



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
MILLER'S CREEK CULVERT REPLACEMENT (SITE NO. 45X-0153/C0)
HIGHWAY 11, DISTRICT OF RAINY RIVER, ONTARIO
AGREEMENT 6019-E-0023, WORK ORDER 22
G.W.P. 6121-17-00; W.P. 6121-17-01**

GEOCRES NO. 52D10-001

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PART A: FACTUAL INFORMATION

1. INTRODUCTION

Thurber Engineering (Thurber) has been retained by Hatch on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services to support the preliminary design of the replacement of Miller's Creek Culvert on Highway 11 near Rainy River, under Work Item No. 22 of Agreement No. 6019-E-0023.

This report presents the results of the foundation investigation carried out for the proposed culvert replacement 8.6 km west of Highway 11/621 intersection, referred to as Miller's Creek Culvert, in the Township of Atwood, Ontario.

The purpose of this investigation was to explore the subsurface conditions at the culvert site by borehole drilling and laboratory testing and to prepare a borehole location plan, stratigraphic profiles, records of boreholes, laboratory test results, and a description of the subsurface conditions.

It is a condition of this report that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

2. SITE DESCRIPTION

The existing Miller's Creek Culvert is a twin-culvert site, located on Highway 11, approximately 8.6 km west of the intersection with Highway 621 near Rainy River, Ontario. Details of the existing twin culvert are as follows:

Township and Station	Culvert Size and Type	Length of Culvert (m)	Invert Elevation at Inlet (m) (North)	Invert Elevation at Outlet (m) (South)
Atwood STA 10+225	Diameter: 2.7 m (each) Corrugated Steel Pipe Culverts (x 2)	33.1 (each)	322.0 (West Culvert)	322.0 (West Culvert)
			322.1 (East Culvert)	322.2 (East Culvert)

The existing Miller's Creek culverts were originally constructed in 2001.

The existing twin culvert allows flow in a north to south direction under the highway embankment with approximately 3.2 m of fill above the twin culvert obverts. The surface of the highway is at approximately Elev. 328.0 m. Near the culvert, the embankment slopes have a gradient of about 1.5H:1V to 2H:1V.

There are existing CN tracks approximately 15 m north of the inlets of the Miller's Creek Culverts. There are twin culverts under the CN tracks; the CN culverts have bevelled ends and are each approximately 2.4 m in diameter and 51.1 m in length. Please refer to the Site Plan included in Appendix A for the location of nearby site features for Miller's Creek.

The 2017 OSIM Report for the Miller's Creek culverts reports settlements of 300 mm for the west CSP culvert and 200 mm for the east CSP culvert at the highway centreline. MTO's discussion with the maintenance staff indicated they noted no settlement issues at the Miller's Creek culverts. There is no settlement monitoring data available to confirm culvert settlements.

Based on visual observation, no signs of slope instability were observed near the inlet and outlet of the culvert site; however, minor erosion of the embankment was observed near the twin culvert inlet. The culvert inlet was surrounded by grass, small trees, and had cobbles and boulders at surface, while the outlet was generally surrounded by grass. Overhead wires are present along the north side of the highway (i.e. beyond the shoulder of the westbound lane). Site photographs are provided in Appendix A.

Highway 11 comprises two paved lanes with narrow, partially paved shoulders.

3. INVESTIGATION PROCEDURES

3.1 Field Investigation

The field investigation and testing for this project was carried out between July 20 and July 25, 2023, and consisted of drilling and sampling seven boreholes, designated as Boreholes 23-01,

23-01-PVT, 23-02, 23-03, 23-03B, 23-04, and 23-04-PVT. All boreholes were advanced through the highway embankment, to depths of between 3.0 m and 20.9 m (Elev. 325.2 m and 307.2 m).

The Record of Borehole sheets for the boreholes are included in Appendix B.

Utility clearances were obtained prior to mobilization to the site. The borehole co-ordinates and elevations were determined using the digital terrain model CAD file from Hatch. The coordinate system MTM NAD 83, Zone 16 was used for the boreholes.

All boreholes were drilled with a truck-mounted Diedrich 90 drill rig using 105 mm outside diameter solid stem augers and HQ casing employing wash boring technique. HQ Coring was used to continue borehole advancement in Boreholes 23-01 and 23-03 where cobbles and wood were encountered. Soil samples were obtained at selected intervals using split-spoon samplers in general accordance with ASTM D1586.

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

Groundwater conditions observed in open boreholes are not considered stabilized due to the introduction of water throughout the drilling operations. One monitoring well was installed in Borehole 23-02 to measure groundwater levels and conduct groundwater sampling and slug testing during the field program, and was decommissioned prior to demobilization from site. Groundwater level readings observed upon completion of drilling are shown on the Record of Borehole sheets. The borehole completion details are summarized below.

Borehole	Borehole Depth / Borehole Termination Elevation (m)	Northing and Easting MTM NAD83 Zone 16	Completion Details
23-01	20.8 / 307.7	N 5,399,349.9 E 191,049.5	Backfilled with bentonite holeplug granular, and asphalt patch at surface.
23-01-PVT	3.0 / 325.2	N 5,399,352.2 E 191,063.2	Backfilled with bentonite holeplug and asphalt patch at surface.
23-02	20.4 / 307.6	N 5,399,352.3 E 191,072.5	Monitoring well installed. Decommissioned and backfilled with bentonite holeplug and asphalt patch at surface.
23-03	6.1 / 321.9	N 5,399,348.7 E 191,084.4	Backfilled with bentonite holeplug and asphalt patch at surface.
23-03B	20.4 / 307.6	N 5,399,348.8 E 191,086.4	Backfilled with bentonite holeplug and asphalt patch surface.

Borehole	Borehole Depth / Borehole Termination Elevation (m)	Northing and Easting MTM NAD83 Zone 16	Completion Details
23-04	20.9 / 307.2	N 5,399,351.5 E 191,102.8	Backfilled with bentonite holeplug and asphalt patch surface.
23-04-PVT	3.0 / 325.0	N 5,399,348.0 E 191,093.2	Backfilled with bentonite holeplug and asphalt patch surface.

Boreholes 23-02, 23-03, and 23-03B were drilled in the vicinity of the culvert. Boreholes 23-01 and 23-04 were drilled for design of temporary protection systems (TPS) and potential foundation design of temporary modular bridge (TMB).

3.2 Laboratory Testing

All recovered soil samples were subjected to visual identification (VI) and natural moisture content determination. Selected samples were subjected to grain size distribution analyses (sieve and hydrometer), Atterberg Limits testing. Three incremental loading consolidation tests were carried out on samples recovered from the sandy clayey silt to sandy silty clay deposit. The results of this testing program are summarized on the Record of Borehole sheets in Appendix B and are shown on the figures included in Appendix C.

Testing was carried out on samples of the native soil to assess the potential for sulphate attack on buried concrete structures, as well as the potential for corrosion associated with buried steel elements of the structures. The results of the analytical testing are summarized in Section 6 of this report and presented in Appendix C.

4. SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain Study (NOEGTS) mapping, the Miller's Creek Culverts site lies on a glaciolacustrine plain with an alluvial plain to the south, and the primary materials are clay and clayey silts. The site topography in the area surrounding the culvert is a low relief.

From the Ontario Geological Survey Bedrock Geology map, the site lies within an area underlain by mafic and ultramafic igneous bedrock (such as gabbro and anorthosite). From available Ministry of Environment (MOE) Well Records, where bedrock was encountered and noted on the records, the depth to bedrock in Rainy River, in the vicinity of the culvert site, was about 29 m.

4.2 Subsurface Conditions

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and interpreted stratigraphic profile and section are presented on the Borehole Locations and Soil Strata Drawings in Appendix D. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following sections. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description for interpretation of the site conditions. Classification and descriptions of coarse and fine-grained soils are made in accordance with ASTM D2487, and MTO's Soil Classification Manual (as amended), respectively.

The boundaries between soil deposits on the record of boreholes have been inferred from non-continuous sampling, observation of the progress of drilling, and the results of Standard Penetration Testing and HQ coring. Therefore, the boundaries represent the transitions between soil deposits rather than exact planes of geological change. Variation on the stratigraphic boundaries between and beyond boreholes will exist and is to be expected.

In general, the subsurface conditions encountered consisted of non-cohesive and cohesive embankment fill, underlain by native deposits of sand to sandy silt and organic silt, which in turn is underlain by a sandy clayey silt to sandy silty clay deposit, and a lower silty sand and gravel and clayey sand deposit.

4.3 Asphalt

All boreholes were advanced through the paved portion of Highway 11, and the measured thickness of the asphalt ranged between 255 mm and 290 mm.

4.4 Embankment Fill

Non-cohesive embankment fill consisting of sand to silty sand to sandy silt, trace gravel to gravelly, trace to some fines, was encountered immediately below the asphalt in all boreholes. The sand to silty sand to sandy silt fill layer ranged in thickness from 1.5 m to 4.9 m and extended to depths of 1.8 m to 5.2 m (Elev. 326.3 m to 322.8 m). Sandy silty gravel fill was encountered at a depth of 3.8 m in Borehole 23-02 below the sand fill layer and extended to a depth of 7.2 m (Elev. 320.8 m). A recovered sample of this layer from Borehole 23-03 was observed to contain concrete pieces. Borehole 23-01-PVT was terminated in the sandy silt fill at a depth of 3.0 m (Elev. 325.2 m).

Cohesive embankment fill consisting of sandy silty clay to silty clay, some gravel was encountered in Boreholes 23-04 and 23-04-PVT at depths of 1.8 and 2.4 m (Elev. 326.3 m and 325.6 m). The sandy silty clay to silty clay fill layer was measured to be 1.6 m to at least 0.6 m thick and extended to depths of 3.4 m (324.7 m) to at least 3.0 m (Elev. 325.0 m). Borehole 23-04-PVT was terminated in this fill layer. Clayey silt and sand, trace gravel fill was encountered in Borehole 23-01 at a depth of 2.3 m (Elev. 326.3 m). The clayey silt and sand fill layer was measured to be 2.6 m thick and extended to a depth of 4.9 m (Elev. 323.7 m).

SPT 'N' values recorded in the non-cohesive embankment fill generally ranged from 12 blows to 62 blows per 0.3 m penetration, indicating a compact to very dense condition. However, an SPT 'N' value of 83 blows per 0.3 m of penetration was also recorded in Borehole 23-03 at a depth from 4.5 m to 5.2 m, where concrete pieces were recovered. SPT 'N' values recorded in the cohesive embankment fill generally ranged from 8 blows to 35 blows per 0.3 m penetration, suggesting a stiff to hard consistency. A SPT 'N'-value of 0 (i.e. weight of hammer) was measured in Borehole 23-01. The measured moisture contents in the embankment fill generally ranged from 7 per cent to 29 per cent. A sample of the cohesive fill from Borehole 23-04 measured a moisture content of about 52 per cent.

The results of grain size analyses carried out on selected samples of the non-cohesive and cohesive embankment fill are shown on the Record of Borehole sheets in Appendix B and presented in Figures C1 and C2 of Appendix C. The results are summarized as follows:

Soil Particle	Percentage (%) Non-Cohesive Fill	Percentage (%) Cohesive Fill
Gravel	7 to 49	3
Sand	30 to 73	38
Silt	-	38
Clay	-	21
Silt and Clay	10 to 25	-

The results of the Atterberg Limits test carried out on a sample of the fines portion of the clayey silt and sand embankment fill is shown on the Record of Borehole logs in Appendix B and presented in Figure C3 of Appendix C. The result is summarized as follows:

Index Property	Percentage (%)
Liquid Limit	31
Plastic Limit	17
Plastic Index	14

The results of the Atterberg Limits testing indicate the material is clay of low plasticity (CL).

4.5 Wood

Approximately 0.9 m of wood was encountered below the sand fill in Borehole 23-03 at a depth of 5.2 m (Elev. 322.8). A photograph of the recovered wood sample, collected by HQ coring, is presented in Photograph 9 of Appendix A.

Borehole 23-03 was terminated at a depth of 6.1 m after recovering the cored wood, and sampling below this depth was resumed in Borehole 23-03B, located approximately 2.0 m east of Borehole 23-03.

Concrete pieces (possible debris and rubble) were encountered above the wood in Borehole 23-03. Discussion with MTO indicates that no wood was used to construct the road and the piece of wood is likely a random piece in the fill that was placed for the existing culvert. However, if additional concrete rubble or wood is encountered near the subgrade during excavation for the replacement of the culvert, such materials must be sub-excavated from the subgrade and replaced with compacted granular fill.

4.6 Organic Silt

An approximately 0.3 m thick layer of organic silt was encountered below the sandy silty clay to silty clay fill at a depth of 3.4 m in Borehole 23-04 (Elev. 324.7 m).

The SPT 'N' value measured in the organic silt was 9 blows per 0.3 m of penetration, indicating a loose relative density. The measured moisture content was 19 per cent.

4.7 Sand to Sandy Silt

A deposit of sand to sandy silt was encountered below the cohesive embankment fill at depths of 4.9 m and 3.7 m in Boreholes 23-01 and 23-04 (Elev. 323.7 m and 324.4 m), respectively. The deposit was measured to be about 1.2 m and 1.9 m thick in Boreholes 23-01 and 23-04, respectively.

SPT 'N' values recorded in the sand to sandy silt ranged from 5 blows to 11 blows per 0.3 m of penetration, indicating a loose to compact condition. The measured moisture contents generally ranged between 17 per cent and 26 per cent. A moisture content of 39 per cent was also measured in this deposit.

4.8 Sandy Clayey Silt to Sandy Silty Clay

A deposit of clayey silt to silty clay, some sand to sandy, trace gravel was encountered below the sand at a depth of 6.1 m in Borehole 23-01 (Elev. 322.4 m) below the silty sand to sandy silt at a depth of 5.6 m in Borehole 23-04 (Elev. 322.5 m), and below the sand to sandy silty gravel embankment fill in Boreholes 23-02 and Borehole 23-03 at depths of 7.2 m and at least 6.1 m (Elev. 320.8 and at least 321.9 m in the adjacent Borehole 23-03B), respectively. The deposit was measured to be about 13.7 m and 12.6 m thick in Boreholes 23-01 and 23-02. The deposit was measured at least 13.4 m and 15.3 m thick in Boreholes 23-03B and 23-04, respectively, which were terminated in this deposit.

SPT 'N' values recorded in the clayey silt to silty clay generally ranged from 0 blows (i.e. weight of hammer) to 12 blows per 0.3 m of penetration. The measured moisture contents generally ranged between 22 per cent and 30 per cent, with some moisture contents of 35 per cent to 44 per cent measured in this deposit. Field shear vane tests performed in the sandy clayey silt to sandy silty clay measured undrained shear strengths ranging from 42 kPa to greater than 162 kPa, suggesting firm to very stiff consistency with sensitivity values between approximately 1 and 3.

The results of grain size analysis carried out on samples of the sandy clayey silt to sandy silty clay deposit is shown on the Record of Borehole sheets in Appendix B and presented in Figures C4A and 4B of Appendix C. The result is summarized as follows:

Soil Particle	Percentage (%)
Gravel	0 to 6
Sand	12 to 30
Silt	41 to 63
Clay	19 to 34

The results of the Atterberg Limits tests carried out on samples of the sandy clayey silt to sandy silty clay deposit is shown on the Record of Borehole logs in Appendix B and presented in Figures C5A and 5B of Appendix C. The result is summarized as follows:

Index Property	Percentage (%)
Liquid Limit	27 to 45
Plastic Limit	18 to 23
Plastic Index	10 to 23

The results of the Atterberg Limits testing indicate the material is clay of low plasticity (CL) to clay of intermediate plasticity (CI).

The results of incremental loading consolidation tests performed on three (3) samples of the clayey silt to silty clay deposit are summarized in the table below and included in Appendix C.

Table 5.1 – Summary of IL Consolidation Test Results

Borehole	23-02	23-02	23-03B
Test Type	Incremental Loading	Incremental Loading	Incremental Loading
Sample No.	TP10	TP12	TP5
Depth (m)	11.0	14.0	12.5
Elevation (m)	317.0	314	315.5
Soil Type	Silty Clay (CI)	Silty Clay (CI)	Silty Clay (CI)
Initial moisture content	27	27	24
Bulk Unit Weight (kN/m ³)	19.6	19.1	20.1
e ₀ - Initial Void Ratio	0.714	0.760	0.635
P ₀ - In situ effective vertical stress (kPa)	165	195	180
P _c - Preconsolidation Pressure (kPa)	246	239	208
OCR - Overconsolidation Ratio	1.5	1.2	1.2
C _c - Compression Index	0.277	0.258	0.196
Cr - Recompression Index	0.019	0.027	-
C _v – Coefficient of Consolidation in normally-consolidated range (cm ² /yr)	1.1×10 ⁻³ to 9.3×10 ⁻³	1.3×10 ⁻³ to 5.0×10 ⁻³	7.0×10 ⁻⁴ to 2.0×10 ⁻³
C _{vr} – Coefficient of Consolidation in over-consolidated range (cm ² /yr)	1.5×10 ⁻⁴ to 5.0×10 ⁻⁴	3.9×10 ⁻⁴ to 4.8×10 ⁻⁴	1.9×10 ⁻⁴ to 4.4×10 ⁻⁴

4.9 Silty Sand and Gravel

A layer of silty sand and gravel, containing cobbles, was encountered underlying the clayey silt to silty clay deposit at a depth of 19.8 m (Elev. 308.7 m) in Borehole 23-01. The deposit was at least 1.0 m thick. Borehole 23-01 was terminated in this deposit at a depth of 20.8 m (Elev. 307.7 m). Coring was required to advance the borehole through cobbles in this deposit. A photograph of the cobble and gravel-sized pieces recovered from coring is provided in Appendix A (Photograph 8).

The SPT 'N' value recorded in the silty sand and gravel was 50 blows per 0.10 m penetration, indicating a very dense condition, however, the high 'N'-value may be attributed to spoon refusal on a probable cobble. The measured moisture content was 13 per cent.

The results of grain size analyses carried out on a sample of the silty sand and gravel are shown on the Record of Borehole sheets in Appendix B and presented in Figure C6 of Appendix C. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	36
Sand	48
Silt and Clay	16

4.10 Clayey Sand

A deposit of clayey sand, some gravel was encountered underlying the clayey silt to silty clay deposit at a depth of 19.8 m (Elev. 308.2 m) in Borehole 23-02. The deposit was at least 0.6 m thick. Borehole 23-02 was terminated in this deposit at a depth of 20.4 m (Elev. 307.6 m).

The SPT 'N' value recorded in the silty sand and gravel was 30 blows per 0.3 m penetration, indicating a hard condition.

The results of grain size analyses carried out on a sample of the clayey sand are shown on the Record of Borehole sheets in Appendix B and presented in Figure C7 of Appendix C. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	14
Sand	45
Silt	36
Clay	5

4.11 Groundwater Conditions

Details of the water level observed in the boreholes upon completion of drilling and in the monitoring well are presented on the record of boreholes and summarized below.

Borehole	Date of Measurement	Groundwater Level (m)		Remark
		Depth	Elevation	
23-01-PVT	July 22, 2023	-	-	Dry upon completion of drilling.
23-02	July 23, 2023	5.2	322.8	Measured from monitoring well.
23-04-PVT	July 25, 2023	-	-	Dry upon completion of drilling.

The water level in the culvert shown on the General Arrangement Drawing was at Elev. 322.7 m (July 2020), which is about 0.5 m and above the culvert outlet.

The water levels measured in the borehole upon completion of drilling, monitoring well, and creek are short-term observations and subject to seasonal fluctuations. In particular, the water levels may be at a higher elevation during spring and after periods of significant or prolonged precipitation.

4.12 Single Well Response Test

A single-well test was conducted on July 23, 2023 at the monitoring well installed in Borehole 23-02. Hydraulic conductivity estimates were obtained using the Hvorslev method (1951). The hydraulic conductivity for the screened material consisting of sandy silt fill was estimated to be 2.8×10^{-5} m/s.

The hydraulic conductivity value calculated from the in-situ slug test is summarized in the table below.

Monitoring Well	Well Screen Bottom Elevation	Well Screen Top Elevation	Screened Geological Unit	Hydraulic Conductivity (m/s)
23-02	320.4	323.4	Sandy Silt Fill	2.8×10^{-5}

4.13 Groundwater Quality Sampling and Analysis

A groundwater quality sample was collected from the monitoring well installed in 23-02. The groundwater quality sample was sent to AGAT Laboratories (AGAT) for testing against the Provincial Water Quality Objectives (PWQO), and the results are included in Appendix C and summarized in the following table.

Sample ID	Parameter	Criteria	Parameter Limit (mg/L)	Result (mg/L)
23-02 (Groundwater)	Boron (Total)	PWQO – 0.2	mg/L	0.246
	Cobalt (Total)	PWQO -0.0009	mg/L	0.0254
	Copper (Total) ¹	PWQO – 0.05 PWQO (interim) – 0.001	mg/L	0.068
	Iron (Total)	PWQO – 0.3	mg/L	37.2
	Molybdenum (Total)	PWQO – 0.04	mg/L	0.042
	Nickel (Total)	PWQO – 0.025	mg/L	0.053
	Thallium (Total)	PWQO – 0.0003	mg/L	0.0009
	Tungsten (Total)	PWQO - 0.030	mg/L	0.058
	Uranium (Total)	PWQO - 0.005	mg/L	0.0086
	Vanadium (Total)	PWQO - 0.006	mg/L	0.082
	Zinc (Total)	PWQO - 0.03	mg/L	0.117
	Zirconium (Total)	PWQO - 0.004	mg/L	0.021

¹ Copper interim PWQO follows a scale based on measured hardness as CaCO₃. The interim PWQO of 0.001 mg/L is set for water with less than 20 mg/L hardness as CaCO₃. The interim PWQO of 0.005 mg/L is set for water with greater than 20 mg/L hardness as CaCO₃. Hardness (as CaCO₃) was not analyzed. For conservative analysis, the lowest interim PWQO limit of 0.001 mg/L was used.

² Lead interim PWQO and PWQO follows a scale based on measured alkalinity as CaCO₃. The following limits of PWQO are set based on the following:

If alkalinity as CaCO₃ is less than 20 mg/L, then the PWQO limit is 0.005 mg/L. If alkalinity as CaCO₃ is between 20 - 40 mg/L, then the PWQO limit is 0.01 mg/L. If Alkalinity as CaCO₃ is between 40 - 80 mg/L, then the PWQO limit is 0.02 mg/L. If Alkalinity as CaCO₃ is greater than 80 mg/L, then the PWQO limit is 0.025 mg/L.

The following limits of interim PWQO are set based on the following:

If alkalinity as CaCO₃ is less than 30 mg/L, then the PWQO limit is 0.001 mg/L. If Alkalinity as CaCO₃ is between 30 - 80 mg/L, then the PWQO limit is 0.003 mg/L. If Alkalinity as CaCO₃ is greater than 80 mg/L, then the PWQO limit is 0.005 mg/L.

5. OBSTRUCTION

During sampling of Borehole 23-03B, approximately 6.1 m of steel drilling rods and the attached 0.7 m long split-spoon sampler were inadvertently dropped down the borehole and not able to be recovered by the drilling subcontractor, despite several attempts / methods for retrieval. Borehole 23-03B was terminated and the steel rods and split-spoon sampler were abandoned in the borehole. The top of the steel rods is at a depth of approximately 13.6 m at this location (Elev. 314.4 m) and extends to a depth of approximately 20.4 m (Elev. 307.6 m). The top of the abandoned rods should be below the proposed subgrade level (Elev. 321.7 m at the outlet) of the

replacement culvert and the rods should not be encountered during excavation for the culvert replacement.

6. ANALYTICAL LABORATORY TESTING

Two samples of the native sandy silty clay soils at the Miller's Creek Culverts site were submitted for corrosivity analysis and sulphide content. The analytical results for the native soil are presented in Appendix C and are summarized below.

Borehole	23-02	23-03B
Sample	SS11	SS1
Depth (m)	12.2 – 12.8	6.1 – 6.7
Elevation (m)	315.8 – 315.2	321.9 – 321.3
Sulphide (%)	0.25	0.09
Chloride (µg/g)	3	78
Sulphate (µg/g)	863	411
pH	8.15	8.26
Conductivity (mS/cm)	0.992	0.630
Resistivity (Ohm-cm)	1,010	1,590

7. MISCELLANEOUS

RPM Drilling of Thunder Bay, Ontario supplied and operated the drilling, sampling, and in-situ testing equipment for the field investigation. The field investigation was supervised on a full-time basis by Mr. Matthew Macaskill, EIT. The overall management of the field program was conducted by Ms. Alysha Kobylinski, P.Eng.

Geotechnical laboratory testing on soil samples was carried out in Thurber's geotechnical laboratory. Testing for corrosivity potential of soil was carried out by Agat Laboratories, a CALA accredited analytical laboratory in Mississauga, Ontario.

Interpretation of the field data and preparation of this report was carried out by Ms. Alysha Kobylinski, P.Eng and Ian Ross, EIT. The report was reviewed by Dr. P.K. Chatterji, Ph.D., P.Eng., a Designated Principal Contact for MTO Foundations Projects at Thurber.



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Date: **December 7, 2023**
File: **36227**

**FOUNDATION DESIGN REPORT
MILLER'S CREEK CULVERT REPLACEMENT (SITE NO. 45X-0153/C0)
HIGHWAY 11, DISTRICT OF RAINY RIVER, ONTARIO
AGREEMENT 6019-E-0023, WORK ORDER 22
G.W.P. 6121-17-00, W.P. 6121-17-01**

GEOCRES NO. 52D10-001

PART B: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8. GENERAL

This report provides an interpretation of the geotechnical data in the foundation investigation report and presents foundation design recommendations for the preliminary design of the proposed Miller's Creek culvert replacement at Highway 11, in the District of Rainy River, Ontario.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, Ontario, and the designer, Hatch, to carry out the preliminary design of the culvert replacement and shall not be used or relied upon for any other purposes or by any other parties including the constructor or design-build contractor. The constructor or contractor must make their own interpretation based on the data provided in factual portion of the report (Part A).

Where comments are made on construction, they are provided to highlight those aspects which could affect the design of the project. The constructor or contractor must make their own interpretation of the factual data as such interpretation may affect equipment selection, proposed construction methods, scheduling, and the like.

