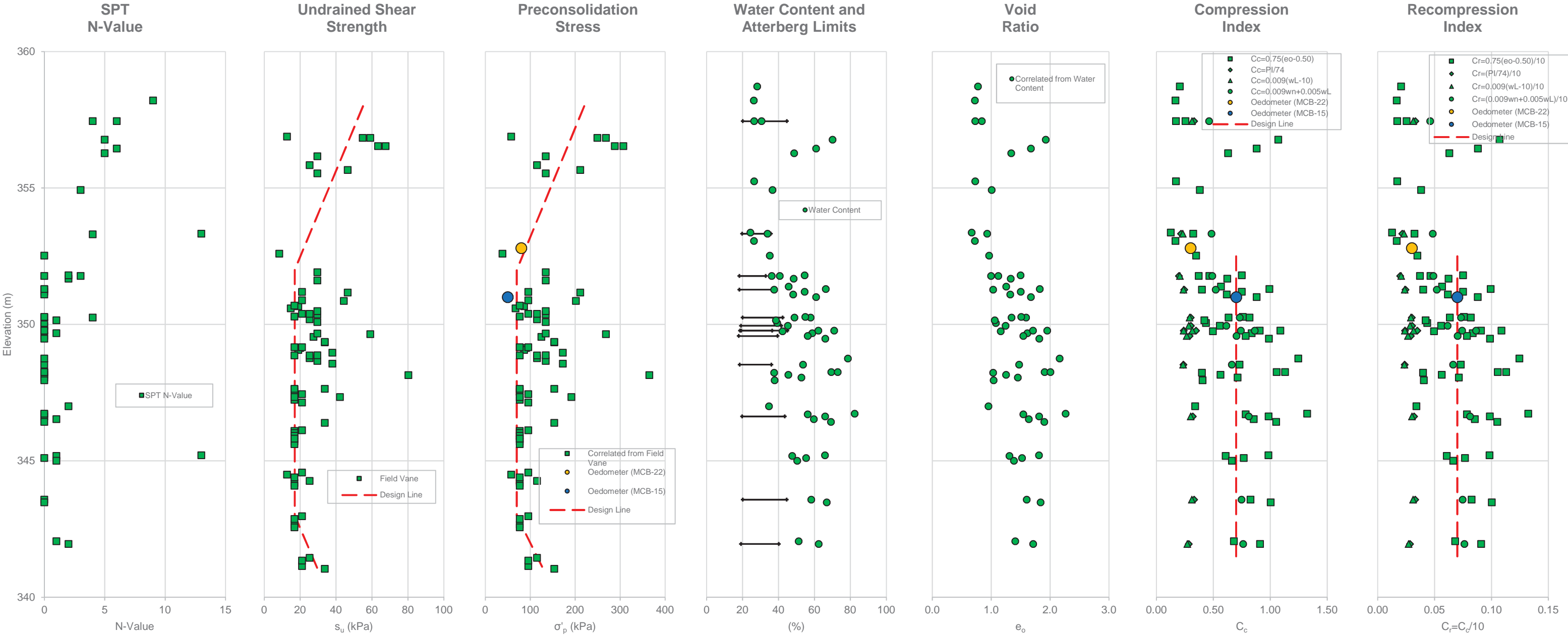
FIGURE F1





SUMMARY OF ENGINEERING PARAMETERS FOR CLAY  
MOOSE CREEK BRIDGE REPLACEMENT

FIGURE F2

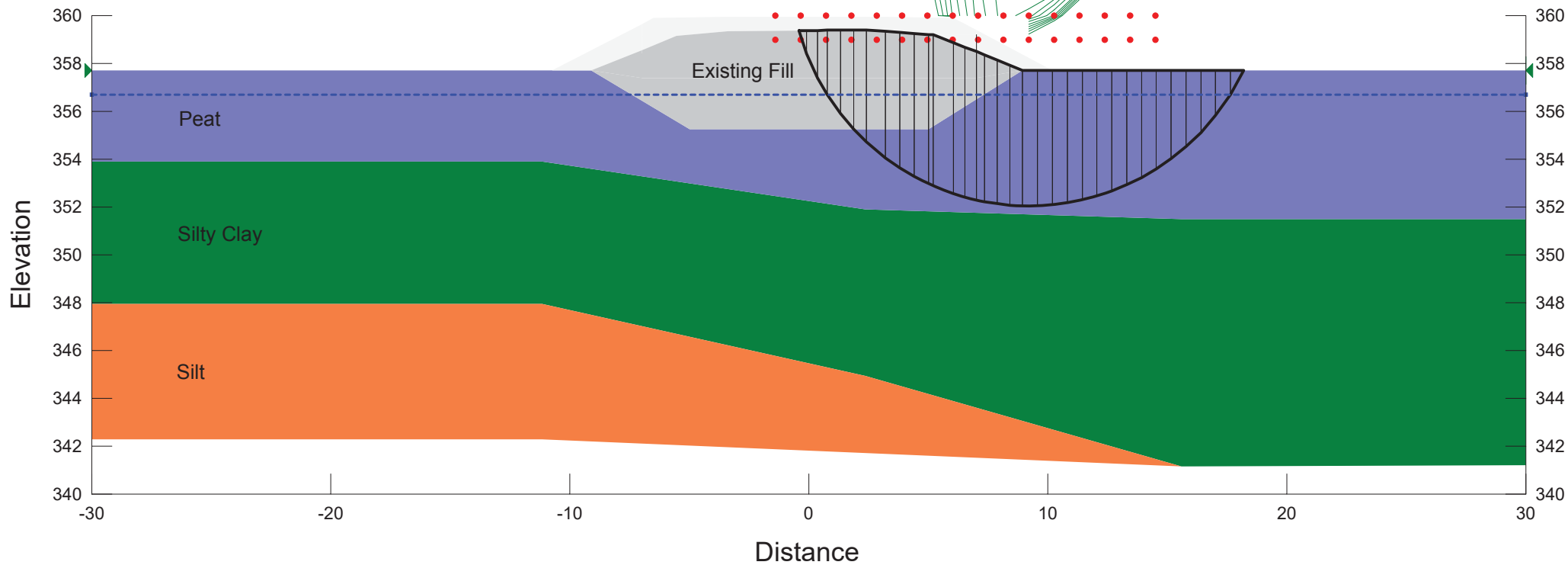


# EXISTING EMBANKMENT SIDESLOPE ESA (STA. 17+725) MOOSE CREEK BRIDGE REPLACEMENT

FIGURE F3A

Existing Fill	21 kN/m <sup>3</sup>	0 kPa	30 °	1
Peat (ESA)	11 kN/m <sup>3</sup>	0 kPa	23 °	1
Silty Clay (ESA)	17 kN/m <sup>3</sup>	5 kPa	23 °	1
Silt	19 kN/m <sup>3</sup>	0 kPa	29 °	1

Method: Morgenstern-Price, Half-Sine  
Minimum Slip Surface Depth: 1 m  
Seismic: 0  
Center: (9.201, 362.03) m

