FOUNDATION INVESTIGATION AND DESIGN REPORT

for

BAUDETTE - RAINY RIVER BRIDGE REPLACEMENT
MNDOT BRIDGE NO. 39016 / MTO SITE NO. 45-110
MN TH 72 / HIGHWAY 11
MNDOT PROJECT NO. SP 3905-09
MNDOT CONTRACT NO. 02047
BAUDETTE, MINNESOTA / RAINY RIVER, ONTARIO

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PML Ref.: 17TF029
Index No.: 017FIR and 018FDR
GEOCRES No.: 52D-33
December 21, 2017

Peto MacCallum Ltd.
CONSULTING ENGINEERS

PART A – FOUNDATION INVESTIGATION REPORT

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PART A- FOUNDATION INVESTIGATION REPORT
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Baudette - Rainy River Bridge Replacement
MnDOT Bridge No. 39016 / MTO Site No. 45-110
MN TH 72 / Highway 11
MnDOT Project No. SP 3905-09
MnDOT Contract No. 02047, GWP 6046-08-00
Baudette, Minnesota / Rainy River, Ontario

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1. INTRODUCTION

Stantec Consulting Services Inc. (Stantec) has retained Peto MacCallum Ltd. (PML) on behalf of the Minnesota Department of Transportation (MnDOT) and the Ministry of Transportation of Ontario (MTO) to provide foundation engineering services for detailed design of the Baudette – Rainy River International Bridge Replacement. The existing Baudette-Rainy River Bridge, known as MnDOT Bridge No. 39016 or MTO Site No. 45-110, connects the Minnesota Trunk Highway (MN TH) 72 and the Ontario Provincial Highway 11 (Kings Highway). The bridge is owned and maintained by the State of Minnesota and the Province of Ontario under a joint ownership agreement.

The location of the existing and the proposed replacement bridge is given on a site plan provided on Drawing RR-1 in Appendix A. The proposed replacement bridge will be constructed on the south side, approximately 1 m (3 ft.) upstream of the existing bridge. The new bridge will be a five-span structure with a total length of 411.5 m (1350 ft.) and 14.7 m (48.3 ft.) wide, and will maintain two lanes of traffic, shoulders and a sidewalk. The substructure will consist of four (4) piers (Pier 1, Pier 2, Pier 3, and Pier 4). Pier 1 and Pier 2 will be located on the US side of the river and Pier 3 and Pier 4 will be placed on the Canadian side. The project will also include reconstruction of the approach embankments on the U.S. and Canadian sides, to tie into the existing highways.

Previously, a preliminary foundation investigation on the Canadian side of the proposed replacement bridge was carried out in 2016 by PML, and the following report was submitted to MTO:

- *Preliminary Foundation Investigation and Design Report, Baudette – Rainy River Bridge Replacement, MnDOT Bridge No. 39016 / MTO Site No. 45-110, MN TH 72 / Highway 11, Geocres No. 52D-28, December 21, 2016.*

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The foundation investigation on the US side of the proposed replacement bridge was conducted by others and MTO provided a copy of the following reports to PML.

- *Draft Foundation Analysis and Design Recommendations, Minnesota Trunk Highway 72 and Ontario Provincial Highway 11 over Rainy River, Bridge 39016 (72 and 11 over Rainy River), Minnesota State Project No. 3905-09, Minnesota Department of Transportation, Office of Materials and Road Research, November 14, 2016.*
- *Preliminary Foundation Analysis and Design Report (FADR), TH 72 / Hwy 11 over Rainy River – Piers 1-4, Baudette, Minnesota and Rainy River, Ontario, Bridge No.: 39016, Dan Brown Associates Project No.: 17-042, August 2, 2017.*

The contract agreement for this project was completed on August 22, 2017, and work was conducted under a Sub-consultant Change Order Number 1. Under this agreement, PML was retained by Stantec to carry out foundation investigations on both sides of the border, with the exception of the abutment and approach embankment on the US side. The fieldwork for this investigation started on September 5, 2017 and completed on October 5, 2017.

The purpose of the foundation investigation was to identify the subsurface conditions along the proposed bridge alignment, and provide geotechnical recommendations for the detailed design based on the interpretation of the borehole information and laboratory test results.

2. SITE DESCRIPTION

At the bridge location, the Rainy River flows from southeast to northwest, and is about 350 m (1148.3 ft.) wide. The water level in the river during the fieldwork in September, 2017, was found to be at El. 322.9 m (1059.4 ft.), similar to the level recorded during the fieldwork carried out in August, 2016. The top of the approach embankment on the Canadian side was at El. 328 m (1076.1 ft.). Both the north and south slopes of this approach embankment were at 2H:1V, and were moderately vegetated with grass, shrubs and few trees. The river banks on both the Canadian and US side were approximately 3 m (10 ft.) high and were relatively gentle and highly vegetated.

A railway bridge that stretches along the same southwest-northeast direction is located approximately 85 m (280 ft.) north of the existing bridge.

Photographs (Photographs P1 – P3) of the site are provided in Appendix B.

3. FIELDWORK

The fieldwork for foundation investigation in this project consisted of drilling six (6) boreholes. Table 3 provides a summary of the termination depth and elevation of these boreholes. Boreholes 17-1, 17-3, 17-4 and 17-5 were drilled close to proposed pier locations, to levels in the range of El. 290.3 m (1037 ft.) to El. 283.3 m (929.5 ft.). In Borehole 17-2, early refusal was encountered at El. 299.8 m (1037.7 ft.), and the investigation to the required depth was completed 3 m (10 ft.) further south of the original location designated as Borehole 17-2A. During the preliminary foundation investigation in 2016, Borehole 16-2 was drilled close to the location of Borehole 17-5 to the level of El. 303 m (994 ft.). Therefore, the purpose of drilling Borehole 17-5, was to extend the depth of investigation to El. 283 m (928 ft.). For this reason, sampling in Borehole 17-5 started at the depth of El. 306.1 m (1004.3 ft.) as similar soil conditions are assumed. Borehole 17-6 was drilled at the abutment on the Canadian side, to El. 298.2 m (978.4 ft.).

Drawings RR-1 in Appendix A present the location of boreholes relative to piers and the abutment.

TABLE 3 - BOREHOLE LOCATIONS, DEPTH AND TERMINATION CONDITIONS

BOREHOLE NO.	BOREHOLE LOCATION	DEPTH FROM DRILLING PLATFORM / EXISTING GRADE (m)	ELEVATION FROM DRILLING PLATFORM / EXISTING GRADE (m)	REMARK
17-1	Close to Pier 1 of the proposed bridge	34.1 (102 ft.)	290.3 (1037.4 ft.)	Refusal on Bedrock
17-2	Close to Pier 2 of the proposed bridge	24.6 (67.3 ft.)	299.8 (1037.7 ft.)	Refusal on Cobbles and Probable Boulders
17-2A	Close to Pier 2 of the proposed bridge	40.3 (132.2 ft.)	284.1 (932.1 ft.)	-
17-3	Close to Pier 3 of the proposed bridge	40.6 (133.2 ft.)	283.8 (931.1 ft.)	-
17-4	Close to Pier 4 of the proposed bridge	40.4 (132.5 ft.)	284.0 (931.8 ft.)	-
17-5	Close to Pier 4 of the proposed bridge	41.1 (134.8 ft.)	283.3 (929.5 ft.)	-
17-6	At the Abutment, on the Canadian side	28.0 (92 ft.)	298.2 (978.4 ft.)	-

All boreholes were drilled using a CME-850 all-terrain drill rig. In the river, the rig was mounted on a spud barge that was directed by a tugboat. Drilling started at Borehole 17-2 using hollow stem augers. However, because of difficult drilling conditions, drilling in the other boreholes were conducted using wash boring inside a 75 mm (2.95 in.) diameter (NW) casing. NQ size diamond coring was used to advance the boreholes through hard layers containing cobbles and boulders.

The drill rig was supplied and operated by Cartwright Drilling Inc (Cartwright), a specialist-drilling contractor based in Goose Bay, Newfoundland and Labrador, with an office in Thunder Bay, Ontario. Cartwright used George Armstrong Co. Ltd., based in Fort Francis, Ontario to supply the barge and tugboat. The fieldwork was completed under the supervision of a PML field supervisor.

Soil samples were obtained at selected intervals using a split-spoon sampler in accordance with the Standard Penetration Test (SPT) procedures described in ASTM D1586. In-situ vane tests were carried out using an MTO 'N'-size vane according to the procedures outlined in ASTM D2573. The vane tests were required to assess the strength of cohesive soils. Thin wall (Shelby) tube samples of cohesive soils were also obtained in Borehole 17-6 in accordance with ASTM D1587.

Soil samples were visually examined as they were retrieved from boreholes, and placed in moisture-proof bags and transported to the PML laboratory in Toronto.

The groundwater condition at the abutment was observed during drilling by visual examination of soil samples, sampler and drill rods as the samples were retrieved.

Upon completion of drilling, all boreholes were grouted with cement and sealed with bentonite to the depth of about 9 m (30 ft.). At the abutment, Borehole 17-6 was backfilled with cement grout to the depth of 6 m (20 ft.), and sealed with bentonite to the ground surface.

Surveying was conducted by TBT Engineering Consulting Group based in Thunder Bay, Ontario, under contract to PML. In the river, the location of boreholes were identified using the existing bridge and piers as references. Surveying was completed once the barge was anchored and immediately before the start of drilling. At the abutment, the borehole was staked by PML field staff before drilling and surveying of the as-drilled borehole location was carried out after the drilling operation was completed. TBT provided

coordinates in UTM NAD 83 northing and easting as well as MTM NAD 83 for use on Record of Borehole Sheets. All the elevations given in this report are geodetic.

4. LABORATORY TESTS

The soil samples and rock cores were transported to PML laboratory in Toronto for detailed visual examination and testing. The laboratory tests of soil samples included the following:

- Natural Moisture Content Determination (74)
- Atterberg Limit Tests (13)
- Grainsize Distribution (34)
- Consolidation (1)

Laboratory tests were performed on representative samples of each stratigraphic layer encountered in the boreholes. All the laboratory tests of soil samples were conducted in accordance with MTO procedures, which follow ASTM guidelines with the exception of hydrometer testing (LS-702).

In addition to index tests, a consolidation test was conducted on a Shelby tube sample taken from Borehole 17-6, at a depth of 7.0 m (23 ft.), El. 319.2 m (1047.2 ft.) to 318.7 m (1045.6 ft.), to determine the consolidation characteristics of clayey soils. The test was carried out in accordance with ASTM D 2435 using two load cycles to a maximum consolidation pressure of 3,000 kPa (435 psi).

Moreover, a point load test was carried out on rock cores retrieved from Borehole 17-1, to assess the strength of bedrock. The test was performed in accordance with the method suggested by International Society for Rock Mechanics (ISRM). An unconfined compressive test was also conducted on the same rock core to verify the results obtained from point load strength index.

Chemical tests were carried out on eight (8) representative soil samples taken from all Boreholes to determine the corrosivity characteristics at the location of foundation elements. The tests were conducted by AGAT Laboratories located in Mississauga, Ontario. These tests included the determination of sulphate, sulphide and chloride contents, pH value, and resistivity.

All laboratory soil index test results are provided on Record of Borehole Sheets given in Appendix C. Plasticity charts are presented on Figures PC-1, PC-2A, and PC-2B. Grainsize distribution curves are

given on Figures GS 17-1, GS 17-2, GS 17-3A, GS 17-3B, GS 17-4A, GS 17-4B, and GS 17-4C. The consolidation test results are given on Figure RR-C-1. The plasticity charts and grainsize distribution curves provided in the preliminary foundation investigation and design report prepared by PML in 2016, are revised based on recent findings, and updated charts and curves are given in Appendix C.

5. SITE GEOLOGY

Based on the Quaternary Geology map of Fort Frances - Rainy River area, published in 2001 by Ontario Geological Survey, the site is located within the Superior Province of the Precambrian bedrock formation. Rock outcrops are reported to be less common, but regional mapping and stratigraphic correlation indicate that the bedrock in the region contains mafic meta-volcanic rocks of granite and granodiorite/tonalite. In the Rainy River area, these rocks are overlain by glacio-lacustrine tills and glacio-fluvial deposits. The Geology map indicates that the channel of the Rainy River contains alluvial deposits made up of pebbly fine to medium sand. The overburden is primarily clay and silt (clayey silt or silty clay), with occasional sand and gravel layers.

The thickness of Quaternary sediment containing clay, silt and sand, tend to be greatest adjacent to the river and diminish rapidly to the north-northeast direction. Depths to bedrock of 40 m (131 ft.) to about 50 m (164 ft.) occur along the river's course between Fort Frances and Emo and decrease to 25 m (82 ft.) to 35 m (114 ft.) between Emo and Lake of the Woods.

6. SUBSURFACE CONDITIONS

A stratigraphic profile along the proposed bridge alignment is provided on Drawing RR-2 in Appendix A. Additional profiles across Pier 2, Pier 3, Pier 4 and the Canadian side abutment, are provided on Drawing RR-3. The boundaries between the soil strata shown on Drawings RR-2 and RR-3, are established at borehole locations only. The boundaries between and beyond the boreholes, are assumed and may vary from location to location. For complete understanding of the subsurface conditions, the Records of Boreholes 16-1, 16-2, 16-3, 16-4, 16-5 and 16-6 drilled by PML in 2016, at locations shown on Drawing RR-1, are provided in Appendix C. The Records of Boreholes T10, B100, B101, and B102, drilled by others on the US side of the proposed bridge, are also given in Appendix C.

In summary, the subsurface at the abutment on the Canadian side consisted of a fill made up of clayey silt, with some sand and trace gravel. Beneath this material, a silty sand deposit was encountered. This silty sand deposit was underlain by silty clay to clayey silt material. The lower part of the stratigraphy to the full depth of investigation consisted of sand to silty sand deposit.

The upper part of the subsurface in the river consisted of 1.2 m (4 ft.) to 4.6 m (15 ft.) thick sandy layer with trace to some gravel. In Borehole 17-1, this sand layer was overlain by an alluvium consisting of silty clay and organic deposits. Beneath the sand layer, a silty clay to clayey silt deposit was encountered at El. 319.1 m (1046.9 ft.). This silty clay to clayey silt deposit is underlain by sand to silty sand glacial till to the maximum level of the current investigation of El. 283.8 m (931.1 ft.). The till contained cobbles and occasional boulders. In Borehole 17-1, a bedrock formation was encountered at a depth of El. 296.4 m (972.4 ft.), below the sand to silty sand till deposit.

For classification purposes, the soils and bedrock at the site are divided into the following units.

a) Clayey Silt, Some Sand (Fill)
b) Silty Clay (Alluvium)
c) Sand, Trace to Some Gravel, Trace to Some Silt
d) Silty Clay to Clayey Silt, Trace to Some Sand, Trace Gravel
e) Sand to Silty Sand, Trace to Some Gravel, Trace Clay
f) Bedrock

6.1. Clayey Silt, Some Sand (Fill)

A fill unit containing clayey silt material was encountered beneath the ground surface in Borehole 17-6. The clayey silt fill was brown to grey in color and wet during drilling. It has a total thickness of 2.3 m (11.5 ft.), and extends to El. 323.9 m (1062.7 ft.). The SPT-“N” values measured within the clayey silt deposit ranged from 6 to 7 blows/300mm (blows/foot) indicating firm consistency.

The moisture content of samples from the clayey silt fill was found to be in the range of 14.5% to 29.1%. Atterberg limit tests of a sample taken at depth of El. 325 (1066 ft.) provided a liquid limit of 29 and a plastic limit of 13, resulting in a plasticity index of 16. Based on these results, the clayey silt fill may be classified as inorganic clays of low plasticity (CL) in the Unified Soil Classification System (USCS). The plasticity chart is provided on Figure PC 17-1, in Appendix C.

A grainsize analysis was conducted on a sample taken at a depth of 1.7 m (5.6 ft.), El. 324.5 m (1064.6 ft.). The results indicated the presence of 5% gravel, 27% sand, 38% silt and 30% clay. The grainsize distribution curve is provided on Figure GS 17-1, in Appendix C.

6.2. Silty Clay (Alluvium)

A silty clay (alluvium) deposit containing wood fragments, organic inclusions and rootlets was encountered in Borehole 17-1, beneath the river bottom. This alluvial deposit was dark grey in color and wet. Its thickness was about 2.7 m (8.8 ft.), extending to EL. 320.6 m (1051.8 ft.).

The SPT-"N" value measured within the silty clay ranged from 0 (weight of the rod and hammer) to 2 blows/300mm (blows/foot), indicating very soft consistency. The moisture content of samples from this layer ranged from 27.3% to 42%.

6.3. Sand, Trace to Some Gravel, Trace to Some Silt

A sand layer was encountered below the river bottom in boreholes drilled in the river. This sand deposit underlies the silty clay (alluvium) in Borehole 17-1. A sand to silty sand material with varying proportions of gravel and trace clay was also encountered in Borehole 17-6. The thickness of the sand varied from 1.2 m (4 ft.) in Borehole 17-2 to 4.6 m (4.6 ft.) in Borehole 17-3.

The SPT-"N' values measured within the sand layer, were in the range of 0 (weight of a hammer) to 14 blows/300mm (blows/foot), indicating a very loose to compact state of denseness. The high blow counts were measured in Borehole 17-6 because of larger proportion of gravel.

The results of a sieve analysis performed on a sample taken from Borehole 17-1 at a depth of 4 m (13.1 ft.), El. 320.3 m (1050.9 ft.), indicated that the sand layer was composed of 0% gravel, 86% sand, and 14% fines. The grainsize distribution curve is given on Figure GS 17-2, in Appendix C.

6.4. Silty Clay to Clayey Silt, Trace to Some Sand, Trace Gravel

The sand layer is underlain by a silty clay to clayey silt deposit with varying proportions of sand and trace gravel. The depth to the silty clay to clayey silt deposit ranged from El. 320.9 m (1052.8 ft.) to El. 312.2 m (1024.3 ft.). In Boreholes 17-1 and 17-6, occasional cobbles were encountered within

the deposit. The thickness of the clayey silt ranged from 2.1 m (6.9 ft.) in Borehole 17-3 to 10.9 m (35.8 ft.) in Borehole 17-6, showing an increase towards the west and east abutments.

The SPT "N"-values ranged from 0 (weight of a rod and hammer) to higher than 59 blows/300 mm (blows/foot) penetration, indicating very soft to hard consistency. The in-situ vane shear test conducted within this deposit provided an undrained shear strength (C_U) ranged from 34 kPa (4.9 psi) to more than 100 kPa (14.5 psi), with higher values measured in Borehole 17-6. This indicates a firm to very stiff consistency.