The highway embankment is up to about 5.9 m high at the existing culvert location (approximately 3.2 m of fill above the existing culvert obvert) and the proposed replacement culvert is intended to be installed by open cut methods. It is understood that Highway 11 will be open to traffic during construction and therefore, temporary roadway protection systems or a Temporary Modular Bridge (TMB) spanning the open excavation are required.

The existing configuration is a twin corrugated steel pipe culvert, each with a diameter of 2.7 m, with inlet and outlet inverts at approximate Elev. 322.0 to 322.2 m. The existing highway grade at the culvert is at approximately Elev. 328.0 m. The local creek water level was measured at about Elev. 322.7 m in July 2020.

The 2017 OSIM Report for the Miller's Creek culverts reports settlements of 300 mm for the west CSP culvert and 200 mm for the east CSP culvert at the highway centreline. MTO's discussion with the maintenance staff indicated they noted no settlement issues at the Miller's Creek culverts. There is no settlement monitoring data available to confirm culvert settlements.

9. CULVERT DESIGN

9.1 Culvert Alternatives

Based on the General Arrangement (GA) Drawings for the various replacement options from Hatch, it is understood that the existing twin culvert will be replaced generally along the same alignment. The proposed type, size, length, and installation methods considered for the culvert replacement are summarized below.

- Option 1: Twin SPCSP Culverts
 - 3.67 m diameter, 30.9 m length
 - Considering both 4 mm thick pipe (if meeting CHBDC Zone 3 backfill requirements) and 7 mm thick pipe (if not meeting CHBDC Zone 3 backfill requirements).
 - Temporary Modular Bridge (TMB) to span open excavation
 - RSS (Retained Soil System) wire wall at the north side to keep the replacement culvert within the MTO right-of-way
- Option 2: Single Precast Concrete Box Culvert
 - 6.0 m span, 3.0 m rise, 30.8 m length
 - TMB to be used to span open excavation
 - RSS wire wall at the north side to keep the replacement culvert within the MTO right-of-way
- Option 3: Twin Precast Concrete Box Culvert
 - Each 3.6 m span, 3.6 m rise, 30.4 m length
 - TMB to be used to span open excavation
 - RSS wire wall at the north side to keep the replacement culvert within the MTO right-of-way

A comparison of the culvert types and foundation alternatives based on their respective advantages and disadvantages is included in Appendix E. It is understood that Option 1 (Twin SPCSP Culverts, not meeting CHBDC Zone 3 backfill requirements) is the preferred method of culvert replacement at this site.

Consideration was given to raising the grade at the culvert site to change the sag curve from K-25 (70 km/hr design speed) to K-30 (80km/hr design speed) to K-45 (100 km/hr design speed). This will involve a grade raise of 1 to 2 m. After additional discussion, MTO decided to maintain the existing highway alignment.

9.2 Summary of Subsurface Conditions

In general, the subsurface stratigraphy encountered in the boreholes consisted of asphalt and sand to silty sand to sandy silt embankment fill and sandy silty clay to silty clay embankment fill, underlain by native organic silt and sand to sandy silt, underlain by an extensive deposit of sandy clayey silt to sandy silty clay, further underlain by silty sand and gravel and clayey sand. While drilling at Borehole 23-03, located east of the existing culvert, wood was encountered at an approximate elevation of 322.8 m. Further, concrete pieces (possible debris and rubble) were encountered above the wood, in the sand fill. If additional concrete rubble or wood is encountered near the subgrade during excavation for the replacement of the culvert, such materials must be sub-excavated / removed from the subgrade and replaced with compacted granular fill

The groundwater level measured in the monitoring well installed at this site was approximately Elevation 322.8 m. The local creek water level was reportedly measured at Elev. 322.7 m in July 2020.

9.3 Foundation Design for Culverts

The invert level of the existing twin culverts (bottom of culvert) is at approximate Elevation 322.0 m and 322.1 m at the inlets (north) and 322.0 m and 322.2 m at the outlets (south).

Foundation design aspects for the replacement culvert include subgrade conditions and preparation, geotechnical bearing capacities, settlement of foundation soils under any grade raise, lateral earth pressures, groundwater control, cofferdams, temporary stream diversion pipes, temporary roadway protection system design / temporary modular bridge foundation recommendations, and restoration of the roadway embankment.

9.3.1 Structural Plate CSP (SPSCP) Replacement

Replacement of the culvert with a single or multiple SPCSPs along or close to the existing alignment may be considered for this site. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading due to the culvert replacement, except where the culvert is to be lengthened beyond the existing culvert footprint. The GA drawing provided by Hatch shows a design including twin 3.67 m diameter SPCSPs, with an invert level (bottom of pipe) at approximate Elev. 321.7 m.

If this alternative is selected, the pipes should be placed on a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements as per OPSD 802.010. Preliminary GA drawings indicate 1 m of granular is proposed under the RSS wall. The bedding material should be placed on the native, undisturbed, prepared subgrade as soon as practical, following its inspection and approval. The underside of the bedding layer should be placed at or below Elev. 320.8 m on the firm to stiff native sandy clayey silt to sandy silty clay. Any buried topsoil, excessively soft soil, large cobbles and boulders, and any soft, very loose organic or other deleterious material encountered during subgrade preparation (such as tree trunks / branches) should be sub-excavated and replaced with compacted granular material to provide a uniformly competent subgrade condition. The subgrade preparation, placement and compaction of bedding should be carried out in the dry. Adequate preparation of the subgrade will be essential for good performance of the culvert. Section 9.3.4 should also be referred to for recommendation on subgrade preparation. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction. A separation layer consisting of a non-woven geotextile should be placed between the subgrade soils and the bedding material. The geotextile should meet the specifications for the OPSS Class II (OPSS 1860) and have a fabric opening size (FOS) not greater than 212 µm.

9.3.2 Concrete Box Culvert Replacement

Replacement of the twin culverts with a new single or twin concrete box culvert is also a viable alternative for this site. The box culvert replacement would be on a shifted alignment of approximately 5.3 m or 2.0 m east of the existing culvert for the single and twin options respectively. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading due to this option, except where the replacement culvert is longer than the existing culvert. The GA drawings provided by Hatch show the replacement culvert being either a 30.8 m long, 6.0 m wide by 3.0 m tall single-cell box culvert or

two 30.4 m long, 3.6 m wide by 3.6 m tall box culverts. Invert levels (bottom of box culvert) are proposed at approximately Elev. 321.2 m.

To provide a uniform foundation subgrade and to achieve sufficient bearing capacity, a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements should be provided under the base of the box culvert, similar to as shown on OPSD 803.010. The bedding material should be placed on the native, undisturbed, prepared subgrade as soon as practicable following its inspection and approval. The underside of the bedding layer for the replacement culvert should be placed on the firm to stiff native sandy clayey silt to sandy silty clay at or below Elev. 320.8 m. Any buried topsoil, excessively soft soil, large cobbles and boulders, and any soft, very loose organic or other deleterious material (such as tree trunks / branches) encountered during subgrade preparation should be sub-excavated and replaced with compacted granular material to provide a uniformly competent subgrade condition. The subgrade preparation and placement and compaction of the bedding material should be carried out in the dry. Adequate preparation of the subgrade will be essential for performance of the culvert. Section 9.3.4 should also be referred to for recommendation on subgrade preparation. A separation layer consisting of a non-woven geotextile should be placed between the subgrade soils and the bedding material. The geotextile should meet the specifications for the OPSS Class II, and have a fabric opening size (FOS) not greater than 212 μm . The subgrade surface prepared to support the box units should have a 75 mm minimum thick top levelling course consisting of uncompacted Granular A as per OPSS 422. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction.

The following geotechnical resistances are recommended for the design of a box culvert with a 3.6 m wide bearing width founded at or below Elevation 321.2 m on a 300 mm thick granular pad over the native firm to stiff sandy clayey silt to sandy silty clay:

Geotechnical Resistance	Twin 3.6 m wide Culvert
Factored Geotechnical Resistance at ULS	225 kPa
Geotechnical Resistance at SLS (for up to 25 mm settlement)	150 kPa

A consequence factor of 1.0 was utilized in this design adopting the typical consequence level. The geotechnical resistance factor of 0.5 for bearing and 0.8 for settlement, both adopted for typical degree of understanding, were used to obtain the above values, as per Canadian Highway Bridge Design Code (CHBDC) 2019, Section 6.9.

The factored ultimate resistance and settlement are dependent on the culvert size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed if the culvert width or founding/invert elevation differs significantly from that given above.

The above geotechnical resistances are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance values used in design must be reduced in accordance with CHBDC 2019, Clause 6.10.5.3.

Resistance to sliding should be calculated assuming ultimate coefficients of friction of 0.45 between the concrete and the underlying Granular A or B Type II bedding material, and 0.35 between the bedding material and the native sandy, silty clay.

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

9.3.3 Frost Cover

The depth of frost penetration at this site is approximately 2.3 m based on OPSD 3090.100. The frost cover requirement does not apply to the pipe and box culvert options.

Frost treatment / tapers should be in accordance with OPSD 803.031 for a pipe culvert replacement or 803.010 for a box culvert replacement. Pavement designers should be consulted on whether a new frost taper is required at this site.

9.3.4 Subgrade Preparation

Performance of the replacement culvert will depend on the preparation of the subgrade.

Any buried topsoil, excessively soft soil, large cobbles and boulders, and any soft, very loose organic or other deleterious material encountered during subgrade preparation should be sub-excavated and replaced with compacted granular material to provide a uniformly competent subgrade condition. Large pieces of wood were encountered during the field investigation, in Borehole 23-03, and as such, any pieces of organic material shall be completely removed from the excavation prior to subgrade preparation or backfilling. An NSSP for Subgrade Preparation has been included in Appendix F.

In the event that subgrade preparation is required, the width of sub-excavation should be defined by a line extending from 0.3 m beyond the outside edge of the proposed culvert, outward and

downward at 1H:1V. The sub-excavated area should then be backfilled with granular material meeting OPSS.PROV 1010 Granular A or Granular B Type II requirements and be compacted as per OPSS.PROV 501. The subgrade preparation and placement and compaction of the bedding material must be carried out in the dry.

Construction equipment should not be allowed to travel on the prepared subgrade, which must be protected from disturbance during construction. Suggested wording for an Operational Constraint on Subgrade Preparation is included in Appendix F.

9.3.5 Settlement

The replacement culvert options are proposed to be constructed up to about 5.3 m east of the existing culvert alignment and with a similar or larger opening size as the existing culvert with no grade raise on the overlying embankment. As the replacement culvert will generally be of the same length as the existing culvert (or shorter, with a RSS wall, where property constraints are present), placement of additional fill is not required to widen the embankment slopes. Foundation settlement of the native firm to stiff sandy clayey silt to sandy silty clay is estimated to be negligible under the conditions that there is no additional loading due to grade raise of the embankment.

Should a grade raise be required, settlement of the foundation soils is expected to occur and the selected culvert option shall be designed to accommodate the settlement imposed by the additional embankment loading. The maximum settlement magnitudes under embankment grade raises are summarized below and presented graphically along the culvert profile in Appendix G.

Location	1 m Grade Raise	2 m Grade Raise
Culvert Centreline	25 mm	60 mm
Toe of Slope	15 mm	30 mm

9.3.6 RSS Wire Wall

Due to the property constraint at the north side of the existing highway embankment, the use of a wire wall (welded wire cage) facing for a 4.3 m high RSS is considered at the location of the culvert inlet. The RSS wall is to be designed by the supplier.

The following geotechnical resistances are recommended for the design of the welded wire cage itself, with an approximately 2 m wide bearing width founded at or below Elevation 321.7 m on a granular pad at least 0.5 m thick, over the native firm to stiff sandy clayey silt to sandy silty clay:

Geotechnical Resistance	2 m wide footing for wire wall
Factored Geotechnical Resistance at ULS	225 kPa
Geotechnical Resistance at SLS (for up to 25 mm settlement)	150 kPa

A consequence factor of 1.0 was utilized in this design adopting the typical consequence level. The geotechnical resistance factor of 0.5 for bearing and 0.8 for settlement, both adopted for typical degree of understanding, were used to obtain the above values, as per Canadian Highway Bridge Design Code (CHBDC) 2019, Section 6.9.

The factored ultimate resistance and settlement are dependent on the footing size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed if the footing width or founding elevation differs significantly from that given above.

It should be noted that the embankment fill to be retained by the wire wall is sloping with an inclination of 2H:1V. The design of the wire wall must include the appropriate higher coefficient of earth pressure for the sloping fill being retained by the wire wall.

The rock backfill in the welded wire cage must consist of durable hard rock with a minimum unconfined compressive strength (UCS) of 100 MPa and follow the gradation and durability requirements for gabion stones in OPSS 1004. Soft friable rocks (such as shale, limestone, etc.) are not permitted as wire wall backfill. The rocks used as backfill within the welded wire cage shall be produced from a Designated Sources for Materials (DSM) source according to DSM 3.05.25.

9.3.7 Recommended Approach for Culvert Replacement

From a foundation engineering perspective, replacement with twin SPCSP pipes or concrete box culverts are both considered to be feasible culvert replacement options.

10. EXCAVATION AND GROUNDWATER CONTROL

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the granular and cohesive fill soils at this site are classified as a Type 3 soil above the water table. Below the water table (i.e., if the groundwater flow is not controlled), the fill soils would be classified as Type 4 soils. The native sandy silty clay is classified as Type 3 soil, however the stability analyses for the approximately 7 m deep

temporary excavations for installation of new culverts (see Section 16.1) indicate that 1H:1V temporary excavation slopes are not recommended at this site and that side slopes of 2H:1V above the groundwater level and 3H:1V below the groundwater level are required to maintain an adequate factor of safety for temporary conditions.

Excavation and backfilling for culvert construction should be carried out in accordance with OPSS.PROV 902. Excavations for culvert replacement will be carried out through the existing fill, native organic silt and sand to sandy silt and into the native sandy clayey silt to sandy silty clay. It should be noted that obstructions may be encountered within the fill and native deposits including concrete pieces, large pieces of wood (such as tree trunks / branches), cobbles and boulders. Suggested wording for an NSSP on obstructions is included in Appendix F. Perched groundwater may be encountered in the granular fill soils, above the groundwater level or creek level.

Installation of the culvert should be carried out in the dry. It is anticipated that excavation for the culvert replacement will be carried out below the creek water level, and diversion of the surface water flow will be required. Furthermore, surface runoff and groundwater seepage from the embankment fill should be anticipated and will accumulate in the excavations if not controlled. A combination of cofferdam enclosures and stream diversion along with pumping from properly filtered sumps within an enclosure will be required to maintain dry excavations for the duration of construction.

The design of any dewatering systems is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility and to design the system in accordance with SP FOUN0003 and OPSS.PROV 517. A preconstruction survey is not required at this site, thus Designer Fill-In ** in SP FOUN0003 should be "N/A".

The groundwater level will fluctuate and the minimum groundwater elevation at the time of the proposed work should be taken as the creek water level or the design storm return period defined by the contract documents for the temporary dewatering system.

11. STREAM DIVERSION PIPE

It is understood that the west barrel of the existing twin culverts at this site is being used as the stream diversion during construction of the replacement culverts.

12. DEWATERING ASSESSMENT

Groundwater taking for construction dewatering is governed by the Ontario Water Resources Act (OWRA), Environmental Protection Act (EPA) and the Water Taking and Transfer Regulation 387/04, a regulation under the OWRA.

If the water taking rate will be greater than 50,000 L/day and less than 400,000 L/day then registration on the Environmental Activity and Sector Registry (EASR) will be required. If the water taking rate will be greater than 400,000 L/day, then a Category 3 Permit To Take Water (PTTW) will be required. Regulation 300/21 amended Regulation 63/16 wherein storm water is no longer accounted for in the water taking volume. It must; however, be accounted for with respect to discharge.

It is understood that culvert replacement will be via open cut methods. Based on the preliminary GA drawings, the dimensions and conditions that were assumed for the preliminary dewatering assessment are provided in the table below. For full dewatering to the base of the temporary excavation, the geologic unit that will need to be dewatered is the sandy silt fill.

Structure	Assumed Excavation Footprint (m)	Lowest Assumed Elevation of Excavation (m)	Assumed Groundwater Elevation (m)	Geologic Unit(s) to Dewater
Twin Culvert Replacement SPCSP	23 x 32	321	323.8	Sandy Silt Fill

For the purpose of estimating water taking flow rates, it was assumed that surface water flow would be directed around the excavation such that surface water will not enter the excavation at a significant rate.

The water taking will be temporary in nature for the purpose of construction dewatering for installation of the culvert. The hydraulic conductivity of the fill was assumed based on the results of the in-situ slug test described in Section 4.1.2. Dewatering rates were estimated using the Dupuit analytical solution. The radius of influence was calculated using the Sichardt equation. It is assumed the water level will be lowered to about 1 m below the proposed excavation in order to facilitate a dry, stable work area.

A maximum water level elevation of 324.8 m was assumed for the dewatering calculations based on the high-water level (25-year design flow returns) as indicated on the Miller's Creek Culvert GA Drawing Option 1, dated October 2023 provided by Hatch. The groundwater level recorded during the investigation was recorded to be 322.8 m based on a single water level measurement collected at the time of single well response testing. Previous water levels as indicated on the GA

indicates a similar range (322.7 m). However, additional water level measurements would augment such findings.

12.1 Dewatering Estimates

The following approach was used to estimate the budgeted peak water taking rate for the grade separation options:

- A base ground water extraction flow rate was estimated, and a factor of safety of three was applied to this flow rate to provide an allowance for removal of water from soil storage, variation in hydraulic conductivity, actual excavation dimensions and geometry, and ground water levels due to seasonality or other factors;
- An allowance for removal of rainfall into the excavation was included, assuming 24 hours are used to remove 50 mm of rainfall; and,
- Lowering of groundwater to about 1 m below the base of the excavation to facilitate a dry, stable work area was assumed.

The water taking will be temporary in nature for the purpose of construction dewatering. Dewatering rates were estimated using the Dupuit analytical solution for an unconfined aquifer provided in Powers et al. (2003).

The estimated maximum construction dewatering pump rates and radii of influence for the analyzed excavations are summarized in the table below.

Construction Element	Base Groundwater Flow (L/day)	Groundwater Flow with Safety Factor of 3 (L/day)	Stormwater Allowance (L/day)	Estimated Peak Flow Rate (L/day)	Approx. Radius of Influence (m)
Twin Culvert Replacement SPCSP	18,000	54,000	38,000	92,000	53

The preliminary peak water taking considering the estimated peak water taking rate is greater than 50,000 L/day; an EASR registration will be required.

Some perched water may exist in the gravelly sand to silt and gravel fill that may need to be temporarily managed. It is anticipated the fill will not be a source of continuous groundwater flow

into the excavation; however, dewatering flow rates may be temporarily higher than the budgeted dewatering rate initially.

13. CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the culvert should consist of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS.PROV 1010. Reference should be made to the backfill arrangements stipulated in OPSD 802.010 or 803.010, as appropriate. Backfilling for the culvert should be in accordance with OPSS.PROV 401 for a SPCSP and OPSS.PROV 902 for a box culvert. All fills should be placed in regular lifts and be compacted in accordance with OPSS.PROV 501. The backfill should be placed and compacted in simultaneous lifts on both sides of the culvert, and the top of backfill elevation should not differ by more than 500 mm on each side of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and on the roof / obvert of the culverts. Compaction equipment to be used adjacent to the culvert should be restricted in accordance with OPSS.PROV 501.

Lateral earth pressures acting on the culvert walls may be assumed to be a triangular distribution. For a fully drained backfill, the pressures should be computed in accordance with the CHBDC 2019, but are generally given by the expression:

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

where

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

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

Loading Condition	OPSS Granular A or Granular B Type II $\phi = 35^\circ$; $\gamma = 22 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ$; $\gamma = 21 \text{ kN/m}^3$	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48
At-rest (Restrained Wall)	0.43	0.62	0.47	0.70
Passive	3.7	-	3.2	

Note: Submerged unit weight should be used below the groundwater level/high creek level.

For rigid structures such as concrete box culverts, at-rest horizontal earth pressures should be used for design. Active earth pressures should be used for any unrestrained wall.

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

In accordance with Clause 6.12.3 of the CHBDC 2019, a compaction surcharge should be added. The magnitude of the surcharge should be 12 kPa at the top of fill and decrease to 0 kPa at a depth of 1.7 m for Granular B Type I, or at a depth of 2.0 m for Granular A or B Type II.

14. SEISMIC CONSIDERATIONS

In accordance with the CHBDC 2019, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy. Based on the presence of generally stiff sandy clayey silt to sandy silty clay native soil, the site is classified as Seismic Site Class D in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC. The peak ground acceleration, PGA, for a 2% in 50-year probability of exceedance at this site is 0.069 g as per the National Building Code of Canada (NBCC).

In accordance with Section 6.14.7 of the CHBDC 2019, the culvert walls should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in the table below may be used:

Condition	Earth Pressure Coefficient (K)		
	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22 \text{ kN/m}^3$	Existing Granular Fill or OPSS Granular B Type I (modified) or Type III $\phi = 32^\circ, \gamma = 22 \text{ kN/m}^3$	Existing Fill or Native Silty Clay $\phi = 25^\circ, \gamma = 20 \text{ kN/m}^3$
Active (K_{AE}) ¹	0.29	0.33	0.43
Passive (K_{PE}) ²	3.6	3.2	2.4
At Rest (K_{OE}) ³	0.49	0.53	0.64

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

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

Note 3: Wood, J. H. 1973, earthquake induced soil pressures on structures, PhD Thesis, California Institute of Technology, Pasadena, CA.

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

15. COFFERDAMS

Construction of cofferdams will be required for stream diversion and constructing the culvert replacement in the dry. Options for cofferdams include interlocking sheet piles. Sheet pile cofferdams are anticipated to be feasible at this site as they can be driven into the native sandy clayey silt to sandy silty clay. The recommendations provided in Section 16 below for Temporary Protection Systems are also applicable to sheet pile cofferdams.

16. SLOPE STABILITY

16.1 Temporary Excavation Slopes

Excavations for culvert replacement will extend through the existing embankment fill, consisting of compact to very dense sand to silty sand, compact sandy silty gravel, very soft to stiff clayey silt and sand, and stiff to hard sandy silty clay to silty clay. The excavation will extend to a depth of at least 6.7 m at the location of the culvert replacement.

Assessment of the stability of temporary excavation slopes for installation of the new culvert was also carried out, and the conditions considered are summarized in the following table.

Figure	Scenario / Condition	Factor of Safety
H1, H2	temporary excavation slopes of 3H:1V below the groundwater table and 1.5H:1V above the groundwater table	1.0 Not acceptable
H3, H4	temporary excavation slopes of 3H:1V below the groundwater table and 2H:1V above the groundwater table	1.3
H5, H6	temporary excavation slopes of 3H:1V below the groundwater table and 2H:1V above the groundwater table, with Temporary Modular Bridge (100 kPa surcharge)	1.3

To achieve a minimum Factor of Safety of about 1.3 for stability of the temporary excavation slopes, the slopes above the groundwater level should be inclined at no steeper than 2H:1V and the TMB footing should have a setback of at least 2 m from the crest of slope.

Suggested wording for an Operational Constraint on Temporary Excavation Slopes is included in Appendix F.

16.2 Permanent Slopes

Slope stability analyses were conducted for the embankment side slopes of Highway 11 at the location of the culvert replacement. The stability assessments assume the embankment fill will consist of Granular B Type II, constructed at a 2H:1V slope. Based on discussions with Hatch, it is understood that property constraints and the proximity to existing utilities on the north side of Highway 11 limit the space available for the widened embankment. Therefore, the stability assessments also considered a wire rock wall with 2H:1V side slopes of the fill above the water level. The contractor is responsible for the design of the wire rock wall at the embankment. The results of the slope stability analyses are summarized in the following table.

Figure	Scenario / Condition	Factor of Safety
H7	Long term stability, Granular Fill (2H:1V)	1.5
H8	Long term stability, Granular Fill (2H:1V) with wire rock wall	1.4

17. TEMPORARY PROTECTION SYSTEMS

A temporary roadway protection system, if utilized in place of an open cut excavation with temporary modular bridge, should be implemented in accordance with OPSS.PROV 539 and designed for Performance Level 2. Interlocking sheet piles can be considered feasible for this site as they can be driven into the native sandy clayey silt to sandy silty clay. The soil parameters in

the table below may apply for the design of the temporary roadway protection system with horizontal backfill.

Soil Parameter	Existing Granular Fill	Native or Fill Silty Clay
ϕ (angle of internal friction)	32°	26°
γ (total unit weight)	22 kN/m ³	18 kN/m ³
γ_w (submerged unit weight)	12 kN/m ³	10 kN/m ³
K_a	0.31	0.39
K_p	3.25	2.56

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

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

The design of the temporary protection system is the responsibility of the Contractor. The actual pressure distribution acting on the protection/shoring system is a function of the construction sequence and the relative flexibility of the wall, and these factors must be considered when designing the shoring system. All protection systems should be designed by a Professional Engineer experienced in such designs, who will determine an appropriate support system.

18. TEMPORARY MODULAR BRIDGE

An inline temporary modular bridge (TMB) is planned at this site for traffic staging purposes during construction of the replacement culvert. It is understood that the design of the temporary bridge is the responsibility of the contractor. The contractor will be responsible to retain a Professional Engineer, experienced in bridge design, to design the temporary bridge.

It is understood that widening of the Highway 11 roadway embankment is not required for the construction of the TMB.

The modular bridge may be supported on precast concrete footings founded on engineered granular fill pads. Based on the project drawings and discussions with the Hatch team, it is anticipated that the concrete footings will be 2.5 m wide and placed at approximately 1.6 m below

the existing highway grade level, or approximate Elev. 326.5 m. The footings should be placed on engineered granular fill pads with a minimum thickness of 1 m, consisting of OPSS Granular A or Granular B Type II, placed in 150 mm thick lifts and compacted to 100% of the SPMDD at $\pm 2\%$ of Optimum Moisture Content (OMC).

The footings should be embedded a minimum of 0.8 m below the finished grade in front of the footing. A footing set back of a minimum of 2 m from the crest of the temporary excavation slopes at the top of the footing level is required for achieving an adequate factor of safety for global stability. A surcharge load of 100 kPa from the TMB was considered in the global stability analyses. Refer to the stability Figures H1 and H2 in Appendix H.