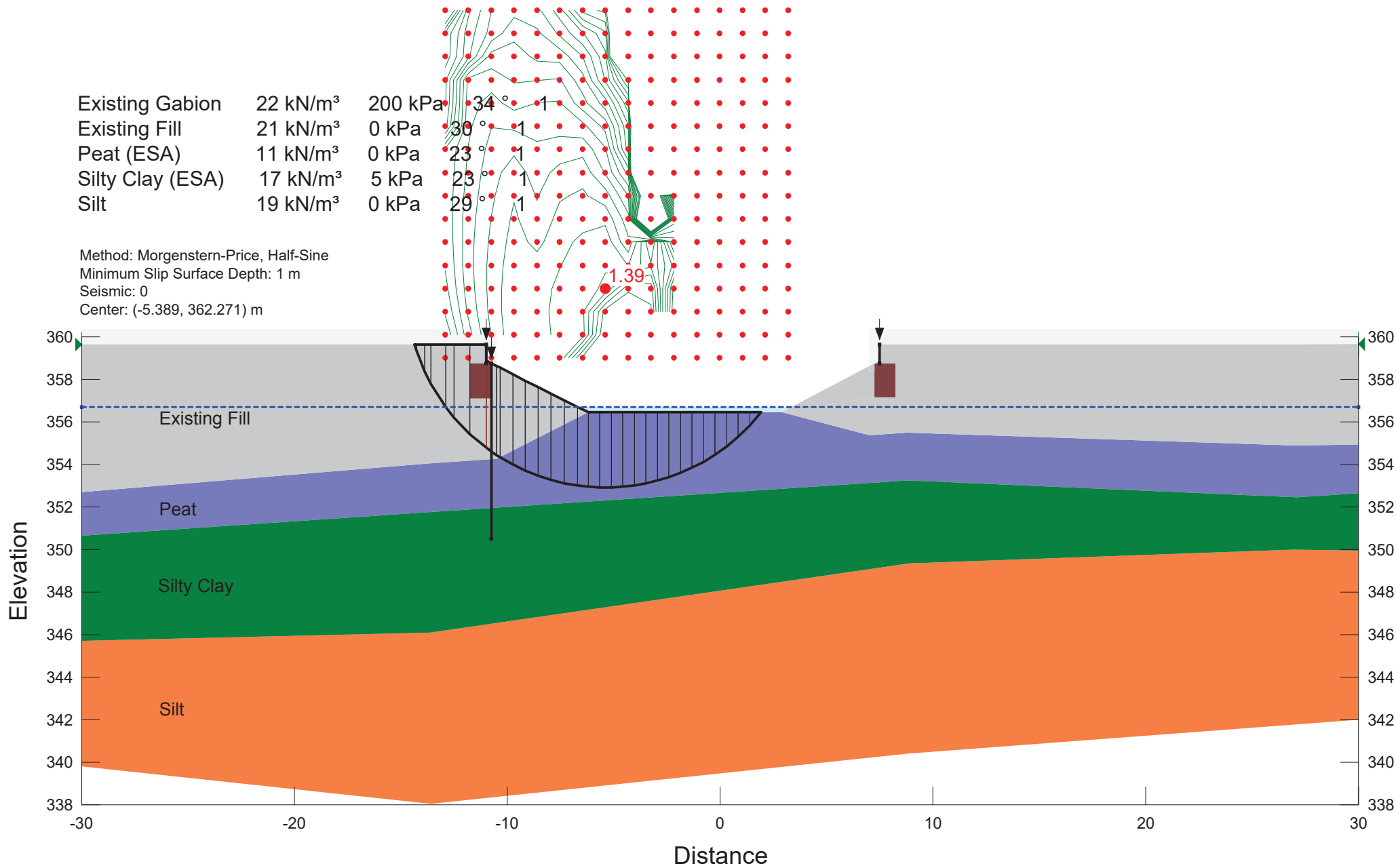


# EXISTING ABUTMENT FORESLOPE WITH TIMBER PILES ESA MOOSE CREEK BRIDGE REPLACEMENT

FIGURE F3B

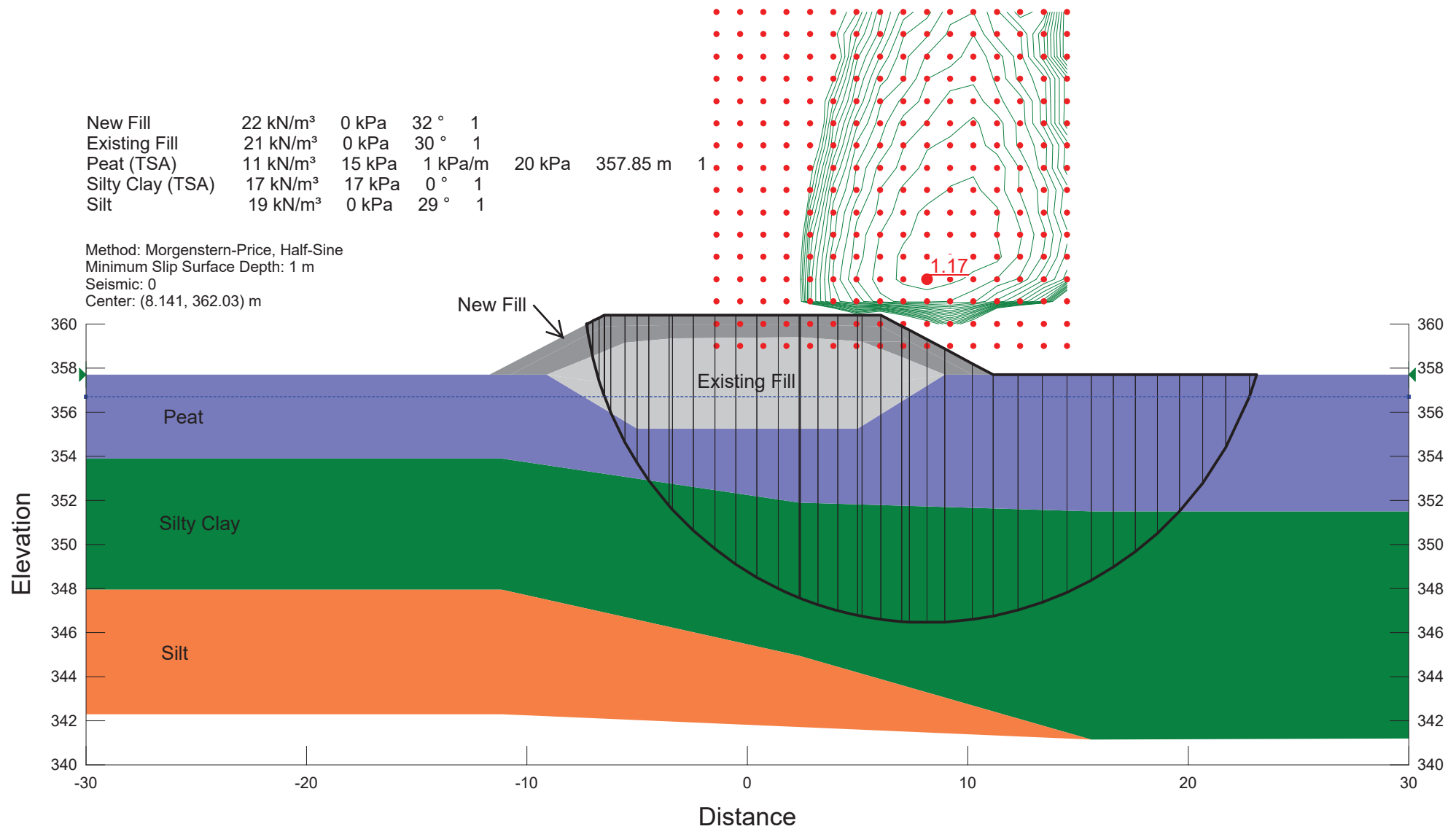
Existing Gabion	22 kN/m <sup>3</sup>	200 kPa
Existing Fill	21 kN/m <sup>3</sup>	0 kPa
Peat (ESA)	11 kN/m <sup>3</sup>	0 kPa
Silty Clay (ESA)	17 kN/m <sup>3</sup>	5 kPa
Silt	19 kN/m <sup>3</sup>	0 kPa

Method: Morgenstern-Price, Half-Sine  
Minimum Slip Surface Depth: 1 m  
Seismic: 0  
Center: (-5.389, 362.271) m



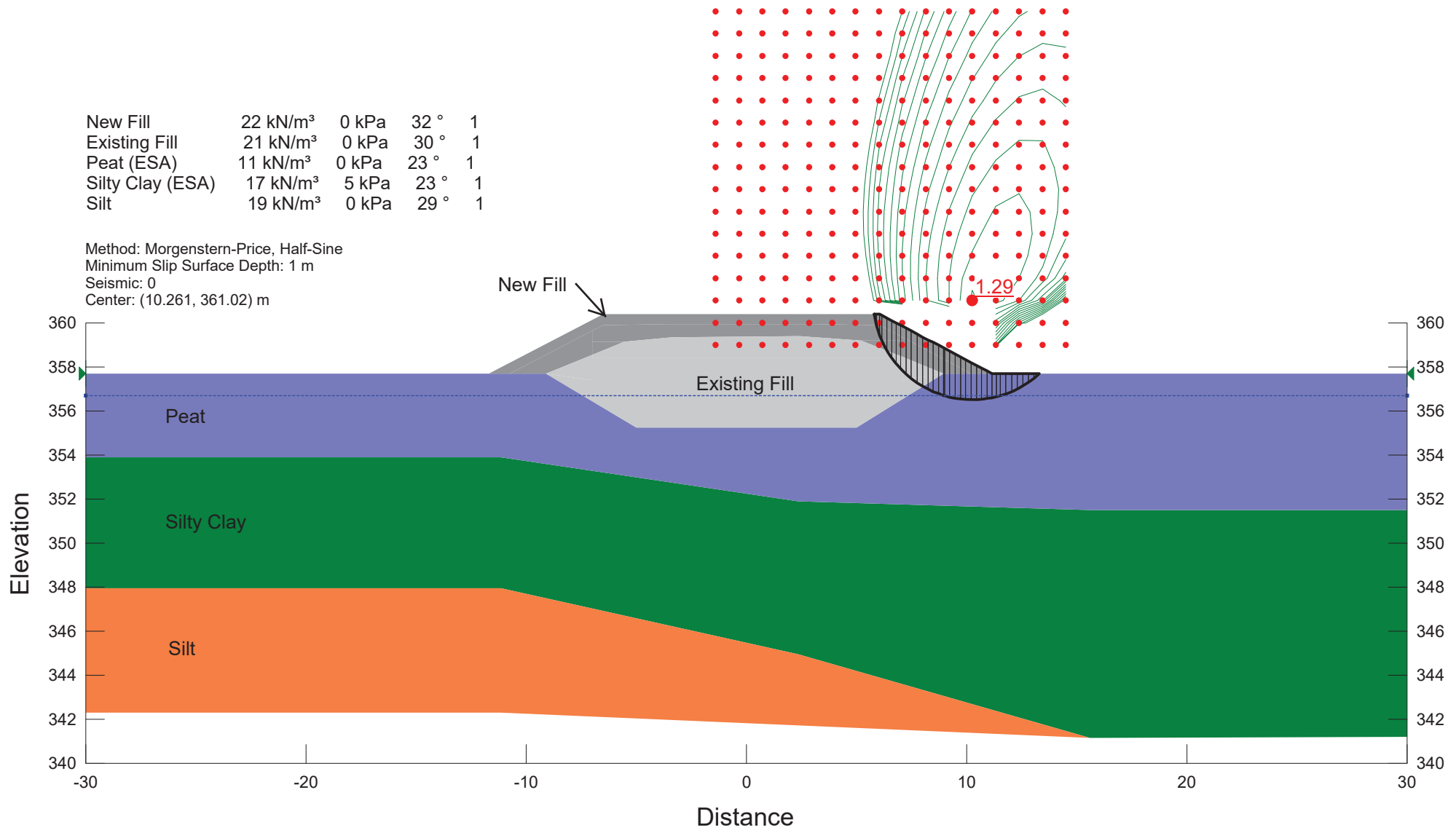
# EXISTING EMBANKMENT SIDESLOPE WITH GRADE RAISE TSA (STA. 17+725) MOOSE CREEK BRIDGE REPLACEMENT