The moisture content of samples from the silty clay to clayey silt deposit was in the range of 9.6% to 31.8%. The liquid limit values ranged from 20 to 43 and the plastic limits varied from 15 to 32, resulting in plasticity index of 3 to 24. Based on the results of Atterberg limit tests, the clayey silt may be classified as inorganic clays of low plasticity (CL) in the Unified Soil Classification System (USCS). Some samples from Boreholes 17-2, 17-4 and 17-6 fall in the zone of inorganic clays of medium plasticity (CI). The corresponding plasticity chart is provided on Figures PC 17-2A and PC 17-2B, in Appendix C.

The grainsize analyses of samples taken from the silty clay to clayey silt deposit indicated the presence of 0% - 9% gravel, 2% - 48% sand, 38% - 71% silt, and 6% - 36% clay. The grainsize distribution curves are provided on Figures GS 17-3A and GS 17-3B, in Appendix C.

The result of the consolidation test conducted on an undisturbed Shelby tube sample taken from Borehole 17-6, at the depth of 7 m (23 ft.), El. 319.2 m (1047.2 ft.) to 318.7 m (1045.6 ft.), is provided on Figure RR-C-1, in Appendix C. The test result indicated a pre-consolidation pressure of 340 kPa (49.3 psi), compared to the effective overburden pressure of about 70 kPa (14.5 psi). The computed initial void ratio (e_o) was 0.561 and the compression index (Cc) was 0.11.

6.5. Sand to Silty Sand, Trace to Some Gravel, Trace Clay (Till)

The sand to silty sand till was encountered below the silty clay to clayey silt deposit in all boreholes, at levels between El. 310.1 m (1017.4 ft.) and El. 309.2 m (1014.4 ft.). It extends to the maximum depth of 41.1 m (134.8 ft.), El. 283.3 m (929.5 ft.), and contains occasional gravel and cobble layers, as well as probable boulders throughout the full depth of investigation.

In Borehole 17-6, the SPT-"N' values were in the range of 25 to over 100 blows/300 mm (blows/foot), indicating a "compact" to "very dense" state of denseness. In boreholes drilled in the river, the till was found to be very dense with refusal to drive the split spoon.

The moisture content of the sand to silty sand till ranged from 1.2% to 25.1%. The grainsize analysis of representative samples of the sand to silty sand till, taken from all boreholes resulted in 0% - 49% gravel, 27% - 72% sand, 11% - 62% silt and 1% - 14% clay. The grainsize distribution curves are provided on Figures GS 17-4A, GS 17-4B, and GS 17-4C, in Appendix C.

Photographs P4 and P5 in Appendix D, show core and grab samples of the till encountered in Borehole 17-3. Photograph P6 in Appendix D, presents the cobbles retrieved from Borehole 17-6.

6.6. Bedrock

Bedrock was encountered in Borehole 17-1 at an El. 296.4 m (972.4 ft.). The presence of bedrock was proven by NQ size rock coring to a minimum length of 3 m (10 ft.). The core samples retrieved from the borehole were visually described and logged in the field. In addition, the rock cores were examined in the laboratory by a professional geologist.

The bedrock was described to be a diorite, monozonite, and granodiorite suite, with competent black, white and pink minerals. Measured core recovery ranged from 90% to 100%, and the RQD was between 53% and 83%. Based on the RQD values, the quality of the rock may be described as fair to good. Lower RQD values correspond to the upper part of the bedrock where significant fracturing, alteration and disintegration was observed.

A point load test was carried out on a rock core taken from the depth between El. 291.4 m (956 ft.) and El 290.4 m (952.8 ft.). The test measures the point load strength index ($I_{s(50)}$), and the result is often used for strength classification of rock materials. A total of 19 axial tests were conducted in accordance with the method suggested by ISRM, The specimens were tested at their natural water content. The results provided an average strength index of 0.72 MPa (104.4 psi). The unconfined compressive strength (UCS) was computed to be about 17 MPa (2465.6 psi).

Further, an unconfined compressive strength (UCS) test was carried out on the same rock core taken at a similar depth. The UCS test was required to verify the results of the point load test. The results indicate a UCS value of 20.7 MPa (3002 psi).

Photographs P7 and P8, and the complete description of the rock cores is provided in Appendix E. The results of the point load and UCS tests are also given in Appendix E.

7. GROUNDWATER

The groundwater level in boreholes drilled in the river was El. 322.9 m (1059.3 ft.), the same as the elevation of the water surface. Groundwater was not encountered in Borehole 17-6, immediately after the completion of drilling.

The groundwater level at the project site is influenced by the water level in the river and the level may fluctuate due to seasonal changes of precipitation.

8. CHEMICAL TEST RESULTS

A summary of the corrosivity test results conducted on samples of silty clay, clayey silt and sand to silty sand deposits is provided in Table 8. The samples were taken from all boreholes. The details of these results and a description of the test method are given in Appendix F.

Table 8 – Summary of Corrosivity Test Results

BOREHOLE NO.	SAMPLE No.	ELEVATION (m)	SOIL TYPE	SULPHIDE (%)	SULPHATE (μg/g, ppm)	CHLORIDE (μg/g, ppm)	pH	RESISTIVITY (Ohm-cm)
17-1	SS2	321 (1053.2 ft.)	Silty Clay	<0.05	20	22	7.95	5210
17-1	SS6	318 (1043.3 ft.)	Silty Clay to Clayey Silt	<0.05	31	77	8.27	3790
17-2	SS4	314.2 (1030.8 ft.)	Silty Clay to Clayey Silt	0.08	443	4	8.17	1760
17-3	SS2	315.8 (1036.1 ft.)	Sand, Trace Silt	<0.05	88	6	8.50	6060
17-4	SS4	312.8 (1026.3 ft.)	Silty Clay to Clayey Silt	0.19	293	4	8.27	2090
17-5	--	287.4 (942.9 ft.)	Sand to Silty Sand	<0.05	73	4	9.34	4980
17-6	SS3	324.5 (1064.6 ft.)	Silty Clay to Clayey Silt	<0.05	5	14	8.58	6760
17-6	SS8	320.5 (1051.5 ft.)	Silty Sand	0.25	205	20	8.24	2680

9. CLOSURE

The drilling work was supervised by Mr. Shane Aziz under the direction of Lulseged Yimam, PhD. P.Eng of PML. The drilling equipment was supplied and operated by Cartwright Drilling Inc. of Goose Bay, Newfoundland and Labrador, with an Office in Thunder bay, Ontario. The barge and the tugboat were contracted by RPM from George Armstrong Co. Ltd, based in Fort Francis, Ontario. The laboratory tests on soils and rocks were conducted at the PML laboratory in Toronto. Chemical tests were carried out by AGAT Laboratories of Mississauga, Ontario. Surveying was performed by TBT Engineering Consulting Ltd. of Thunder Bay, Ontario.

This report was prepared by Lulseged Yimam, PhD, P.Eng., and reviewed by M. Vasavithasan, M.Sc. Eng., P. Eng., Senior Engineer, Geotechnical Services. Mr. C.M.P. Nascimento, P.Eng., Principal Consultant, conducted an independent review of the report.

Yours very truly,

Peto MacCallum Ltd.

Lulseged Yimam, PhD, P.Eng.
Senior Engineer, Geotechnical Services

Carlos M.P. Nascimento, P.Eng.
Project Manager and
MTO Designated Principal Contact

LY/MV/CN:nk

APPENDIX A

Site Plan

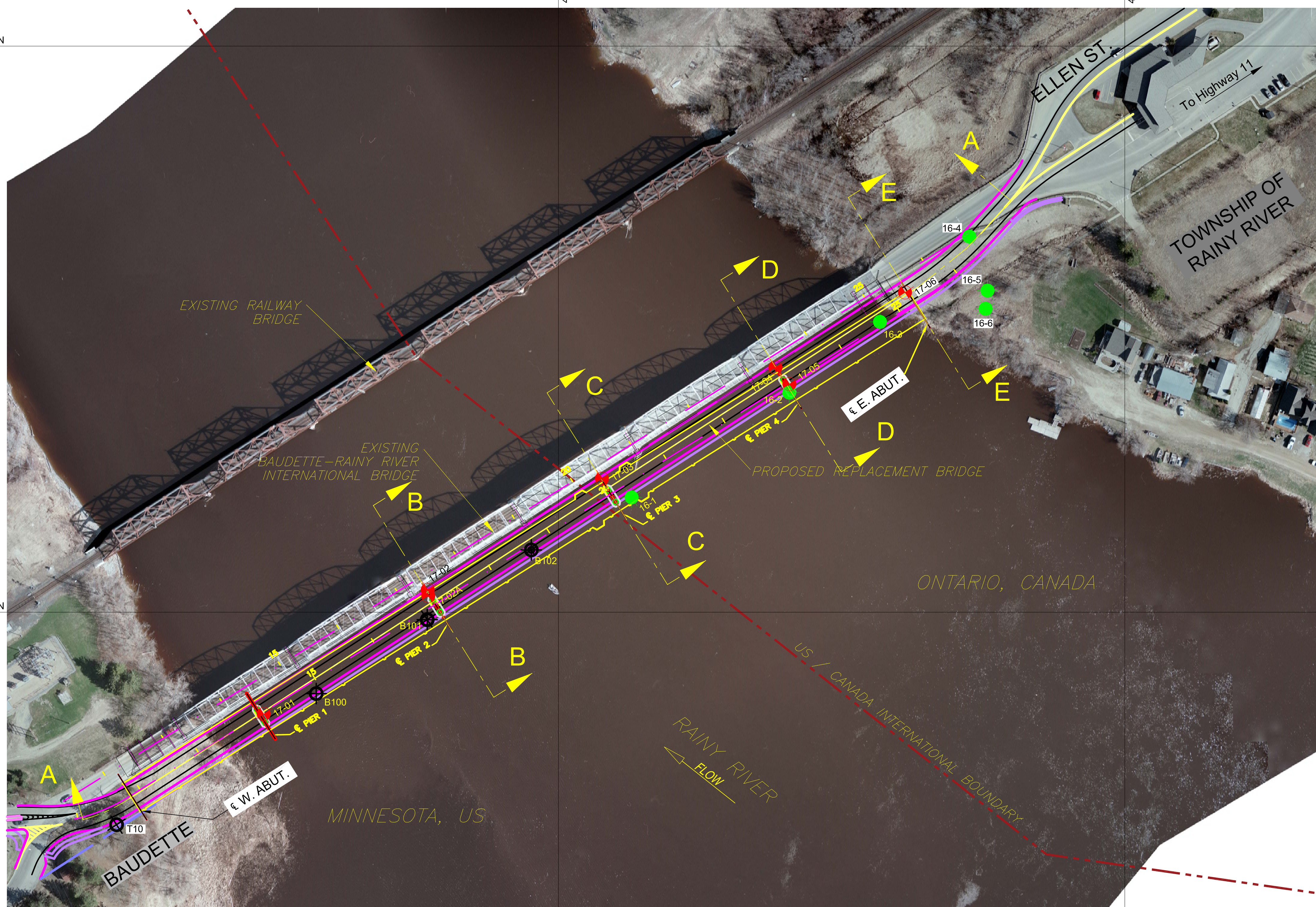
Borehole Locations and Soil Strata

G.W.P. No. 6046-08-00
MnDOT Contract No. 02047
MnDOT Project No. SP 3905-09

BAUDETTE – RAINY RIVER BRIDGE REPLACEMENT SITE PLAN

SHEET

Peto MacCallum Ltd.
CONSULTING ENGINEERS



PLAN

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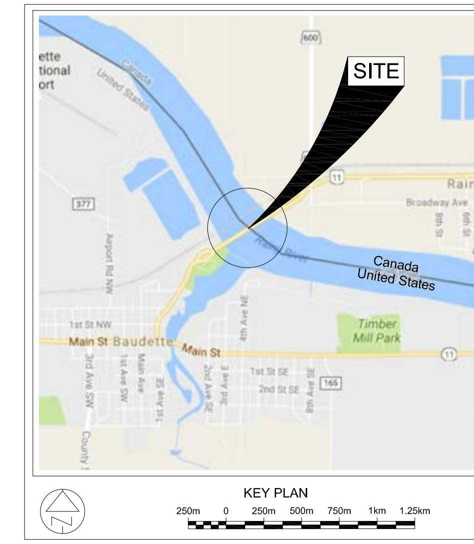


KEY PLAN

LEGEND

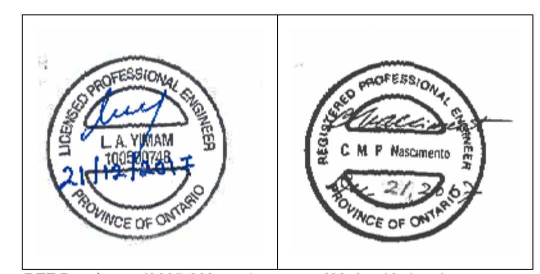
- Borehole under Present Investigation
- Previous PML Borehole
- Borehole by Others

BH No	ELEVATION	NORTHINGS	EASTINGS
17-01	324.4	5 398 705.0	408 369.9
17-02	324.4	5 398 759.8	408 442.3
17-02A	324.4	5 398 757.2	408 442.5
17-03	324.4	5 398 809.0	408 519.2
17-04	324.4	5 398 858.1	408 595.8
17-05	324.4	5 398 850.7	408 602.0
17-06	326.2	5 398 891.3	408 653.0
Previous PML Boreholes			
16-1	323.5	5 398 800.7	408 532.3
16-2	323.4	5 398 847.0	408 601.9
16-3	323.5	5 398 878.2	408 642.0
16-4	328.3	5 398 915.9	408 681.4
16-5	324.4	5 398 892.0	408 689.4
16-6	325.0	5 398 884.0	408 688.6
Previous Boreholes by Others			
T10	329.2	5 398 656.1	408 304.9
B100	324.3	5 398 713.9	408 393.1
B101	324.4	5 398 746.7	408 442.1
B102	324.3	5 398 777.5	408 488.0

– NOTE –
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

NOTES:

1. THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
2. REFER TO DRAWING RR-2 FOR PROFILE A-A ALONG CENTRELINE OF PROPOSED BRIDGE, DRAWING RR-3 FOR SECTIONS ALONG C/L OF PIER 2 AND C/L PIER 3 AND DRAWING RR-4 FOR SECTIONS ALONG C/L PIER 4 AND C/L EAST ABUTMENT.
3. THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
4. DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.
5. ELEVATION OF BOREHOLES WERE PROVIDED BY THE CONSULTANT AND ARE MEASURED AT THE TOP OF DRILLING PLATFORM OVER THE BOREHOLE LOCATION IN THE RIVER AND GROUND SURFACE ON LAND.



REF Drawing: cd3905-009_gm1c_mtmnad83.dwg Undated

REVISIONS DATE	BY	DESCRIPTION

Geocres No. 52D-33

HWY No 11		DIST THUNDER BAY	MnDOT Bridge No. 39016
SUBM'D NA	CHECKED LY	DATE DEC. 21, 2017	MTO SITE No. 45-110
DRAWN NA	CHECKED MV	APPROVED CN	DWG RR-1

G.W.P. No. 6046-08-00
MnDOT Contract No. 02047
MnDOT Project No. SP 3905-09

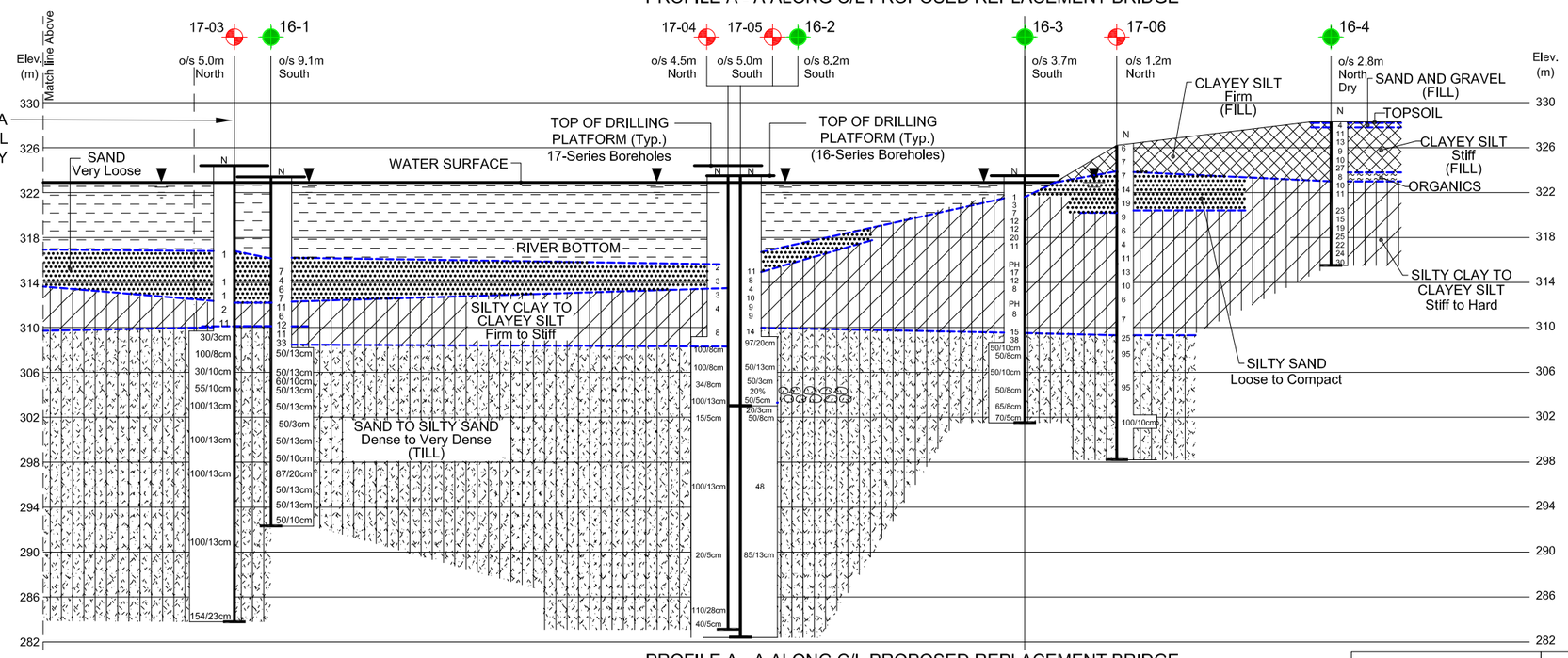
BAUDETTE – RAINY RIVER BRIDGE REPLACEMENT

Borehole Locations and Soil Strata

SHEET

Peto MacCallum Ltd.
CONSULTING ENGINEERS

PROFILE A - A ALONG C/L PROPOSED REPLACEMENT BRIDGE



PROFILE A - A ALONG C/L PROPOSED REPLACEMENT BRIDGE

NOTES:

1. THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
2. REFER TO DRAWING RR-1 FOR BOREHOLE LOCATION PLAN, DRAWING RR-3 FOR SECTIONS ALONG C/L PIER 2 AND C/L PIER 3 AND DRAWING RR-4 FOR SECTIONS ALONG C/L PIER 4 AND C/L EAST ABUTMENT.
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5. ELEVATION OF BOREHOLES WERE PROVIDED BY THE CONSULTANT AND ARE MEASURED AT THE TOP OF DRILLING PLATFORM OVER THE BOREHOLE LOCATION IN THE RIVER AND GROUND SURFACE ON LAND.