The following geotechnical resistances are recommended for design of minimum 2.5 m wide concrete spread footings placed on minimum 1 m thick engineered granular fill pads prepared as outlined above with the underside of the fill pad at approximate Elev. 325.5 m:

Geotechnical Resistance	Temporary Modular Bridge with 2.5 m Wide Spread Footings on 1 m Thick Engineered Fill Pads
Factored Geotechnical Resistance at ULS	175
Geotechnical Resistance at SLS (for up to 25 mm settlement)	100

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

The forward slopes in front of the TMB abutments should be no steeper than 2H:1V, discussed further in Section 18, and protected from erosion.

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

19. EMBANKMENT RESTORATION

Embankment restoration after completion of the culvert replacement should be carried out in accordance with OPSS.PROV 206. The embankment reconstruction material should consist of imported Granular B Type II. The restored embankment beyond the culvert should be reinstated at the existing slope inclination, but no steeper than 2H:1V if constructed with granular fill or 1.5H:1V if constructed with rock fill. Soils generated from the culvert excavation should not be used for reinstatement of the embankment.

In general, surface vegetation, peat, topsoil, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from the areas around the culvert inlets and outlets, and within the embankment footprints. Inspection and approval of the foundation surfaces by qualified geotechnical personnel should be conducted.

If any slope instability is observed during the work (e.g. signs of sloughing, seepage, cracking or movement), remedial actions (e.g. slope flattening or backfilling the excavation) must be taken immediately to ensure the stability of the excavation and the safety of workers.

The magnitude of the embankment self-compression constructed with granular materials is in the order of 0.5% of the newly reconstructed embankment height and is expected to occur predominantly during fill placement.

20. SCOUR AND EROSION PROTECTION

Erosion protection should be provided at the culvert inlet and outlet. Design of the erosion protection measures should consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field in accordance with OPSD 810.010, OPSS 511 and OPSS.PROV 804.

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

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

accordance with OPSS.PROV 1205. A geosynthetic clay liner may be used in place of a compacted clay seal.

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

21. CORROSION POTENTIAL

Based on results of corrosivity testing on samples of the native sandy silty clay, the following statements can be made in reference to the MTO Gravity Pipe Design Guideline. However, it should be noted that effects of road de-icing salts/chemicals should be considered when selecting pipe material and/or corrosion mitigation measures.

- The resistivity of the native sandy silty clay was measured to be 1,010 ohm-cm and 1,590 ohm-cm, which indicates the soil has a severe corrosion potential ($2,000 \text{ ohm-cm} < R$) according to Table 3.2 of the MTO Gravity Pipe Design Guideline.
- The sulphate concentration of the native sandy silty clay was measured to be 863 µg/g and 411 µg/g, which is considered to have a negligible degree of sulphate attack on concrete according to Table 7.2 of the MTO Gravity Pipe Design Guideline.
- The pH level of the native sandy silty clay was measured to be 8.2 and 8.3, and according to Section 7.1.1 of the MTO Gravity Pipe Design Guideline, pH levels between 5.5 and 8.5 in soil or water are not considered detrimental to the durability of the culvert.

22. CONSTRUCTION CONCERNS

During construction, qualified geotechnical personnel should be retained to observe activities related to the culvert replacement and advise the Contract Administrator on construction concerns related to performance of the embankment and instability of slopes.

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

- Poor quality fill encountered near the culvert subgrade during the field investigation (i.e. tree branches in embankment fill). Fill must be removed and replaced with granular material for bedding and backfilling.
- The complete removal and replacement of unsuitable foundation soils with compacted granular backfill should be carried out in the area of the culvert replacement as outlined in the preceding sections.



- An adequate dewatering system should be implemented to avoid the instability/boiling of the base of the sub-excavation. The contractor should be prepared to take appropriate measures to construct the bedding and backfill in a dry and stable environment.
- Disturbance of subgrade soil. Where fine-grained soils are exposed at the culvert subgrade, these areas will become softened and moisture sensitive and may become heavily disturbed when subjected to construction traffic. Construction traffic must not be allowed on the final silt and silty clay subgrade. The final subgrade should be protected with geotextile and granular bedding materials.



THURBER ENGINEERING LTD.

23. SIGNATURES/CLOSURE

Preparation of the design report and engineering analysis was carried out by Ms. Alysha Kobylinski, P.Eng., a Geotechnical Engineer. Dr. P.K. Chatterji, Ph.D., P.Eng., a Designated Principal Contact for MTO Foundations Projects conducted an independent review of this report.



Alysha Kobylinski, P. Eng.
Geotechnical Engineer



P.K. Chatterji, P. Eng., Ph.D.
Partner
Designated MTO Contact

Date: **December 7, 2023**

File: **36227**

STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

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5. INTERPRETATION OF THE REPORT

- a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.
- b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.
- c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.
- d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

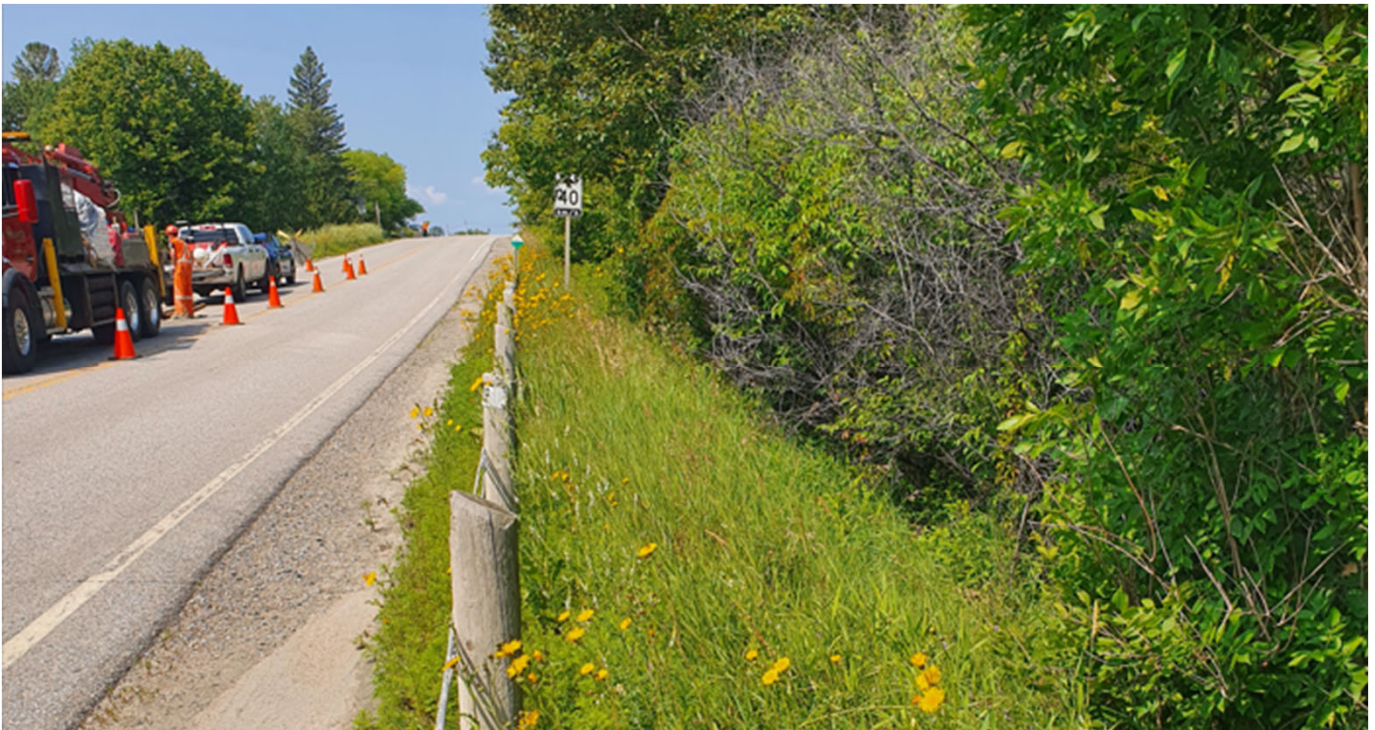
7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

APPENDIX A
SITE PLAN AND SITE PHOTOGRAPHS



DATE	REVISIONS AND ADDITIONS		
MINISTRY OF TRANSPORTATION ENGINEERING OFFICE GEOMATICS SECTION			
CULVERT SITE PLAN			
CULVERT CROSSING AT MILLER CREEK AND HIGHWAY 11			
TOWNSHIP OF ATWOOD			
SCALE 1 : 500 Hor. 1 : 500 Ver.	OPERATIONAL DISTRICT THUNDER BAY		REGION NORTHWESTERN
WO 2018-8-7014	PLAN ETR-915-11/05-0		
SURVEY JULY 2018		PLAN AUGUST 2018	
DRAWN BY: SB			
SITE 45-153/C	PLAN E-915-11-1		



Photograph #1 – Highway 11 embankment at the culvert centerline, facing west. (July 2023)



Photograph #2 – Highway 11 embankment at the culvert centerline, facing east. (July 2023)



Photograph #3 – Culvert outlets, at the south toe of Highway 11 embankment, facing facing west. (July 2023)



Photograph #4 – South-facing slope of Highway 11 embankment, near the embankment toe, facing east (July 2023)



Photograph #5 – Millers Creek culvert inlets, facing north. (July 2023)



Photograph #6 – Millers Creek culvert outlets, facing west. (July 2023)



Photograph #7 – Vegetated north-facing embankment slope with cobbles and boulders, near the culvert inlets, facing west (July 2023)



Photograph #8 – Cobbles and gravel recovered from Run 1 of Borehole 23-01.



Photograph #9 – Cored wood and gravel recovered from Borehole 23-03.

APPENDIX B
RECORD OF BOREHOLE SHEETS

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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



4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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

 Water Level
 Shear Strength Determination by Pocket Penetrometer

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

UNIFIED SOILS CLASSIFICATION

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

RECORD OF BOREHOLE No 23-01

1 OF 3

METRIC

GWP# 6121-17-00 LOCATION N 5 399 349.9 E 191 049.5 ORIGINATED BY MM
DIST Rainy River HWY 11 BOREHOLE TYPE 110 mm O.D. Solid Stem Augers, Wash Boring (H-casing), HQ Coring COMPILED BY AK
DATUM Geodetic DATE 2023.07.20 - 2023.07.21 LATITUDE 48.722216 LONGITUDE -94.546168 CHECKED BY PKC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W _P	W	W _L			WATER CONTENT (%)			
328.5	GROUND SURFACE							20	40	60	80	100					GR	SA	SI	CL
0.0	ASPHALT:(280 mm)							20	40	60	80	100								
328.3																				
0.3	SILTY SAND trace gravel Dense Brown Moist (FILL)		1	SS	43		328													
			2	SS	48		327													
	Brown to black below a depth of 1.8 m.																			
326.3																				
2.3	CLAYEY SILT and SAND, trace gravel Very Soft to Stiff Grey Wet (FILL) No recovery in SS4		3	SS	10		326													
			4	SS	WH		325													
			5	SS	8		324													
			6	SS	11		323													
323.7																				
4.9	SAND, trace silt Compact Grey Wet																			
	Containing organics at a depth of 4.9 m.																			
322.4																				
6.1	Clayey SILT to SILTY CLAY, some sand to sandy, trace gravel Stiff to Hard Grey Wet		7	SS	9		322													
			8	SS	9		321													
			9	SS	11		320													
							319													

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 23-01

2 OF 3

METRIC

GWP# 6121-17-00 LOCATION N 5 399 349.9 E 191 049.5 ORIGINATED BY MM
DIST Rainy River HWY 11 BOREHOLE TYPE 110 mm O.D. Solid Stem Augers, Wash Boring (H-casing), HQ Coring COMPILED BY AK
DATUM Geodetic DATE 2023.07.20 - 2023.07.21 LATITUDE 48.722216 LONGITUDE -94.546168 CHECKED BY PKC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE		WATER CONTENT (%) w _p w w _L			
	Continued From Previous Page							20 40 60 80 100		20 40 60			
	Clayey SILT to SILTY CLAY , some sand to sandy, trace gravel Stiff to Hard Grey Wet						318	2.3 +					
		10	SS	9			317	1.8 +					
		11	SS	8			316						
							315	1.5 +					
		12	SS	9			314						
							313						
		13	SS	9			312						
							311						
		14	SS	9			310						
							309						
308.7			15	SS	12			2.0 +					
19.8			16	SS	50/0.100			1.0 +					

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

RECORD OF BOREHOLE No 23-01

3 OF 3

METRIC

GWP# 6121-17-00 LOCATION N 5 399 349.9 E 191 049.5 ORIGINATED BY MM
DIST Rainy River HWY 11 BOREHOLE TYPE 110 mm O.D. Solid Stem Augers, Wash Boring (H-casing), HQ Coring COMPILED BY AK
DATUM Geodetic DATE 2023.07.20 - 2023.07.21 LATITUDE 48.722216 LONGITUDE -94.546168 CHECKED BY PKC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%)						
						20	40	60	80	100	20	40	60				
307.7	Silty SAND and GRAVEL containing cobbles Very Dense Grey Wet		1	HQ													
20.8	END OF BOREHOLE AT 20.8 m. NOTES: 1. Water level measured in casing at a depth of 1.3 m prior to HQ coring.																

METRIC

SOIL PROFILE						SAMPLES								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	SHEAR STRENGTH kPa	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
328.2	GROUND SURFACE													
0.0	ASPHALT:(255 mm)													
328.0														
0.3	SAND, trace to some gravel, trace silt Very Dense Brown Dry (FILL)		1	SS	57									
327.3														
0.9	SAND, some gravel to gravelly, some non-plastic fines Dense to Very Dense Brown Moist (FILL) Black, containing organics below a depth of 1.8 m		2	SS	53									26 62 12 (SI+CL)
325.8														
2.4	Sandy SILT, trace gravel Compact Grey Moist (FILL)		3	SS	33									16 73 11 (SI+CL)
325.2														
3.0	END OF BOREHOLE AT 3.0 m. NOTES: 1. Open borehole dry upon completion of drilling.		4	SS	26									

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 23-02

1 OF 3

METRIC

GWP# 6121-17-00 LOCATION N 5 399 352.3 E 191 072.5 ORIGINATED BY MM
DIST Rainy River HWY 11 BOREHOLE TYPE 110 mm O.D. Solid Stem Augers, Wash Boring (H-casing), HQ Coring COMPILED BY AK
DATUM Geodetic DATE 2023.07.22 - 2023.07.22 LATITUDE 48.722243 LONGITUDE -94.545855 CHECKED BY PKC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)			
328.0	GROUND SURFACE							20	40	60	80	100					GR	SA	SI	CL
0.0	ASPHALT:(290 mm)																			
327.8																				
0.3	SAND, some gravel, trace non-plastic fines Compact Brown Moist (FILL)		1	SS	19															
			2	SS	27															
			3	SS	22															
			4	SS	14															
324.2																				
3.8	Sandy SiltyGRAVEL, black staining Compact Brown Wet (FILL)		5	SS	22															
			6	SS	21															
	No sample recovery in SS7		7	SS	24															
320.8																				
7.2	Sandy SILTY CLAY, trace gravel Very Soft to Stiff Grey Wet		8	SS	8															
			9	TP	PH															

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Sensitivity 20
15 10 5 (%) STRAIN AT FAILURE

METRIC

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+³, ×³: Numbers refer to Sensitivity

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RECORD OF BOREHOLE No 23-02

3 OF 3

METRIC

GWP# 6121-17-00 LOCATION N 5 399 352.3 E 191 072.5 ORIGINATED BY MM
DIST Rainy River HWY 11 BOREHOLE TYPE 110 mm O.D. Solid Stem Augers, Wash Boring (H-casing), HQ Coring COMPILED BY AK
DATUM Geodetic DATE 2023.07.22 - 2023.07.22 LATITUDE 48.722243 LONGITUDE -94.545855 CHECKED BY PKC




SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
307.6	Clayey SAND , some gravel Hard Grey Wet		16	SS	30		308										14 45 36 5
20.4	END OF BOREHOLE AT 20.4 m. Monitoring well installation consists of 44 mm diameter schedule 40 PVC pipe with a 3.1 m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2023.07.23 5.2 322.8																

RECORD OF BOREHOLE No 23-03

1 OF 1

METRIC

GWP# 6121-17-00 LOCATION N 5 399 348.7 E 191 084.4 ORIGINATED BY MM
DIST Rainy River HWY 11 BOREHOLE TYPE 110 mm O.D. Solid Stem Augers, Wash Boring (H-casing), HQ Coring COMPILED BY AK
DATUM Geodetic DATE 2023.07.24 - 2023.07.24 LATITUDE 48.722212 LONGITUDE -94.545693 CHECKED BY PKC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
328.0	GROUND SURFACE														
0.0	ASPHALT(280 mm)														
327.7															
0.3	Gravelly SAND , trace non-plastic fines Compact Brown Moist (FILL)		1	SS	30										
			2	SS	30										
			3	SS	20										
			4	SS	12										
			5	SS	16										
323.5															
4.5	SAND , trace fines, containing concrete pieces, red staining Very Dense Brown Moist (FILL) Split spoon refusal at a depth of 5.1 m.		6	SS	83										
322.8															
5.2			1	HQ	--										
	WOOD Brown to Black														
321.9															
6.1	END OF BOREHOLE AT 6.1 m.														
	NOTES: 1. Borehole terminated at a depth of 6.1 m. Soil sampling resumed at a depth of 6.1 m in Borehole 23-03B, located 2 m E of Borehole 23-03.														

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METRIC

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RECORD OF BOREHOLE No 23-03B

2 OF 3

METRIC

GWP# 6121-17-00 LOCATION N 5 399 348.8 E 191 086.4 ORIGINATED BY MM
DIST Rainy River HWY 11 BOREHOLE TYPE 110 mm O.D. Solid Stem Augers, Wash Boring (H-casing) COMPILED BY AK
DATUM Geodetic DATE 2023.07.24 - 2023.07.25 LATITUDE 48.722213 LONGITUDE -94.545666 CHECKED BY PKC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W _p	W	W _L			
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%)								
	Continued From Previous Page						20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100				
	Silty CLAY , some sand to sandy, trace gravel Firm to Hard Grey Wet																
			4	SS	2		317										
							316										
			5	TP	PH		315										2 29 43 26
							314										
			6	SS	5		313										
							312										
			7	TP	PH		311										
							310										
			8	SS	5		309										
308.5																	
19.5	SS10 not recovered														0 12 63 25		

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 23-03B

3 OF 3

METRIC

GWP# 6121-17-00 LOCATION N 5 399 348.8 E 191 086.4 ORIGINATED BY MM
DIST Rainy River HWY 11 BOREHOLE TYPE 110 mm O.D. Solid Stem Augers, Wash Boring (H-casing) COMPILED BY AK
DATUM Geodetic DATE 2023.07.24 - 2023.07.25 LATITUDE 48.722213 LONGITUDE -94.545666 CHECKED BY PKC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page		10	SS	32												
307.6																	
20.4	END OF BOREHOLE AT 20.4 m. NOTES: 1. 6.1 m of steel rods and attached split spoon sampler not able to be recovered from borehole. Borehole terminated and steel rods and sampler abandoned in borehole between depths of approximately 13.7 m and 20.4 m.																

RECORD OF BOREHOLE No 23-04

1 OF 3

METRIC

GWP# 6121-17-00 LOCATION N 5 399 351.5 E 191 102.8 ORIGINATED BY MM
DIST Rainy River HWY 11 BOREHOLE TYPE 110 mm O.D. Solid Stem Augers, Wash Boring (H-casing) COMPILED BY AK
DATUM Geodetic DATE 2023.07.22 - 2023.07.23 LATITUDE 48.722241 LONGITUDE -94.545443 CHECKED BY PKC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
328.1	GROUND SURFACE							20 40 60 80 100					
0.0	ASPHALT(280 mm)						328	20 40 60 80 100					
327.8								20 40 60 80 100					
0.3	SAND, trace to some gravel, trace silt Dense to Very Dense Brown Moist (FILL)		1	SS	57		327	20 40 60 80 100					
326.3			2	SS	35			20 40 60 80 100					
1.8	Sandy SiltyCLAY to Silty CLAY Stiff to Hard Grey Moist (FILL)		3	SS	14		326	20 40 60 80 100					
324.7			4	SS	9		325	20 40 60 80 100					
3.4	ORGANIC SILT							20 40 60 80 100					
324.4	Loose Dark Brown Moist		5	SS	5		324	20 40 60 80 100					
3.7	SILTY SAND to Sandy SILT, Loose Grey Wet		6	SS	8		323	20 40 60 80 100					
322.5								20 40 60 80 100					
5.6	Silty CLAY, some sand to sandy, trace gravel Soft to Very Stiff Grey Wet		7	SS	6		322	20 40 60 80 100					1 28 44 27
			8	SS	4		321	20 40 60 80 100					
								20 40 60 80 100					
			9	SS	5		320	20 40 60 80 100					
								20 40 60 80 100					
							319	20 40 60 80 100					0 27 42 31

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

METRIC

SOIL PROFILE			SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		NATURAL MOISTURE CONTENT	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	W P W W L		
Continued From Previous Page											
	Silty CLAY , some sand to sandy, trace gravel Soft to Very Stiff Grey Wet					318	27 +				
			10	SS	7	317			○		
							22 +				
			11	SS	5	316			○		
						315	21 +				
			12	SS	7	314			○		
							24 +				
			13	SS	6	313			○		
						312	25 +				
			14	SS	7	311			○		1 17 48 3
							22 +				
			15	SS	4	310			○		
						309		-			

+³, ×³: Numbers refer to Sensitivity

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RECORD OF BOREHOLE No 23-04

3 OF 3

METRIC

GWP# 6121-17-00 LOCATION N 5 399 351.5 E 191 102.8 ORIGINATED BY MM
 DIST Rainy River HWY 11 BOREHOLE TYPE 110 mm O.D. Solid Stem Augers, Wash Boring (H-casing) COMPILED BY AK
 DATUM Geodetic DATE 2023.07.22 - 2023.07.23 LATITUDE 48.722241 LONGITUDE -94.545443 CHECKED BY PKC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
307.2	Silty CLAY , some sand to sandy, trace gravel Soft to Very Stiff Grey Wet		16	SS	1		308										
20.9	END OF BOREHOLE AT 20.9 m. NOTES: 1. Borehole terminated at a depth of 20.9 m. Backfilled with bentonite and asphalt patch. Water level not accurate in casing due to the addition of water, and clay sealed.																