FIGURE F4A



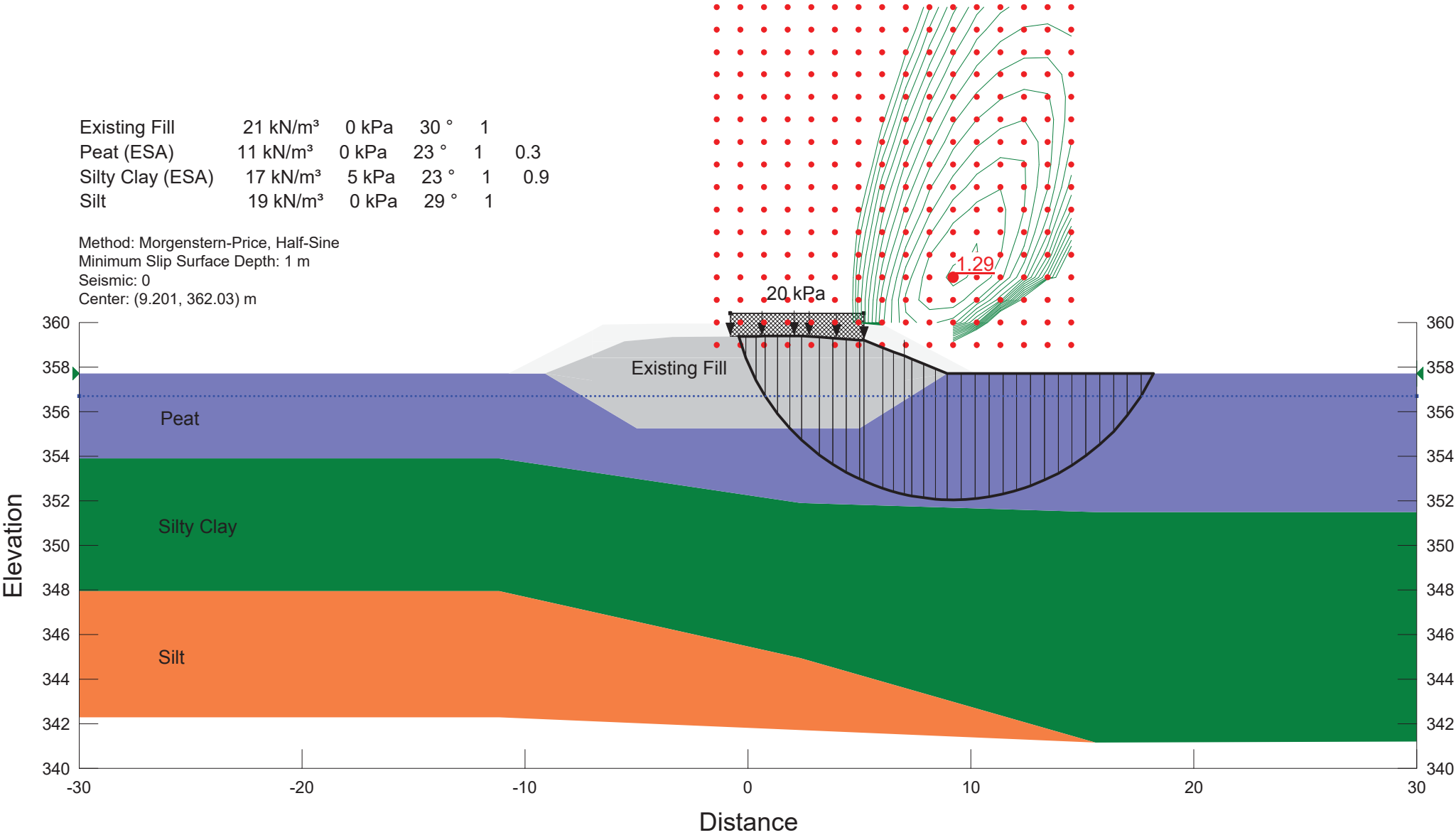
# EXISTING EMBANKMENT SIDESLOPE WITH GRADE RAISE ESA (STA. 17+725) MOOSE CREEK BRIDGE REPLACEMENT

FIGURE F4B



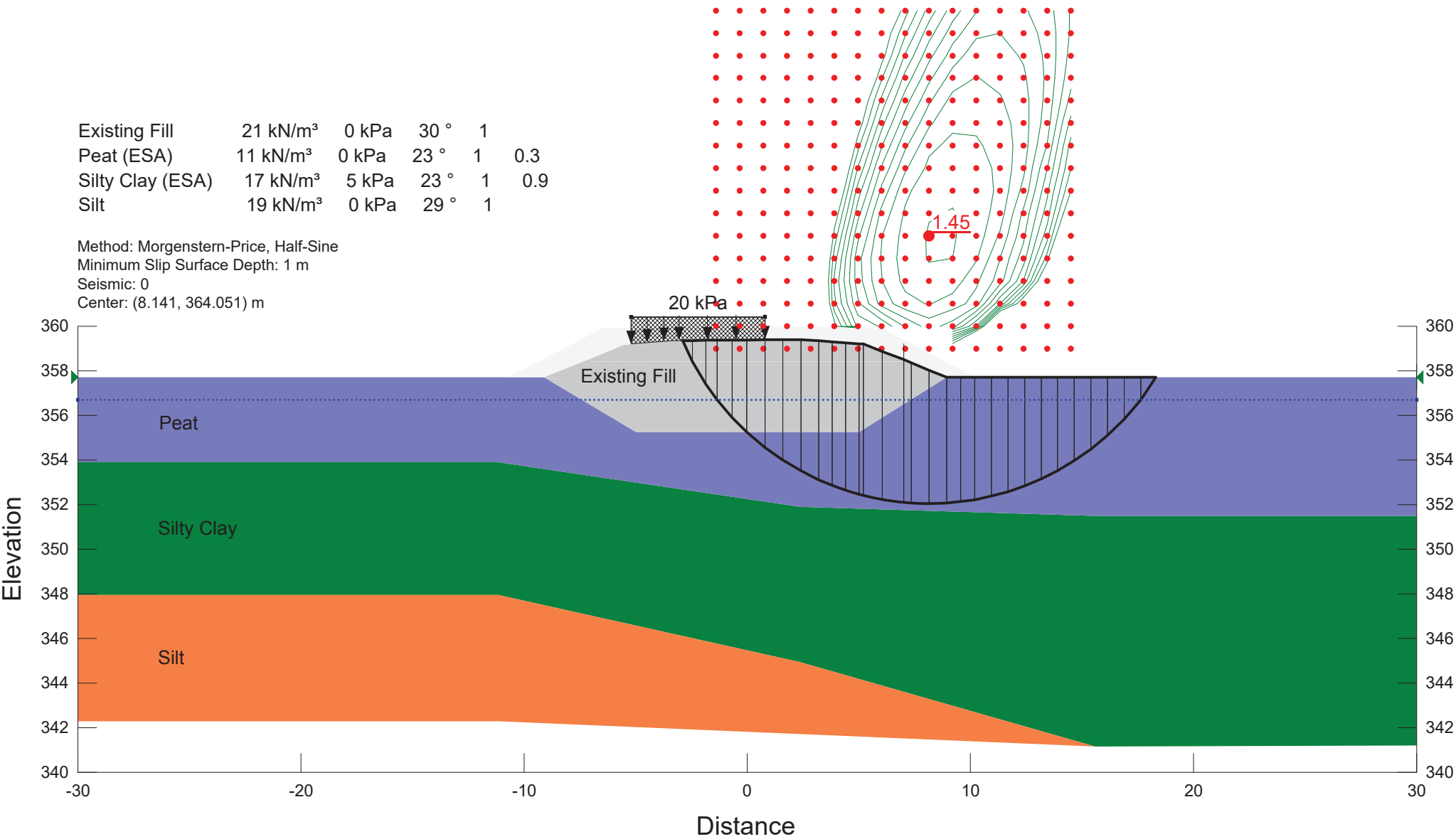
EXISTING EMBANKMENT SIDESLOPE WITH 20kPa PILING RIG NEAR SIDE ESA (STA. 17+725)  
MOOSE CREEK BRIDGE REPLACEMENT

FIGURE F5A



EXISTING EMBANKMENT SIDESLOPE WITH 20kPa PILING RIG FAR SIDE ESA (STA. 17+725)  
MOOSE CREEK BRIDGE REPLACEMENT

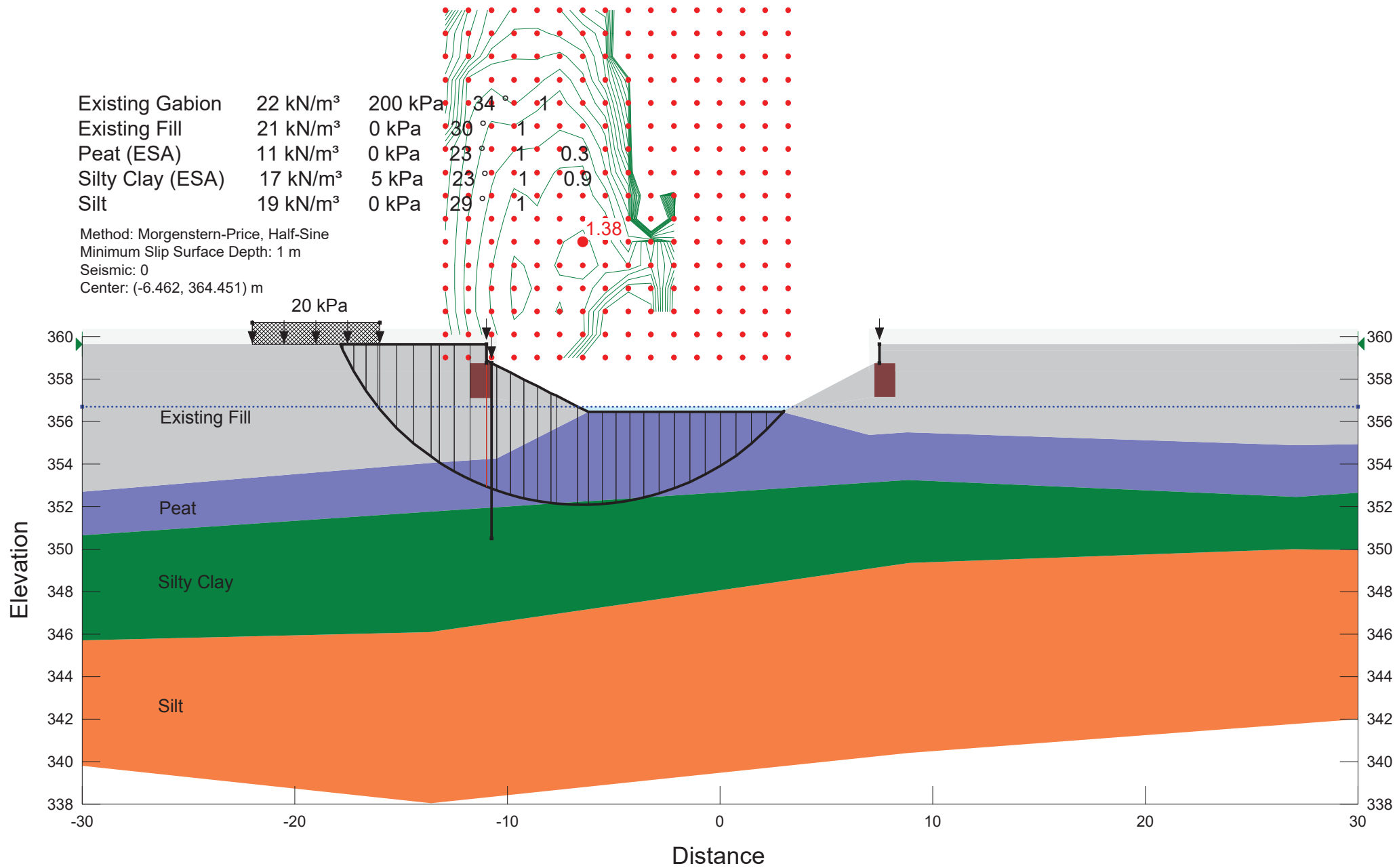
FIGURE F5B



# EXISTING ABUTMENT FORESLOPE WITH TIMBER PILES PLUS 20kPa PILING RIG 5m FROM ABUTMENT ESA      **FIGURE F6** MOOSE CREEK BRIDGE REPLACEMENT