SCALE
HORIZONTAL
10 0 10 20m
VERTICAL
5 0 5 10m

REF Stantec Drawing: cd3905-009_gm1c_mtmnad83.dwg Undated

LEGEND

- Borehole under Present Investigation
- Previous PML Borehole
- Borehole by Others
- Water Level (August 2016, Sept. & October 2017)
- * Water Level is indeterminate due to use of drilling fluids

BH No	ELEVATION	NORTHINGS	EASTINGS

Refer to Drawing RR-1, for details

– NOTE –
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

REVISIONS			
DATE	BY	DESCRIPTION	

LICENSED PROFESSIONAL ENGINEER L. A. YIMAM 100150078 PROVINCE OF ONTARIO 21/12/2017

REGISTERED PROFESSIONAL ENGINEER C M P Nascimento PROVINCE OF ONTARIO Dec. 21, 2017

Geocres No. 52D-33

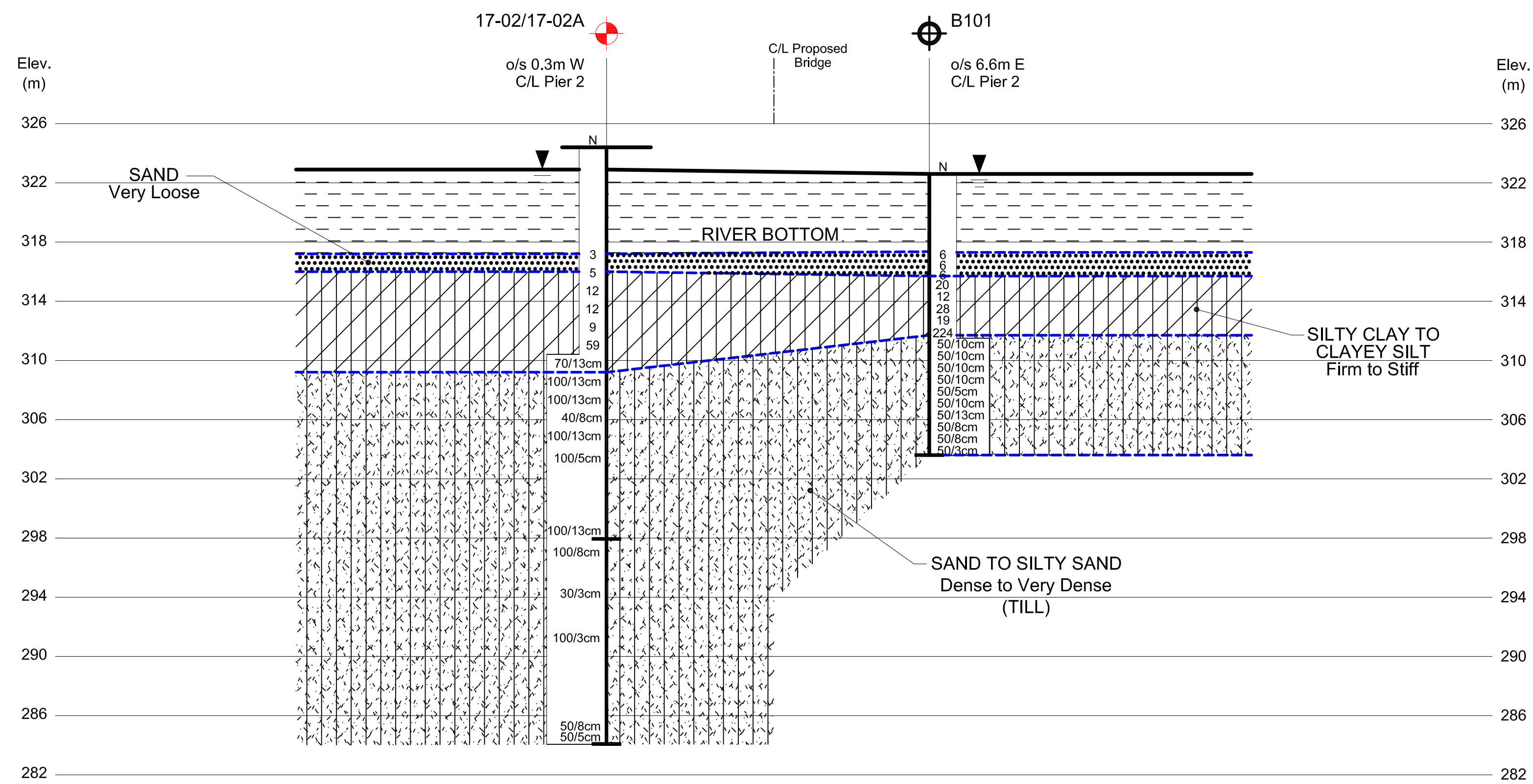
HWY No	11		DIST	THUNDER BAY	MnDOT Bridge No. 39016
SUBMD	NA	CHECKED LY	DATE	DEC. 21, 2017	MTO SITE No. 45-110
DRAWN	NA	CHECKED MV	APPROVED	CN	DWG RR-2

G.W.P. No. 6046-08-00
MnDOT Contract No. 02047
MnDOT Project No. SP 3905-09

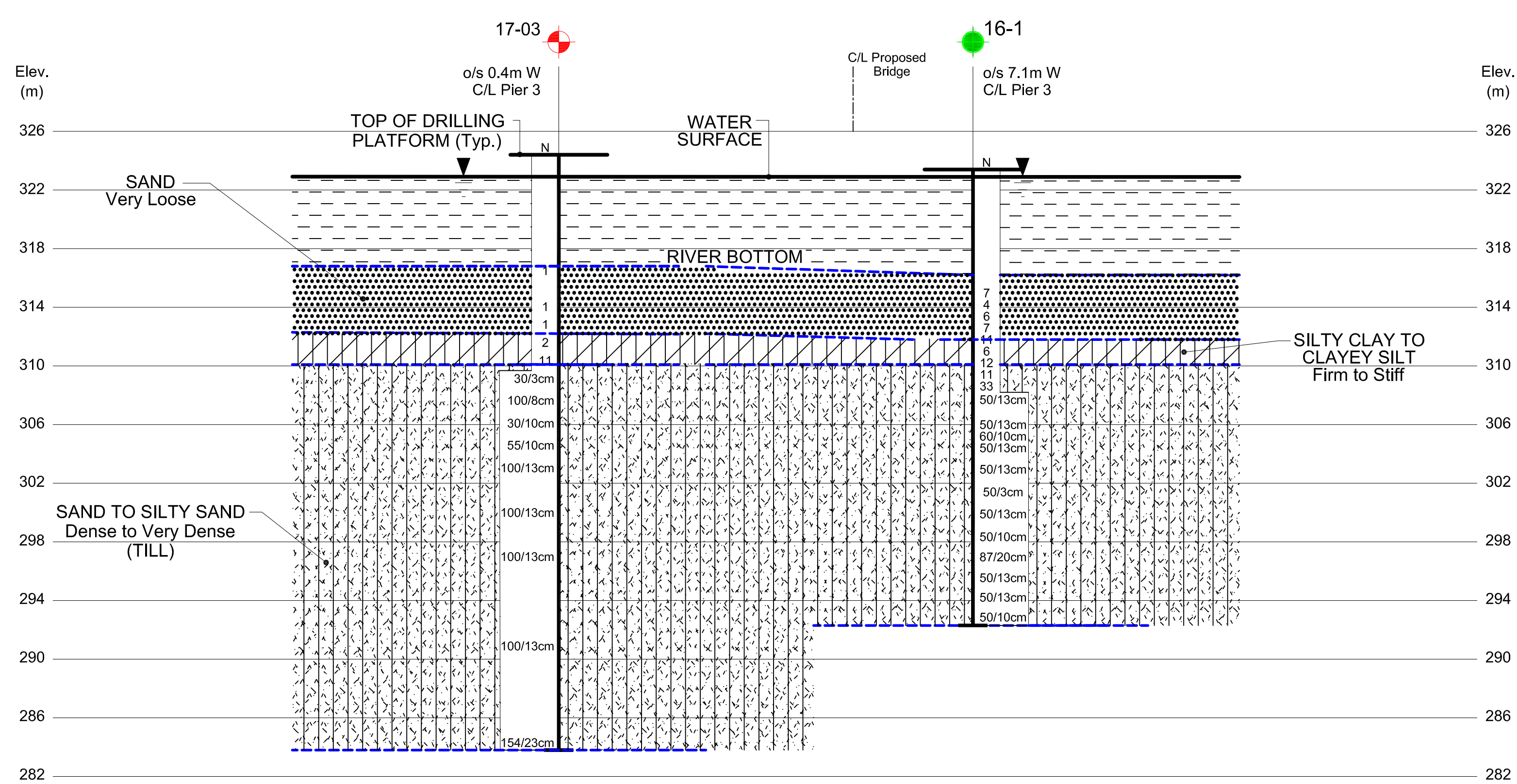
SHEET

BAUDETTE – RAINY RIVER BRIDGE REPLACEMENT
Borehole Locations and Soil Strata

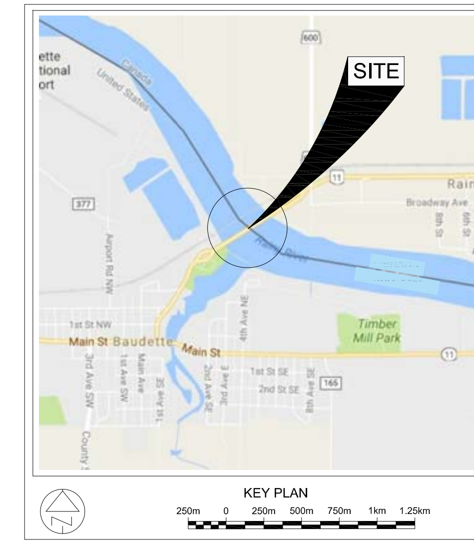
Peto MacCallum Ltd. CONSULTING ENGINEERS



SECTION B - B ALONG C/L PIER 2



SECTION C - C ALONG C/L PIER 3



KEY PLAN

250m 0 250m 500m 750m 1km 1.25km

LEGEND

- Borehole under Present Investigation
- Previous PML Borehole
- Borehole by Others
- Water Level (August 2016, Sept. & October 2017)

BH No	ELEVATION	NORTHINGS	EASTINGS
Refer to drawing RR-1, for details			

– NOTE –
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

NOTES:

1. THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
2. REFER TO DRAWING RR-1 FOR BOREHOLE LOCATION PLAN, RR-2 FOR PROFILE A-A ALONG C/L OF PROPOSED BRIDGE AND DRAWING RR-4 FOR SECTIONS ALONG C/L PIER 4 AND C/L EAST ABUTMENT.
3. THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
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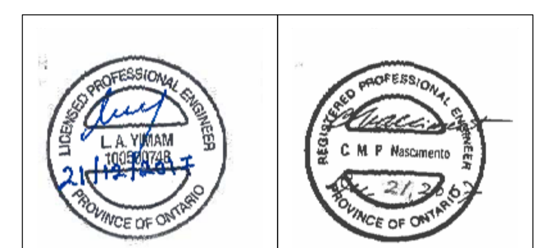
5. ELEVATION OF BOREHOLES WERE PROVIDED BY THE CONSULTANT AND ARE MEASURED AT THE TOP OF DRILLING PLATFORM OVER THE BOREHOLE LOCATION IN THE RIVER AND GROUND SURFACE ON LAND.

SCALE
HORIZONTAL 2.5 0 2.5 5m
VERTICAL 5 0 5 10m



REF Drawing: cd3905-009_gm1c_mtmnad83.dwg Undated

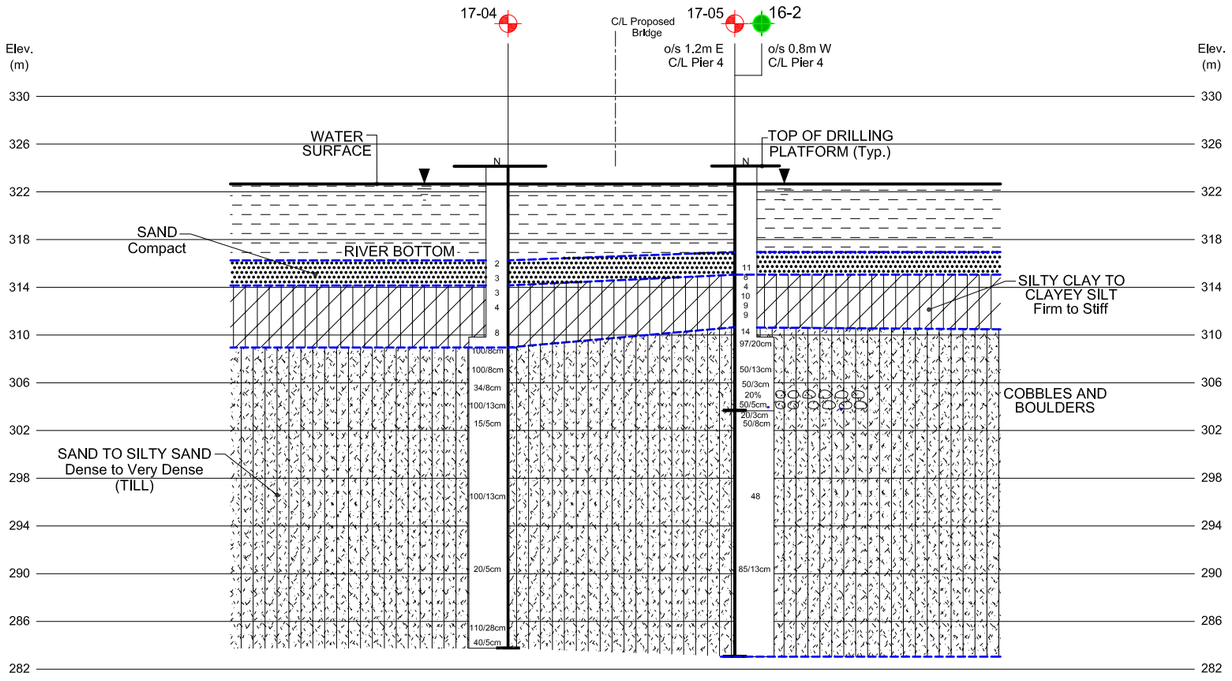
REVISIONS DATE	BY	DESCRIPTION

Geocres No. 52D-33

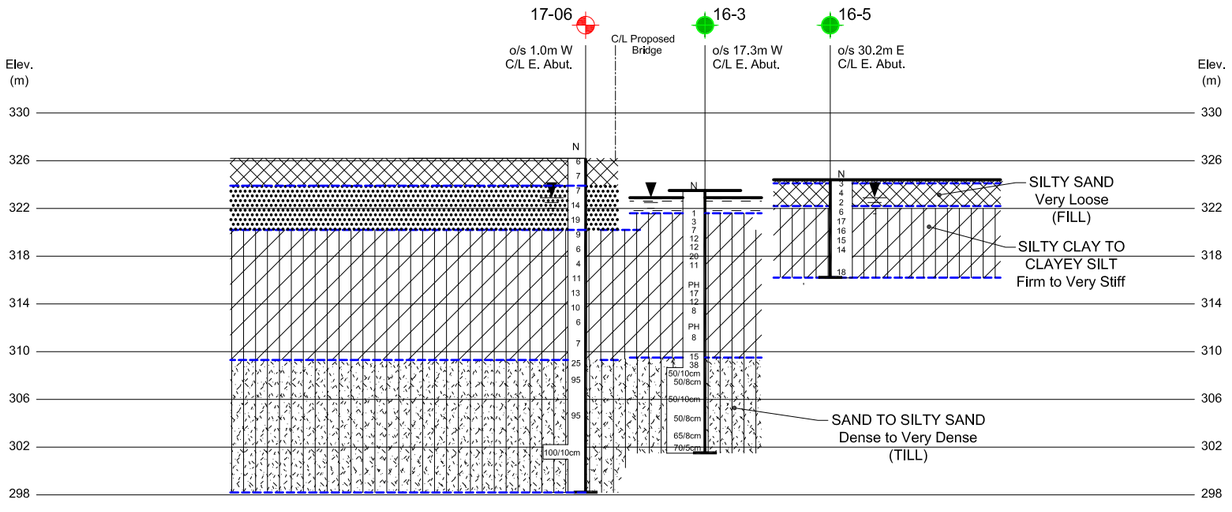
HWY No 11		DIST THUNDER BAY	MnDOT Bridge No. 39016
SUBM'D NA	CHECKED LY	DATE DEC. 21, 2017	MTO SITE No. 45-110
DRAWN NA	CHECKED MV	APPROVED CN	DWG RR-3

G.W.P. No. 6046-08-00 MnDOT Contract No. 02047 MnDOT Project No. SP 3905-09	
BAUDETTE – RAINY RIVER BRIDGE REPLACEMENT Borehole Locations and Soil Strata	SHEET

Peto MacCallum Ltd.
CONSULTING ENGINEERS



SECTION D - D ALONG C/L PIER 4



SECTION E - E ALONG C/L EAST ABUTMENT

LEGEND

- Borehole under Present Investigation
- Previous PML Borehole
- Borehole by Others
- Water Level (August 2016, Sept. & October 2017)

BH No	ELEVATION	NORTHINGS	EASTINGS

Refer to Drawing RR-1, for details

NOTES:

1. THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
2. REFER TO DRAWING RR-1 FOR BOREHOLE LOCATION PLAN, RR-2 FOR PROFILE A-A ALONG C/L OF PROPOSED BRIDGE AND DRAWING RR-3 FOR SECTIONS ALONG C/L PIER 2 AND C/L PIER 3.
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5. ELEVATION OF BOREHOLES WERE PROVIDED BY THE CONSULTANT AND ARE MEASURED AT THE TOP OF DRILLING PLATFORM OVER THE BOREHOLE LOCATION IN THE RIVER AND GROUND SURFACE ON LAND.