RECORD OF BOREHOLE No 23-04-PVT

1 OF 1

METRIC

GWP# 6121-17-00 LOCATION N 5 399 348.0 E 191 093.2 ORIGINATED BY MM
DIST Rainy River HWY 11 BOREHOLE TYPE 110 mm O.D. Solid Stem Augers COMPILED BY AK
DATUM Geodetic DATE 2023.07.25 - 2023.07.25 LATITUDE 48.722208 LONGITUDE -94.545573 CHECKED BY PKC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
328.0	GROUND SURFACE							20	40	60	80	100					
0.0	ASPHALT(280 mm)						328										
327.8																	
0.3	SAND, some gravel, some non-plastic fines Very Dense Brown Dry (FILL)		1	SS	59									○			20 68 12 (SI+CL)
327.1														○			
0.9	Silty SAND, some gravel Dense to Very Dense Grey Moist (FILL)		2	SS	62		327							○			13 69 18 (SI+CL)
														○			
			3	SS	45		326							○			
325.6																	
2.4	Sandy SILTY CLAY, some gravel Stiff Grey Moist (FILL)		4	SS	11									○			
325.0							325										
3.0	END OF BOREHOLE AT 3.0 m. NOTES: 1. Open borehole dry upon completion of drilling																

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

APPENDIX C

GEOTECHNICAL AND ANALYTICAL LABORATORY TEST RESULTS

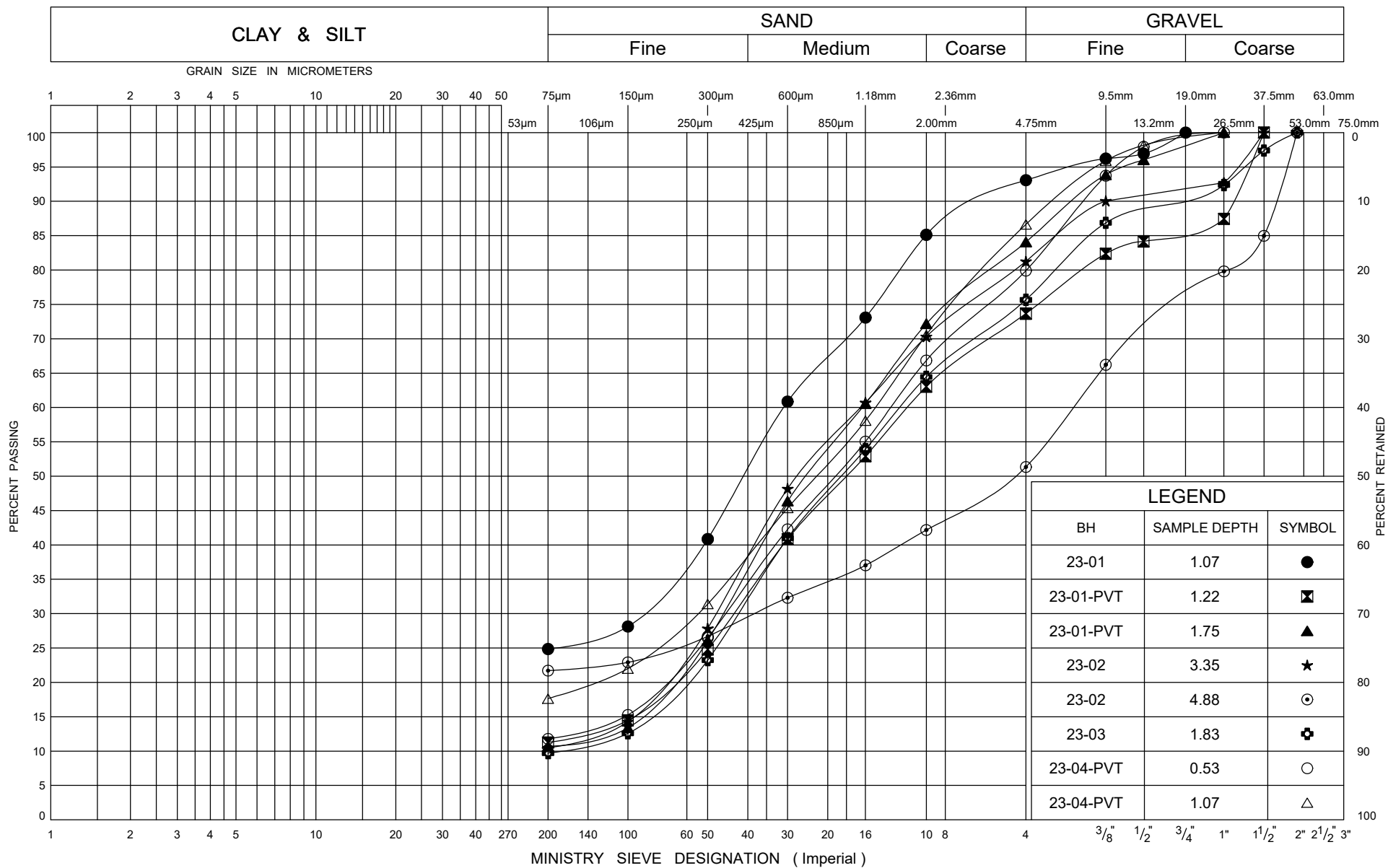
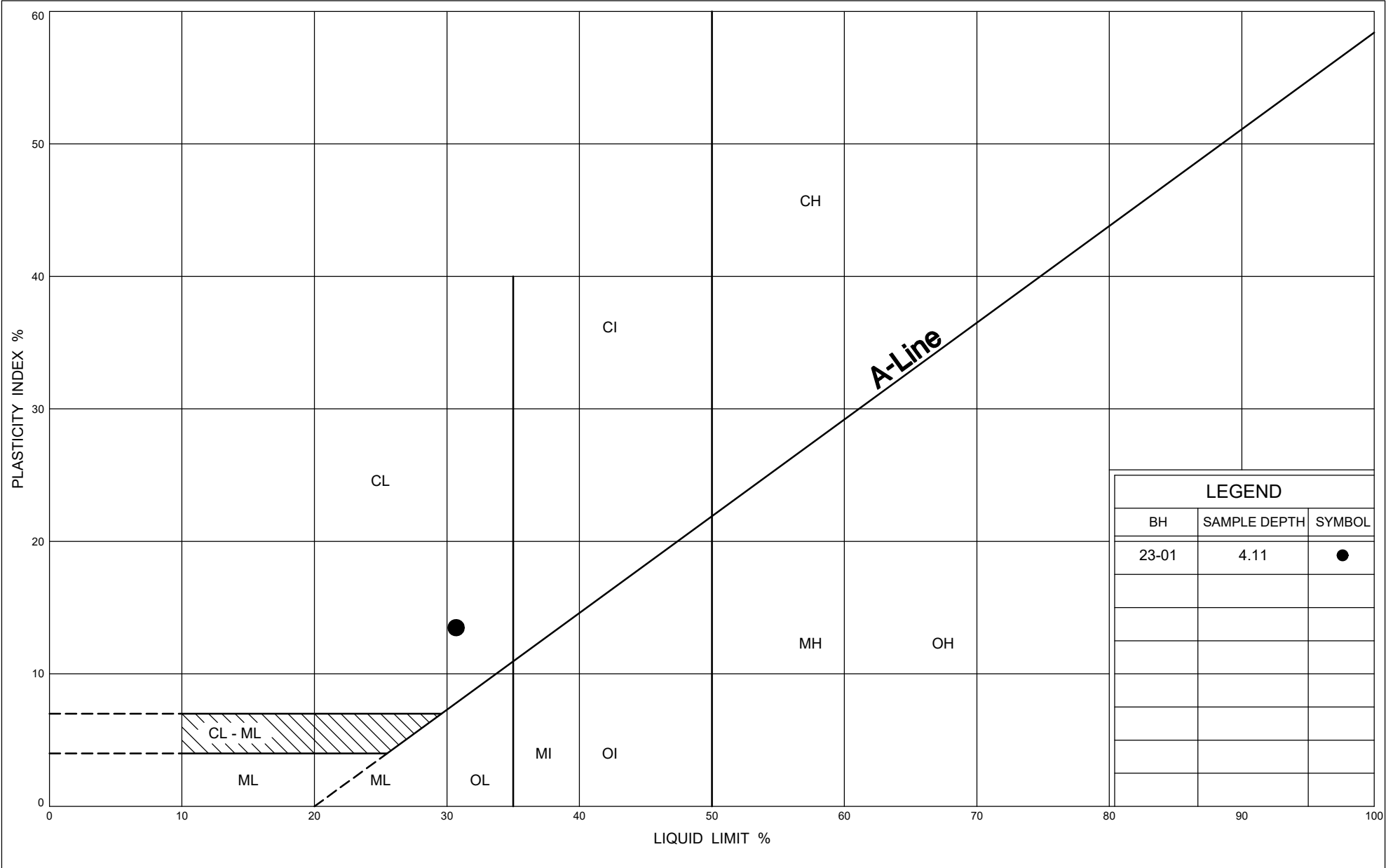
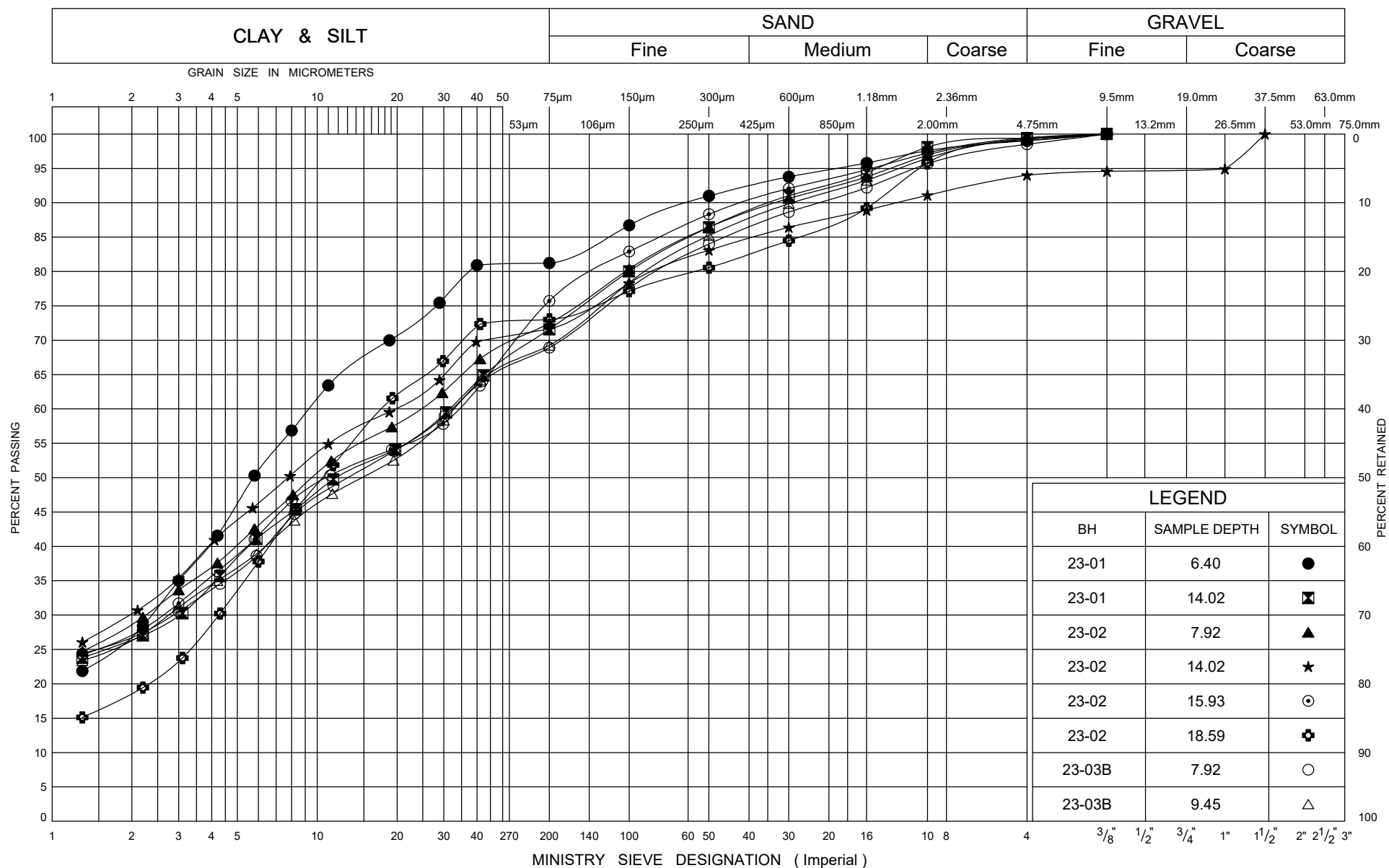




Figure C2
GWP# 6121-17-00





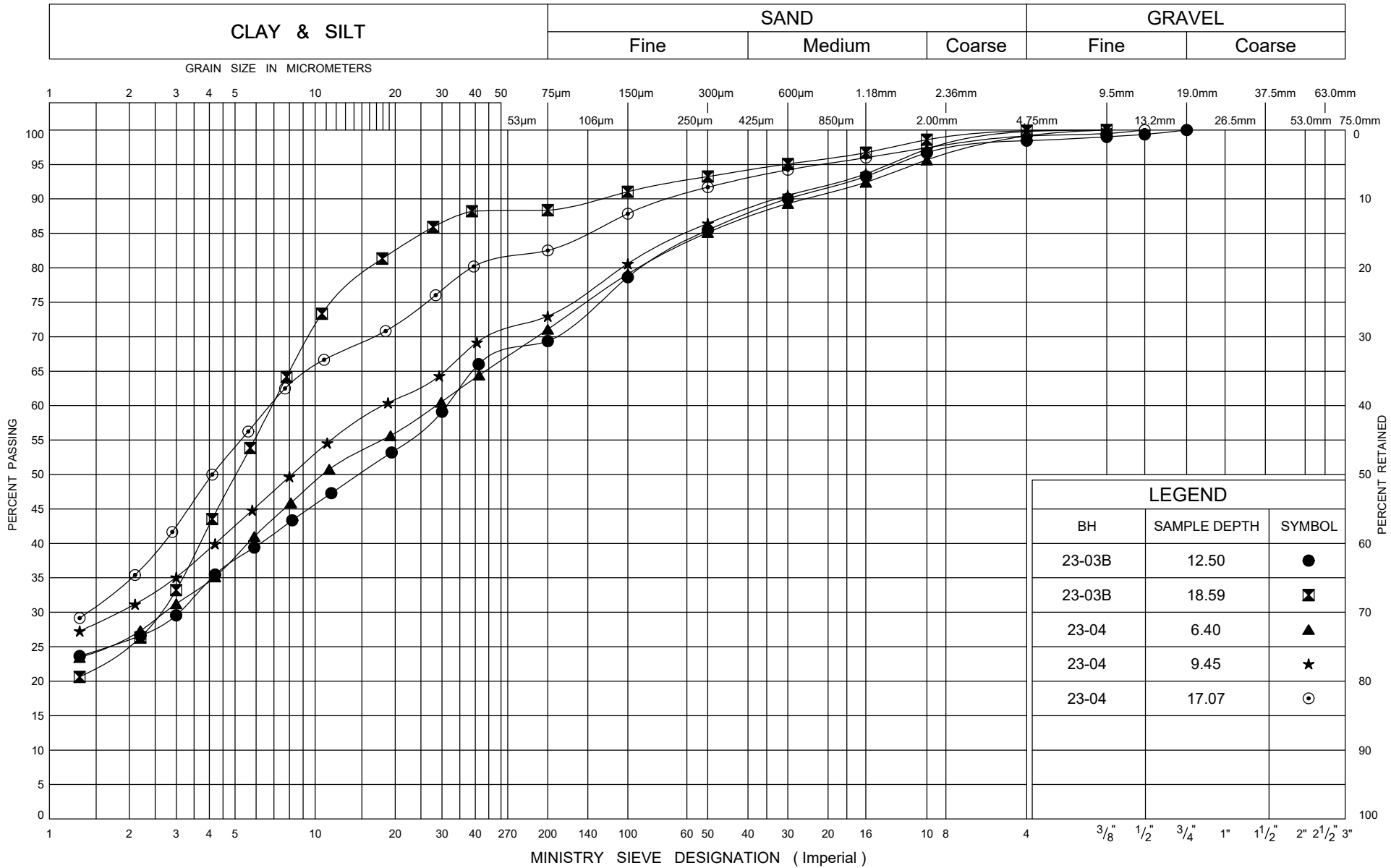
Ministry of
Transportation

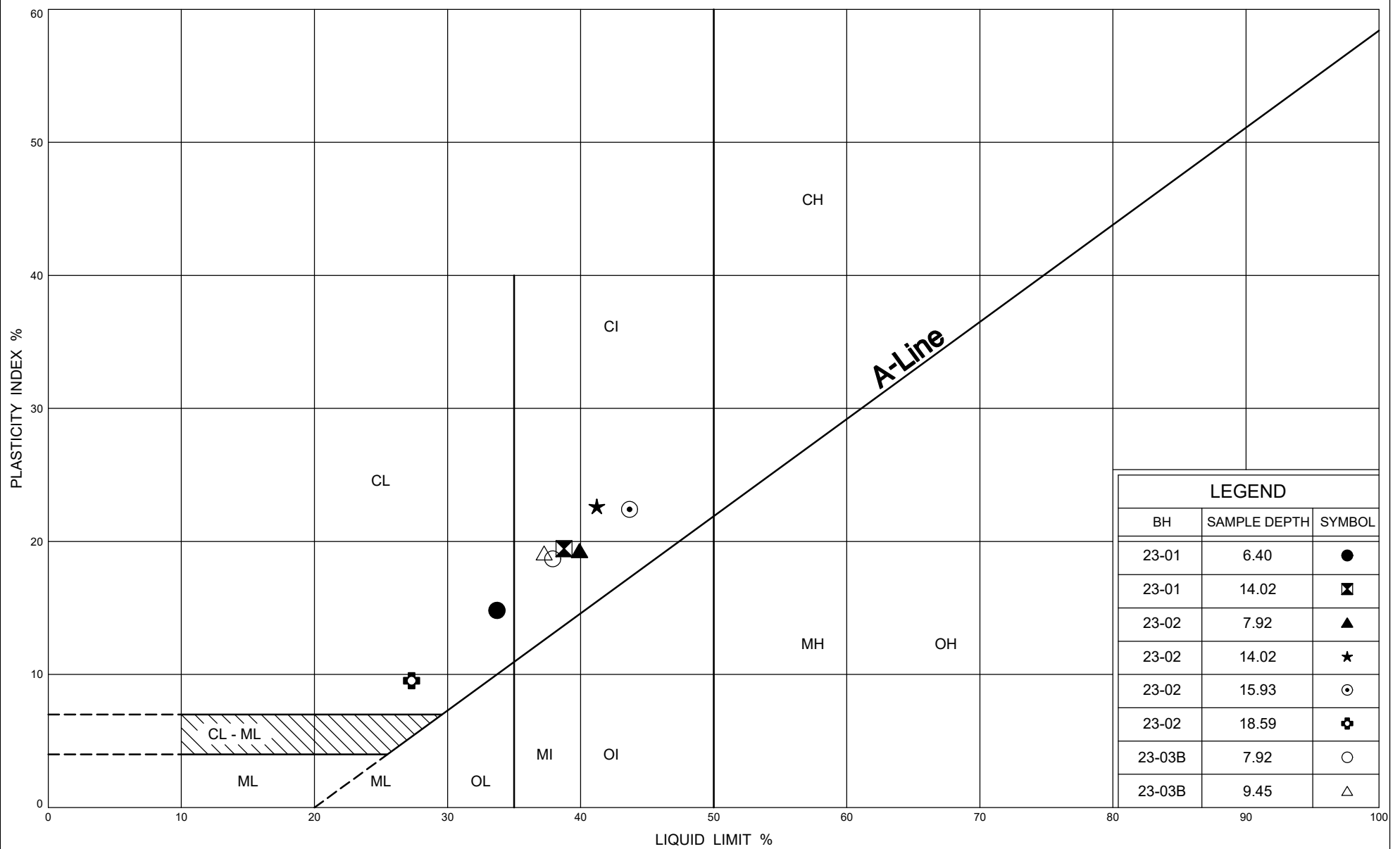
GRAIN SIZE DISTRIBUTION

Sandy CLAYEY SILT to to Sandy SILTY CLAY

Figure C4A

GWP# 6121-17-00





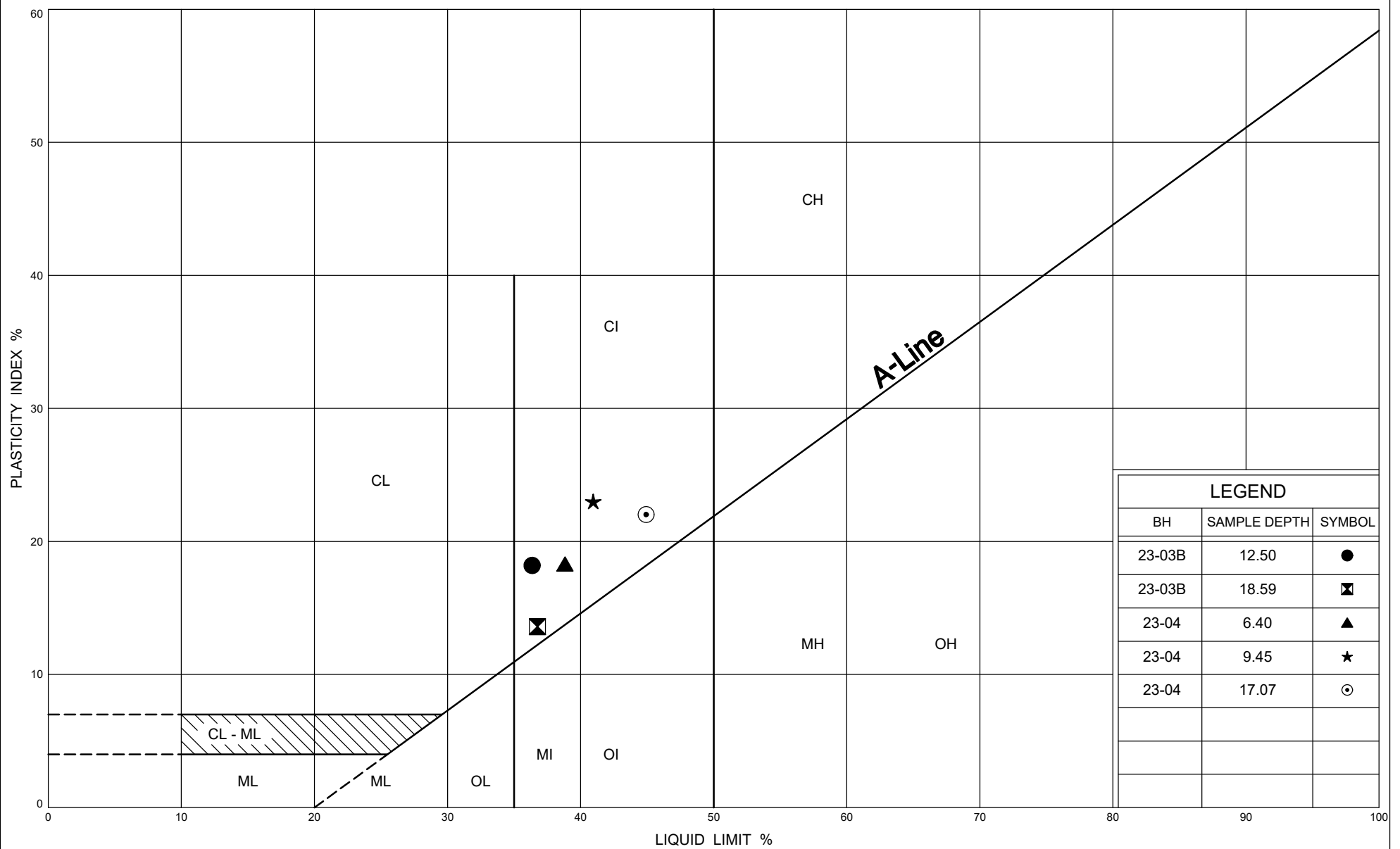
Ministry of
Transportation

PLASTICITY CHART

Sandy CLAYEY SILT to Sandy SILTY CLAY

Figure C5A

GWP# 6121-17-00



Ministry of
Transportation

PLASTICITY CHART

Sandy SILTY CLAY to SILTY CLAY

Figure C5B

GWP# 6121-17-00

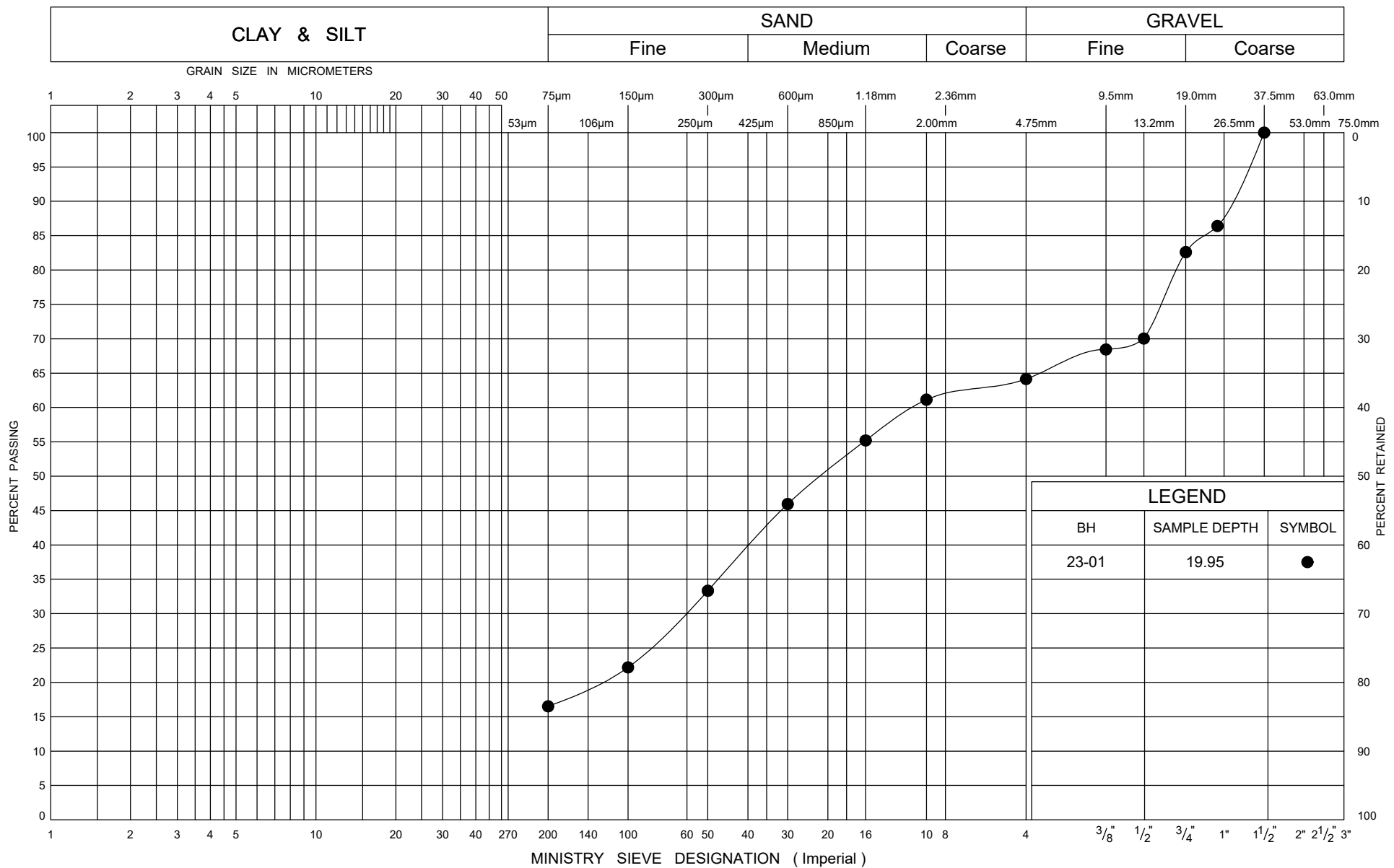
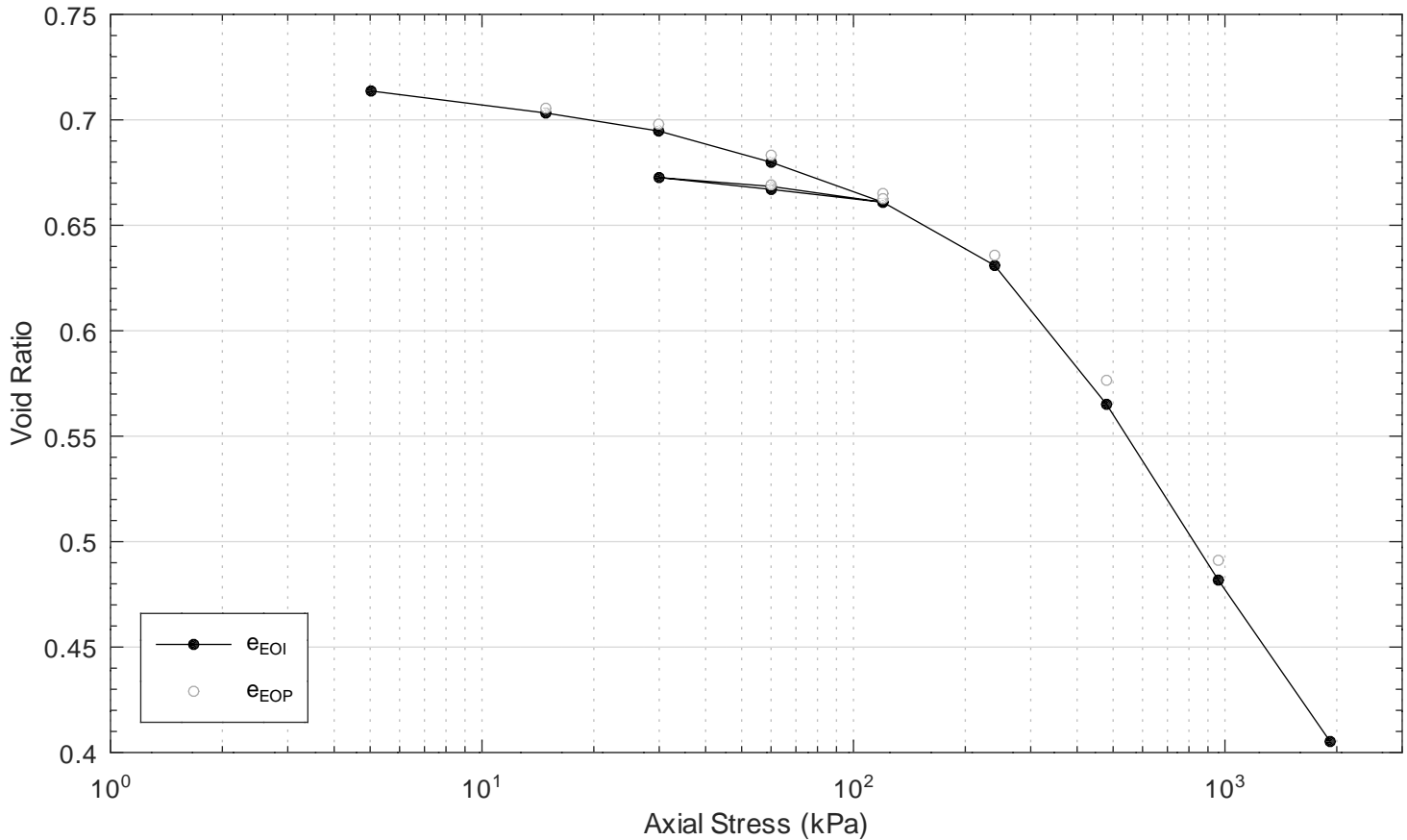