Existing Gabion	22 kN/m <sup>3</sup>	200 kPa
Existing Fill	21 kN/m <sup>3</sup>	0 kPa
Peat (ESA)	11 kN/m <sup>3</sup>	0 kPa
Silty Clay (ESA)	17 kN/m <sup>3</sup>	5 kPa
Silt	19 kN/m <sup>3</sup>	0 kPa

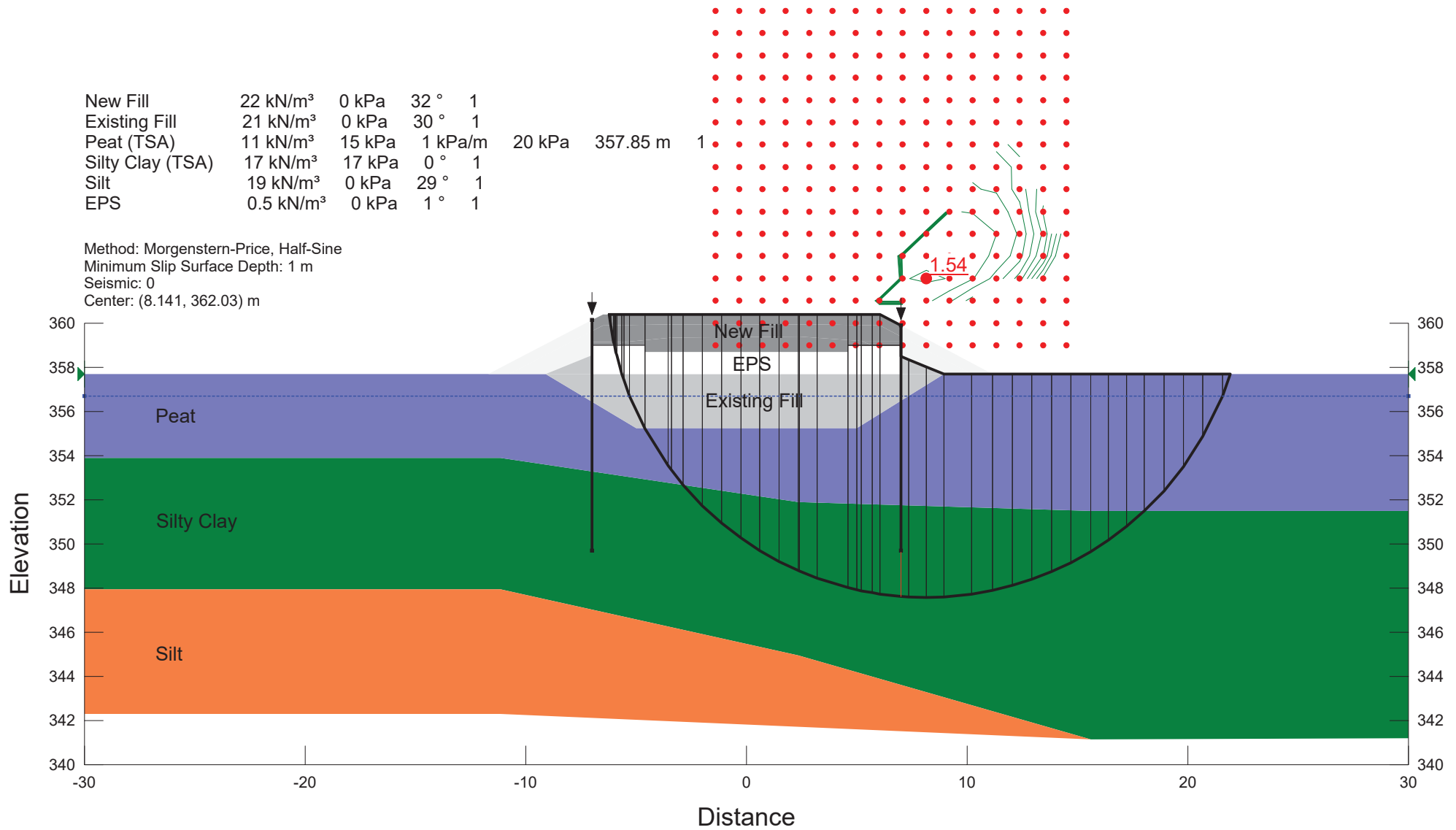
Method: Morgenstern-Price, Half-Sine  
Minimum Slip Surface Depth: 1 m  
Seismic: 0  
Center: (-6.462, 364.451) m





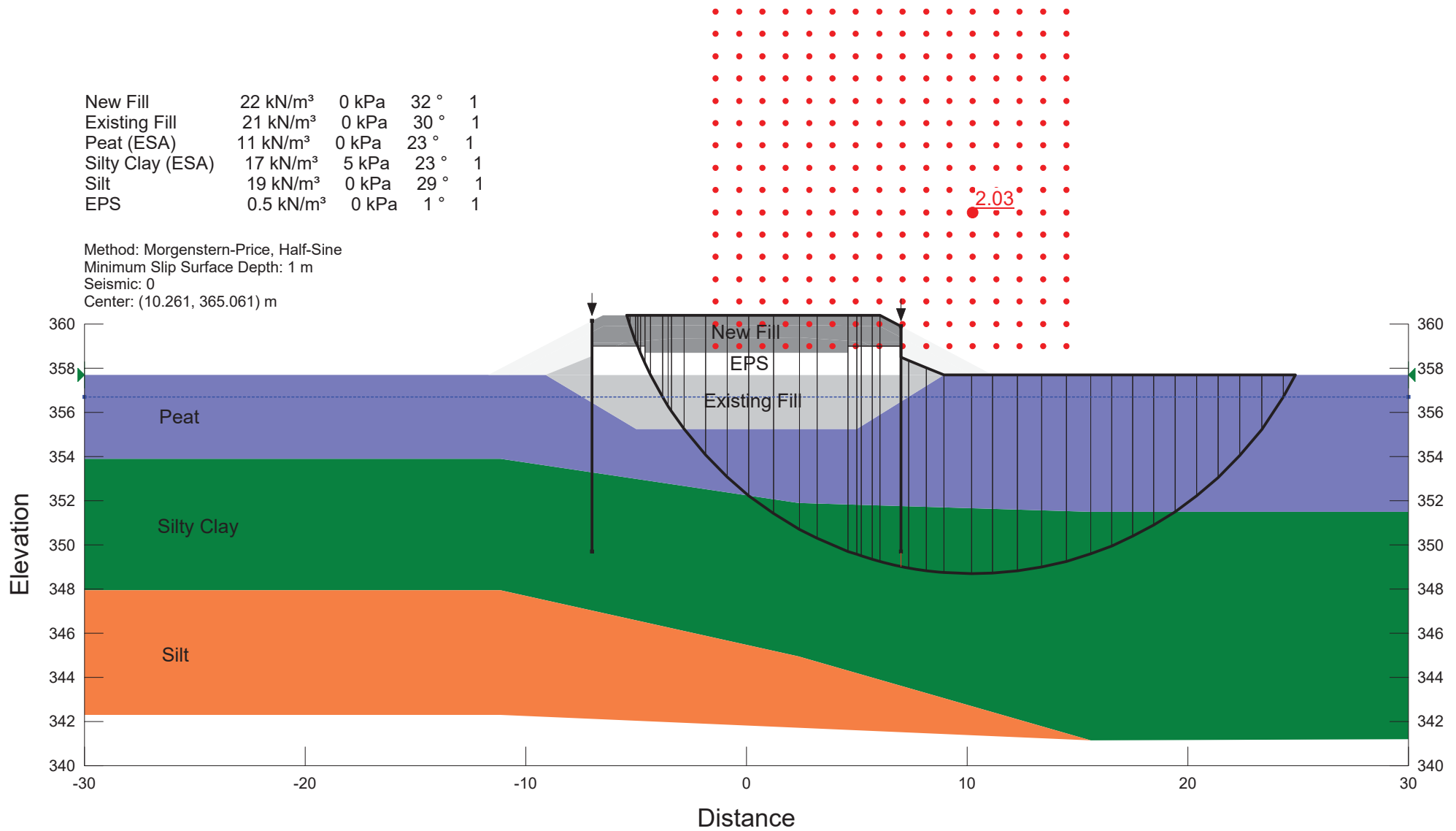
# FINISHED EMBANKMENT SIDESLOPE WITH SHEET PILES, EPS AND GRADE RAISE TSA (STA. 17+725) MOOSE CREEK BRIDGE REPLACEMENT