SCALE
HORIZONTAL
2.5 0 2.5 5m
VERTICAL
5 0 5 10m

LICENSED PROFESSIONAL ENGINEER L.A. VIKRAM 100097018 PROVINCE OF ONTARIO 21/12/2017

REGISTERED PROFESSIONAL ENGINEER C.M.P. Nascimento Dec. 21, 2017 PROVINCE OF ONTARIO

REF Drawing: cd3905-009_gm1c_mtmnad83.dwg Undated

– NOTE –
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

REVISIONS			
DATE	BY	DESCRIPTION	

Geocres No. 52D-33

HWY No	11		DIST THUNDER BAY	MnDOT Bridge No. 39016	
SUBMD	NA	CHECKED LY	DATE DEC. 21, 2017	MTO SITE No. 45-110	
DRAWN	NA	CHECKED MV	APPROVED CN	DWG RR-4	

APPENDIX B

Site Photographs

Photograph P1 – Set up at the Location of Borehole 17-1, near the Pier 1 of the Proposed Bridge the US side (September 30, 2017).

Photograph P2 – Drilling at the Location of Borehole 17-2, near Pier 2 of the Proposed Bridge on the US side (September 08, 2017).

Photograph P3 – Drilling at the Location of Borehole 17-6, at the East Abutment of the Proposed Bridge on the Canadian side (October 03, 2017).

APPENDIX C

Explanation of Terms used in the Report

Record of Borehole Sheets, Boreholes 17-1 to 17-6, Boreholes 16-1 to 16-6, Boreholes T10, B100, B101, B102

Plasticity Charts - Figures PC 17-1, PC 17-2A, PC 17-2B

Grainsize Distribution - Figures GS 17-1, GS 17-2, GS 17-3A, GS 17-3B, GS 17-4A, GS 17-4B, GS 17-4C

Revised Plasticity Charts and Grainsize Distribution Curves Provided in 2016

Consolidation Test Result - Figure RR-C-1

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS $\bar{N}$.

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

COMPOSITION: SECONDARY SOIL COMPONENTS ARE DESCRIBED ON THE BASIS OF PERCENTAGE BY MASS OF THE WHOLE SAMPLE AS FOLLOWS:

PERCENT BY MASS	0 – 10	10 – 20	20 – 30	30 – 40	> 40
	TRACE	*SOME*	*WITH*	*ADJECTIVE (SILTY)*	*AND (AND SILT)*

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	>200
	VERY SOFT	*SOFT*	*FIRM*	*STIFF*	*VERY STIFF*	*HARD*

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	>50
	VERY LOOSE	*LOOSE*	*COMPACT*	*DENSE*	*VERY DENSE*

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (R Q D), FOR MODIFIED RECOVERY, IS:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	*POOR*	*FAIR*	*GOOD*	*EXCELLENT*

JOINTING AND BEDDING:

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	>3m
JOINTING	*VERY CLOSE*	*CLOSE*	*MOD. CLOSE*	*WIDE*	*VERY WIDE*
BEDDING	*VERY THIN*	*THIN*	*MEDIUM*	*THICK*	*VERY THICK*

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE
F V	FIELD VANE		

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES
ρ_w	kg/m^3	DENSITY OF WATER
γ_w	kN/m^3	UNIT WEIGHT OF WATER
ρ	kg/m^3	DENSITY OF SOIL
γ	kN/m^3	UNIT WEIGHT OF SOIL
ρ_d	kg/m^3	DENSITY OF DRY SOIL
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL
e	1,%	VOID RATIO
n	1,%	POROSITY
w	1,%	WATER CONTENT
S_r	%	DEGREE OF SATURATION
w_L	%	LIQUID LIMIT
w_P	%	PLASTIC LIMIT
w_S	%	SHRINKAGE LIMIT
I_P	%	PLASTICITY INDEX = $w_L - w_P$
I_L	1	LIQUIDITY INDEX = $\frac{w - w_P}{I_P}$
I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_P}$
DTPL		DRIER THAN PLASTIC LIMIT
APL		ABOUT PLASTIC LIMIT
WTPL		WETTER THAN PLASTIC LIMIT
e_{max}	1,%	VOID RATIO IN LOOSEST STATE
e_{min}	1,%	VOID RATIO IN DENSEST STATE
I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
D	mm	GRAIN DIAMETER
D_n	mm	n PERCENT - DIAMETER
C_U	1	UNIFORMITY COEFFICIENT
h	m	HYDRAULIC HEAD OR POTENTIAL
q	m^3/s	RATE OF DISCHARGE
v	m/s	DISCHARGE VELOCITY
i	1	HYDRAULIC GRADIENT
k	m/s	HYDRAULIC CONDUCTIVITY
j	kN/m^3	SEEPAGE FORCE

RECORD OF BOREHOLE No 17-1

1 OF 3 **METRIC**

G.W.P. 6046-08-00 LOCATION 5 398 705.0 N ; 408 368.9 E ORIGINATED BY S.A.

DIST TB-61 HWY 11 BOREHOLE TYPE Wash Boring with Casing + Core Barrel COMPILED BY L.Y.

DATUM Geodetic DATE 2017.09.30 - 2017.10.01 LATITUDE _____ LONGITUDE _____ CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
324.4	TOP OF DRILLING PLATFORM						324				
0.0											
322.9	Water surface					▽▼	323				
1.5											
322.3	River bottom										
2.1	SILTY CLAY wood fragments, rootlets Very soft, Dark grey, Wet		1	SS	WH**		322				
			2	SS	2		321				
320.6	(ALLUVIUM)										
3.8	SAND trace to some silt, trace gravel Very loose, Grey, Wet		3	SS	1		320				0 86 (14)
			4	SS	WH						
319.1							319				
5.3	SILTY CLAY TO CLAYEY SILT trace to some sand, trace gravel Stiff to hard, Light grey, Wet		5	SS	WH						0 48 38 14
			6	SS	8		318				
			7	SS	50/3cm		317				Poor recovery
	occasional cobbles		8	SS	47		315				Poor recovery
			9	SS	13		314				0 12 62 26
			10	SS	37		312				
			11	SS	45		311				1 15 57 27
309.4							310				

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-1

2 OF 3 **METRIC**

G.W.P. 6046-08-00 LOCATION 5 398 705.0 N ; 408 368.9 E ORIGINATED BY S.A.

DIST TB-61 HWY 11 BOREHOLE TYPE Wash Boring with Casing + Core Barrel COMPILED BY L.Y.

DATUM Geodetic DATE 2017.09.30 - 2017.10.01 LATITUDE _____ LONGITUDE _____ CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
309.4											
15.0	SAND TO SILTY SAND trace to some gravel, trace clay Very dense, Grey, Wet		12	SS	105/28cm		309		○		
	cobbles						308				
			13	SS	100/13cm						No recovery
							307				
	gravel		14	SS	100/13cm		306		○		49 32 (19)
							305				
	silty clay seams		15	SS	100/13cm				○		
							304				
			16	SS	100/10cm		303		○		
	occasional cobbles						302				
							301				
							300				
							299				
							298				
	(TILL)										
			17	SS	100/13cm		297		○		8 73 15 4
296.4											
28.0	GRANODIORITE BEDROCK (Refer tp Appendix E of the Report for detail description of bedrock.)		18	RC NQ	REC 100%		296				RQD 53%
							295				
294.4											

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-1

3 OF 3 **METRIC**

G.W.P. 6046-08-00 LOCATION 5 398 705.0 N ; 408 368.9 E ORIGINATED BY S.A.

DIST TB-61 HWY 11 BOREHOLE TYPE Wash Boring with Casing + Core Barrel COMPILED BY L.Y.

DATUM Geodetic DATE 2017.09.30 - 2017.10.01 LATITUDE _____ LONGITUDE _____ CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
294.4											
30.0	GRANODIORITE BEDROCK (Refer tp Appendix E of the Report for detail description of bedrock.)		19	RC NQ	REC 92%		294				RQD 72%
			20	RC NQ	REC 90%		293				RQD 78%
							292				
			21	RC NQ	REC 100%		291				RQD 84%
290.3											
34.1	End of borehole										

▽ Top of River water during drilling

▼ Top of River water after completion of drilling

WH** denotes penetration due to weight of rods and hammer

NOTES:

1. Borehole backfilled with cement grout to the depth of 12 m (EL. 312.4m) and then bentonite to 9 m (EL. 315.4 m)
2. Difficult drilling conditions and slow progress because of cobbles starting from the depth of 7.0 m (EL.317.4m).

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-2

1 OF 2

METRIC

G.W.P. 6046-08-00 LOCATION 5 398 759.8 N ; 408 442.3 E ORIGINATED BY S.A.

DIST TB-61 HWY 11 BOREHOLE TYPE Hollow Stem Augers + Core Barrel COMPILED BY L.Y.

DATUM Geodetic DATE 2017.09.07 - 2017.09.11 LATITUDE LONGITUDE CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
324.4	TOP OF DRILLING PLATFORM						324				
0.0											
322.9	Water surface					▽▼	323				
1.5							322				
							321				
							320				
							319				
							318				
317.2	River bottom										
7.2	SAND, trace to some silt trace to some gravel Very loose, Grey, Wet		1	SS	3		317				Poor recovery
316.0											
8.4	SILTY CLAY TO CLAYEY SILT trace to some sand, trace gravel Firm to hard, Grey, Moist		2	SS	5		316		○		9 29 43 19
			3	SS	12		315		⊢●⊣		1 2 71 26
	silt seams		4	SS	12		314		○		
			5	SS	9		313		⊢○⊣		4 8 58 30
			6	SS	59		312		⊢○⊣		1 18 65 16
			7	SS	70/13cm		311		○		
309.4							310				

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-2

2 OF 2 **METRIC**

G.W.P. 6046-08-00 LOCATION 5 398 759.8 N ; 408 442.3 E ORIGINATED BY S.A.

DIST TB-61 HWY 11 BOREHOLE TYPE Hollow Stem Augers + Core Barrel COMPILED BY L.Y.

DATUM Geodetic DATE 2017.09.07 - 2017.09.11 LATITUDE _____ LONGITUDE _____ CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
309.4											
309.2											
15.2	SAND TO SILTY SAND trace to some gravel, trace clay Very dense, Grey, Wet		8	SS	100/13cm		309				
			9	SS	100/13cm		308		○		4 62 (34)
			10	SS	40/8cm		307		○		
			11	SS	100/13cm		306		○		13 52 (35)
			12	SS	100/5cm		305				
	Cobbles and boulders		12A	RC	REC 100%		304				Poor recovery
			12B	RC	REC 92%		303				
			12C	RC	REC 100%		302				
	(TILL)		13	SS	100/13cm		301				
299.8							300				
24.6	End of borehole Refusal on probable boulders										

▽ Top of River water during drilling

▼ Top of River water after completion of drilling water

NOTES:

1. Auger grinding from the depth of 15.2m (EL. 309.2), changed to core barrel from the depth of 18.2 m (EL. 306.4 m) because of difficult drilling conditions and slow progress.
2. Borehole terminated because of very difficult ground conditions consisting of cobbles and occasional boulders and backfilled with cement grout and bentonite to depth of 9m (EL. 315.4)

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-2A

1 OF 3

METRIC

G.W.P. 6046-08-00 LOCATION 5 398 757.2 N ; 408 442.5 E ORIGINATED BY S.A.

DIST TB-61 HWY 11 BOREHOLE TYPE Wash Boring + Core Barrel COMPILED BY L.Y.

DATUM Geodetic DATE 2017.09.12 - 2017.09.14 LATITUDE _____ LONGITUDE _____ CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
324.4	TOP OF DRILLING PLATFORM										
0.0							324				
322.9	Water surface					▽▼	323				
1.5							322				
							321				
							320				
							319				
							318				
316.8	River bottom						317				
7.6											
316.0							316				
8.4	Borehole was not sampled to 27.7 m depth (EL. 296.7) for stratigraphy details refer to Borehole 17-2						315				Casing advanced by washing with mud drilling to the depth of 27.7 m (EL. 296.7m)
							314				
							313				
							312				
							311				
309.4							310				

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-2A

2 OF 3 **METRIC**

G.W.P. 6046-08-00 LOCATION 5 398 757.2 N ; 408 442.5 E ORIGINATED BY S.A.

DIST TB-61 HWY 11 BOREHOLE TYPE Wash Boring + Core Barrel COMPILED BY L.Y.

DATUM Geodetic DATE 2017.09.12 - 2017.09.14 LATITUDE LONGITUDE CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
309.4											
309.2											
15.2	Borehole was not sampled to 27.7 m depth (EL. 296.7) for stratigraphy details refer to Borehole 17-2						309				
							308				
							307				
							306				
							305				
							304				
							303				
							302				
							301				
	gravel and cobbles						300				
							299				
							298				
							297				
296.7											
27.7	SAND TO SILTY SAND trace to some gravel, trace clay Very dense, Brown/grey, Wet (TILL)		1	SS	100/8cm		296				Poor recovery
							295				
294.4											

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-2A

3 OF 3 **METRIC**

G.W.P. 6046-08-00 LOCATION 5 398 757.2 N ; 408 442.5 E ORIGINATED BY S.A.

DIST TB-61 HWY 11 BOREHOLE TYPE Wash Boring + Core Barrel COMPILED BY L.Y.

DATUM Geodetic DATE 2017.09.12 - 2017.09.14 LATITUDE ____ LONGITUDE ____ CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
294.4											
30.0	SAND TO SILTY SAND trace to some gravel, trace clay Very dense, Grey, Wet						294				
			2	SS	30/3cm				○		18 70 11 1
							293				
							292				
							291				
			3	SS	100/3cm						No recovery
	rounded cobbles						290				
							289				
							288				
							287				
	(TILL)						286				
							285				
			4	SS	50/8cm				○		1 27 62 10
284.1			5	SS	50/5cm				○		
40.3	End of borehole										

▽ Top of River water during drilling

▼ Top of River water after completion of drilling

NOTES:

1. Borehole backfilled with portland cement, to 33.5m depth and then sealed with bentonite to 9.2 m depth (EL. 315.2).
2. Casing advanced without sampling by washing with mud rotary drilling to the depth of 27.4 m (EL. 297.0).
3. Difficult drilling conditions because of cobbles and probable boulders starting from 13 m depth (EL. 311.4).

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ONTARIO MTO 17TF029.GPJ ONTARIO MTO.GDT 1/12/17

RECORD OF BOREHOLE No 17-3

1 OF 3

METRIC

G.W.P. 6046-08-00 LOCATION 5 398 809.0 N ; 408 519.2 E ORIGINATED BY S.A.

DIST TB-61 HWY 11 BOREHOLE TYPE Wash Boring with Casing + Core Barrel COMPILED BY L.Y.

DATUM Geodetic DATE 2017.09.16 - 2017.09.18 LATITUDE _____ LONGITUDE _____ CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
324.4	TOP OF DRILLING PLATFORM						324				
0.0											
322.9	Water surface					▽▼	323				
1.5							322				
							321				
							320				
							319				
							318				
316.8	River bottom						317				
7.6	SAND, trace silt, trace to some gravel Very loose, Grey, Wet		1	SS	1				○		
			2	SS	WH**		316		○		
			3	SS	1		315		○		
			4	SS	1		314		○		
			5	SS	2		313		○		
312.2											
12.2	SILTY CLAY TO CLAYEY SILT trace to some sand, trace gravel Stiff, Grey, Wet		6	SS	11		312		○		
				VANE			311	+3			
310.1			7	TW	PH						Shelby tube refusal
14.3	SAND TO SILTY SAND trace to some gravel, trace clay						310				
309.4											

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-3

2 OF 3 **METRIC**

G.W.P. 6046-08-00 LOCATION 5 398 809.0 N ; 408 519.2 E ORIGINATED BY S.A.

DIST TB-61 HWY 11 BOREHOLE TYPE Wash Boring with Casing + Core Barrel COMPILED BY L.Y.

DATUM Geodetic DATE 2017.09.16 - 2017.09.18 LATITUDE _____ LONGITUDE _____ CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR SA SI CL
309.4 / 15.0	SAND TO SILTY SAND trace to some gravel, trace clay Very dense, Grey, Wet		8	SS	30/3cm		309		○		Poor recovery
			9	SS	100/8cm		308				Poor recovery
			10	SS	30/10cm		307		○		7 53 36 4
	occasional cobbles		11	SS	55/10cm		306		○		12 58 27 3
			12	SS	100/13cm		305		○		
			13	SS	100/13cm		304		○		21 48 26 5
			14	SS	100/13cm		303		○		
	(TILL)						302				
294.4							301				
							300				
							299				
							298				
							297				
							296				
							295				

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-3

3 OF 3 **METRIC**

G.W.P. 6046-08-00 LOCATION 5 398 809.0 N ; 408 519.2 E ORIGINATED BY S.A.

DIST TB-61 HWY 11 BOREHOLE TYPE Wash Boring with Casing + Core Barrel COMPILED BY L.Y.

DATUM Geodetic DATE 2017.09.16 - 2017.09.18 LATITUDE _____ LONGITUDE _____ CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
294.4											
30.0	___ ___ ___ ___						294				
							293				
							292				
							291		○		15 72 12 1
	occasional cobbles		15	SS	100/13cm		290				
							289				
							288				
	(TILL)						287				
							286				
							285				
283.8			16	SS	154/23cm		284		○		0 30 59 11
40.6	End of borehole										

▽ Top of River water during drilling

▼ Top of River water after completion of drilling water

WH** denotes penetration due to weight of rods and hammer

PH Pushed hydraulically

NOTES:

1. Borehole backfilled with cement grout to the depth of 12 m (EL. 312.4) and bentonite to the depth of 9 m (EL. 315.4)
2. Difficult drilling conditions because of cobbles starting from 15.2 m (EL. 309.2).

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

RECORD OF BOREHOLE No 17-4

1 OF 3

METRIC

G.W.P. 6046-08-00 LOCATION 5 398 858.1 N ; 408 595.8 E ORIGINATED BY S.A.

DIST TB-61 HWY 11 BOREHOLE TYPE Wash Boring with Casing + Core Barrel COMPILED BY L.Y.