Figure C7
GWP# 6121-17-00

Project: 36227
 Highway 11 Millers Creek Culvert
 Borehole: BH23-02
 Sample: TP10
 Depth: 11.0m
 Client: Ministry of Transportation of Ontario



Start of Test		2023-08-30	
Diameter of Sample	cm	D	5.077
Height of Sample	cm	H _o	2.559
Height of Solids	cm	H _s	1.493
Water Content	%	w _o	26.79
Dry Density	g/cm ³	ρ _d	1.58
Moist Unit Weight	kN/m ³	γ	19.6
Void Ratio	-	e _o	0.714
Degree of Saturation	-	S _{ro}	1.01
Specific Gravity	-	G _s	2.700
End of Test		2023-09-11	
Height of Sample	cm	H _f	2.098
Water Content	%	w _f	18.70
Void Ratio	-	e _f	0.405

TRIMMING: the specimen was manually trimmed to the size of the consolidation ring, then mounted in a fixed ring consolidometer

LOADING: the consolidometer was flooded with water with the seating load adjusted to limit swelling

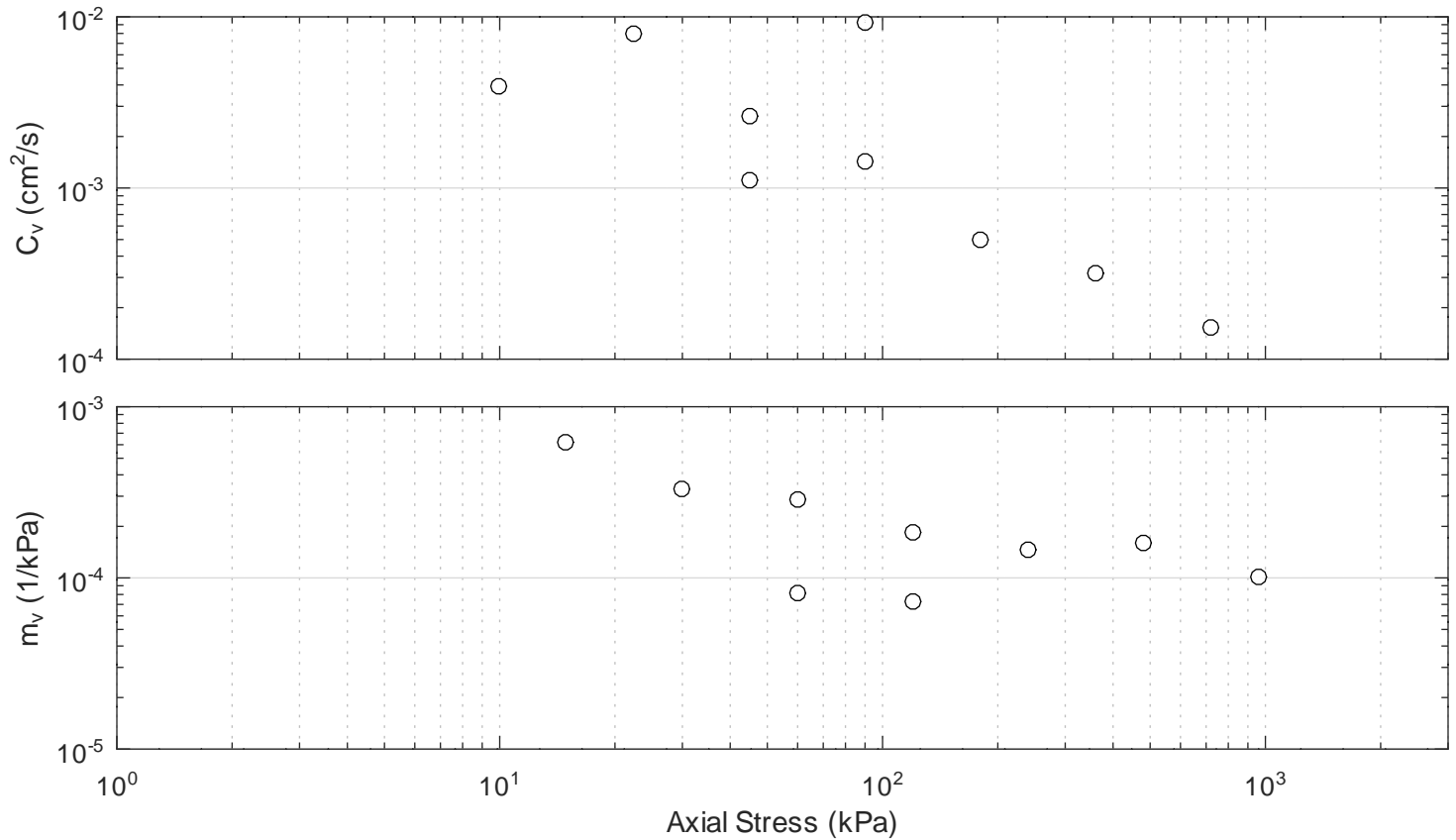
CALCULATIONS: coefficients of consolidation were calculated by the square root time method, secondary consolidation was calculated based on the available duration of the time step

Interpreted Results

Recompression Index (reloading)	-	C _r	0.019
Compression Index	-	C _c	0.277
Recompression Index (unloading)	-	C _r	
Probable Preconsolidation Pressure	kPa	p' _c	246

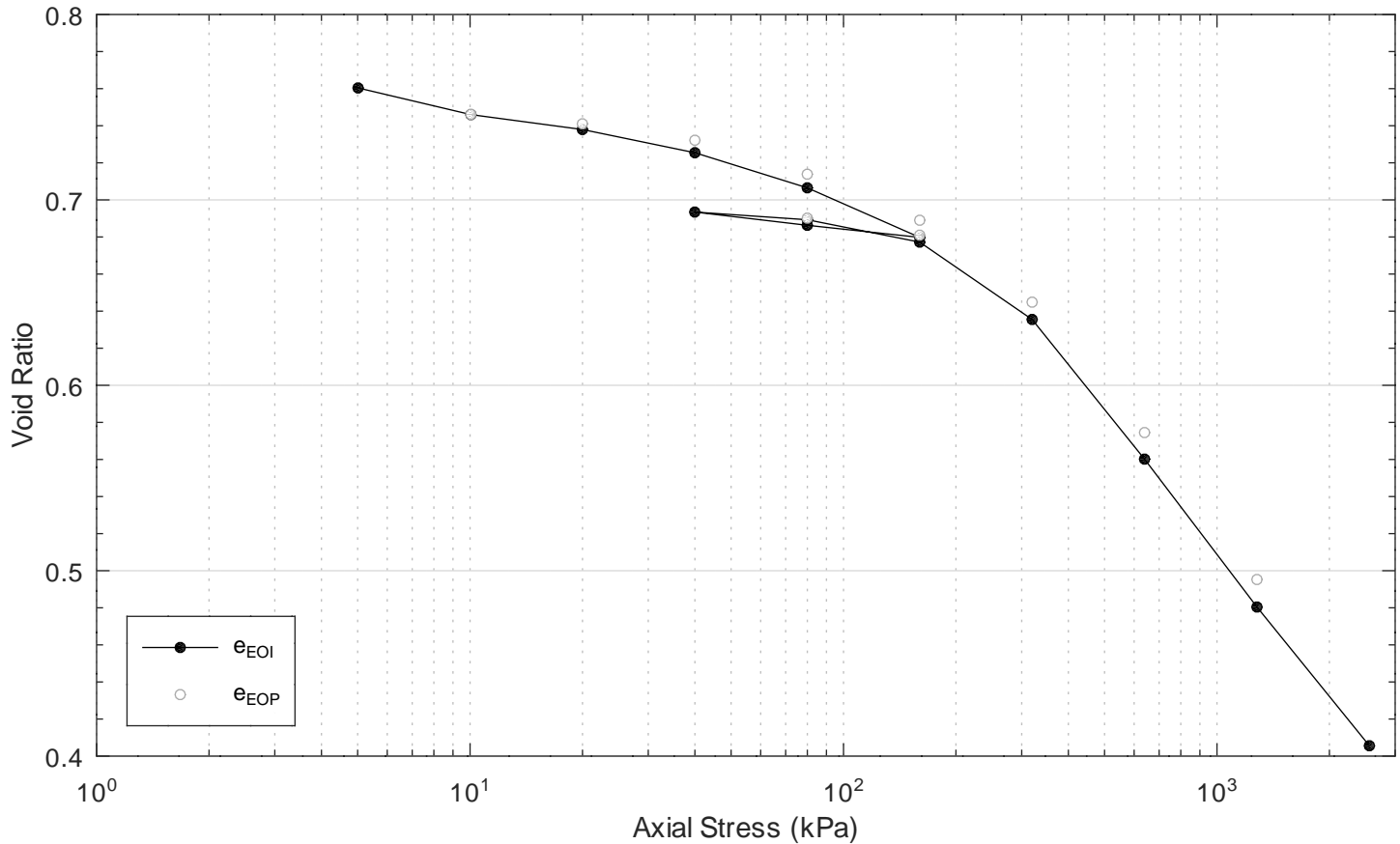
Check: MO Review: _____

Project: 36227
 Highway 11 Millers Creek Culvert
 Borehole: BH23-02
 Sample: TP10
 Depth: 11.0m
 Client: Ministry of Transportation of Ontario



Load No.	Axial Stress	Load Duration	System Deflec.	Dial	Sample Height	Axial Strain	Void Ratio	Void Ratio	Time U(0.99)	C_v	k_v	C_{ae}
	kPa	min	mm	mm	cm	%	(EOI)	(EOP)	min	cm ² /s	cm/s	-
0				10.000	2.559	0.00	0.714					
1	5.0	55.2	0.000	9.996	2.559	0.02	0.714					
2	14.9	1440.4	0.000	9.840	2.543	0.62	0.703	0.706	11.4	3.93e-03	2.39e-07	0.0005
3	29.9	1440.1	0.000	9.712	2.530	1.12	0.695	0.698	5.9	7.97e-03	2.59e-07	0.0006
4	60.0	1440.0	0.000	9.491	2.508	1.99	0.680	0.683	40.7	1.11e-03	3.13e-08	0.0012
5	120.0	1440.2	0.000	9.208	2.480	3.09	0.661	0.665	30.6	1.43e-03	2.59e-08	0.0011
6	60.1	1440.0	0.000	9.299	2.489	2.74	0.667					
7	30.0	1440.2	0.000	9.384	2.497	2.41	0.673					
8	60.0	1440.3	0.000	9.321	2.491	2.66	0.668	0.669	17.3	2.63e-03	2.10e-08	0.0001
9	120.1	1440.4	0.000	9.209	2.480	3.09	0.661	0.663	4.8	9.27e-03	6.62e-08	0.0004
10	239.9	1440.3	0.000	8.762	2.435	4.84	0.631	0.636	80.4	4.98e-04	7.14e-09	0.0018
11	480.0	1440.0	0.000	7.779	2.337	8.68	0.565	0.577	99.2	3.18e-04	4.99e-09	0.0065
12	959.9	1440.5	0.000	6.535	2.212	13.55	0.482	0.491	159.8	1.53e-04	1.52e-09	0.0060
13	1919.7	1440.2	0.000	5.392	2.098	18.01	0.405					

Project: 36227
 Highway 11 Millers Creek Culvert
 Borehole: BH23-02
 Sample: TP12
 Depth: 14.0m
 Client: Ministry of Transportation of Ontario



Start of Test		2023-08-16	
Diameter of Sample	cm	D	5.085
Height of Sample	cm	H _o	2.574
Height of Solids	cm	H _s	1.462
Water Content	%	w _o	27.14
Dry Density	g/cm ³	ρ _d	1.53
Moist Unit Weight	kN/m ³	γ	19.1
Void Ratio	-	e _o	0.760
Degree of Saturation	-	S _{ro}	0.96
Specific Gravity	-	G _s	2.700
End of Test		2023-08-29	
Height of Sample	cm	H _f	2.055
Water Content	%	w _f	17.80
Void Ratio	-	e _f	0.406

TRIMMING: the specimen was manually trimmed to the size of the consolidation ring, then mounted in a fixed ring consolidometer

LOADING: the consolidometer was flooded with water with the seating load adjusted to limit swelling

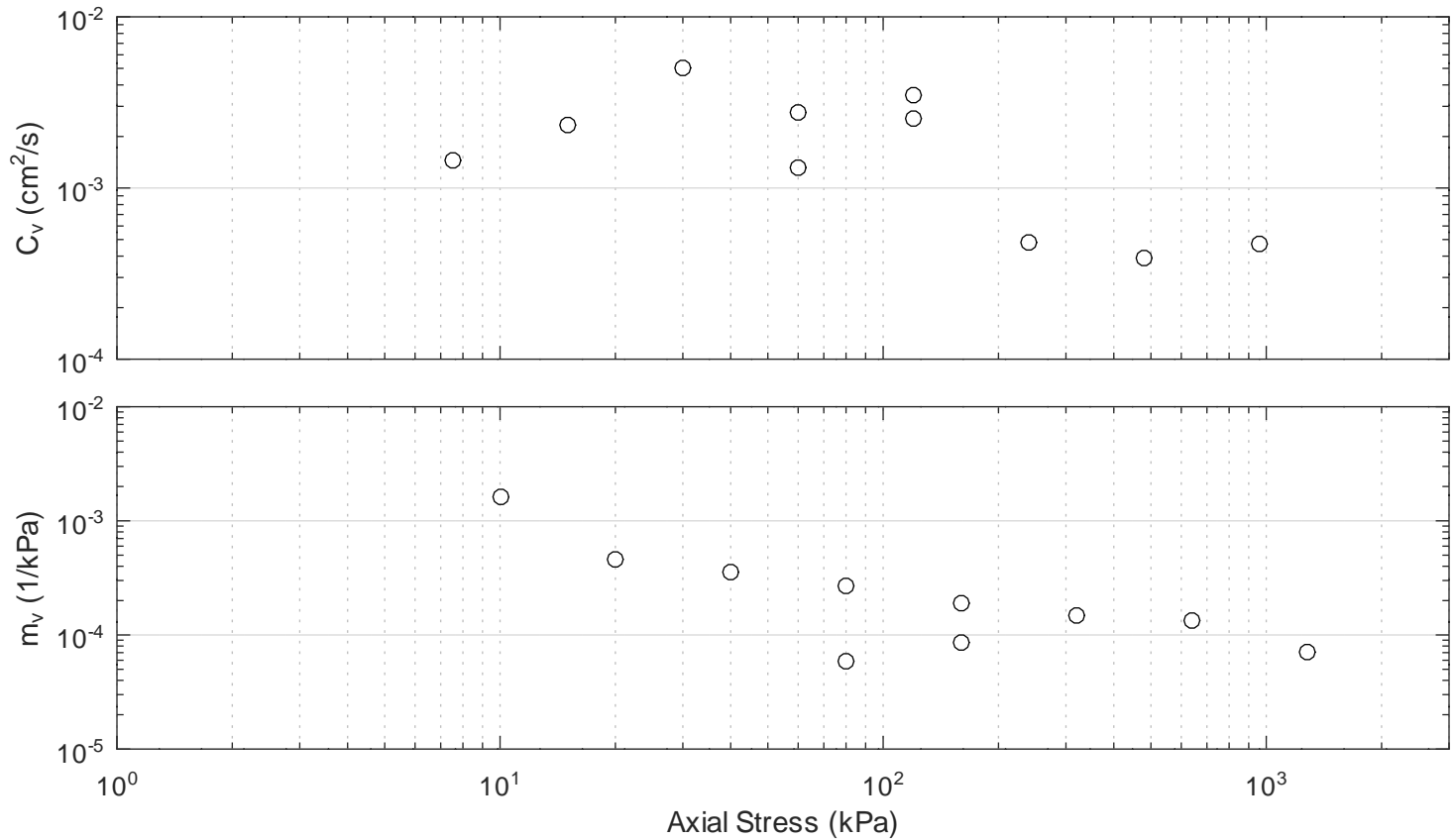
CALCULATIONS: coefficients of consolidation were calculated by the square root time method, secondary consolidation was calculated based on the available duration of the time step

Interpreted Results

Recompression Index (reloading)	-	C _r	0.027
Compression Index	-	C _c	0.258
Recompression Index (unloading)	-	C _r	
Probable Preconsolidation Pressure	kPa	p' _c	239

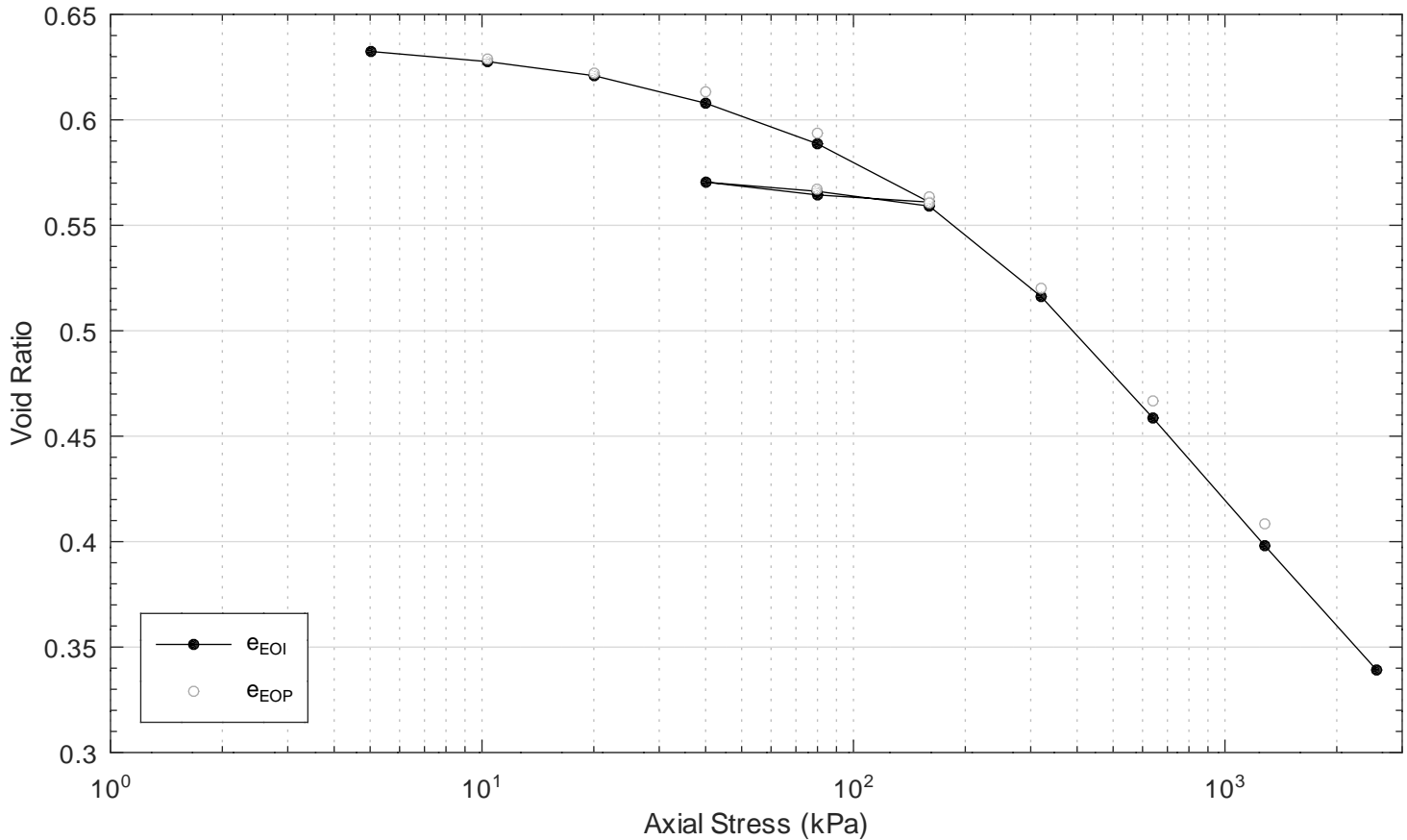
Check: MO Review: _____

Project: 36227
 Highway 11 Millers Creek Culvert
 Borehole: BH23-02
 Sample: TP12
 Depth: 14.0m
 Client: Ministry of Transportation of Ontario



Load No.	Axial Stress	Load Duration	System Deflec.	Dial	Sample Height	Axial Strain	Void Ratio	Void Ratio	Time U(0.99)	C_v	k_v	C_{ae}
	kPa	min	mm	mm	cm	%	(EOI)	(EOP)	min	cm ² /s	cm/s	-
0				10.000	2.574	0.00	0.760					
1	5.0	55.2	0.000	9.998	2.574	0.01	0.760					
2	10.0	1440.2	0.000	9.789	2.553	0.82	0.746	0.746	30.5	1.45e-03	2.31e-07	0.0000
3	20.0	1440.3	0.000	9.672	2.541	1.28	0.738	0.741	20.2	2.33e-03	1.05e-07	0.0011
4	40.0	1440.4	0.000	9.489	2.523	1.99	0.725	0.732	9.3	5.03e-03	1.75e-07	0.0016
5	80.0	1440.1	0.000	9.212	2.495	3.07	0.707	0.714	16.1	2.76e-03	7.29e-08	0.0019
6	160.0	1440.2	0.000	8.822	2.456	4.58	0.680	0.689	16.5	2.55e-03	4.74e-08	0.0022
7	80.0	1440.4	0.000	8.917	2.466	4.21	0.686					
8	40.0	1440.4	0.000	9.022	2.476	3.81	0.693					
9	80.0	1440.2	0.000	8.961	2.470	4.04	0.689	0.690	34.0	1.31e-03	7.59e-09	0.0003
10	159.9	1440.1	0.000	8.784	2.453	4.73	0.677	0.681	12.5	3.49e-03	2.93e-08	0.0009
11	319.9	1440.5	0.000	8.174	2.392	7.10	0.636	0.645	77.9	4.81e-04	6.99e-09	0.0042
12	639.7	1440.1	0.000	7.073	2.281	11.38	0.560	0.575	73.9	3.90e-04	5.12e-09	0.0062
13	1279.5	1440.1	0.000	5.906	2.165	15.91	0.480	0.495	52.8	4.72e-04	3.28e-09	0.0059
14	2559.0	1440.2	0.000	4.813	2.055	20.16	0.406					

Project: 36227
 Highway 11 Millers Creek Culvert
 Borehole: BH23-03B
 Sample: TP5
 Depth: 12.5m
 Client: Ministry of Transportation of Ontario



Start of Test		2023-08-16	
Diameter of Sample	cm	D	5.081
Height of Sample	cm	H _o	2.538
Height of Solids	cm	H _s	1.552
Water Content	%	w _o	24.21
Dry Density	g/cm ³	ρ _d	1.65
Moist Unit Weight	kN/m ³	γ	20.1
Void Ratio	-	e _o	0.635
Degree of Saturation	-	S _{ro}	1.03
Specific Gravity	-	G _s	2.700
End of Test		2023-08-29	
Height of Sample	cm	H _f	2.078
Water Content	%	w _f	15.78
Void Ratio	-	e _f	0.339

TRIMMING: the specimen was manually trimmed to the size of the consolidation ring, then mounted in a fixed ring consolidometer

LOADING: the consolidometer was flooded with water with the seating load adjusted to limit swelling