FIGURE F7A



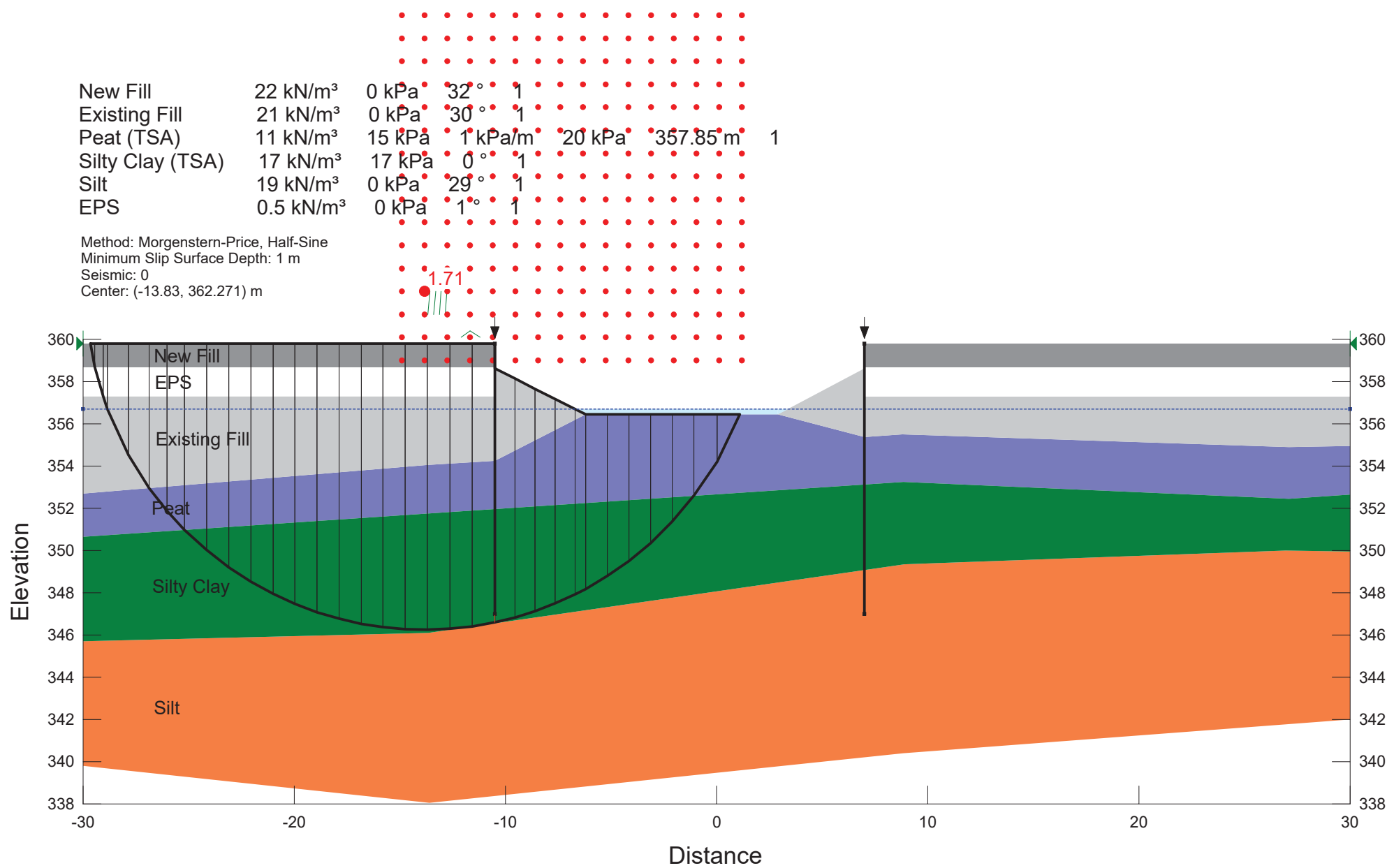
# FINISHED EMBANKMENT SIDESLOPE WITH SHEET PILES, EPS AND GRADE RAISE ESA (STA. 17+725) MOOSE CREEK BRIDGE REPLACEMENT

FIGURE F7B



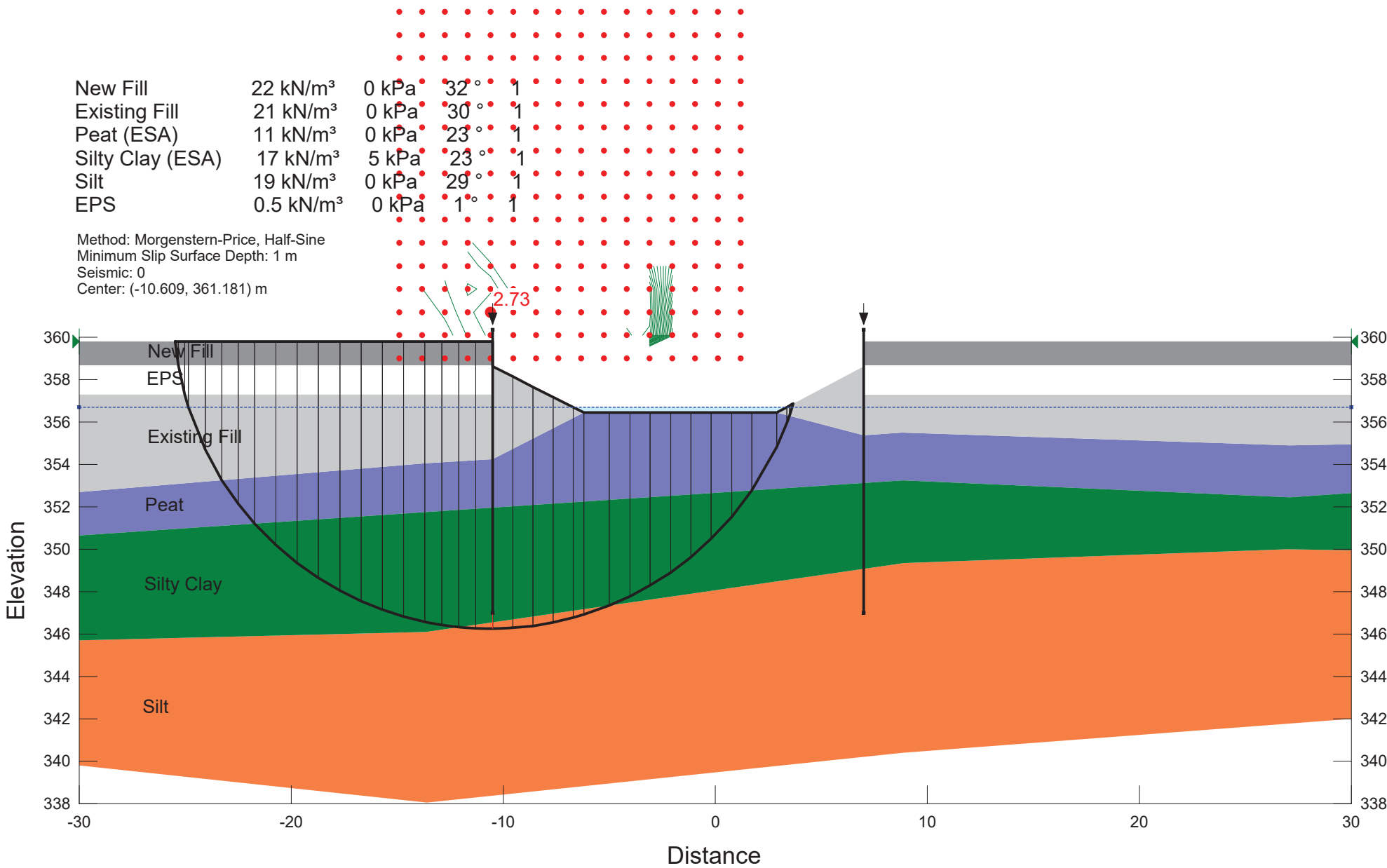
FINISHED ABUTMENT FORESLOPE WITH SHEET PILES, EPS AND GRADE RAISE TSA  
MOOSE CREEK BRIDGE REPLACEMENT

FIGURE F8A



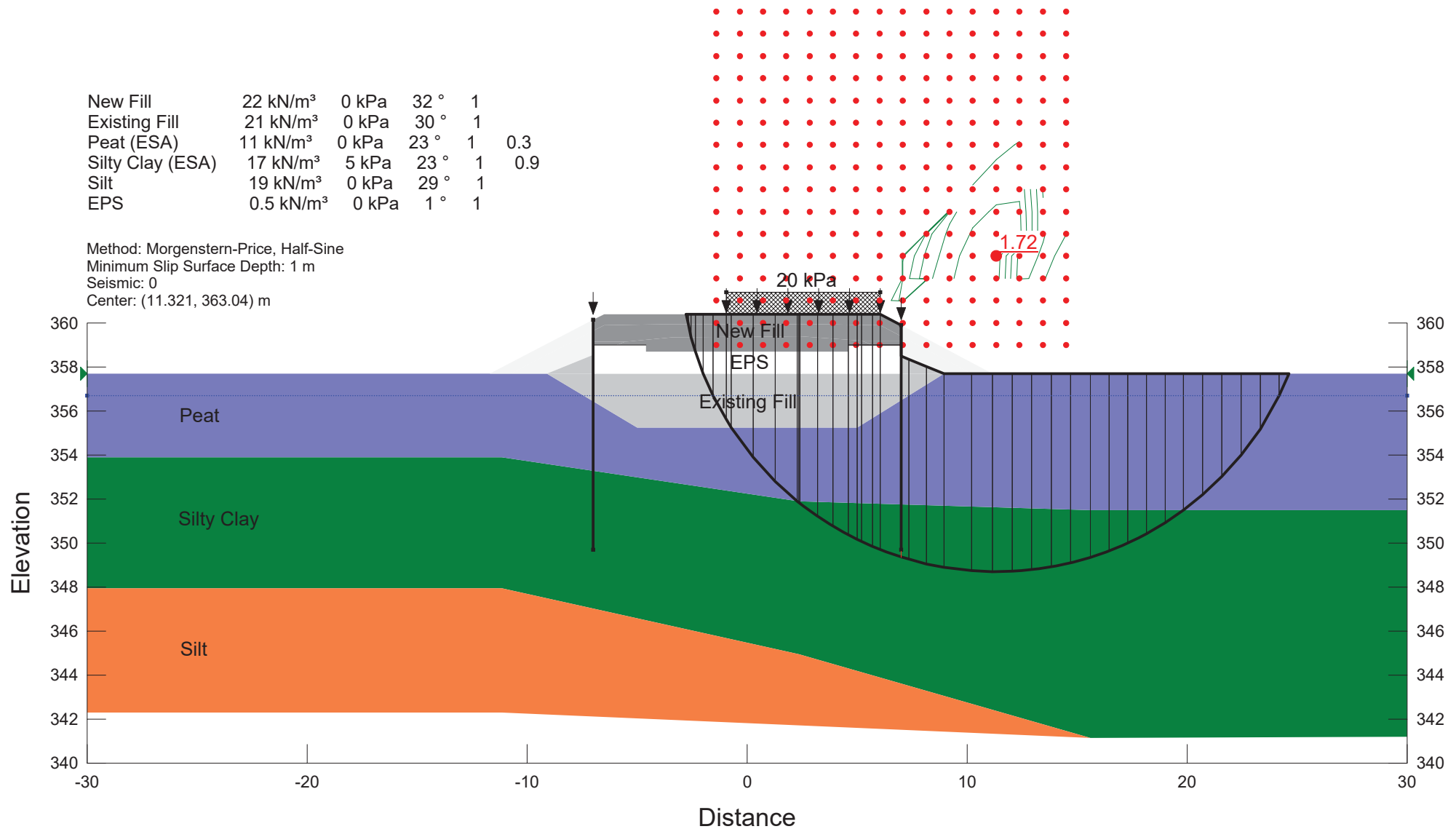
FINISHED ABUTMENT FORESLOPE WITH SHEET PILES, EPS AND GRADE RAISE ESA  
MOOSE CREEK BRIDGE REPLACEMENT