DATUM Geodetic DATE 2017.09.25 - 2017.09.26 LATITUDE _____ LONGITUDE _____ CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
324.4	TOP OF DRILLING PLATFORM						324				
0.0											
322.9	Water surface					▽▼	323				
1.5							322				
							321				
							320				
							319				
							318				
							317				
316.5	River bottom										
7.9	SAND, trace to some gravel, trace silt Very loose, Wet		1	SS	2		316		○		
			2	SS	3		315		○		
314.4											
10.0	SILTY CLAY TO CLAYEY SILT trace to some sand, trace gravel Firm to stiff, Dark grey, Wet		3	SS	3		314		○		2 23 39 36
			4	SS	4		313		○		
				VANE			312	4 +			
			5	SS	8		311		○		
309.4				VANE			310	2 +			

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-4

2 OF 3 **METRIC**

G.W.P. 6046-08-00 LOCATION 5 398 858.1 N ; 408 595.8 E ORIGINATED BY S.A.

DIST TB-61 HWY 11 BOREHOLE TYPE Wash Boring with Casing + Core Barrel COMPILED BY L.Y.

DATUM Geodetic DATE 2017.09.25 - 2017.09.26 LATITUDE _____ LONGITUDE _____ CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
309.4											
309.2											
15.2	SAND TO SILTY SAND trace to some gravel, trace clay Very dense, Grey, Moist to wet		6	SS	100/8cm		309		○		
			7	SS	100/8cm		308		○		
			8	SS	34/8cm		307		○		16 45 33 6
			9	SS	100/13cm		306		○		37 36 (27)
			10	SS	15/5cm		305		○		13 63 19 5
	cobbles and occasional boulders		11	SS	100/13cm		304		○		
	(TILL)						303		○		
							302				
							301				
							300				
							299				
							298				
							297				
							296				
294.4							295				

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-4

3 OF 3 **METRIC**

G.W.P. 6046-08-00 LOCATION 5 398 858.1 N ; 408 595.8 E ORIGINATED BY S.A.

DIST TB-61 HWY 11 BOREHOLE TYPE Wash Boring with Casing + Core Barrel COMPILED BY L.Y.

DATUM Geodetic DATE 2017.09.25 - 2017.09.26 LATITUDE _____ LONGITUDE _____ CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
294.4											
30.0	SAND TO SILTY SAND trace to some gravel, trace clay Very dense, Grey, Wet (TILL)						294				
							293				
							292				
							291		○		
			12	SS	20/5cm		290				
							289				
							288				
							287				
							286				
							285				
			13	SS	110/28cm				○		10 37 46 7
284.0			14	SS	40/5cm		284		○		
40.4	End of borehole										

▽ Top of River water during drilling

▼ Top of River water after completion of drilling

NOTES:

1. Borehole backfilled with cement grout to the depth of 30 m (EL. 294.4) and bentonite to 9 m depth (EL. 315.4).
2. Difficult drilling conditiond and slow progress because of occasional cobbles starting from the depth of 10 m (EL. 314.4)

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-5

1 OF 3

METRIC

G.W.P. 6046-08-00 LOCATION 5 398 850.7 N ; 408 602.0 E ORIGINATED BY S.A.

DIST TB-61 HWY 11 BOREHOLE TYPE Wash Boring with Casing + Core Barrel COMPILED BY L.Y.

DATUM Geodetic DATE 2017.09.27 - 2017.09.28 LATITUDE _____ LONGITUDE _____ CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
324.4	TOP OF DRILLING PLATFORM						324				
0.0											
322.9	Water surface					▽▼	323				
1.5							322				
							321				
							320				
							319				
							318				
							317				
316.5	River bottom										
7.9							316				
	Borehole was not sampled to 18.3 m depth (EL. 306.1) for stratigraphy details refer to Borehole 16-2										Wash boring with Casing ro 18.3 m (EL.306.1)
315.3											
9.1							315				
							314				
							313				
							312				
310.9							311				
13.5											
309.4							310				

Continued Next Page

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

RECORD OF BOREHOLE No 17-5

2 OF 3 **METRIC**

G.W.P. 6046-08-00 LOCATION 5 398 850.7 N ; 408 602.0 E ORIGINATED BY S.A.

DIST TB-61 HWY 11 BOREHOLE TYPE Wash Boring with Casing + Core Barrel COMPILED BY L.Y.

DATUM Geodetic DATE 2017.09.27 - 2017.09.28 LATITUDE _____ LONGITUDE _____ CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR SA SI CL
309.4											
15.0	Borehole was not sampled to 18.3 m depth (EL. 306.1) for stratigraphy details refer to Borehole 16-2						309				
							308				
							307				
306.1											
18.3	SAND TO SILTY SAND trace to some gravel, trace clay Dense to very dense, Grey, Wet		1	SS	20/3cm		306		○		17 55 22 6
							305				
							304				
			2	SS	50/8cm		303		○		12 51 30 7
	cobbles						302				
							301				
							300				
							299				
							298				
			3	SS	48		297		○		0 34 54 12
	(TILL)						296				
							295				
294.4											

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-5

3 OF 3 **METRIC**

G.W.P. 6046-08-00 LOCATION 5 398 850.7 N ; 408 602.0 E ORIGINATED BY S.A.

DIST TB-61 HWY 11 BOREHOLE TYPE Wash Boring with Casing + Core Barrel COMPILED BY L.Y.

DATUM Geodetic DATE 2017.09.27 - 2017.09.28 LATITUDE _____ LONGITUDE _____ CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
294.4											
30.0	SAND TO SILTY SAND trace to some gravel, trace clay Very dense, Grey, Wet (TILL)						294 293 292 291 290 289 288 287 286				
			4	SS	85/13cm		291		○		6 38 42 14
285.4											
39.0	Boulder		5	RC NQ	REC 100%		285				RQD 100%
			6	RC NQ	REC 99%		284				RQD 60%
283.3											
41.1	End of borehole										

▽ Top of River water during drilling

▼ Top of River water after completion of drilling water

NOTES:

1. Borehole backfilled with cement grout to the depth of 12.2 m (EL. 312.2) and bentonite to 9 m depth (EL. 315.4).
2. Washboring and casing advanced without sampling to the depth of 18.3 m (EL. 306.1)
3. Difficult drilling condition and slow progress because of occasional cobbles starting from the depth of 10 m (EL. 314.4)

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ONTARIO MTO 17TF029.GPJ ONTARIO MTO.GDT 1/12/17

RECORD OF BOREHOLE No 17-6

1 OF 3

METRIC

G.W.P. 6046-08-00 LOCATION 5 398 891.3 N ; 408 653.0 E ORIGINATED BY S.A.

DIST TB-61 HWY 11 BOREHOLE TYPE Wash Boring + Core Barrel COMPILED BY L.Y.

DATUM Geodetic DATE 2017.10.03 - 2017.10.04 LATITUDE _____ LONGITUDE _____ CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
326.2	GROUND SURFACE										
0.0	CLAYEY SILT, some sand, trace gravel Firm, Brown/ grey, Moist to wet		1	SS	6		326		○		
			2	SS	7		325		○		
	(FILL)		3	SS	7				○		5 27 38 30
323.9							324		○		
2.3	SILTY SAND trace to some gravel, trace to some clay occasional cobbles Loose to compact, Brown/grey, Moist to wet		4	SS	14				○		
			5	SS	19		323		○		
			6	SS	9		322		○		
			7	SS	6				○		
320.9							321		○		
5.3	SILTY CLAY TO CLAYEY SILT trace to some sand, trace gravel Firm to stiff, Grey, Moist to wet		8	SS	4				○		4 53 26 17
				VANE			320	2			
			8A	TW	PH		319		○	20.5	
			9	SS	11				○		
				VANE			318	150			
			10	SS	13		317		○		3 33 38 26
			11	SS	10		316		○		
							315		○		
			12	SS	6		314		○		4 30 42 24
				VANE				5			
	cobbles						313				
311.2							312				

Continued Next Page

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

RECORD OF BOREHOLE No 17-6

2 OF 3

METRIC

G.W.P. 6046-08-00 LOCATION 5 398 891.3 N ; 408 653.0 E ORIGINATED BY S.A.

DIST TB-61 HWY 11 BOREHOLE TYPE Wash Boring + Core Barrel COMPILED BY L.Y.

DATUM Geodetic DATE 2017.10.03 - 2017.10.04 LATITUDE _____ LONGITUDE _____ CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
311.2							311				
15.0	SILTY CLAY TO CLAYEY SILT trace to some sand, trace gravel Firm to stiff, Grey, Moist to wet		13	SS	7				○		
				VANE			310	1 +			
309.3			13A	TW	PH						
16.9	SAND TO SILTY SAND trace clay, trace gravel occasional cobbles Compact to very dense, Grey, Wet		14	SS	25		309		○		22 43 32 3
			15	SS	95		308		○		
							307				
							306				
			16	SS	95		305		○		7 60 30 3
							304				
							303				
							302				
			17	SS	100/10cm				○		
	(TILL)						301				
							300				
							299				
298.2											
28.0	End of borehole PH Pushed hydraulically										

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-6

3 OF 3 **METRIC**

G.W.P. 6046-08-00 LOCATION 5 398 891.3 N ; 408 653.0 E ORIGINATED BY S.A.

DIST TB-61 HWY 11 BOREHOLE TYPE Wash Boring + Core Barrel COMPILED BY L.Y.

DATUM Geodetic DATE 2017.10.03 - 2017.10.04 LATITUDE _____ LONGITUDE _____ CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
296.2											

NOTES:

1. Borehole backfilled with cement grout to the depth of 6 m (EL. 320.2), then bentonite to the ground surface.
2. Casing refusal at 26.3 m (EL. 300.2)
3. Difficult drilling conditions because of cobbles starting from the depth of 18.7 m (EL. 307.5)

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

Ontario

Peto MacCallum Ltd. CONSULTING ENGINEERS
Foundation Design

RECORD OF BOREHOLE No 16-1 1 of 3 METRIC

MnDOT No. 02047

G.W.P. 6046-08-00 LOCATION Coords: 5 398 800.7 N; 408 532.3 E ORIGINATED BY S.A.

DIST Thunder Bay HWY 11 BOREHOLE TYPE Wash Boring + NW Casing and NQ Coring + Tricone COMPILED BY L.Y.

DATUM Orthometric DATE August 05, 2016 CHECKED BY M.V.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
323.4	Top of Drilling Platform										
0.0 / 322.9	Water surface					▽* ▼*	323				
0.5	Water						322				
							321				
							320				
							319				
							318				
							317				
316.2	River bottom										
7.2	Sand trace silt, trace gravel Loose to compact; Grey/black; Moist to wet		1	SS	7		316		○		0 97 (3)
			2	SS	4		315		○		
			3	SS	6		314		○		
			4	SS	7		313		○		
311.8			5	SS	11		312		○		3 95 (2)
11.6	Silty clay to Clayey silt trace to some sand, trace gravel Firm to stiff, Grey, Wet		6	SS	6		311		○		
310.1			7	SS	12		310		○		
13.3	gravel, cobbles		8	SS	11		309		○		41 30 26 3
	Sand to silty sand trace clay, trace gravel Compact to very dense; Grey; Moist to wet		9	SS	33				○		
308.4	(TILL) Cont'd										

Numbers refer to Sensitivity 5

(%) STRAIN AT FAILURE 20 15 5 10

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RECORD OF BOREHOLE No 16-1 2 of 3 METRIC

MnDOT No. 02047

G.W.P. 6046-08-00 LOCATION Coords: 5 398 800.7 N; 408 532.3 E ORIGINATED BY S.A.

DIST Thunder Bay HWY 11 BOREHOLE TYPE Wash Boring + NW Casing and NQ Coring + Tricone COMPILED BY L.Y.

DATUM Orthometric DATE August 05, 2016 CHECKED BY M.V.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
308.4											
15.0	Sand to silty sand trace clay, trace gravel Very dense Grey Moist to wet (Cont'd)		10	SS	50/13cm		308		○		
			11	SS	50/13cm		307				
			12	SS	50/13cm		306		○		
			13	SS	60/10cm		305		○		
			14	SS	50/13cm		304		○		0 93 (7)
	cobbles		15	SS	50/3cm		303				
			15A	SS	50/13cm		302		○		
			16	SS	50/10cm		301		○		
			17	SS	87/20cm		300		○		
			18	SS	50/13cm		299		○		
	(TILL)						298				
			19	SS	50/13cm		297		○		1 78 (21)
293.4	Cont'd						296				
							295				
							294				

ON MTO_VER3 NEW LOGO 14TF020 REV 20171109.GPJ ON_MOT.GDT 01/12/2017 9:20:08 AM

5 Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

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Ontario

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RECORD OF BOREHOLE No 16-1 3 of 3 METRIC

MnDOT No. 02047

G.W.P. 6046-08-00 LOCATION Coords: 5 398 800.7 N; 408 532.3 E ORIGINATED BY S.A.

DIST Thunder Bay HWY 11 BOREHOLE TYPE Wash Boring + NW Casing and NQ Coring + Tricone COMPILED BY L.Y.

DATUM Orthometric DATE August 05, 2016 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
293.4											
30.0	Sand to silty sand trace clay, trace gravel Very dense Grey Moist to wet (Cont'd)						293				
292.3	(TILL)		20	SS	50/10cm				○		
31.1	End of borehole										

* 2016 08 05

▽ Water level observed during drilling

▼ Water level measured after drilling

Bentonite slurry mud used to stabilize borehole from 7.6m to 31.1m depth.

Difficult drilling conditions and slow progress from a depth of 16.8m (El. 306.6m) to 31.1m (El. 292.3m).

Delay in drilling due to a sand blow at 25.9m (El. 297.5m).

Numbers refer to Sensitivity 5

20 15 5 10 (%) STRAIN AT FAILURE

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RECORD OF BOREHOLE No 16-2 1 of 2 METRIC

MnDOT No. 02047

G.W.P. 6046-08-00 LOCATION Coords: 5 398 847.0 N; 408 601.9 E ORIGINATED BY S.A.

DIST Thunder Bay HWY 11 BOREHOLE TYPE Wash Boring + NW Casing and NQ Coring COMPILED BY L.Y.

DATUM Orthometric DATE August 03, 2016 CHECKED BY M.V.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
323.5	Top of Drilling Platform										
0.0 / 322.9	Water surface					▽* ▼*	323				
0.6	Water						322				
							321				
							320				
							319				
							318				
							317				
316.3	River bottom										
7.2	Sand trace silt, some gravel Compact Grey/ black Moist to wet		1	SS	11		316		○		15 83 (2)
314.4							315				
9.1	Silty clay to Clayey silt some sand Firm to stiff Grey Moist		2	SS	8		314		⊢○⊣		
			3	SS	4		313		○		
			4	SS	10		312		⊢○⊣		0 17 53 30
			5	SS	9		311		○		
			6	SS	9		310		⊢○⊣		
310.0			6A	TW	PH		309				
13.5	Sand to silty sand some gravel, trace clay cobbles Compact to Grey Moist very dense to wet		7	SS	14				○		15 65 (20)
			8	SS	97/20cm						
308.5	(TILL) Cont'd										

ON MTO_VER3 NEW LOGO 14TF020 REV 20171109.GPJ ON_MOT.GDT 01/12/2017 9:20:09 AM

Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

Ontario

Peto MacCallum Ltd. CONSULTING ENGINEERS

Foundation Design

RECORD OF BOREHOLE No 16-2 2 of 2 METRIC

MnDOT No. 02047

G.W.P. 6046-08-00 LOCATION Coords: 5 398 847.0 N; 408 601.9 E ORIGINATED BY S.A.

DIST Thunder Bay HWY 11 BOREHOLE TYPE Wash Boring + NW Casing and NQ Coring COMPILED BY L.Y.

DATUM Orthometric DATE August 03, 2016 CHECKED BY M.V.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
308.5											
15.0	Sand to silty sand some gravel, trace clay cobbles Very dense Grey Wet (Cont.d)						308				
							307				
			9	SS	50/13cm				○		
							306				
			10	SS	50/3cm		305				
	cobbles and boulders (TILL)		10A	RC HQ	REC 20%		304				
303.0			11	SS	50/5cm		303		○		
20.5	End of borehole Refusal on boulders										

* 2016 08 06

▽ Water level observed during drilling

▼ Water level measured after drilling

PH Pushed hydraulically

Bentonite slurry mud used to stabilize borehole from 7.9m to 20.5m depth.

Difficult drilling conditions and slow progress from a depth of 18.1m (El. 305.4m) to 20.5m (El. 303.0m).

Delay in drilling due to grinding on possible boulder.

Numbers refer to Sensitivity 5

20 15 5 10 (%) STRAIN AT FAILURE

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Ontario

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RECORD OF BOREHOLE No 16-3 1 of 2 METRIC

MnDOT No. 02047

G.W.P. 6046-08-00 LOCATION Coords: 5 398 878.2 N; 408 642.0 E ORIGINATED BY S.A.

DIST Thunder Bay HWY 11 BOREHOLE TYPE Wash Boring and NW Casing COMPILED BY L.Y.

DATUM Orthometric DATE August 06, 2016 CHECKED BY M.V.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
323.5	Top of Drilling Platform										
0.0 / 322.9	Water surface					▽* ▼*	323				
0.6 / 321.9	Water / River bottom										
1.6	rootlets, organics wood debris		1	SS	1		322				
	Very soft to soft Dark brown/ black Wet Silty clay to Clayey silt trace sand, trace garvel		2	SS	3		321				
	Firm to very stiff Dark brown/ black Wet		3	SS	7		320				
			4	SS	12						3 28 44 25
			5	SS	12		319				
			6	SS	20		318				
			7	SS	11		317				
				FV				1			
			7A	TW	PH		316				5 27 42 26
			8	SS	17		315				
	rounded cobbles		9	SS	12		314				
			10	SS	8						
				FV			313	1			
			10A	TW	PH		312				
			11	SS	8		311				2 13 54 31
				FV				3			
				FV			310	1			
309.5			12	SS	15						
14.0	Sand to silty sand trace clay, trace gravel						309				
	Dense to Very dense Grey Wet (TILL) Cont'd		13	SS	38						8 60 29 3
308.5											

ON MTO_VER3 NEW LOGO 14TF020 REV 20171109.GPJ ON_MOT.GDT 01/12/2017 9:20:09 AM

Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

Ontario

Peto MacCallum Ltd. CONSULTING ENGINEERS

Foundation Design

RECORD OF BOREHOLE No 16-3 2 of 2 METRIC

MnDOT No. 02047

G.W.P. 6046-08-00 LOCATION Coords: 5 398 878.2 N; 408 642.0 E ORIGINATED BY S.A.

DIST Thunder Bay HWY 11 BOREHOLE TYPE Wash Boring and NW Casing COMPILED BY L.Y.