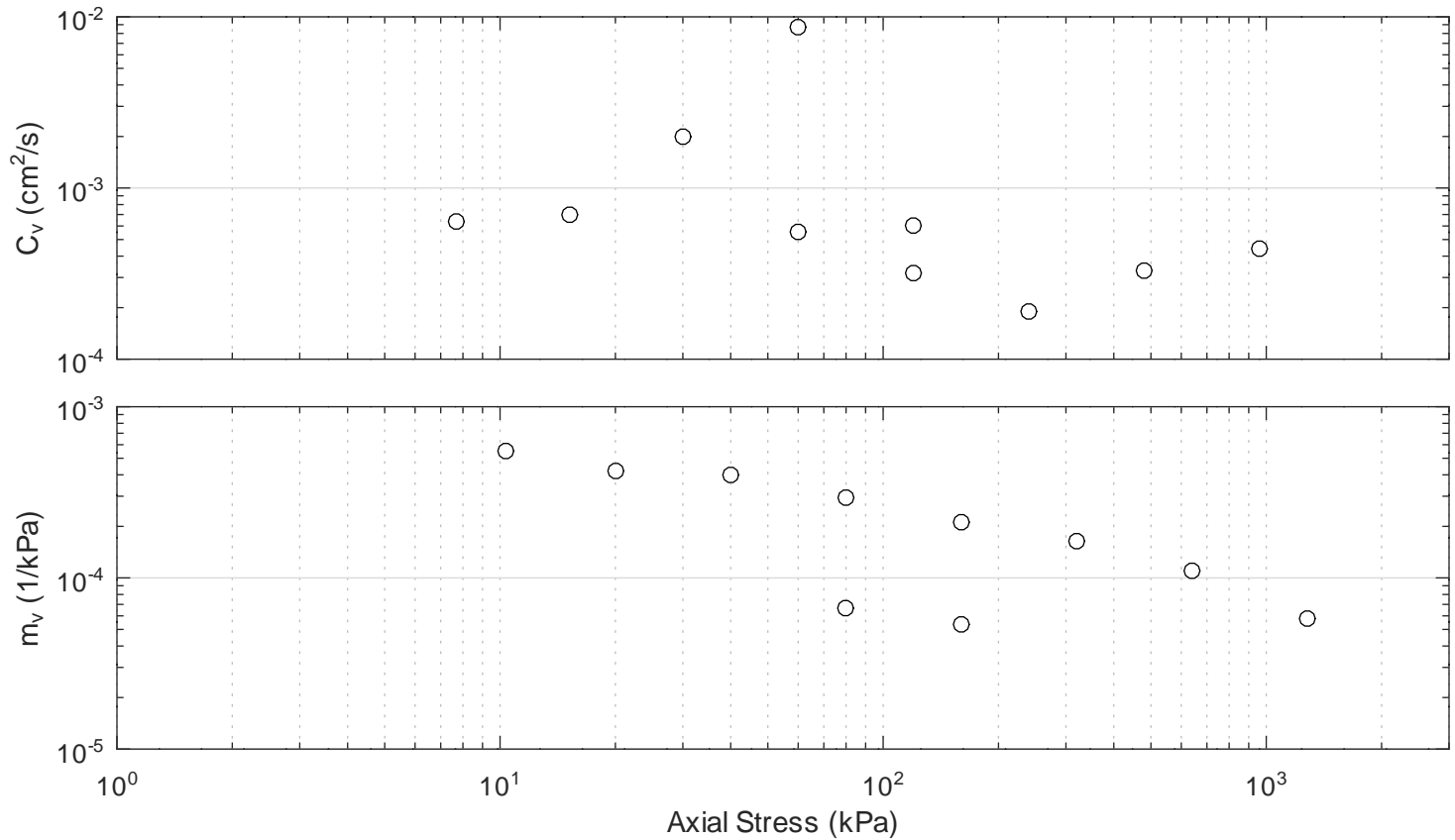
CALCULATIONS: coefficients of consolidation were calculated by the square root time method, secondary consolidation was calculated based on the available duration of the time step

Interpreted Results

Recompression Index (reloading)	-	C _r	0.019
Compression Index	-	C _c	0.196
Recompression Index (unloading)	-	C _r	
Probable Preconsolidation Pressure	kPa	p' _c	208

Check: MO Review: _____

Project: 36227
 Highway 11 Millers Creek Culvert
 Borehole: BH23-03B
 Sample: TP5
 Depth: 12.5m
 Client: Ministry of Transportation of Ontario



Load No.	Axial Stress	Load Duration	System Deflec.	Dial	Sample Height	Axial Strain	Void Ratio	Void Ratio	Time U(0.99)	C_v	k_v	C_{ae}
	kPa	min	mm	mm	cm	%	(EOI)	(EOP)	min	cm ² /s	cm/s	-
0				10.000	2.538	0.00	0.635					
1	5.0	56.0	0.000	9.956	2.534	0.17	0.632					
2	10.4	1440.1	0.000	9.882	2.526	0.47	0.628	0.629	73.1	6.37e-04	3.45e-08	0.0005
3	20.0	1440.1	0.000	9.778	2.516	0.87	0.621	0.622	65.8	6.98e-04	2.89e-08	0.0007
4	40.0	1440.2	0.000	9.576	2.496	1.67	0.608	0.613	22.6	1.99e-03	7.82e-08	0.0018
5	80.0	1440.1	0.000	9.277	2.466	2.85	0.589	0.594	77.4	5.54e-04	1.60e-08	0.0017
6	160.0	1440.0	0.000	8.848	2.423	4.54	0.561	0.563	121.7	3.18e-04	6.61e-09	0.0013
7	80.0	1440.4	0.000	8.901	2.428	4.33	0.564					
8	40.1	1440.0	0.000	8.995	2.437	3.96	0.570					
9	79.8	1440.5	0.000	8.928	2.431	4.23	0.566	0.567	5.0	8.70e-03	5.69e-08	0.0001
10	159.9	1440.4	0.000	8.819	2.420	4.65	0.559	0.561	70.7	6.03e-04	3.17e-09	0.0008
11	320.0	1440.4	0.000	8.152	2.353	7.28	0.516	0.520	181.4	1.90e-04	3.05e-09	0.0027
12	640.0	1440.4	0.000	7.259	2.264	10.80	0.459	0.467	89.9	3.29e-04	3.55e-09	0.0039
13	1280.0	1440.2	0.000	6.319	2.170	14.50	0.398	0.408	60.3	4.42e-04	2.51e-09	0.0041
14	2559.9	1440.3	0.000	5.405	2.078	18.11	0.339					

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

ATTENTION TO: Alysha Kobylinski
PROJECT: Miller Creek Culvert

AGAT WORK ORDER: 23T078552

ROCK ANALYSIS REVIEWED BY: Jewel Shibu, Lab Supervisor

SOIL ANALYSIS REVIEWED BY: Sukhwinder Randhawa, Inorganic Team Lead

DATE REPORTED: Oct 17, 2023

PAGES (INCLUDING COVER): 7

VERSION*: 1

Should you require any information regarding this analysis please contact your client services representative at (403) 735-2005

*Notes

Disclaimer:

- All work conducted herein has been done using accepted standard protocols, and generally accepted practices and methods. AGAT test methods may incorporate modifications from the specified reference methods to improve performance.
- All samples will be disposed of within 30 days after receipt unless a Long Term Storage Agreement is signed and returned. Some specialty analysis may be exempt, please contact your Client Project Manager for details.
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- This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
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- All reportable information as specified by ISO/IEC 17025:2017 is available from AGAT Laboratories upon request.
- For environmental samples in the Province of Quebec: The analysis is performed on and results apply to samples as received. A temperature above 6°C upon receipt, as indicated in the Sample Reception Notification (SRN), could indicate the integrity of the samples has been compromised if the delay between sampling and submission to the laboratory could not be minimized.



AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 23T078552

PROJECT: Miller Creek Culvert

2910 12TH STREET NE
CALGARY, ALBERTA
CANADA T2E 7P7
TEL (403)735-2005
FAX (403)735-2771
<http://www.agatlabs.com>

CLIENT NAME: THURBER ENGINEERING LTD

SAMPLING SITE: Rainy River, ON

ATTENTION TO: Alysha Kobylinski

SAMPLED BY: MM / SG

(284-042) Sulfide (CGY)

DATE RECEIVED: 2023-10-10

DATE REPORTED: 2023-10-17

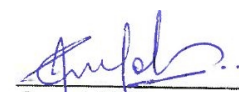
		SAMPLE DESCRIPTION:		23-02 SS11	23-03B SS1
		SAMPLE TYPE:		Soil	Soil
		DATE SAMPLED:		2023-10-06 16:00	2023-10-06 16:00
Parameter	Unit	G / S	RDL	5351742	5351744
Sulfide	%		0.01	0.25	0.09

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

5351742-5351744 Acid Soluble Sulfate Analysis completed at AGAT 2620 Calgary
Total Sulfur Analysis completed at AGAT 2215 Calgary

Analysis performed at AGAT Calgary (unless marked by *)

Certified By:


Jewel Shibu

Certificate of Analysis

AGAT WORK ORDER: 23T078552

PROJECT: Miller Creek Culvert

2910 12TH STREET NE
CALGARY, ALBERTA
CANADA T2E 7P7
TEL (403)735-2005
FAX (403)735-2771
<http://www.agatlabs.com>

CLIENT NAME: THURBER ENGINEERING LTD

SAMPLING SITE: Rainy River, ON

ATTENTION TO: Alysha Kobylinski

SAMPLED BY: MM / SG

Corrosivity Package

DATE RECEIVED: 2023-10-10

DATE REPORTED: 2023-10-17

		SAMPLE DESCRIPTION:		23-02 SS11	23-03B SS1
		SAMPLE TYPE:		Soil	Soil
		DATE SAMPLED:		2023-10-06 16:00	2023-10-06 16:00
Parameter	Unit	G / S	RDL	5351742	5351744
Chloride (2:1)	µg/g		2	3	78
Sulphate (2:1)	µg/g		2	863	411
pH (2:1)	pH Units		NA	8.15	8.26
Electrical Conductivity (2:1)	mS/cm		0.005	0.992	0.630
Resistivity (2:1) (Calculated)	ohm.cm		1	1010	1590
Redox Potential 1	mV		NA	303	263
Redox Potential 2	mV		NA	308	269
Redox Potential 3	mV		NA	312	271

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

5351742-5351744 EC, pH, Chloride and Sulphate were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil). Resistivity is a calculated parameter. Redox potential measured on as received sample. Due to the potential for rapid change in sample equilibrium chemistry with exposure to oxidative/reduction conditions laboratory results may differ from field measured results. Redox potential measurement in soil is quite variable and non reproducible due in part, to the general heterogeneity of a given soil. It is also related to the introduction of increased oxygen into the sample after extraction. The interpretation of soil redox potential should be considered in terms of its general range rather than as an absolute measurement.

Analysis performed at AGAT Toronto (unless marked by *)

Certified By:



SKR

Quality Assurance

CLIENT NAME: THURBER ENGINEERING LTD

PROJECT: Miller Creek Culvert

SAMPLING SITE: Rainy River, ON

AGAT WORK ORDER: 23T078552

ATTENTION TO: Alysha Kobylinski

SAMPLED BY: MM / SG

Rock Analysis

RPT Date: Oct 17, 2023			DUPLICATE			Method Blank	REFERENCE MATERIAL		METHOD BLANK SPIKE			MATRIX SPIKE			
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper

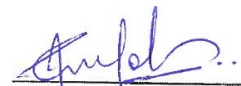
(284-042) Sulfide (CGY)

Total Sulfur	5351742	5351742	0.36	0.34	3.7%	< 0.01	97%	80%	120%
Sulfate	5364236	5364236	0.01	0.01	0.0%	< 0.01	102%	80%	120%

(284-042) Sulfide (CGY)

Sulfate	5351742	5351742	0.11	0.11	0.0%	< 0.01		80%	120%
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Certified By:


Jewel Shibu

Quality Assurance

CLIENT NAME: THURBER ENGINEERING LTD

PROJECT: Miller Creek Culvert

SAMPLING SITE: Rainy River, ON

AGAT WORK ORDER: 23T078552

ATTENTION TO: Alysha Kobylinski

SAMPLED BY: MM / SG

Soil Analysis

RPT Date: Oct 17, 2023			DUPLICATE			Method Blank	REFERENCE MATERIAL		METHOD BLANK SPIKE		MATRIX SPIKE	
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper

Corrosivity Package

Chloride (2:1)	5348591		3000	3030	1.0%	< 2	95%	70%	130%	96%	80%	120%	NA	70%	130%
Sulphate (2:1)	5348591		21	21	0.0%	< 2	96%	70%	130%	98%	80%	120%	100%	70%	130%
pH (2:1)	5352434		8.38	8.38	0.0%	NA	96%	80%	120%						
Electrical Conductivity (2:1)	5352434		1.47	1.21	19.4%	< 0.005	98%	80%	120%						
Redox Potential 1	5351742					NA	100%	90%	110%						

Comments: NA signifies Not Applicable.

pH duplicates QA acceptance criteria was met relative as stated in Table 5-15 of Analytical Protocol document.

Matrix spike NA: Spike level < native concentration. Matrix spike acceptance limits do not apply and are not calculated.

Certified By:


Subhinder Kaur Randhawa

Method Summary

CLIENT NAME: THURBER ENGINEERING LTD

PROJECT: Miller Creek Culvert

SAMPLING SITE: Rainy River, ON

AGAT WORK ORDER: 23T078552

ATTENTION TO: Alysha Kobylinski

SAMPLED BY: MM / SG

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Chloride (2:1)	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
Sulphate (2:1)	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
pH (2:1)	INOR 93-6031	modified from EPA 9045D and MCKEAGUE 3.11	PH METER
Electrical Conductivity (2:1)	INOR-93-6075	modified from MSA PART 3, CH 14 and SM 2510 B	PC TITRATE
Resistivity (2:1) (Calculated)	INOR-93-6036	McKeague 4.12, SM 2510 B, SSA #5 Part 3	CALCULATION
Redox Potential 1	INOR-93-6066	modified from G200-20, SM 2580 B	REDOX POTENTIAL ELECTRODE
Redox Potential 2	INOR-93-6066	modified from G200-20, SM 2580 B	REDOX POTENTIAL ELECTRODE
Redox Potential 3	INOR-93-6066	modified from G200-20, SM 2580 B	REDOX POTENTIAL ELECTRODE

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

ATTENTION TO: Alysha Kobylinski

PROJECT: Miller Creek Culvert

AGAT WORK ORDER: 23T053166

WATER ANALYSIS REVIEWED BY: Yris Verastegui, Report Reviewer

DATE REPORTED: Aug 09, 2023

PAGES (INCLUDING COVER): 10

VERSION*: 1

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

*Notes

Disclaimer:

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- The test results reported herewith relate only to the samples as received by the laboratory.
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- All reportable information as specified by ISO/IEC 17025:2017 is available from AGAT Laboratories upon request.
- For environmental samples in the Province of Quebec: The analysis is performed on and results apply to samples as received. A temperature above 6°C upon receipt, as indicated in the Sample Reception Notification (SRN), could indicate the integrity of the samples has been compromised if the delay between sampling and submission to the laboratory could not be minimized.



AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 23T053166

PROJECT: Miller Creek Culvert

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

CLIENT NAME: THURBER ENGINEERING LTD

SAMPLING SITE: Rainy River, Ontario

ATTENTION TO: Alysha Kobylinski

SAMPLED BY: M. Mawskill

Corrosivity Package (Water)

DATE RECEIVED: 2023-07-31

DATE REPORTED: 2023-08-09

SAMPLE DESCRIPTION: 23-02
SAMPLE TYPE: Water
DATE SAMPLED: 2023-07-23
18:50
5180983

Parameter	Unit	G / S	RDL	
pH	pH Units	6.5-8.5	NA	7.83
Electrical Conductivity	µS/cm		2	1750
Chloride	mg/L		0.12	289
Sulphate	mg/L		0.10	65.4
Resistivity	ohms.cm			571
Redox Potential	mV		NA	343.5
Sulphide	mg/L		0.01	<0.01

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard: Refers to PWQO * Variable - refer to guideline reference document
Guideline values are for general reference only. The guidelines provided may or may not be relevant for the intended use. Refer directly to the applicable standard for regulatory interpretation.

5180983 Dilution required, RDL has been increased accordingly.

Analysis performed at AGAT Toronto (unless marked by *)

Certified By:

Iris Veraástegui



Certificate of Analysis

AGAT WORK ORDER: 23T053166

PROJECT: Miller Creek Culvert

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<http://www.agatlabs.com>

CLIENT NAME: THURBER ENGINEERING LTD

SAMPLING SITE: Rainy River, Ontario

ATTENTION TO: Alysha Kobylinski

SAMPLED BY: M. Mawskill

PWQO - Metals & Inorganics (mg/L)

DATE RECEIVED: 2023-07-31

DATE REPORTED: 2023-08-09

SAMPLE DESCRIPTION: 23-02
SAMPLE TYPE: Water
DATE SAMPLED: 2023-07-23
18:50
5180983

Parameter	Unit	G / S	RDL	
Aluminum-dissolved	mg/L	*	0.004	0.020
Total Antimony	mg/L	0.020	0.006	<0.006
Total Arsenic	mg/L	0.1	0.006	0.011
Total Barium	mg/L		0.004	0.314
Total Beryllium	mg/L	*	0.002	<0.002
Total Boron	mg/L	0.2	0.020	0.246
Total Cadmium	mg/L	0.0002	0.0002	<0.0002
Total Chromium	mg/L		0.006	0.078
Total Cobalt	mg/L	0.0009	0.0010	0.0254
Total Copper	mg/L	0.005	0.002	0.068
Total Iron	mg/L	0.3	0.020	37.2
Total Lead	mg/L	*	0.002	0.019
Total Manganese	mg/L		0.004	1.34
Total Molybdenum	mg/L	0.040	0.004	0.042
Total Nickel	mg/L	0.025	0.006	0.053
Total Selenium	mg/L	0.1	0.004	0.005
Total Silver	mg/L	0.0001	0.0002	<0.0002
Total Strontium	mg/L		0.010	0.628
Total Thallium	mg/L	0.0003	0.0006	0.0009
Total Titanium	mg/L		0.020	0.808
Total Tungsten	mg/L	0.030	0.020	0.058
Total Uranium	mg/L	0.005	0.0010	0.0086
Total Vanadium	mg/L	0.006	0.004	0.082
Total Zinc	mg/L	0.030	0.040	0.117
Total Zirconium	mg/L	0.004	0.020	0.021
Chromium VI	mg/L	0.001	0.001	0.001
Dissolved Mercury	mg/L	0.0002	0.0001	<0.0001
Chloride	mg/L		0.12	289
Nitrate as N	mg/L		0.05	0.68

Certified By:

Iris Veraestegui



AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 23T053166

PROJECT: Miller Creek Culvert

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TEL (905)712-5100
FAX (905)712-5122
<http://www.agatlabs.com>

CLIENT NAME: THURBER ENGINEERING LTD

SAMPLING SITE: Rainy River, Ontario

ATTENTION TO: Alysha Kobylinski

SAMPLED BY: M. Mawskill

PWQO - Metals & Inorganics (mg/L)

DATE RECEIVED: 2023-07-31

DATE REPORTED: 2023-08-09

SAMPLE DESCRIPTION: 23-02
SAMPLE TYPE: Water
DATE SAMPLED: 2023-07-23
18:50
5180983

Parameter	Unit	G / S	RDL	
Nitrite as N	mg/L		0.05	<0.05
Sulphate	mg/L		0.10	65.4
Ammonia as N	mg/L		0.02	0.22
Ammonia-Un-ionized	mg/L	0.02	NA	0.00964
Total Phosphorus	mg/L	*	0.02	0.81
Cyanide, WAD	mg/L	0.005	0.002	0.003
Electrical Conductivity	uS/cm		2	1750
pH	pH Units	6.5-8.5	NA	7.83
Alkalinity (as CaCO ₃)	mg/L		5	401
Lab Filtration Aluminum Dissolved				Y
Lab Filtration mercury				Y

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard: Refers to PWQO * Variable - refer to guideline reference document
Guideline values are for general reference only. The guidelines provided may or may not be relevant for the intended use. Refer directly to the applicable standard for regulatory interpretation.

5180983 Dilution required, RDL has been increased accordingly.
Un-ionized Ammonia detection limit is a calculated RDL. The calculation of Un-ionized Ammonia is based on lab measured parameters (ammonia as N, pH and temperature). Values are reported as calculated.

Analysis performed at AGAT Toronto (unless marked by *)

Certified By:

Iris Veraistegui



Exceedance Summary

AGAT WORK ORDER: 23T053166

PROJECT: Miller Creek Culvert

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

CLIENT NAME: THURBER ENGINEERING LTD

ATTENTION TO: Alysha Kobylinski

SAMPLEID	SAMPLE TITLE	GUIDELINE	ANALYSIS PACKAGE	PARAMETER	UNIT	GUIDEVALUE	RESULT
5180983	23-02	ON PWQO	PWQO - Metals & Inorganics (mg/L)	Total Boron	mg/L	0.2	0.246
5180983	23-02	ON PWQO	PWQO - Metals & Inorganics (mg/L)	Total Cobalt	mg/L	0.0009	0.0254
5180983	23-02	ON PWQO	PWQO - Metals & Inorganics (mg/L)	Total Copper	mg/L	0.005	0.068
5180983	23-02	ON PWQO	PWQO - Metals & Inorganics (mg/L)	Total Iron	mg/L	0.3	37.2
5180983	23-02	ON PWQO	PWQO - Metals & Inorganics (mg/L)	Total Molybdenum	mg/L	0.040	0.042
5180983	23-02	ON PWQO	PWQO - Metals & Inorganics (mg/L)	Total Nickel	mg/L	0.025	0.053
5180983	23-02	ON PWQO	PWQO - Metals & Inorganics (mg/L)	Total Thallium	mg/L	0.0003	0.0009
5180983	23-02	ON PWQO	PWQO - Metals & Inorganics (mg/L)	Total Tungsten	mg/L	0.030	0.058
5180983	23-02	ON PWQO	PWQO - Metals & Inorganics (mg/L)	Total Uranium	mg/L	0.005	0.0086
5180983	23-02	ON PWQO	PWQO - Metals & Inorganics (mg/L)	Total Vanadium	mg/L	0.006	0.082
5180983	23-02	ON PWQO	PWQO - Metals & Inorganics (mg/L)	Total Zinc	mg/L	0.030	0.117
5180983	23-02	ON PWQO	PWQO - Metals & Inorganics (mg/L)	Total Zirconium	mg/L	0.004	0.021



Quality Assurance

CLIENT NAME: THURBER ENGINEERING LTD

PROJECT: Miller Creek Culvert

SAMPLING SITE: Rainy River, Ontario

AGAT WORK ORDER: 23T053166

ATTENTION TO: Alysha Kobylinski

SAMPLED BY: M. Mawskill

Water Analysis															
RPT Date: Aug 09, 2023			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper

PWQO - Metals & Inorganics (mg/L)

Aluminum-dissolved	5186326		0.019	0.018	NA	< 0.004	95%	70%	130%	100%	80%	120%	92%	70%	130%
Total Antimony	5183210		<0.003	<0.003	NA	< 0.003	100%	70%	130%	99%	80%	120%	100%	70%	130%
Total Arsenic	5183210		<0.003	<0.003	NA	< 0.003	94%	70%	130%	93%	80%	120%	97%	70%	130%
Total Barium	5183210		0.011	0.011	0.0%	< 0.002	99%	70%	130%	95%	80%	120%	96%	70%	130%
Total Beryllium	5183210		<0.001	<0.001	NA	< 0.001	94%	70%	130%	115%	80%	120%	109%	70%	130%
Total Boron	5183210		0.019	0.021	NA	< 0.010	101%	70%	130%	114%	80%	120%	108%	70%	130%
Total Cadmium	5183210		<0.0001	<0.0001	NA	< 0.0001	101%	70%	130%	93%	80%	120%	95%	70%	130%
Total Chromium	5183210		<0.003	<0.003	NA	< 0.003	101%	70%	130%	97%	80%	120%	97%	70%	130%
Total Cobalt	5183210		0.0007	0.0006	NA	< 0.0005	101%	70%	130%	98%	80%	120%	94%	70%	130%
Total Copper	5183210		<0.001	<0.001	NA	< 0.001	101%	70%	130%	96%	80%	120%	96%	70%	130%
Total Iron	5183210		3.95	3.73	5.7%	< 0.010	98%	70%	130%	94%	80%	120%	97%	70%	130%
Total Lead	5183210		<0.001	<0.001	NA	< 0.001	98%	70%	130%	98%	80%	120%	99%	70%	130%
Total Manganese	5183210		0.144	0.154	6.7%	< 0.002	104%	70%	130%	99%	80%	120%	95%	70%	130%
Total Molybdenum	5183210		0.005	<0.002	NA	< 0.002	101%	70%	130%	100%	80%	120%	100%	70%	130%
Total Nickel	5183210		<0.003	<0.003	NA	< 0.003	105%	70%	130%	95%	80%	120%	95%	70%	130%
Total Selenium	5183210		<0.002	<0.002	NA	< 0.002	100%	70%	130%	103%	80%	120%	98%	70%	130%
Total Silver	5183210		0.0001	<0.0001	NA	< 0.0001	104%	70%	130%	96%	80%	120%	94%	70%	130%
Total Strontium	5183210		0.025	0.022	NA	< 0.005	102%	70%	130%	99%	80%	120%	100%	70%	130%
Total Thallium	5183210		<0.0003	<0.0003	NA	< 0.0003	95%	70%	130%	95%	80%	120%	98%	70%	130%
Total Titanium	5183210		<0.010	<0.010	NA	< 0.010	114%	70%	130%	90%	80%	120%	125%	70%	130%
Total Tungsten	5183210		<0.010	<0.010	NA	< 0.010	96%	70%	130%	90%	80%	120%	94%	70%	130%
Total Uranium	5183210		<0.0005	<0.0005	NA	< 0.0005	101%	70%	130%	93%	80%	120%	97%	70%	130%
Total Vanadium	5183210		<0.002	<0.002	NA	< 0.002	105%	70%	130%	98%	80%	120%	96%	70%	130%
Total Zinc	5183210		<0.020	<0.020	NA	< 0.020	100%	70%	130%	99%	80%	120%	97%	70%	130%
Total Zirconium	5193488		<0.004	<0.004	NA	< 0.004	118%	70%	130%	117%	80%	120%	114%	70%	130%
Chromium VI	5180983	5180983	0.001	0.001	NA	< 0.001	102%	70%	130%	108%	80%	120%	108%	70%	130%
Dissolved Mercury	5186326		<0.0001	<0.0001	NA	< 0.0001	101%	70%	130%	99%	80%	120%	101%	70%	130%
Chloride	5180199		17.3	16.1	7.2%	< 0.10	94%	70%	130%	101%	80%	120%	101%	70%	130%
Nitrate as N	5180199		1.34	1.38	2.9%	< 0.05	98%	70%	130%	104%	80%	120%	101%	70%	130%
Nitrite as N	5180199		<0.05	<0.05	NA	< 0.05	102%	70%	130%	92%	80%	120%	106%	70%	130%
Sulphate	5180199		10.2	10.1	1.0%	< 0.10	95%	70%	130%	98%	80%	120%	98%	70%	130%
Ammonia as N	5181460		<0.02	<0.02	NA	< 0.02	108%	70%	130%	98%	80%	120%	98%	70%	130%
Total Phosphorus	5168603		1.20	1.18	1.7%	< 0.02	97%	70%	130%	98%	80%	120%	NA	70%	130%
Cyanide, WAD	5164581		<0.002	<0.002	NA	< 0.002	86%	70%	130%	98%	80%	120%	109%	70%	130%
Electrical Conductivity	5182349		154	155	0.6%	< 2	100%	80%	120%						
pH	5182349		6.94	7.16	3.1%	NA	100%	90%	110%						
Alkalinity (as CaCO3)	5182349		60	61	1.7%	< 5	104%	80%	120%						

Corrosivity Package (Water)



Quality Assurance

CLIENT NAME: THURBER ENGINEERING LTD

PROJECT: Miller Creek Culvert

SAMPLING SITE: Rainy River, Ontario

AGAT WORK ORDER: 23T053166

ATTENTION TO: Alysha Kobylinski

SAMPLED BY: M. Mawskill

Water Analysis (Continued)

RPT Date: Aug 09, 2023			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper
pH	5182349		6.94	7.16	3.1%	NA	100%	90%	110%						
Electrical Conductivity	5182349		154	155	0.6%	< 2	100%	90%	110%						
Chloride	5180199		17.3	16.1	7.2%	< 0.10	94%	70%	130%	101%	80%	120%	101%	70%	130%
Sulphate	5180199		10.2	10.1	1.0%	< 0.10	95%	70%	130%	98%	80%	120%	98%	70%	130%
Sulphide	5186668		<0.01	<0.01	NA	< 0.01	102%	90%	110%	101%	90%	110%	100%	80%	120%

Comments: NA signifies Not Applicable.