FIGURE F8B



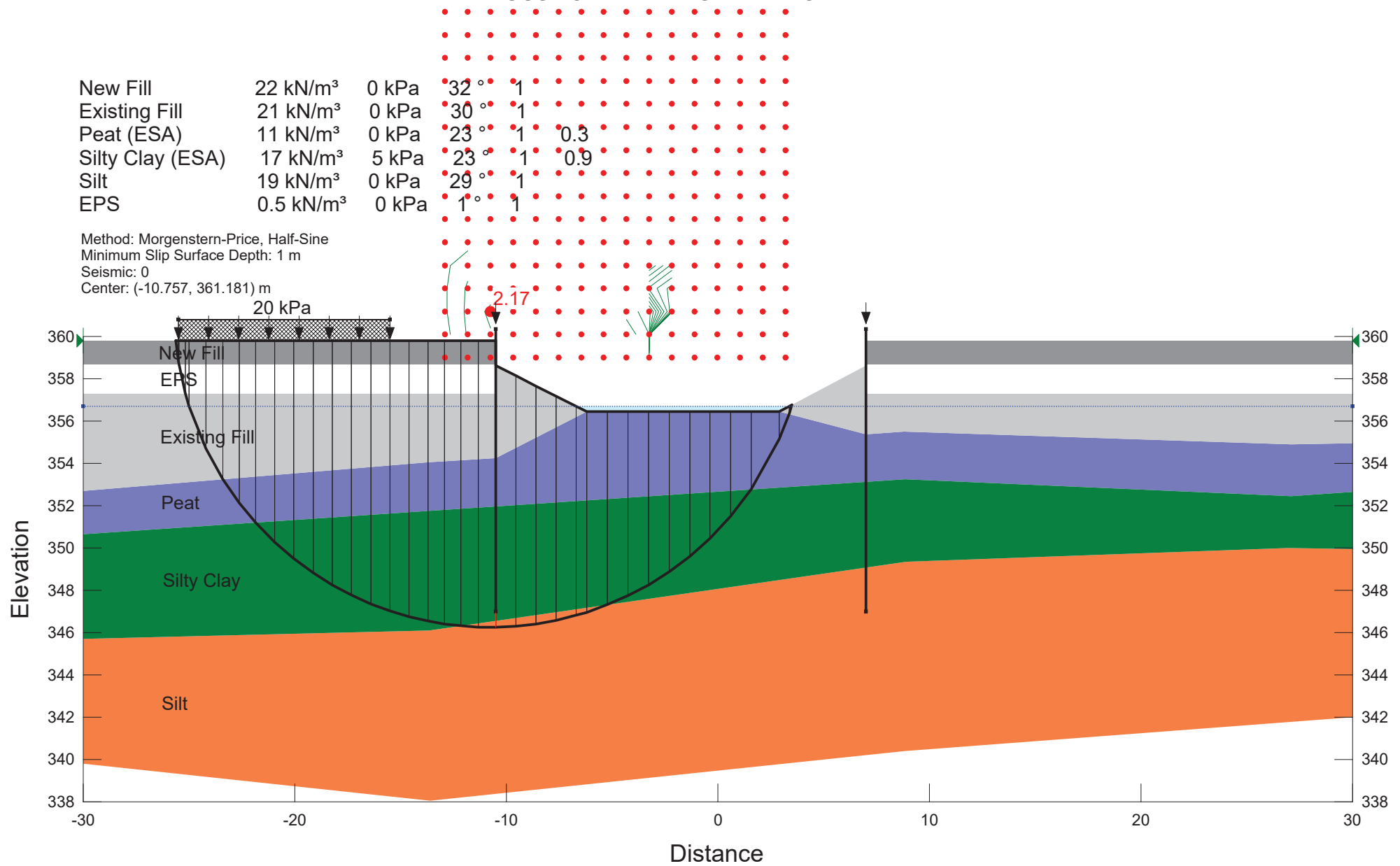
**FINISHED EMBANKMENT SIDESLOPE WITH SHEET PILES, EPS AND GRADE RAISE  
PLUS 20 kPa CRANE LOADING ESA (STA. 17+725)  
MOOSE CREEK BRIDGE REPLACEMENT**

**FIGURE F9A**



# **FINISHED ABUTMENT FORESLOPE WITH SHEET PILES, EPS AND GRADE RAISE PLUS 20 kPa CRANE LOADING ESA MOOSE CREEK BRIDGE REPLACEMENT**

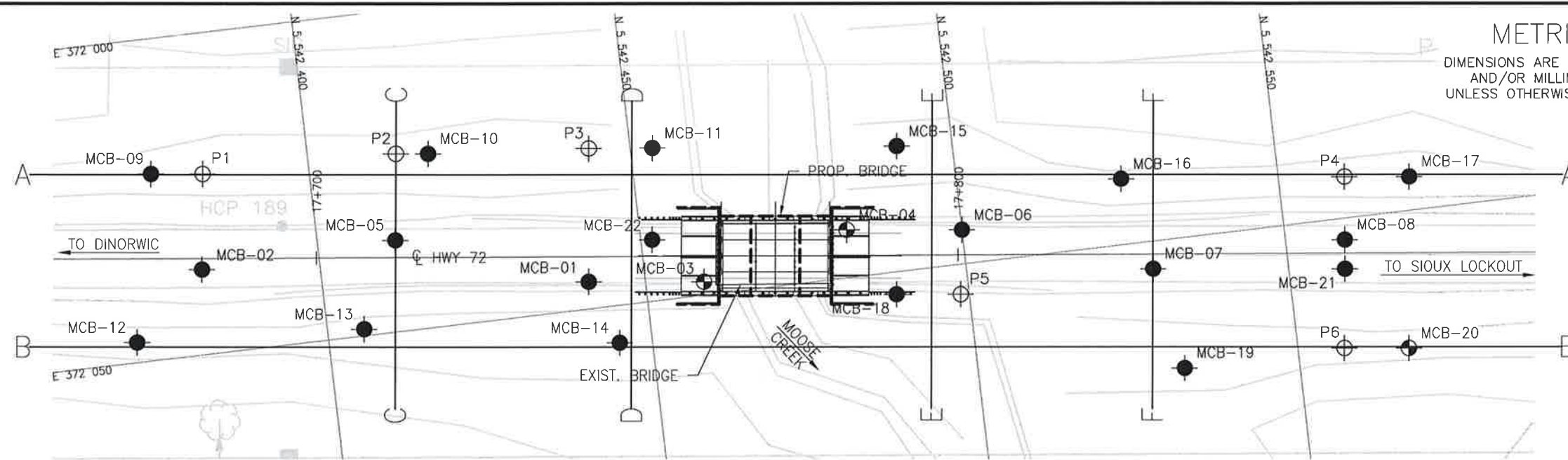
**FIGURE F9B**



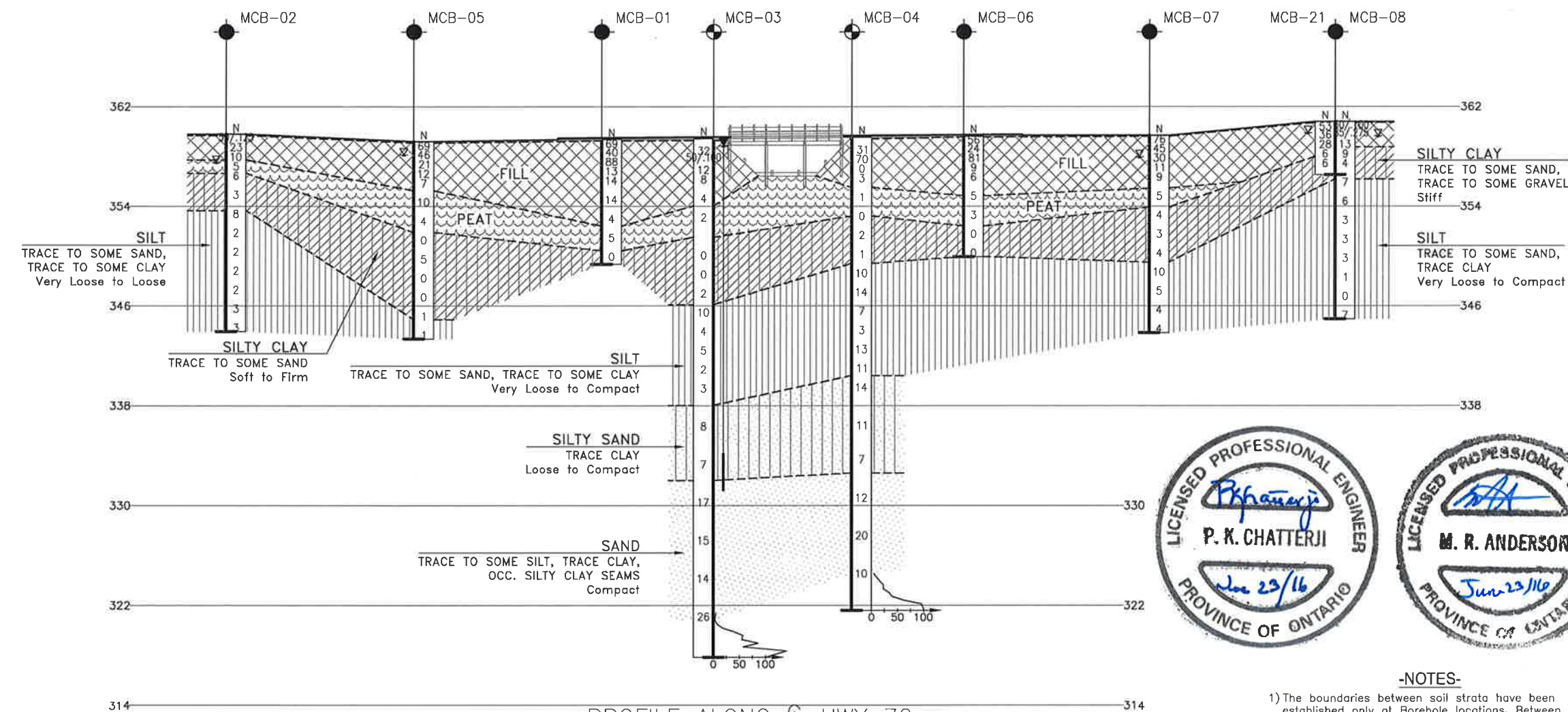
## **Appendix G**

### **Borehole Locations and Soil Strata Drawings**





PLAN  
SCALE 1:800



PROFILE ALONG C HWY 72  
H 1:800  
V 1:400



-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.