DATUM Orthometric DATE August 06, 2016 CHECKED BY M.V.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
308.5											
15.0	Sand to silty sand trace clay, trace gravel Very dense Grey Wet (Cont'd.)		14	SS	50/10cm		308		○		
			15	SS	50/8cm		307				
			16	SS	50/10cm		306		○		7 53 36 4**
			17	SS	50/8cm		305				
							304				
			18	SS	65/8cm		303		○		
	(TILL)						302				
301.5			19	SS	70/5cm						
22.0	End of borehole										

* 2016 08 06

▽ Water level observed during drilling

▼ Water level measured after drilling

PH Pushed hydraulically

** Denotes combined sample of SS15, SS16 & SS17

Bentonite slurry mud used to stabilize borehole from 1.2 to 21.0m depth.

Difficult drilling conditions and slow progress from a depth of 14.3m (El. 309.2m) to 22.0m (El. 301.5m).

Numbers refer to Sensitivity 5

20 15 5 10 (%) STRAIN AT FAILURE

Ontario

Peto MacCallum Ltd. CONSULTING ENGINEERS
Foundation Design

RECORD OF BOREHOLE No 16-4 1 of 1 METRIC

MnDOT No. 02047

G.W.P. 6046-08-00 LOCATION Coords: 5 398 915.9 N; 408 681.4 E ORIGINATED BY S.A.

DIST Thunder Bay HWY 11 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY L.Y.

DATUM Orthometric DATE August 11, 2016 CHECKED BY M.V.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
328.3	Ground Surface										
0.0 / 328.2	Topsoil										
0.1	Sand and gravel		1	SS	4		328		○		
	Very loose Grey/ dark brown Moist Clayey silt with sand, trace gravel organic inclusions rootlets, wood debris		2	SS	11				○		
	Stiff Grey/ dark brown (FILL)		3	SS	13		327		○		7 30 44 19
			4	SS	9		326		⊖		
			5	SS	10		325		○		
	Sand and gravel, cobbles Compact Grey/ brown Moist		6	SS	27				○		
4.5 / 323.8	Topsoil, rootlets peat inclusions		7	SS	8		324			○	
5.3 / 323.0	Stiff Dark brown/ black Moist to wet										
	Silty clay to Clayey silt with sand, trace gravel cobbles, Stiff to hard Grey/ brown Moist		8	SS	10		323		⊖		8 30 42 20
			9	SS	11		322		○		
			10	SS	23		321		⊖		1 29 46 24
			11	SS	15		320		○		
			12	SS	19		319		○		
			13	SS	25		318		○		3 26 46 25
			14	SS	22				⊖		
			15	SS	24		317		○		
315.5			16	SS	30		316		○		
12.8	End of borehole										

* Borehole dry

Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

Ontario

Peto MacCallum Ltd. CONSULTING ENGINEERS

Foundation Design

RECORD OF BOREHOLE No 16-5 1 of 1 METRIC

MnDOT No. 02047

G.W.P. 6046-08-00 LOCATION Coords: 5 398 892.0 N; 408 689.4 E ORIGINATED BY S.A.

DIST Thunder Bay HWY 11 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY L.Y.

DATUM Orthometric DATE August 10, 2016 CHECKED BY M.V.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
324.4	Ground Surface										
0.0 / 324.1	Topsoil		1	SS	3		324		○		
0.3	Silty sand, some clay rootlets, organics Very loose Dark brown/ brown Moist (FILL)		2	SS	4	▼*	323		○		
322.2			3	SS	2	▽*			○		
2.2	Silty clay to Clayey silt with sand, trace gravel Firm to very stiff Grey Moist to wet		4	SS	6		322		⊢○⊣		
			5	SS	17		321		○		7 32 41 20
			6	SS	16				○		
			7	SS	15		320		⊢○⊣		
			8	SS	14		319		○		
				FV				+1			
			8A	TW	PH		318				
316.2			9	SS	18		317		⊢○⊣		
8.2	End of borehole										

* 2016 08 10

▽ Water level observed during drilling

▼ Water level measured after drilling

PH Pushed hydraulically

Numbers refer to Sensitivity 5

20 15 5 10 (%) STRAIN AT FAILURE

×

Ontario

Peto MacCallum Ltd. CONSULTING ENGINEERS

Foundation Design

RECORD OF BOREHOLE No 16-6 1 of 1 METRIC

MnDOT No. 02047

G.W.P. 6046-08-00 LOCATION Coords: 5 398 884.0 N; 408 688.6 E ORIGINATED BY S.A.

DIST Thunder Bay HWY 11 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY L.Y.

DATUM Orthometric DATE August 10, 2016 CHECKED BY M.V.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
325.0	Ground Surface							
0.0	Silty sand some gravel, trace clay organics, rootlets topsoil inclusions		1	SS	8			
	Loose Grey/ Moist dark brown		2	SS	6		324	13 57 25 5
	Clayey silt rootlets, topsoil and organic inclusions		3	SS	5		323	
	Firm to stiff Grey/ Moist brown							
322.2	(FILL)		4	SS	9			
2.8	Silt trace sand, trace clay						322	
	Compact Mottled Wet grey/brown		5	SS	12			0 10 80 10
321.3								
3.7	End of borehole							

* Borehole dry

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100

PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L

WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

UNIQUE NUMBER 81130

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
3905-09	39016	MN Trunk Highway 72	T10	1079.9 (Surveyed)

Location: Lake of the Woods/South Zone Coord:X=570041 Y=228434 (ft.)
Latitude (North)=48°43'03.95" Longitude (West)=94°35'35.61"
No Station-Offset Information Available

Drill Machine: 211304 CME 750X
Hammer: CME Automatic Calibrated

SHEET 1 of 2

Drilling Completed: 9/1/16

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil / Rock	Other Tests Or Remarks / Formation or Member
0			slightly plastic Silt Loam (ML-SILT with Sand) with seams and traces of Silt; pockets of IOS and a few roots; browns, moist (Lacustrine-oxidized)							Des Moines Lobe Till - Highly Calcareous
5	5.5 / 1074.4					23	580	123		
			Silty Clay Loam (CL/ML-Silty CLAY) with laminated traces and seams of Silt and Very Fine Sand with IOS; browns, moist (Lacustrine-oxidized)		15	25				
10	10.0 / 1069.9				6	30				
			Silty Clay (CL/ML-Silty CLAY), grays, moist (Lacustrine-oxidized)	PD	10	31				
	13.5 / 1066.4			PD						
15			Silty Clay Loam (CL/ML-Silty CLAY) with thin seams and traces of Silt; malodorous fuel smell; grays, moist (Lacustrine-oxidized)			30	1170	122		
	18.5 / 1061.4				10	29				
			plastic Sandy Loam (SM-Silty SAND with Clay) with pebbles; horizontal traces of Silt and vertical traces and pockets of gray Very Fine Sand with IOS; Malodorous fuel smell; grays and browns, moist (Lacustrine-oxidized)	PD		13	2710	141		
20	21.5 / 1058.4				33	18				
			Silty Clay Loam (ML-SILT with Clay) with pebbles and a few pockets of black organics; traces of Very Fine Sand and Silt with IOS; gray-brown, damp (Lacustrine-oxidized to approx. 25')	PD		16	3910	136		
25					57	18				
	28.0 / 1051.9			PD						
			Sandy Clay (CL-Sandy Lean CLAY) with a few pebbles, gray, moist (Glacial Till)		35	16				
30	31.0 / 1048.9			PD	28	20				
				PD						
35					38	23				
				PD	27	24				
				PD						
40			Clay (CL-Sandy Lean CLAY) with a few pebbles and plastic Silt Loam layers at 50.2'; grays, moist to wet (Glacial Till to approx 48.5', Glacial Lacustrine to 51')		29	22				
				PD	22	29				
				PD						
45					15	42				
				PD	20	24				
50				PD						

Index Sheet Code 3.0

(Continued Next Page)

Soil Class:JAH Rock Class: Edit: Date: 11/7/16

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MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

UNIQUE NUMBER 81130

U.S. Customary Units

Mn/DOT GEOTECHNICAL SECTION - LOG & TEST RESULTS — *SHEET 2 of 2*

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
3905-09	39016	MN Trunk Highway 72	T10	1079.9 (Surveyed)

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil / Rock	Other Tests Or Remarks / Formation or Member
	51.0			PD	54	22				
	1028.9		Loamy Fine Sand (SM-Silty SAND); gray, saturated (Glacial Till)		57	19				
55	55.0			PD						
	1024.9		Sandy Clay Loam (CL-Sandy Lean CLAY); gray, moist (GlacialTill)		35 50/.4	15				
	59.5			PD						
60	1020.4		Loamy Sand (SM-Silty SAND); gray, wet (Glacial Till)							
	62.2				48 50/.2	10 N/A				
	1017.7			WS						start core run at 63.0' voids in rock/boulder
65			Granite Boulders, gray-brown							
	68.0									
	1011.9									core barrel dropped 68'-70' , Remove casing and plugdrill to 74.0'
70			Loamy Sand (SM-Silty SAND); gray, wet (Glacial Till)							
	74.5			PD	50/.2	9				
75	1005.4			PD						High Silt content
					50/.3	MUD				
80			Loamy Sand and Gravel (SM-Silty SAND with Gravel); with cobbles at 83.0' and Granite stone chips and peices at 84.0'; gray and wet (Glacial till)	PD						
					50/.3	N/A				fairly smooth, very hard
85				PD						High Silt content
	88.0									
	991.9				50/.3	9				High Silt content
90			slightly plastic Sandy Loam (SM-Silty SAND with Clay); gray and wet (Glacial Till)	PD						very hard drilling, 40 minutes 93.0'-94.0'
	93.0		Possible Top of Bedrock							
	986.9	+	TONALITE; gray	WS		N/A				
	94.0		Bottom of Hole -94.0'							
	985.9		Water level is inderterminate due to use of drilling fluids							

Soil Class:JAH Rock Class: Edit: Date: 11/7/16

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MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

UNIQUE NUMBER 77676

This boring was taken by EPC under a consultant contract for Mn/DOT

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
3905-09	9412	MN Trunk Highway 72	B100	1063.9 (survey)

Location: Lake of the Woods/South Zone Co. Coordinate: X=570333 (ft) Y=2286220

Latitude (North)=48°43'05.77" Longitude (West)=94°35'31.24"

No Station-Offset Information Available

Drill Machine: CME 750 ATV

Hammer: CME Automatic

SHEET 1 of 1

Drilling Completed: 9/17/13

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil / Rock	Other Tests Or Remarks / Formation or Member
			Top of Driling Platform (0.0 feet ; Elevation 1063.9)							SPT hammer calibrated to 67% efficiency on 9/6/13
▼ 5	5.0 / 1058.9									Drill Rig Platform including barge deck spudded approximateley 50' Northeast of 1st pier. Rainy River
10			Water							
15	16.0 / 1047.9									
	19.5		Clay (C), gray, wet to waterbearing, trace sand, trace gravel, stiff consistency.		10	68				
20	1044.4		Sandy Loam (SL) gray, wet to waterbearing, trace gravel,		8	75				
	21.0		slightly plastic, loose relative density.		10	20				
	1042.9		Clay (C), gray to grayish brown, wet, stiff consistency.		16	20				
25	23.5 / 1040.4		Sand (S), gray to grayish brown, waterbearing, fine to coarse grained, medium dense to loose relative density.		10	17				Boulder encountered
	29.5				9	19		101		Hand Pen. = 1.7 tsf
30	1034.4					23	1690	106		Hydrometer gradation performed on shelby tube from 31 - feet.
					11	23		106		
35			Clay (C), gray, wet, trace gravel, little sand, stiff consistency.			23	1250	106		Hand Pen. = 1.7 tsf
					13	19				Hand Pen. = 1.7 tsf
40						12		128		Hand Pen. = 1.7 tsf Shelby tube pushed a rock. Hard
					85	14				
45	46.0 / 1017.9				121	9		134		Hand Pen. = 5.9 tsf Drillers note: w/gravel, hard drilling
					50/5"	10				
50					50/.5"					Hand Pen. = 4.8 tsf Drillers note: drilled through a boulder at 47.5'
					50/3"	9				
55					50/3"	15				
			Sandy Loam (SL), gray, moist to wet, trace to little gravel, slightly plastic, very dense relative density.		336	9		133		
60					50/1"	7				
					134	11		134		
65					50/4"	11				
					50/3"	9				
70					50/3"	9				
					50/5"	8		127		
75	77.1 / 986.8				50/4" 75/0"	14				Auger refusal at 77.1' probable boulder.

Index Sheet Code 3.0

Soil Class:GEH Rock Class: Edit: Date: 10/16/13

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MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

UNIQUE NUMBER 77677

This boring was taken by EPC under a consultant contract for Mn/DOT

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
3905-09	9412	MN Trunk Highway 72	B101	1064.4 (survey)

Location: Lake of the Woods/South Zone Co. Coordinate: X=570495 (ft) Y=2287125

Latitude (North)=48°43'06.8" Longitude (West)=94°35'28.82"

No Station-Offset Information Available

Drill Machine: CME 750 ATV

Hammer: CME Automatic

SHEET 1 of 2

Drilling Completed: 9/18/13

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil / Rock	Other Tests Or Remarks / Formation or Member
			Top of Driling Platform (0.0 feet ; Elevation 1064.4)							SPT hammer calibrated to 67% efficiency on 9/6/13
▼ 5	5.5 / 1058.9									Drill Rig Platform including barge deck spudded approximateley 50' Northeast of 2nd pier.
10			Water							
15										Rainy River
20										
	23.5 / 1040.9				6	20				
25			Sand (S), gray to grayish brown, waterbearing, trace to little gravel, fine to coarse grained, loose relative density.		6	20				
	28.5 / 1035.9				6	19		104		Hand Pen. = 1.0 tsf
30					20	25		103		Hand Pen. = 1.8 tsf
						24	2000	105		Hand Pen. = 1.4 tsf
35			Clay(C), gray, wet, trace gravel, stiff to very stiff consistency.		12	23				
					28	25				Boulder at 38', attempted shelby tube. Crushed tube.
40					19	15				
	43.5 / 1020.9				224	13		136		
45					50/4"	7				
					50/4"	8				Hydrometer gradation performed on samples from 48.5' to 56.2'.
50					50/4"	8				
					50/4"	10				
55			Sandy Loam (SL), gray, moist to wet to waterbearing, trace to little gravel, trace clay, very dense relative density.		50/2"	10				
					50/4"	8				Hydrometer gradation performed on samples from 58.5' to 66.3'.
60					50/5"	17				
					50/3"	15				
65					50/3"	10				
	68.6 / 995.8				50/1"	10				Cobbles and Boulders encountered
	69.2 / 995.2		Probable boulder, auger refusal at 69.2'.							Drillers note: drilled for 1 hour on boulder/bedrock to get from 67' to 69'. Spent

(Continued Next Page)

Soil Class:GEH Rock Class: Edit: Date: 10/16/13

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MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

UNIQUE NUMBER 77677

This boring was taken by EPC under a consultant contract for Mn/DOT

U.S. Customary Units

Mn/DOT GEOTECHNICAL SECTION - LOG & TEST RESULTS — *SHEET 2 of 2*

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
3905-09	**9412**	**MN Trunk Highway 72**	**B101**	**1064.4** *(survey)*

DEPTH Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N_{60}	MC (%)	COH (psf)	γ (pcf)	Soil	Other Tests Or Remarks
				REC (%)	RQD (%)	ACL (ft)	Core Breaks	Rock	Formation or Member
									1/2 hour drilling from 69' to 69.2'.

Soil Class:GEH Rock Class: Edit: Date: 10/16/13

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MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

UNIQUE NUMBER 77678

This boring was taken by EPC under a consultant contract for Mn/DOT

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
3905-09	**9412**	**MN Trunk Highway 72**	**B102**	**1063.9** *(survey)*

Location Lake of the Woods/South Zone Co. Coordinate: X=570647 (ft) Y=2286[illegible]

Latitude (North)=48°43'07.77" Longitude (West)=94°35'26.55"

No Station-Offset Information Available

Drill Machine **CME 750 ATV**

Hammer **CME Automatic**

SHEET 1 of 2

Drilling Completed **9/24/13**

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N_{60} / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil / Rock	Other Tests Or Remarks / Formation or Member
			Top of Driling Platform (0.0 feet ; Elevation 1063.9)							SPT hammer calibrated to 67% efficiency on 9/6/13
▼ 5	5.0 / 1058.9									Drill Rig Platform including barge deck spudded approximateley 50' Northeast of 3rd pier.
10			Water							
15										
20										
	23.0 / 1040.9				0	10				
25			Sand (S), brown to gray, wet to waterbearing, coarse to fine grained, very loose relative density.		3	40				Wood noticed in sample. Hydrometer gradation performed on samples from 25.5' to 32'.
30					2	18				
					4	18				
	33.0 / 1030.9				8	21		109		Hand Pen. = 1.5 tsf
35						24	1400	101		Hand Pen. = 1.6 tsf
40			Clay (C), gray, wet, trace gravel, little to some sand, medium to soft consistency.		7	23		100		Hand Pen. = 1.3 tsf
						32	560	95		Hand Pen. = 1.8 tsf Hydrometer gradation performed on shelby tube from 41'.
45					10	11				
					16	12				
	48.0 / 1015.9				73	9				
50					50/5"	10				
			Sandy Loam (SL), gray, moist to wet, trace to little gravel, trace clay, slightly plastic, very dense relative density.		50/5"	9		128		
55					50/5"	13				
60					50/2"	9				

Index Sheet Code 3.0

(Continued Next Page)

Soil Class:GEH Rock Class: Edit: Date: 10/16/13

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MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

UNIQUE NUMBER 77678

This boring was taken by EPC under a consultant contract for Mn/DOT

U.S. Customary Units

Mn/DOT GEOTECHNICAL SECTION - LOG & TEST RESULTS — *SHEET 2 of 2*

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
3905-09	**9412**	**MN Trunk Highway 72**	**B102**	**1063.9** *(survey)*

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N_{60} / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil / Rock	Other Tests Or Remarks / Formation or Member
	60.5 1003.4				50/0.5"					Substantial auger refusal at 60.6' - boulder, set up for rock coring.
65					24	10	0.58			Samples 17- 26 were either boulders that were in the core barrel or cuttings from return water.
				WS		18				
70					0		0.00			
75					8					
				WS		20				Drillers Note: Sand recovered in wash cuttings.
80					6	5	0.33			
85			Boulders and Cobbles (4" - 12") mixed with apparent Sandy Loam, gray.							
				WS	5	20				Drillers Note: Sand recovered in wash cuttings.
90										
95					7		0.00			
100										
105				WS	7	19				Drillers Note: Sand recovered in wash cuttings.
110					5		0.00			Formation started caving in around drill rod. Unable to spin drill rod.
115	116.0 947.9		End of boring at 116'							