If the RPD value is NA, the results of the duplicates are under 5X the RDL and will not be calculated.

Matrix spike: Spike level < native concentration. Matrix spike acceptance limits do not apply.

Certified By:

Iris Veraestegui



Method Summary

CLIENT NAME: THURBER ENGINEERING LTD

PROJECT: Miller Creek Culvert

SAMPLING SITE: Rainy River, Ontario

AGAT WORK ORDER: 23T053166

ATTENTION TO: Alysha Kobylinski

SAMPLED BY: M. Mawskill

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Water Analysis			
pH	INOR-93-6000	modified from SM 4500-H+ B	PC TITRATE
Electrical Conductivity	INOR-93-6000	modified from SM 2510 B	PC TITRATE
Chloride	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
Sulphate	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
Resistivity		SM 2510 B	EC METER
Redox Potential		modified from SM 2580 B	REDOX POTENTIAL ELECTRODE
Sulphide	INOR-93-6054	modified from SM 4500 S2- D	SPECTROPHOTOMETER
Aluminum-dissolved	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Total Antimony	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Arsenic	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Barium	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Beryllium	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Boron	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Cadmium	MET -93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Chromium	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Cobalt	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Copper	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Iron	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Lead	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Manganese	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Molybdenum	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Nickel	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Selenium	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Silver	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Strontium	INOR-93-6003	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Thallium	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Titanium	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Tungsten	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Uranium	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Vanadium	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS

Method Summary

CLIENT NAME: THURBER ENGINEERING LTD

PROJECT: Miller Creek Culvert

SAMPLING SITE: Rainy River, Ontario

AGAT WORK ORDER: 23T053166

ATTENTION TO: Alysha Kobylinski

SAMPLED BY: M. Mawskill

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Total Zinc	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Zirconium	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Chromium VI	INOR-93-6073	modified from SM 3500-CR B	SPECTROPHOTOMETER
Dissolved Mercury	MET-93-6100	modified from EPA 245.2 and SM 3112 B	CVAAS
Nitrate as N	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
Nitrite as N	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
Ammonia as N	INOR-93-6059	modified from SM 4500-NH3 H	LACHAT FIA
Ammonia-Un-ionized		MOE REFERENCE, PWQOs Tab 2	CALCULATION
Total Phosphorus	INOR-93-6022	modified from SM 4500-P B and SM 4500-P E	SPECTROPHOTOMETER
Cyanide, WAD	INOR-93-6052	modified from ON MOECC E3015, SM 4500-CN- I, G-387	SEGMENTED FLOW ANALYSIS
Electrical Conductivity	INOR-93-6000	SM 2510 B	PC TITRATE
Alkalinity (as CaCO3)	INOR-93-6000	Modified from SM 2320 B	PC TITRATE
Lab Filtration Aluminum Dissolved	SR-78-9001		FILTRATION
Lab Filtration mercury	SR-78-9001		FILTRATION



Chain of Custody Record

If this is a Drinking Water sample, please use Drinking Water Chain of Custody Form (potable water consumed by humans)

Report Information:

Company: Thurber Engineering Ltd.
Contact: Alysha Kobylinski
Address: 2010 Winston Park Dr #103
Orkville ON
L6H 5R7 Phone: 226 748 9593 Fax: 226 748 9593
Reports to be sent to: 226 748 9593
1. Email: akobylinski@thurber.ca
2. Email:

Project Information:

Project: Miller Creek Culvert
Site Location: Rainy River, ON
Sampled By: M. Mawskill
AGAT Quote #: 807751 PO: 36227
Please note: If quotation number is not provided, client will be billed full price for analysis.

Invoice Information:

Company: _____
Contact: _____
Address: _____
Email: _____
Bill To Same: Yes ☒ No ☐

Regulatory Requirements:

(Please check all applicable boxes)

- ☐ Regulation 153/04 ☐ Regulation 406 ☐ Sewer Use
☐ Sanitary ☐ Storm
Table Indicate One Table Indicate One Region _____
☐ Ind/Com ☐ Res/Park ☐ Agriculture ☐ CCME ☒ Prov. Water Quality Objectives (PWQO)
Soil Texture (Check One) ☐ Coarse ☐ Fine ☐ Other
Indicate One

Is this submission for a
Record of Site Condition?

☐ Yes ☒ No

Report Guideline on
Certificate of Analysis

☒ Yes ☐ No

Sample Matrix Legend

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

Laboratory Use Only

Work Order #: 23T053166
Cooler Quantity: 1 (mixed)
Arrival Temperatures: 1.7 | 0.9 | 0.7
5.3 | 5.7 | 5.1
Custody Seal Intact: ☐ Yes ☐ No ☒ N/A
Notes: melted ice

Turnaround Time (TAT) Required:

Regular TAT ☒ 5 to 7 Business Days

Rush TAT (Rush Surcharges Apply)

☐ 3 Business Days ☐ 2 Business Days ☐ Next Business Day

OR Date Required (Rush Surcharges May Apply):

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

For 'Same Day' analysis, please contact your AGAT CPM

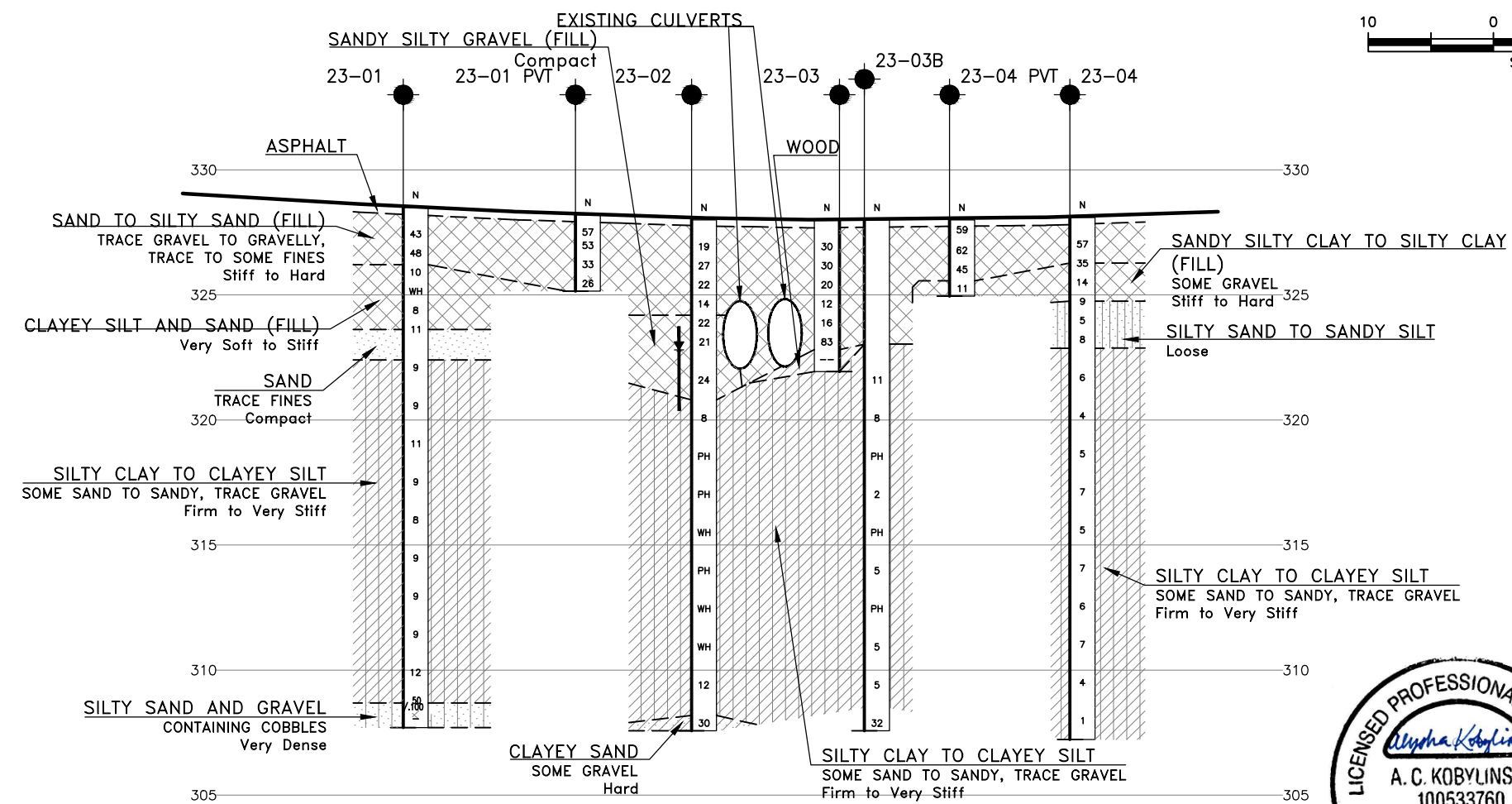
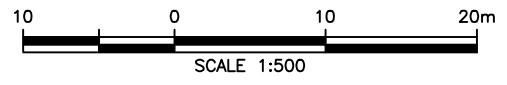
Sample Identification	Date Sampled	Time Sampled	# of Containers	Sample Matrix	Comments/ Special Instructions	Y / N	Field Filtered - Metals, Hg, CrVI, DOC	Metals & Inorganics	Metals - <input type="checkbox"/> CrVI, <input type="checkbox"/> Hg, <input type="checkbox"/> HWSB	BTEX, F1-F4 PHCs	VOC	PAHs	PCBs	POBs: Aroclors <input type="checkbox"/>	Landfill Disposal Characterization TCLP: <input type="checkbox"/> M&M <input type="checkbox"/> VOCs <input type="checkbox"/> ABNs <input type="checkbox"/> Biop <input type="checkbox"/> PCBs	Regulation 406 SPLP Rainwater Leach	Regulation 406 Characterization Package	pH, ICMS Metals, BTEX, F1-F4	Corrosivity: <input type="checkbox"/> Moisture <input checked="" type="checkbox"/> Sulphide	Potentially Hazardous or High Concentration (Y/N)
1. <u>23-02</u>	<u>July 23</u>	<u>6:50 AM</u>	<u>1A</u>	<u>GW</u>		<u>N</u>		<input checked="" type="checkbox"/>												
2.		AM																		
3.		PM																		
4.		AM																		
5.		PM																		
6.		AM																		
7.		PM																		
8.		AM																		
9.		PM																		
10.		AM																		
11.		PM																		

Samples Relinquished By (Print Name and Sign): <u>Matthew Mawskill</u>	Date: <u>July 29</u>	Time: <u>8:30 AM</u>	Samples Received By (Print Name and Sign): <u>Richard Engelman</u>	Date: <u>July 31/23</u>	Time: <u>8:30 AM</u>
Samples Relinquished By (Print Name and Sign): <u>David Wessinger</u>	Date: <u>July 29</u>	Time: <u>8:30 AM</u>	Samples Received By (Print Name and Sign): <u>T.R.</u>	Date: <u>Aug 01</u>	Time: <u>9 AM</u>
Samples Relinquished By (Print Name and Sign):	Date:	Time:	Samples Received By (Print Name and Sign):	Date:	Time:
Page _____ of _____			N#: <u>T-146192</u>		

APPENDIX D
BOREHOLE LOCATION PLAN AND SOIL STRATA DRAWINGS



PLAN



A-A' PROFILE ALONG C HWY 11

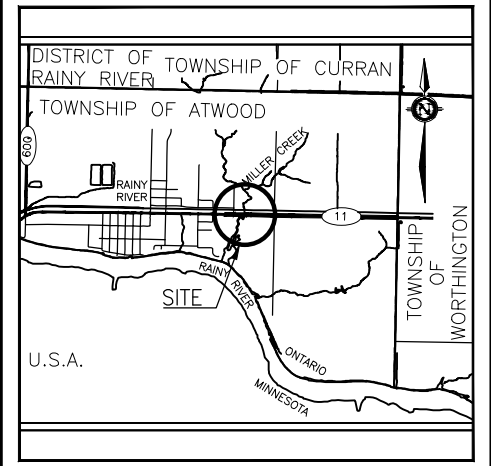


METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
WP No

HIGHWAY 11
MILLERS CREEK CULVERTS
REPLACEMENT
BOREHOLE LOCATION PLAN

SHEET



KEYPLAN

LEGEND

- Borehole
- Borehole and Cone
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60° Cone, 475J/blow)
- PH Pressure, Hydraulic
- Water Level Upon Completion of Drilling
- Water Level in Monitoring Well/Piezometer
- Monitoring Well/Piezometer Screen
- Rock Quality Designation (RQD)
- Auger Refusal

NO	ELEVATION	NORTHING	EASTING
23-01	328.5	5 399 349.9	191 049.5
23-01 PVT	328.2	5 399 352.2	191 063.2
23-02	328.0	5 399 352.3	191 072.5
23-03	328.0	5 399 348.7	191 084.4
23-03B	328.0	5 399 348.8	191 086.4
23-04	328.1	5 399 351.5	191 102.8
23-04 PVT	328.0	5 399 348.0	191 093.2

-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 16.

GEORES No. 52D10-001



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	IR	CHK -	CODE
DRAWN	MFA	CHK IR	SITE 45X-0153C0
LOAD	DATE	DEC 2023	DWG 1

APPENDIX E
GEOTECHNICAL COMPARISON OF FOUNDATION ALTERNATIVES FOR CULVERT
REPLACEMENT

Appendix E

Geotechnical Comparison of Foundation Alternatives for Culvert Replacement

	Structural Steel CSP (SPCSP), or Twin SPCSPs	Structural Steel CSP (SPCSP), or Twin SPCSPs, meeting Zone 3 excavation requirements	Single Precast Concrete Box Culvert, Twin Concrete Box
Advantages	<ul style="list-style-type: none"> a) ease of construction b) segmented pipes can accommodate some potential differential settlement along culvert axis c) less expensive than concrete box culvert option 	<ul style="list-style-type: none"> a) ease of construction b) segmented pipes can accommodate some potential differential settlement along culvert axis c) less expensive than concrete box culvert option d) thinner steel pipe required 	<ul style="list-style-type: none"> a) relatively rapid installation and less disturbance to subgrade soils if pre-cast segments are used. b) segmental option can accommodate some potential differential settlement along culvert axis.
Disadvantages	<ul style="list-style-type: none"> a) steel pipes may have a shorter design life than concrete culverts b) multiple pipes needed to meet hydraulic requirements c) potential for differential settlement where the widened highway meets the existing embankment d) thicker steel pipe required 	<ul style="list-style-type: none"> a) steel pipes may have a shorter design life than concrete culverts b) multiple pipes needed to meet hydraulic requirements c) potential for differential settlement where the widened highway meets the existing embankment d) larger excavation required, necessitating a longer temporary modular bridge and excess soil 	<ul style="list-style-type: none"> a) more expensive than SPCSP culvert option b) potential for differential settlement where the embankment meets the newly loaded existing ground
	Feasible	Feasible	Feasible

APPENDIX F
LIST OF OPSSS AND OPSDS AND SUGGESTED WORDING FOR NSSPS

Appendix F

The following Special Provisions and OPSS Documents are referenced in this report:

OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 401	Construction Specification for Trenching, Backfilling, and Compacting
OPSS.PROV 421	Construction Specification for Pipe Culvert Installation in Open Cut
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cut
OPSS.PROV 501	Construction Specification for Compacting
OPSS 511	Construction Specification for Rip-Rap, Rock Protection, and Granular Sheetting
OPSS.PROV 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS.PROV 902	Construction Specification for Excavating and Backfilling Structures
SP FOUN0003	Dewatering Structure Excavations
OPSS.PROV 1004	Material Specification for Aggregates - Miscellaneous
OPSS 1005	Material Specification for Aggregates – Streambed Material
OPSS.PROV 1010	Material Specification for Aggregates Base, Subbase, Select Subgrade, and Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal
OPSS.PROV 1860	Material Specification for Geotextiles
OPSD 802.010	Flexible Pipe Embedment and Backfill Earth Excavation
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.100	Foundation Frost Penetration Depths for Northern Ontario

Suggested Wording for Operational Constraints

- **Suggested Text for Operational Constraint on Subgrade Preparation**

The Contractor is advised that the soil that will be exposed at the culvert subgrade level is moisture sensitive and may become disturbed or otherwise negatively impacted when subjected to construction or personnel traffic, freeze-thaw actions, ingress or ponding water. The Contractor shall be responsible for protecting the subgrade by implementing adequate groundwater control measures and minimizing construction and personnel traffic on the founding subgrade.

The subgrade preparation and placement and compaction of the bedding material must be carried out in the dry.

Any buried topsoil, excessively soft soil, large cobbles and boulders, tree trunks / branches, and any soft, very loose organic or other deleterious material encountered during subgrade preparation should be sub-excavated and replaced with compacted granular material to provide a uniformly competent subgrade condition.

Immediately following excavation, the base should be inspected by the foundation engineering specialist to confirm that the exposed subgrade surface conforms to the design requirements.

- **Suggested Text for Operational Constraint on Obstructions**

Excavations and installation of temporary protections systems may encounter obstructions such as wood / logs, construction debris, cobbles or boulders embedded in the fill and native soils. The type and presence of obstructions may vary between and beyond the borehole locations. Such obstructions may impede excavation progress and/or temporary protection system installations, if employed. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions to achieve the design depths.

- **Suggested Text for Operational Constraint on Temporary Excavation Slopes**

The Contractor is notified that unsupported temporary slopes at this site, for excavations or otherwise, are not stable if inclined 1H:1V or steeper above the groundwater level. Temporary slopes are therefore restricted to inclinations of no steeper than 3H:1V below the groundwater level and 2H:1V above the groundwater level.

- **Suggested Text for Operational Constraint on Temporary Modular Bridge**

The Contractor is responsible for the detailed design of the Temporary Modular Bridge (TMB) including, but not limited to, slope stability of the temporary excavation slope in front of the TMB abutment footings, determination of bearing capacity for the abutment footings and safe footing set back distance from the open excavation, as well as the performance of the temporary footings throughout construction. As a minimum, the front edge of the modular bridge footings shall be set back a minimum two (2) metres, horizontally, from the top of the temporary excavation. The temporary excavation slope shall be no steeper than two (2) horizontal to one (1) vertical above the groundwater level and no steeper than three (3) horizontal to one (1) vertical below the groundwater level. The contractor is responsible for retaining a RAQS approved Licensed Geotechnical Engineer with a medium-complexity rating (RAQs Category – Geotechnical Structures and Embankment – Medium Complexity) to confirm all aspects of the modular bridge slope stability and foundation design. All final reports and drawings must be sealed and signed by a Professional Engineer, who shall also be a RAQs Designated Contact.

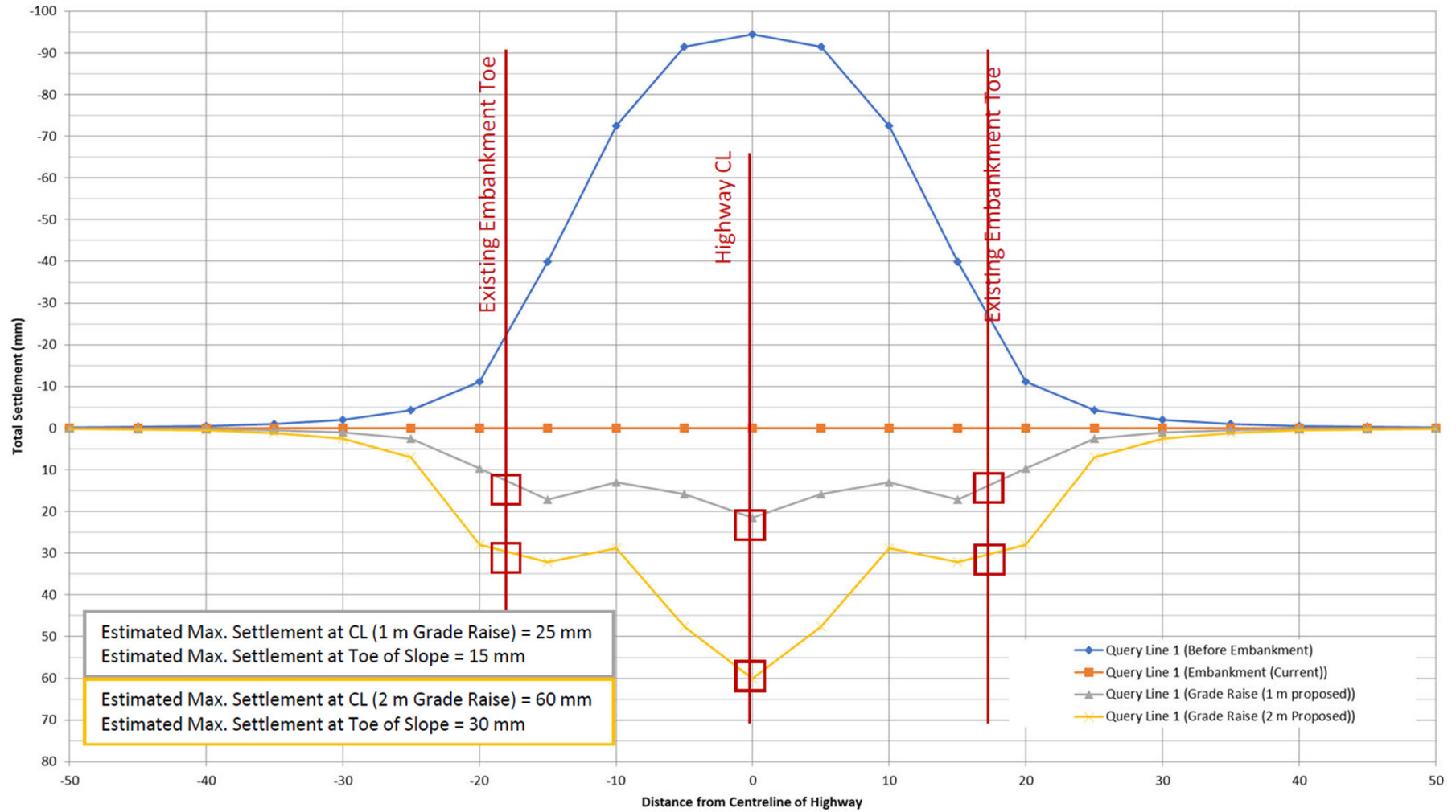
- **Suggested Text for Operational Constraint on Rock Fill for Wire Wall**

Rock fill used in the wire wall product must meet the following gradation requirements: The maximum particle size of the rock fill shall not be greater than 500 mm in any direction and the maximum percentage of particles passing the 75 µm sieve shall not be greater than 10%. The rock fill shall be well graded with the gradation determined as provided in Note 2 of Table 8 within OPSS.PROV 1004 (November 2012). The rock fill particles shall have a minimum unconfined compressive strength (UCS) of 100 MPa and meet the physical property requirements of "Rock Protection" as provided in Table 7 within OPSS.PROV 1004 (November 2012).