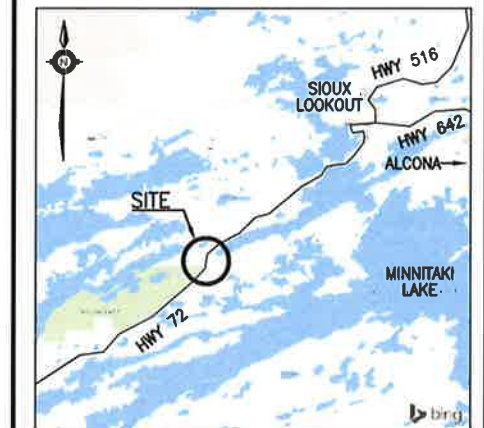
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DESIGN	AMP	CHK PKC CODE
DRAWN	AN	CHK AMP SITE 415-16 STRUCT DWG 2

CONT No  
WP No 473-00-01

HIGHWAY 72  
MOOSE CREEK  
BRIDGE REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA

MMM GROUP

THURBER ENGINEERING LTD.



KEYPLAN  
SCALE 1:500,000

LEGEND

- Borehole
- DCPT (Dynamic Cone Penetration Test)
- Probe (Hand Auger)
- Blows /0.3m (Std Pen Test, 475J/blow)
- Blows /0.3m (60' Cone, 475J/blow)
- Water Level In Open Borehole
- Water Level In Piezometer
- Auger Refusal

NO	ELEVATION	NORTHING	EASTING
MCB-01	359.4	5 542 441.2	372 045.8
MCB-02	359.8	5 542 381.7	372 036.8
MCB-03	359.5	5 542 459.0	372 047.9
MCB-04	359.6	5 542 482.1	372 042.6
MCB-05	359.2	5 542 412.0	372 035.8
MCB-06	359.7	5 542 500.0	372 044.7
MCB-07	359.7	5 542 528.9	372 054.3
MCB-08	360.8	5 542 559.2	372 053.3
MCB-09	358.2	5 542 375.5	372 021.0
MCB-10	357.6	5 542 418.6	372 023.0
MCB-11	357.5	5 542 453.5	372 026.3
MCB-12	358.6	5 542 370.4	372 046.9
MCB-13	358.2	5 542 405.6	372 049.0
MCB-14	357.7	5 542 444.9	372 055.8
MCB-15	357.4	5 542 491.4	372 030.5
MCB-16	358.3	5 542 525.6	372 039.8
MCB-17	359.8	5 542 570.3	372 044.7
MCB-18	357.0	5 542 488.7	372 053.5
MCB-19	357.7	5 542 532.0	372 070.2
MCB-20	358.1	5 542 567.2	372 071.3
MCB-21	360.8	5 542 558.7	372 057.8
MCB-22	359.2	5 542 451.8	372 040.5

GEOCRE No. 52K-014

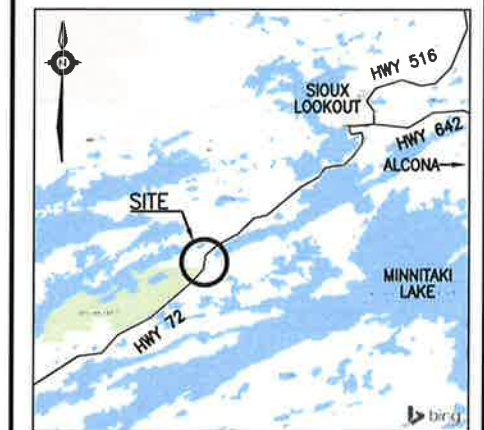


## METRIC

DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWNCONT No  
WP No 473-00-01HIGHWAY 72  
MOOSE CREEK  
BRIDGE REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATASHEET  
19

MMM GROUP

THURBER ENGINEERING LTD.

KEYPLAN  
5.0 km 0 5.0 km  
SCALE 1:500,000

## LEGEND

●	Borehole
⊕	DCPT (Dynamic Cone Penetration Test)
⊙	Probe (Hand Auger)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
▽	Water Level in Open Borehole
↑	Water Level in Piezometer
A/R	Auger Refusal

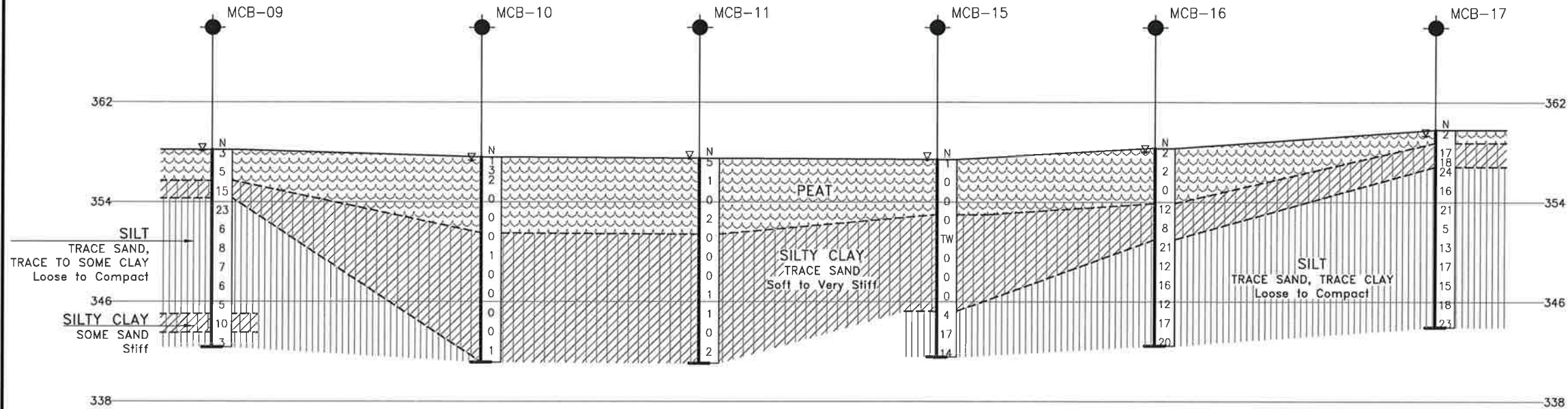
NO	ELEVATION	NORTHING	EASTING
MCB-01	359.4	5 542 441.2	372 045.8
MCB-02	359.8	5 542 381.7	372 036.8
MCB-03	359.5	5 542 459.0	372 047.9
MCB-04	359.6	5 542 482.1	372 042.6
MCB-05	359.2	5 542 412.0	372 035.8
MCB-06	359.7	5 542 500.0	372 044.7
MCB-07	359.7	5 542 528.9	372 054.3
MCB-08	360.8	5 542 559.2	372 053.3
MCB-09	358.2	5 542 375.5	372 021.0
MCB-10	357.6	5 542 418.6	372 023.0
MCB-11	357.5	5 542 453.5	372 026.3
MCB-12	358.6	5 542 370.4	372 046.9
MCB-13	358.2	5 542 405.6	372 049.0
MCB-14	357.7	5 542 444.9	372 055.8
MCB-15	357.4	5 542 491.4	372 030.5
MCB-16	358.3	5 542 525.6	372 039.8
MCB-17	359.8	5 542 570.3	372 044.7
MCB-18	357.0	5 542 488.7	372 053.5
MCB-19	357.7	5 542 532.0	372 070.2
MCB-20	358.1	5 542 567.2	372 071.3
MCB-21	360.8	5 542 558.7	372 057.8
MCB-22	359.2	5 542 451.8	372 040.5

GEOCRES No. 52K-014

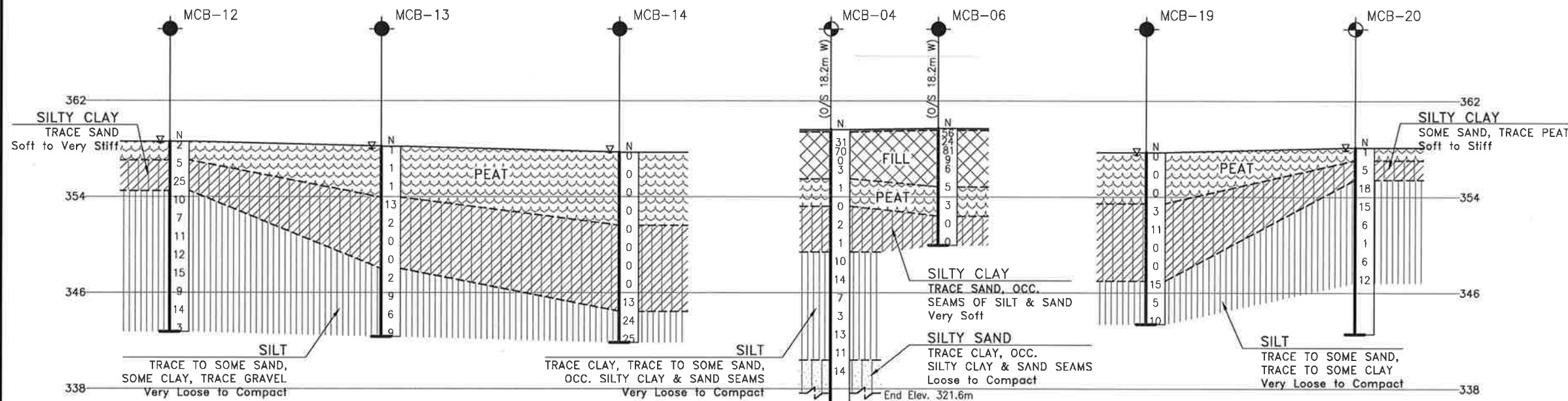
## -NOTES-

- 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.