Soil Class:GEH Rock Class: Edit: Date: 10/16/13

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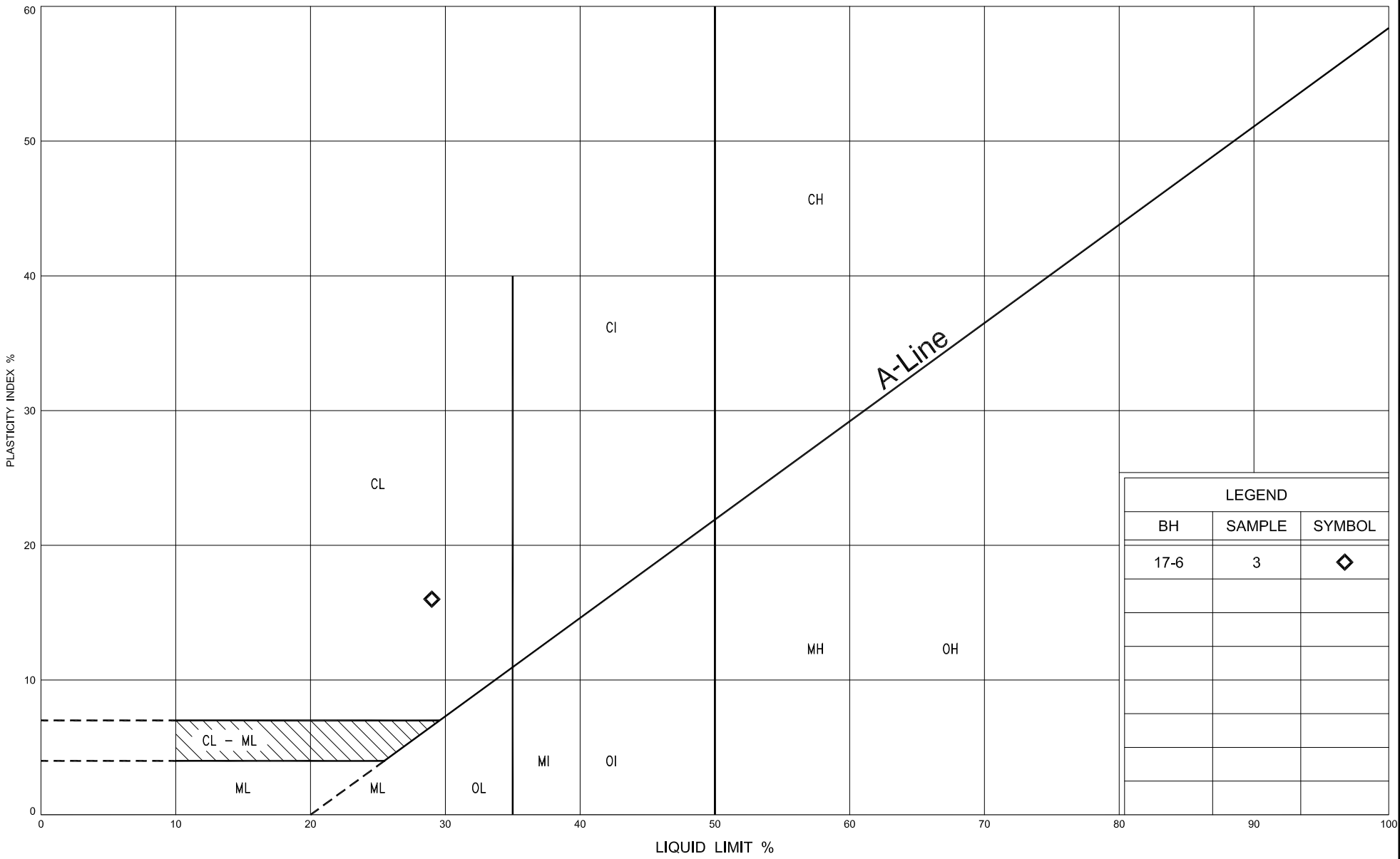

LEGEND		
BH	SAMPLE	SYMBOL
17-6	3	◇

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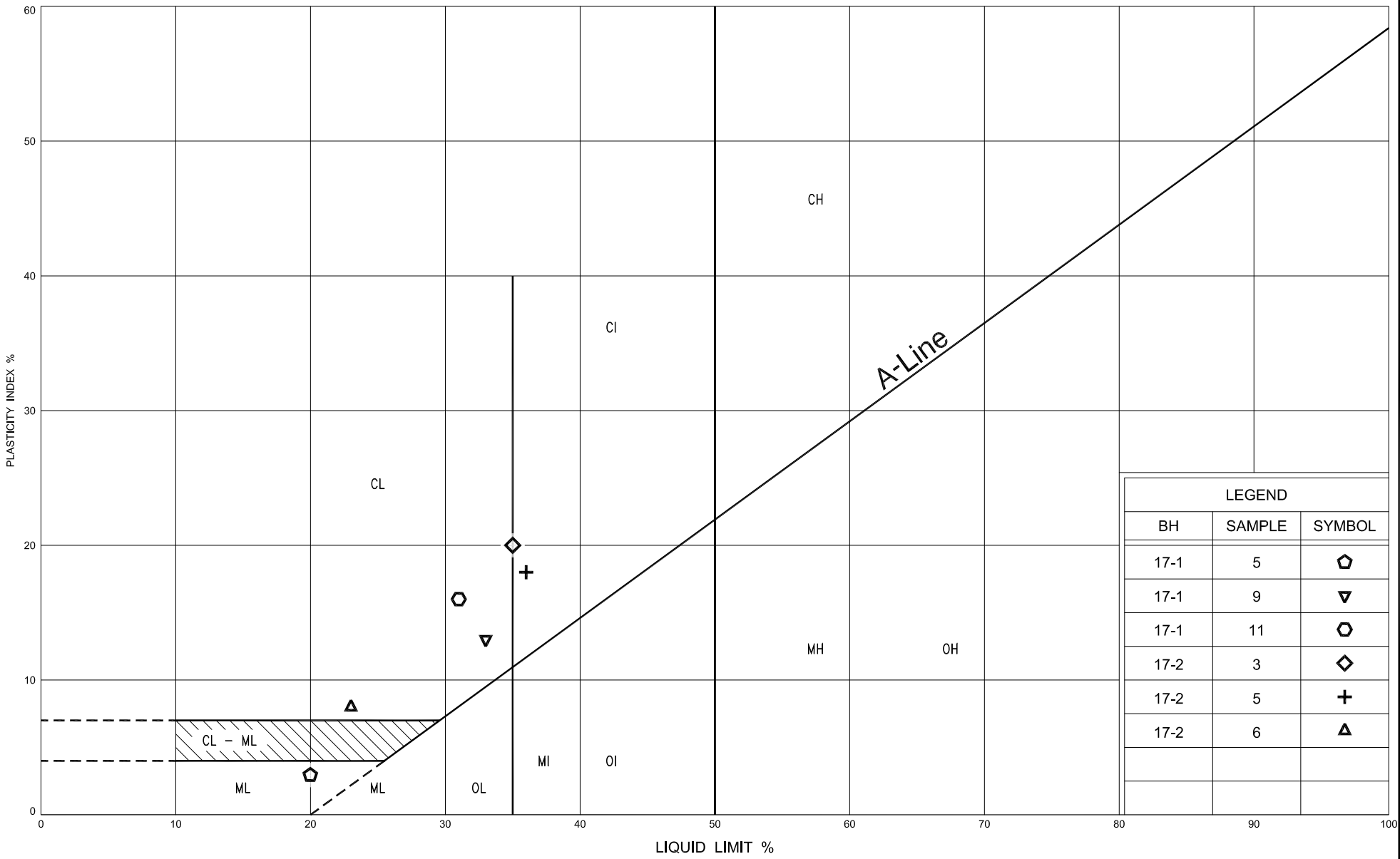
PLASTICITY CHART

CLAYEY SILT, some sand, trace gravel
(FILL)

FIG No.	PC 17-1
HWY	11
MnDOT. No.	02047
G.W.P. No.	6046-08-00

ONTARIO MOT PLASTICITY CHART 6046-08-00_LAB.GPJ ONTARIO MOT.GDT 11/06/17



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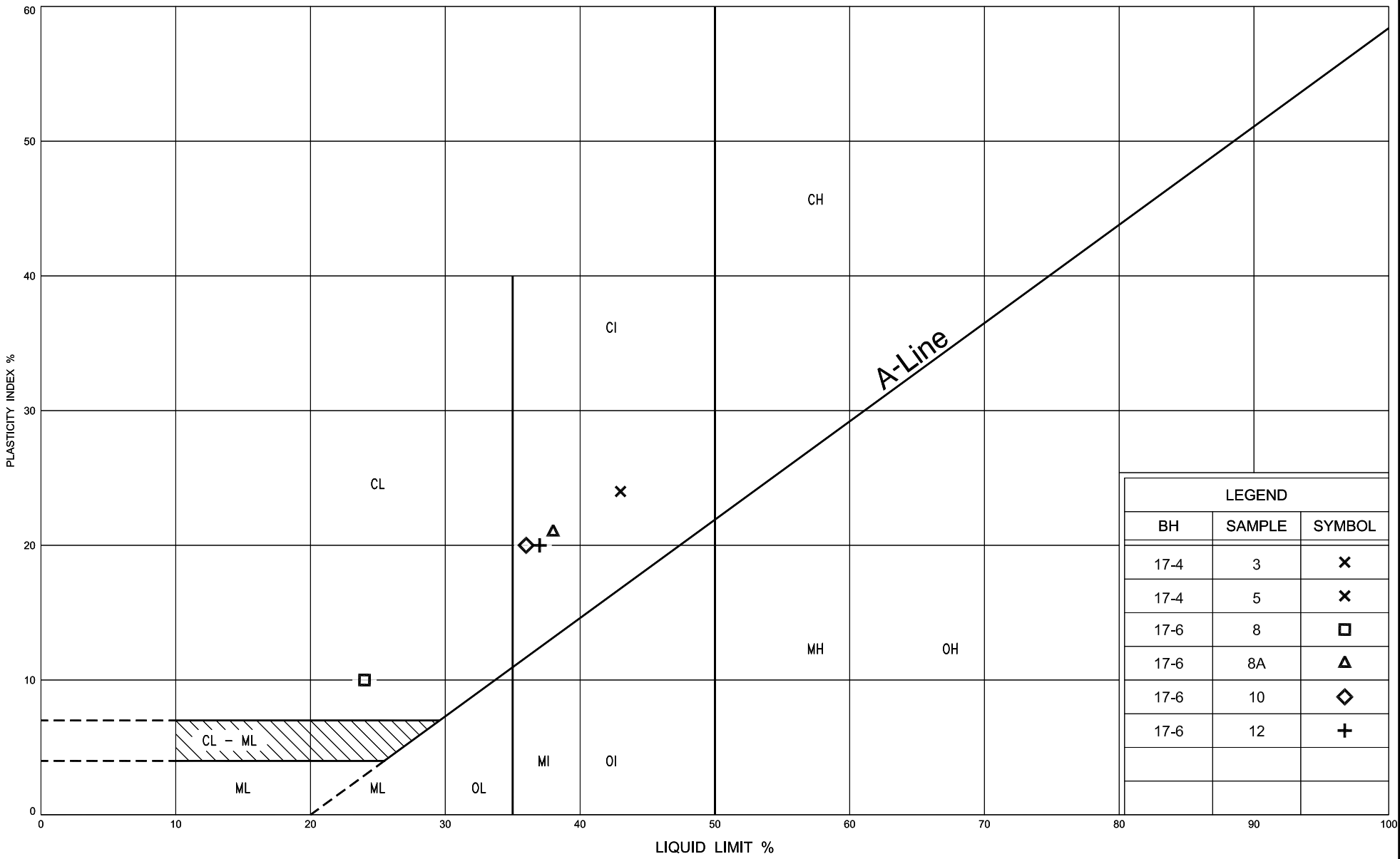
PLASTICITY CHART

SILTY CLAY TO CLAYEY SILT, trace to some sand, trace gravel

FIG No.	PC 17-2A
HWY	11
MnDOT. No.	02047
G.W.P. No.	6046-08-00

ONTARIO MOT PLASTICITY CHART 6046-08-00_LAB.GPJ ONTARIO MOT.GDT 11/06/17



LEGEND		
BH	SAMPLE	SYMBOL
17-4	3	×
17-4	5	×
17-6	8	□
17-6	8A	△
17-6	10	◇
17-6	12	+

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PLASTICITY CHART

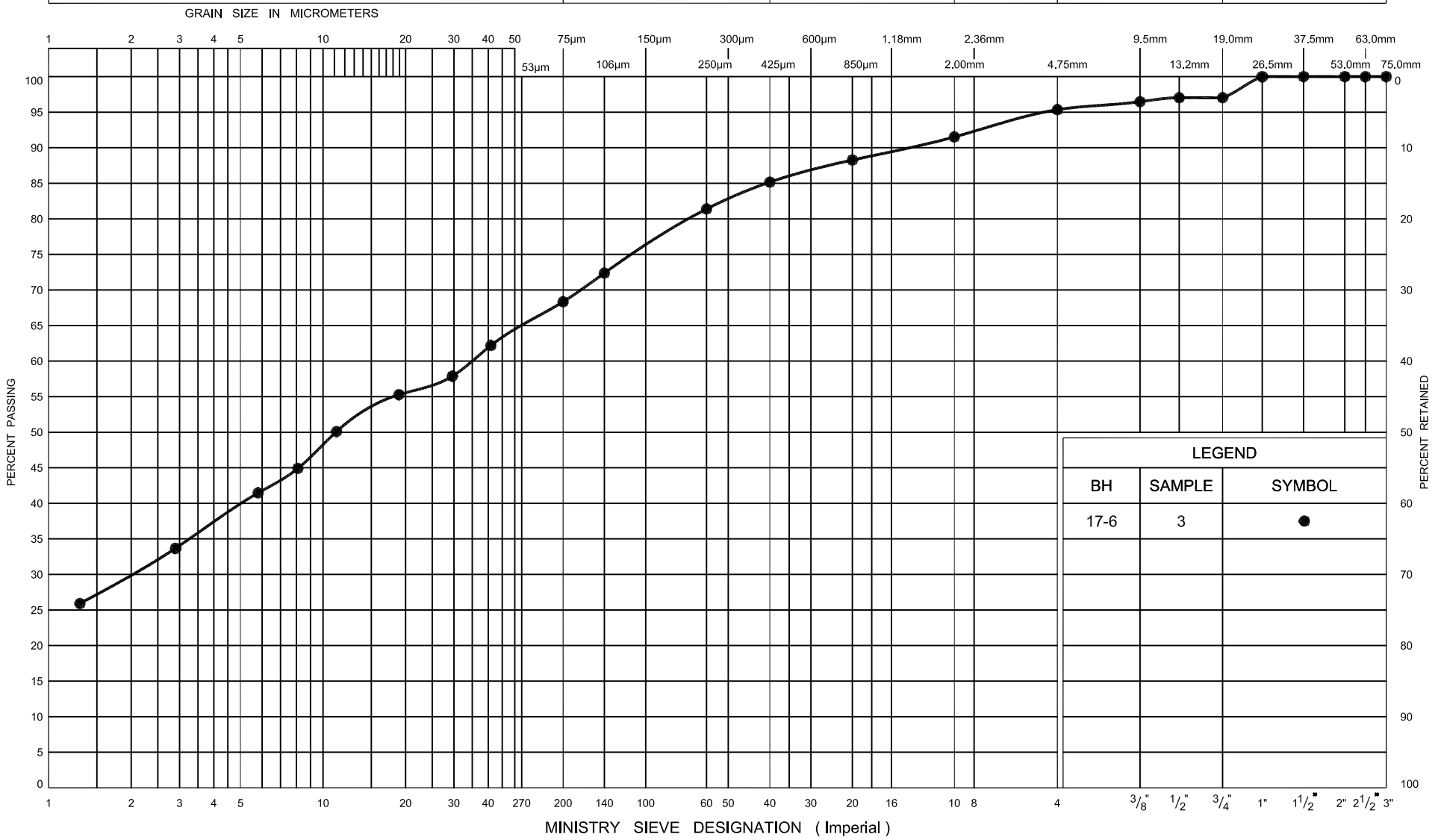
SILTY CLAY TO CLAYEY SILT, trace to some sand, trace gravel

FIG No.	PC 17-2B
HWY	11
MnDOT. No.	02047
G.W.P. No.	6046-08-00

ONTARIO MOT PLASTICITY CHART 6046-08-00_LAB.GPJ ONTARIO MOT.GDT 11/08/17

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



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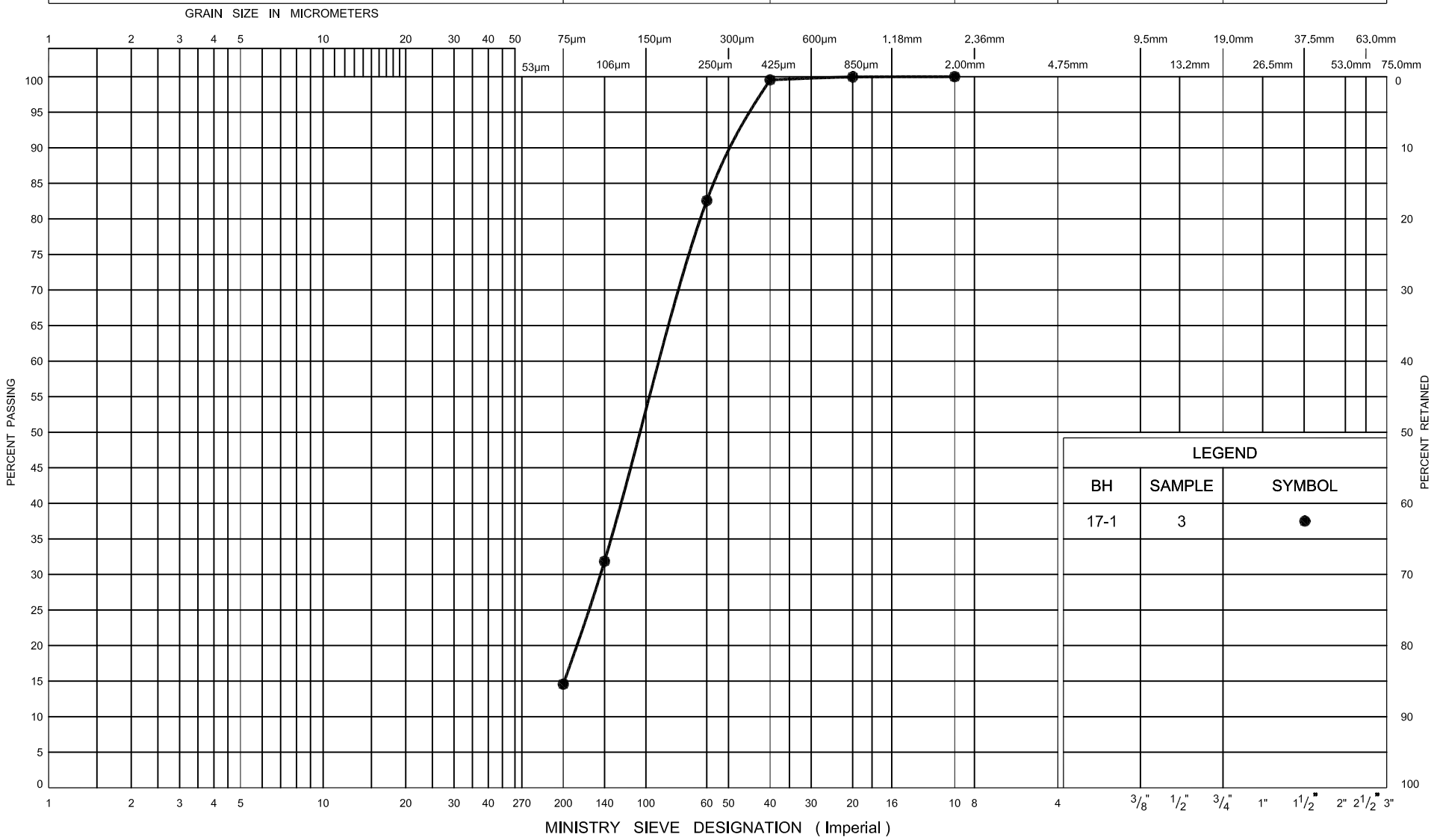
GRAIN SIZE DISTRIBUTION