APPENDIX G
RESULTS OF SETTLEMENT ANALYSES

Miller's Creek Culvert Total Settlement Along Culvert Profile (STA 10+215)

Figure G1

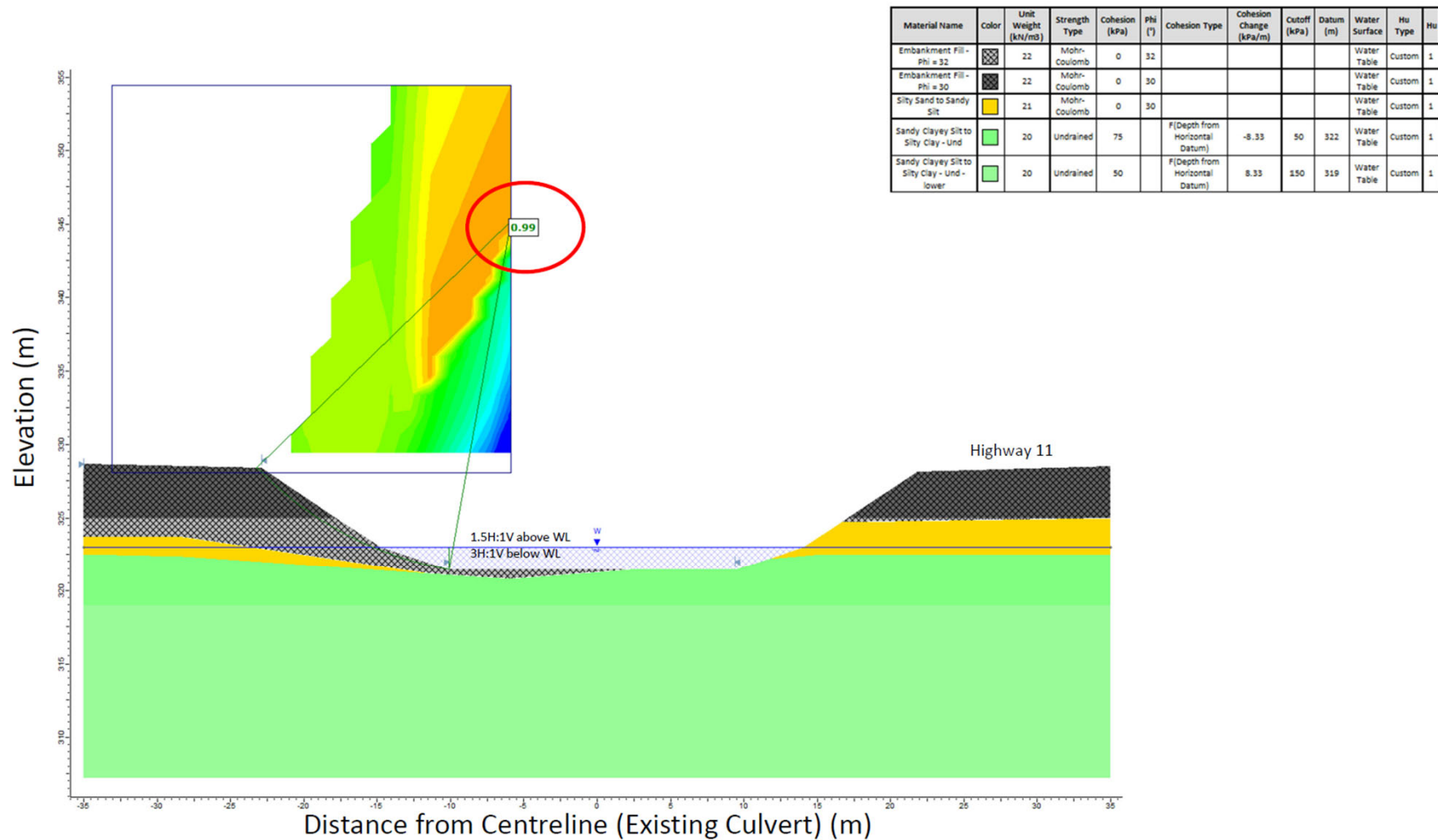


APPENDIX H

RESULTS OF SLOPE STABILITY ANALYSES

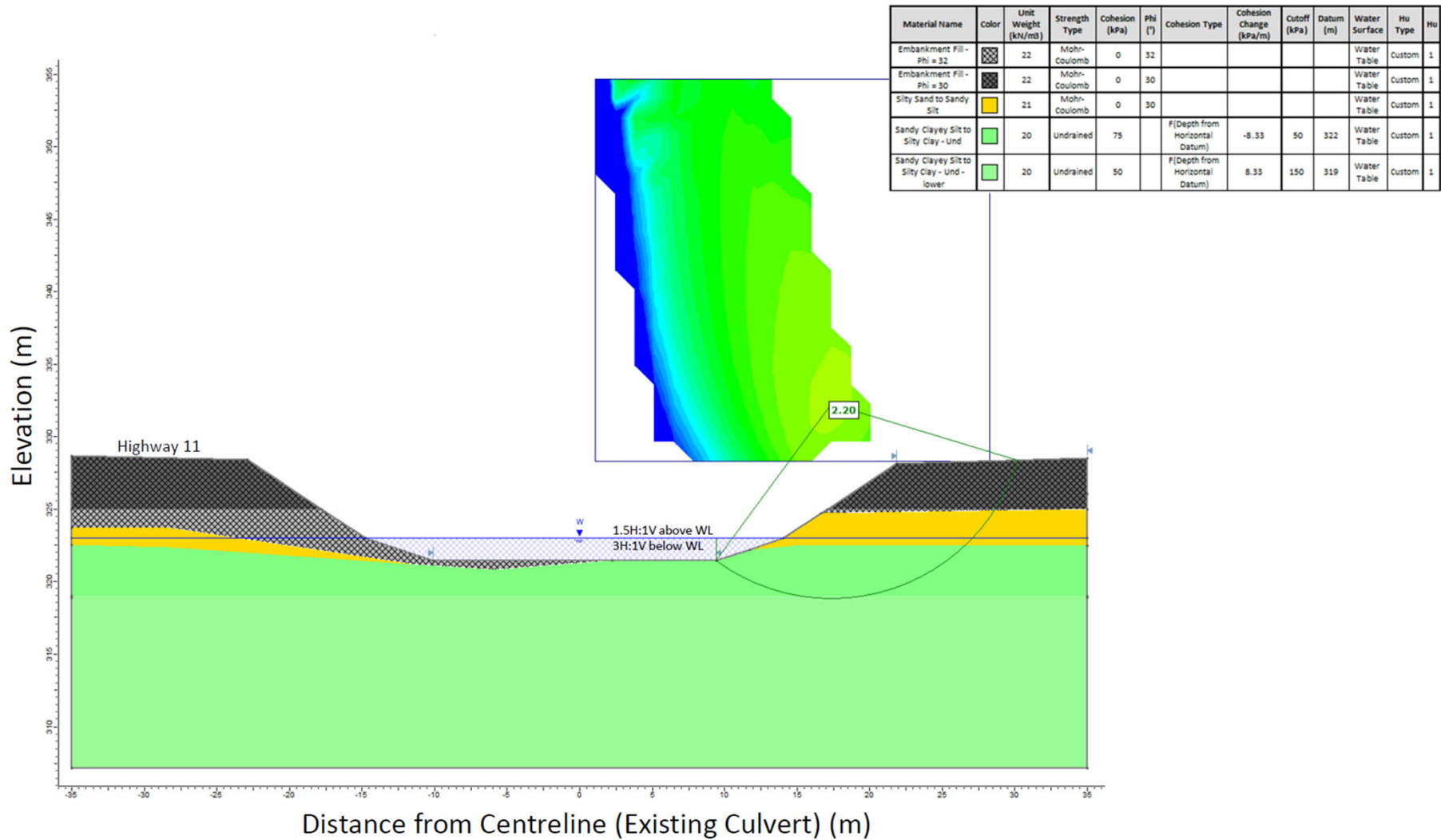
Miller's Creek Culvert – Global Stability Temporary Conditions – Open Cut Slope (1.5H:1V), West Slope

Figure H1



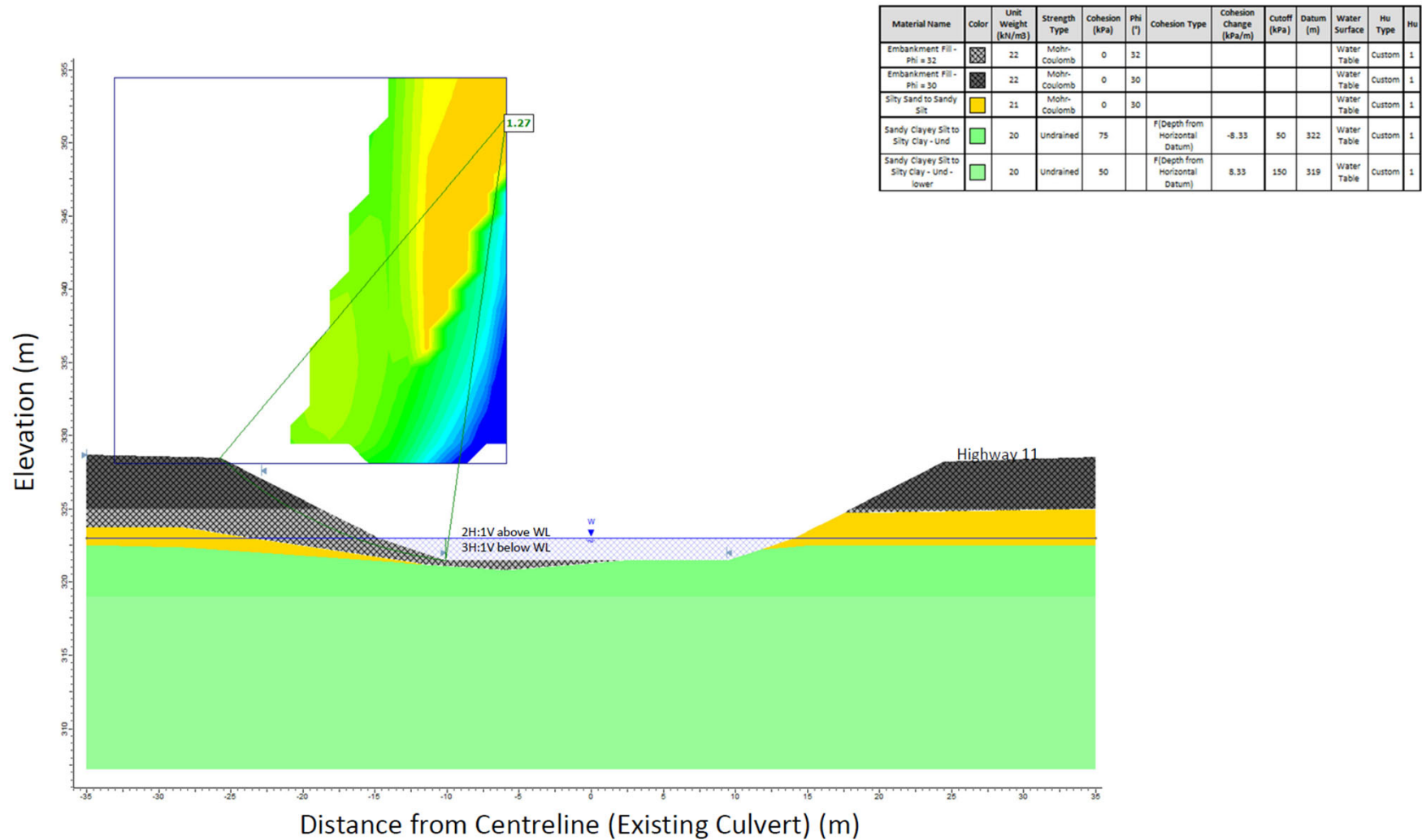
Miller's Creek Culvert – Global Stability Temporary Conditions – Open Cut Slope (1.5H:1V), East Slope

Figure H2



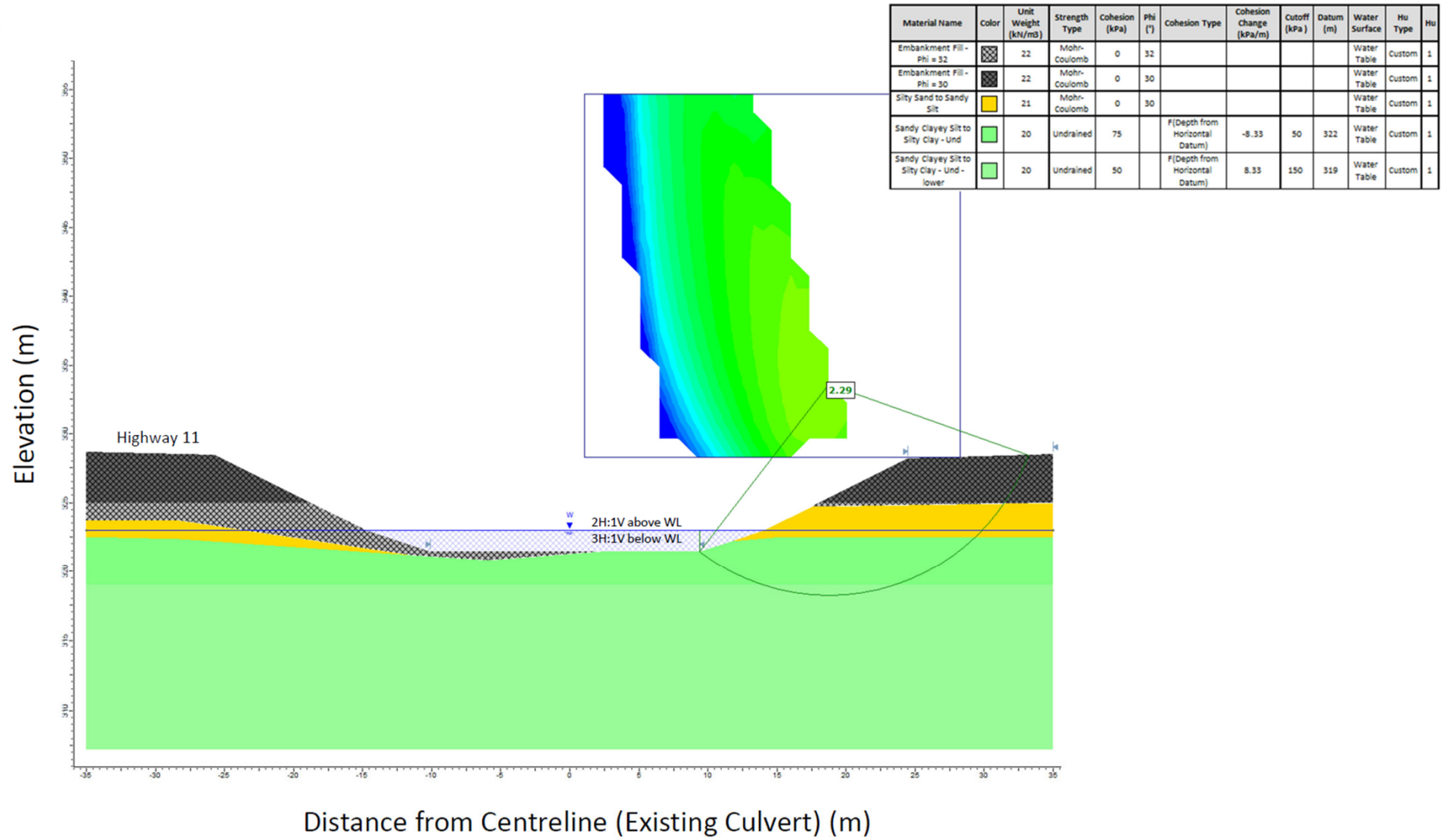
Miller's Creek Culvert – Global Stability Temporary Conditions – Open Cut Slope (2H:1V), West Slope

Figure H3



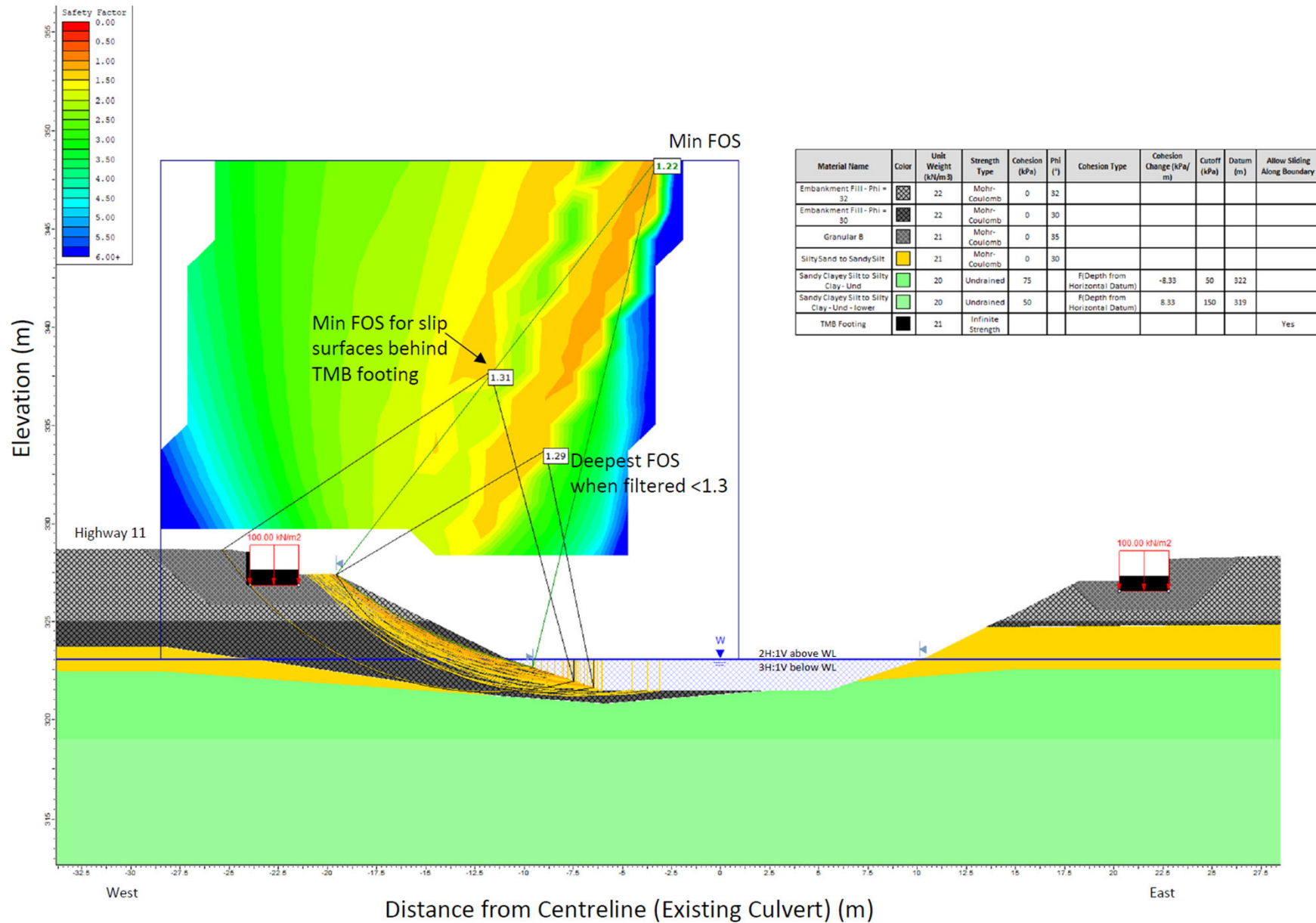
Miller's Creek Culvert – Global Stability Temporary Conditions – Open Cut Slope (2H:1V), East Slope

Figure H4



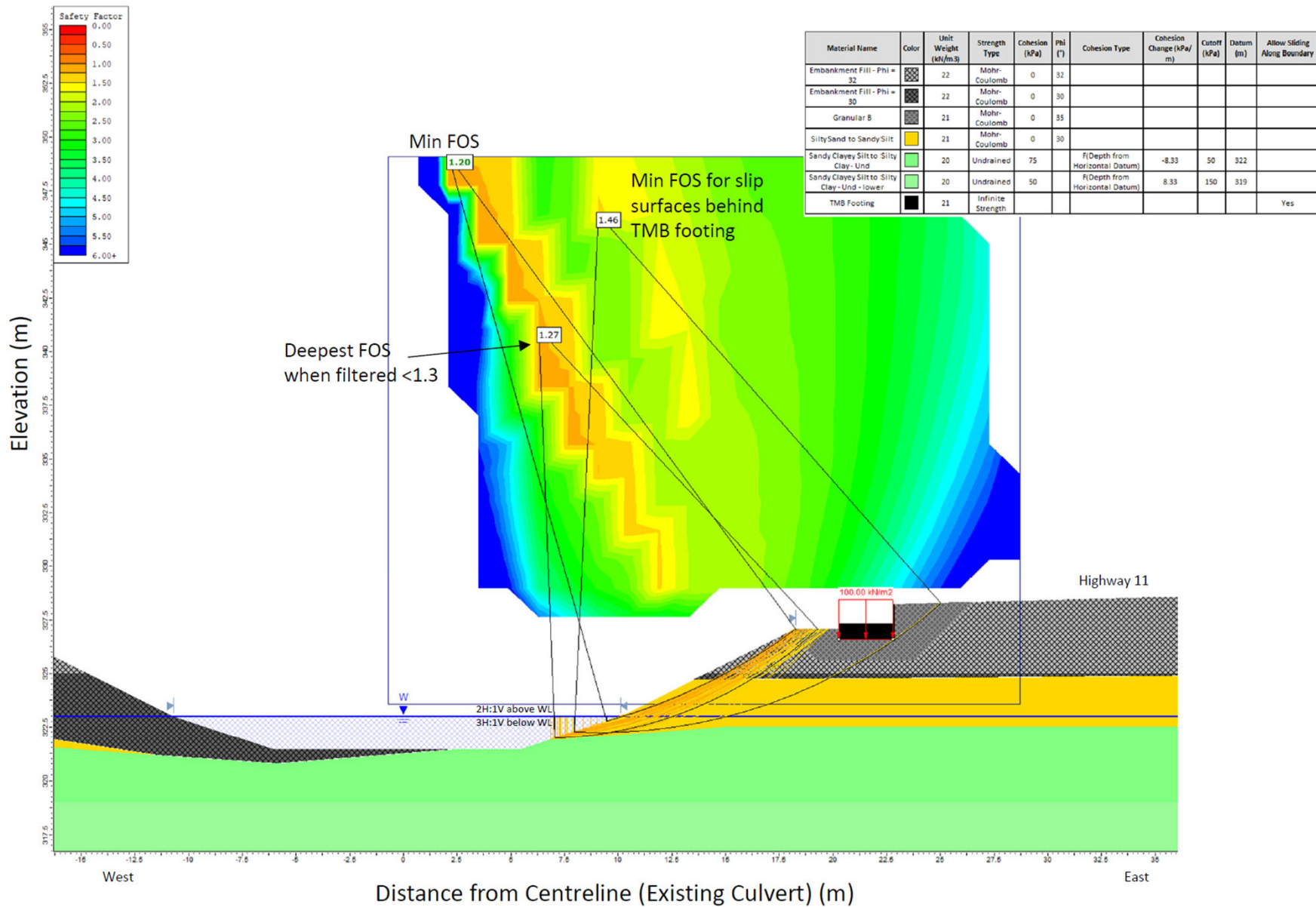
Miller's Creek Culvert – Global Stability
Temporary Conditions – Open Cut Slope (2H:1V), West Slope
2 m setback to 2.5 m wide footing (100 kPa loading)

Figure H5



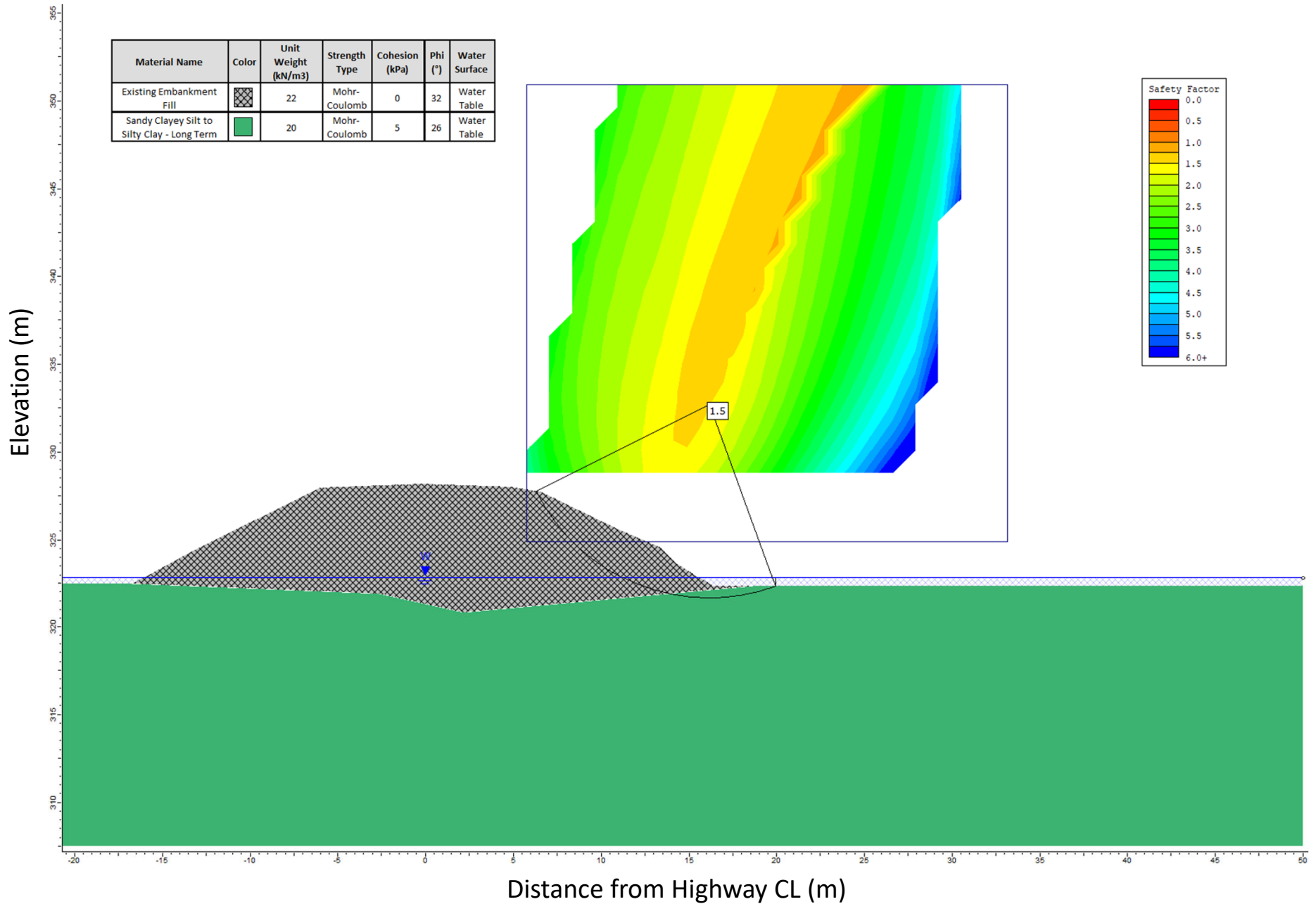
Miller's Creek Culvert – Global Stability
Temporary Conditions – Open Cut Slope (2H:1V), East Slope
2 m setback to 2.5 m wide footing (100 kPa loading)

Figure H6



Miller's Creek Culvert – Global Stability Long-Term – Embankment at STA 10+215, Granular Fill (2H:1V)

Figure H7



Miller's Creek Culvert – Global Stability Long-Term – Embankment at STA 10+215, Granular Fill (2H:1V) with Wire Rock RSS Wall

Figure H8