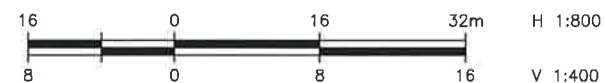
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LOAD	DATE	JUN 2016	



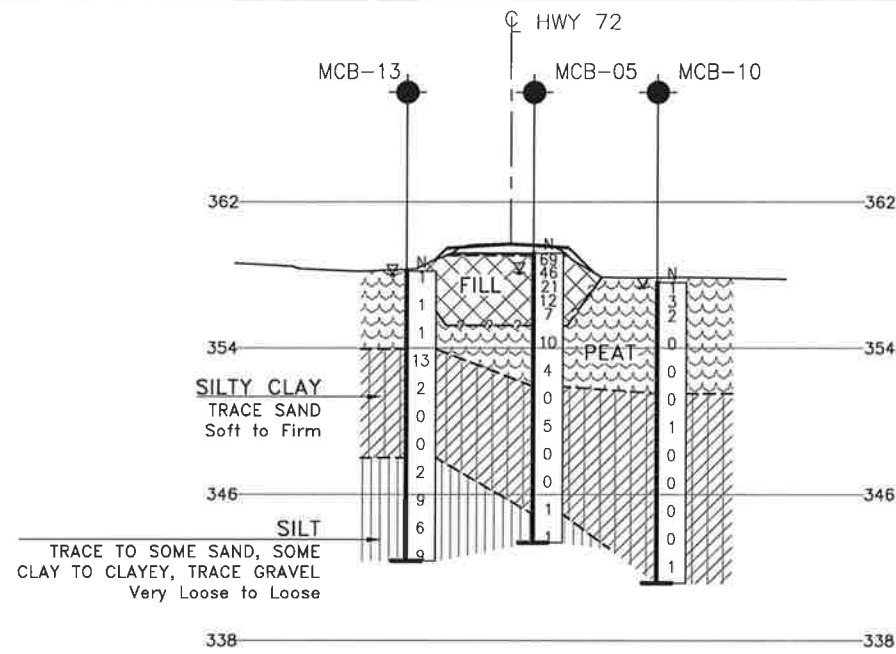
PROFILE ALONG A-A (WEST)



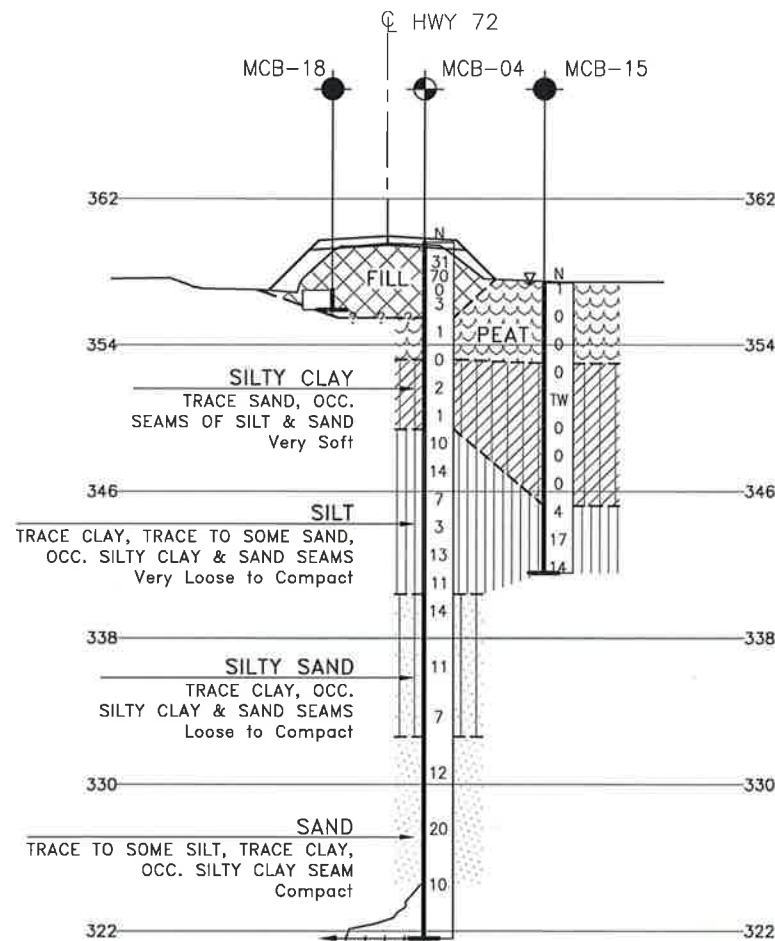
PROFILE ALONG B-B (EAST)



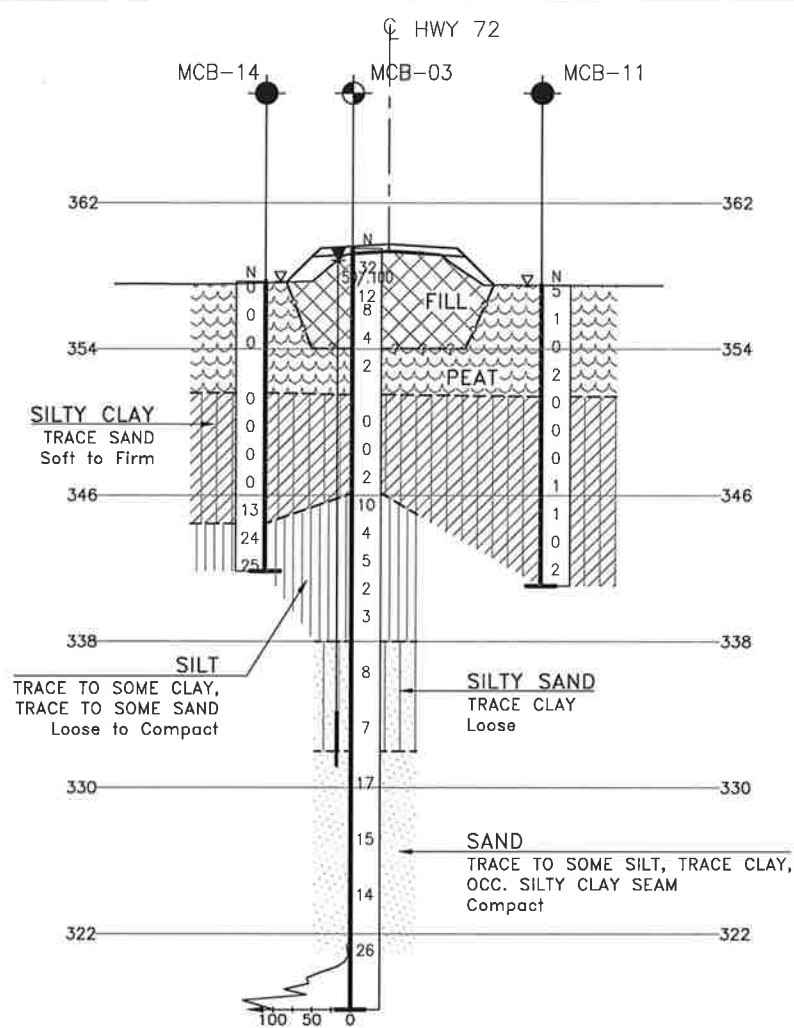




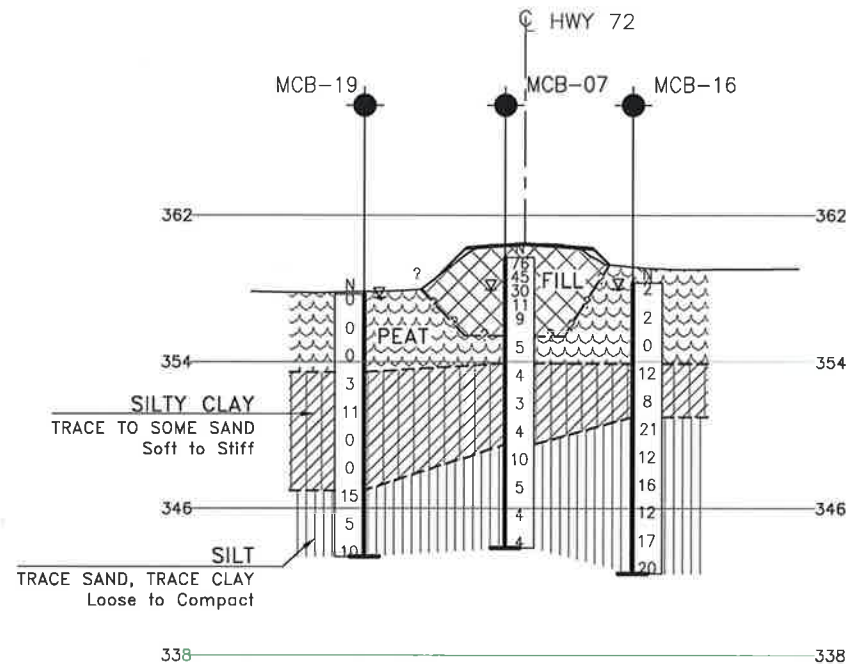
PROFILE ALONG C-C



PROFILE ALONG E-E



PROFILE ALONG D-D



PROFILE ALONG F-F

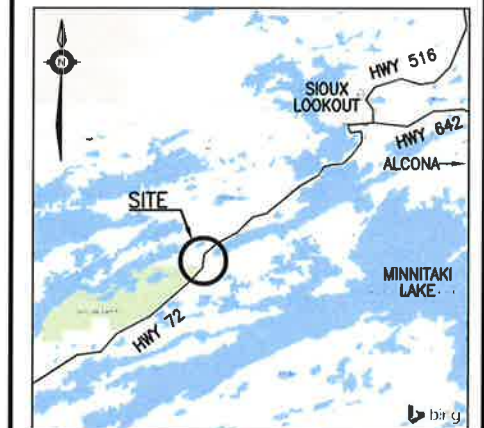


METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

CONT No  
WP No 473-00-01

HIGHWAY 72  
MOOSE CREEK  
BRIDGE REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET  
20



KEYPLAN

5.0 km 0 5.0 km  
SCALE 1:500,000

LEGEND

●	Borehole
⊕	DCPT (Dynamic Cone Penetration Test)
⊙	Probe (Hand Auger)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
W	Water Level In Open Borehole
P	Water Level In Piezometer
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
MCB-01	359.4	5 542 441.2	372 045.8
MCB-02	359.8	5 542 381.7	372 036.8
MCB-03	359.5	5 542 459.0	372 047.9
MCB-04	359.6	5 542 482.1	372 042.6
MCB-05	359.2	5 542 412.0	372 035.8
MCB-06	359.7	5 542 500.0	372 044.7
MCB-07	359.7	5 542 528.9	372 054.3
MCB-08	360.8	5 542 559.2	372 053.3
MCB-09	358.2	5 542 375.5	372 021.0
MCB-10	357.6	5 542 418.6	372 023.0
MCB-11	357.5	5 542 453.5	372 026.3
MCB-12	358.6	5 542 370.4	372 046.9
MCB-13	358.2	5 542 405.6	372 049.0
MCB-14	357.7	5 542 444.9	372 055.8
MCB-15	357.4	5 542 491.4	372 030.5
MCB-16	358.3	5 542 525.6	372 039.8
MCB-17	359.8	5 542 570.3	372 044.7
MCB-18	357.0	5 542 488.7	372 053.5
MCB-19	357.7	5 542 532.0	372 070.2
MCB-20	358.1	5 542 567.2	372 071.3
MCB-21	360.8	5 542 558.7	372 057.8
MCB-22	359.2	5 542 451.8	372 040.5

GEOCREs No. 52K-014



-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.

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	AMP	CHK	PKC
DRAWN	AN	CHK	AMP
SITE	41S-16	STRUCT	DWG 4
LOAD	DATE	JUN 2016	