CLAYEY SILT, some sand, trace gravel
(FILL)

FIG No.	GS 17-1
HWY	11
MnDOT No.	02047
G.W.P. No.	6046-08-00

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



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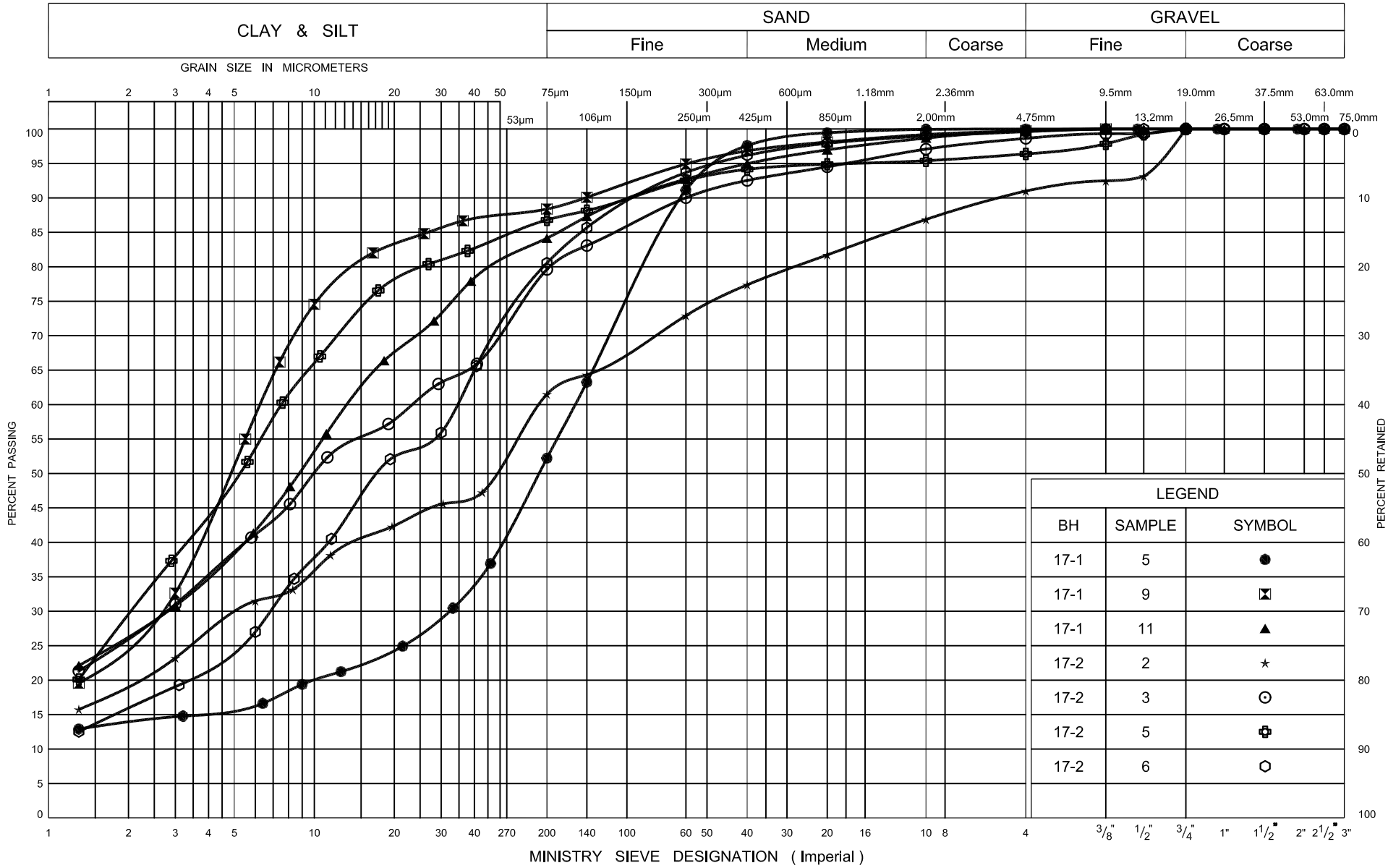
GRAIN SIZE DISTRIBUTION

SAND, trace to some silt, trace gravel

FIG No.	GS 17-2
HWY	11
MnDOT No.	02047
G.W.P. No.	6046-08-00

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of Transportation
Ontario

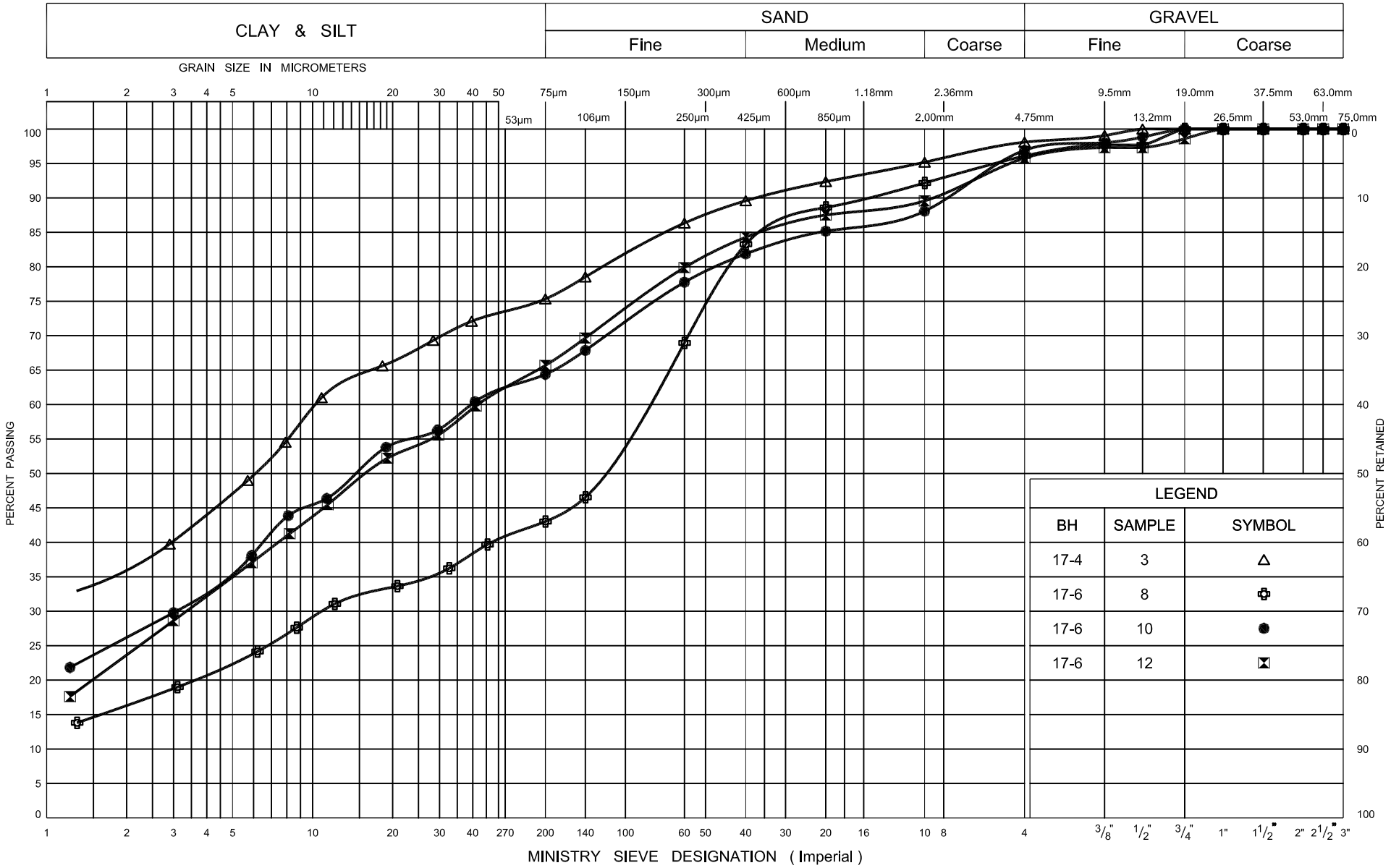
GRAIN SIZE DISTRIBUTION

SILTY CLAY TO CLAYEY SILT, trace to some sand, trace gravel

FIG No.	GS 17-3A
HWY	11
MnDOT No.	02047
G.W.P. No.	6046-08-00

ONTARIO MOT GRAIN SIZE 6046-08-00_LAB.GPJ ONTARIO MOT.GDT 11/06/17

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of Transportation
Ontario

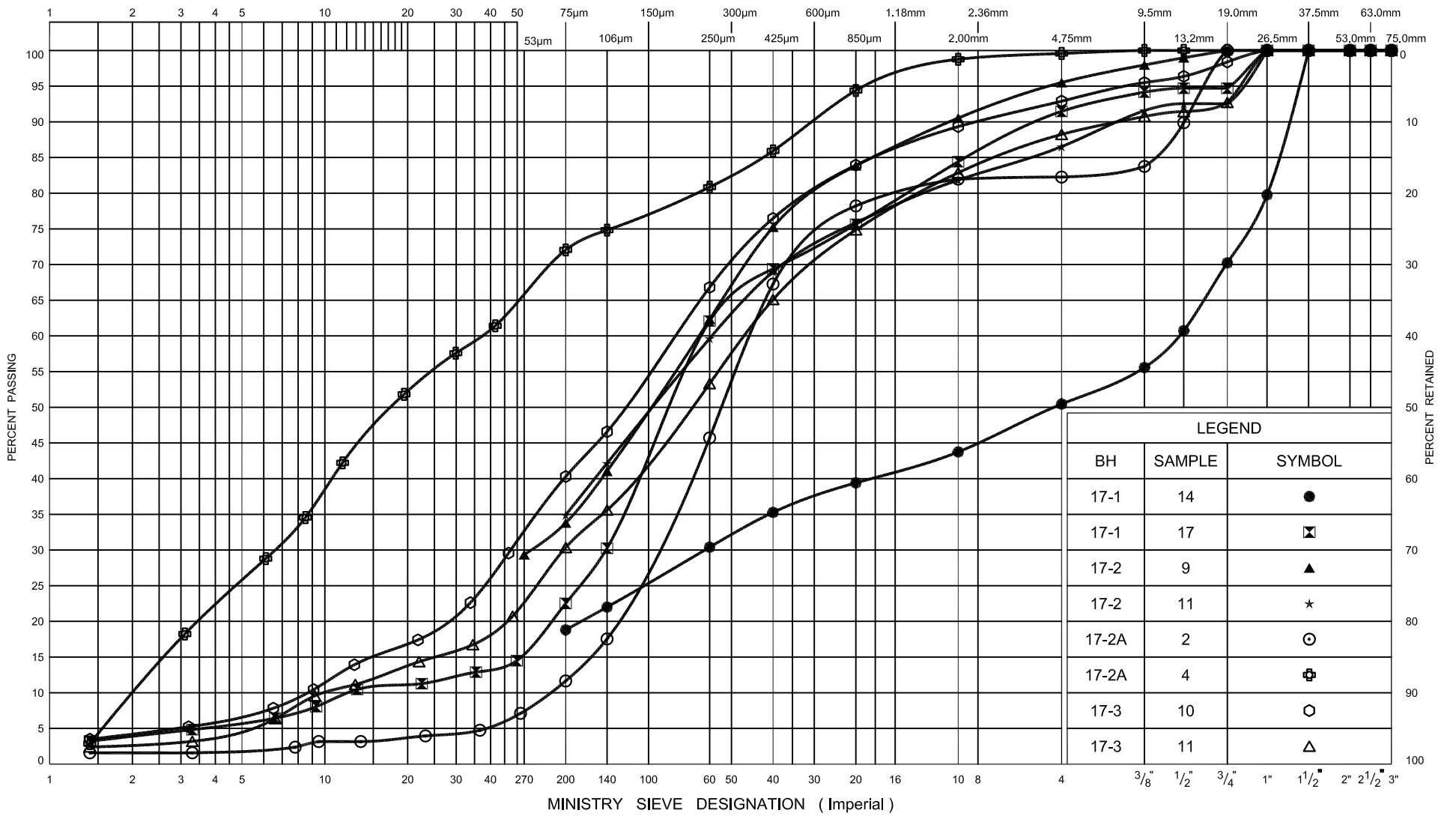
GRAIN SIZE DISTRIBUTION

SILTY CLAY TO CLAYEY SILT, trace to some sand, trace gravel

FIG No.	GS 17-3B
HWY	11
MnDOT No.	02047
G.W.P. No.	6046-08-00

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



LEGEND		
BH	SAMPLE	SYMBOL
17-1	14	●
17-1	17	⧓
17-2	9	▲
17-2	11	★
17-2A	2	⊙
17-2A	4	✿
17-3	10	⬡
17-3	11	△

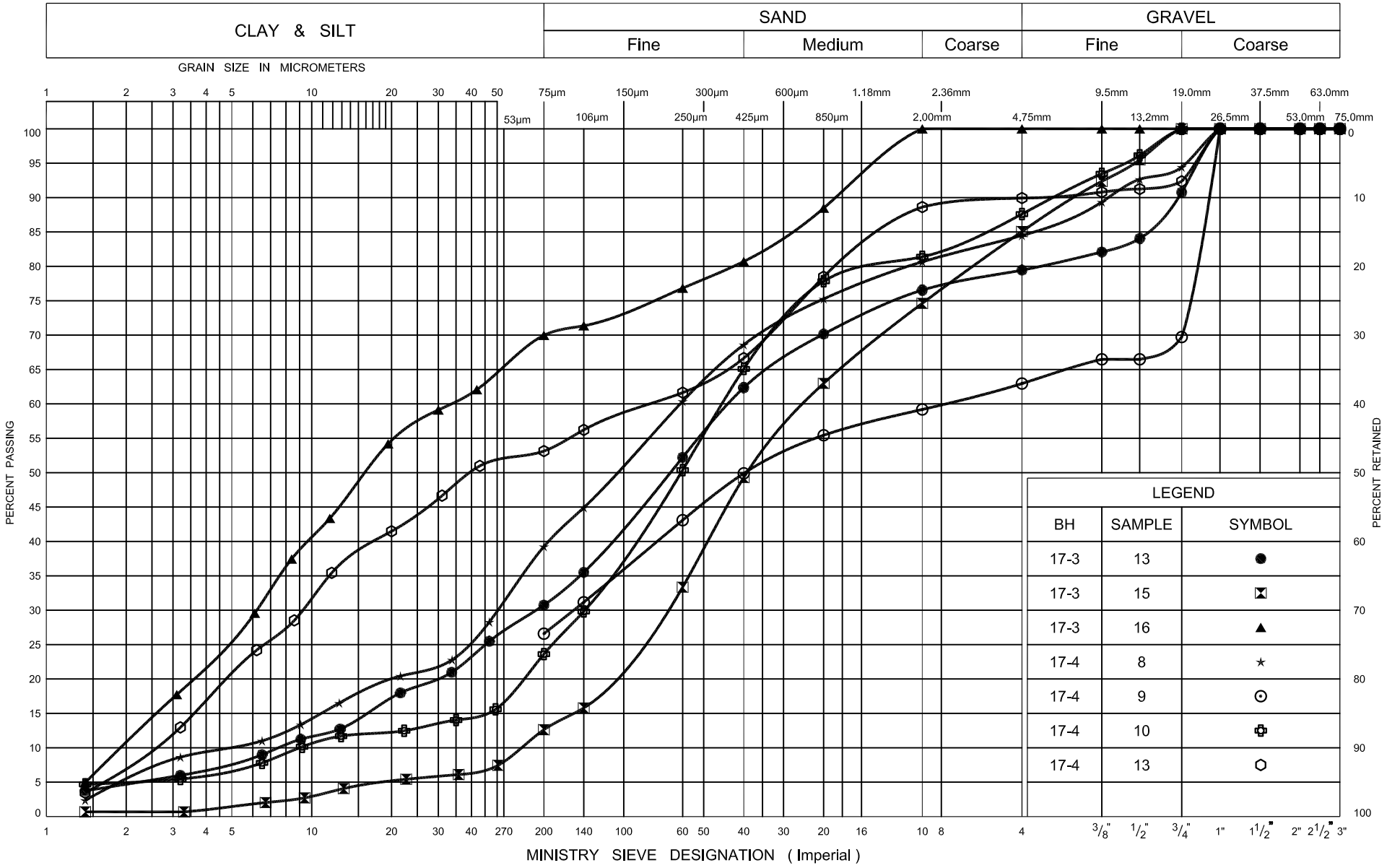
Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

SAND TO SILTY SAND, trace to some gravel, trace clay

FIG No.	GS 17-4A
HWY	11
MnDOT No.	02047
G.W.P. No.	6046-08-00

UNIFIED SOIL CLASSIFICATION SYSTEM



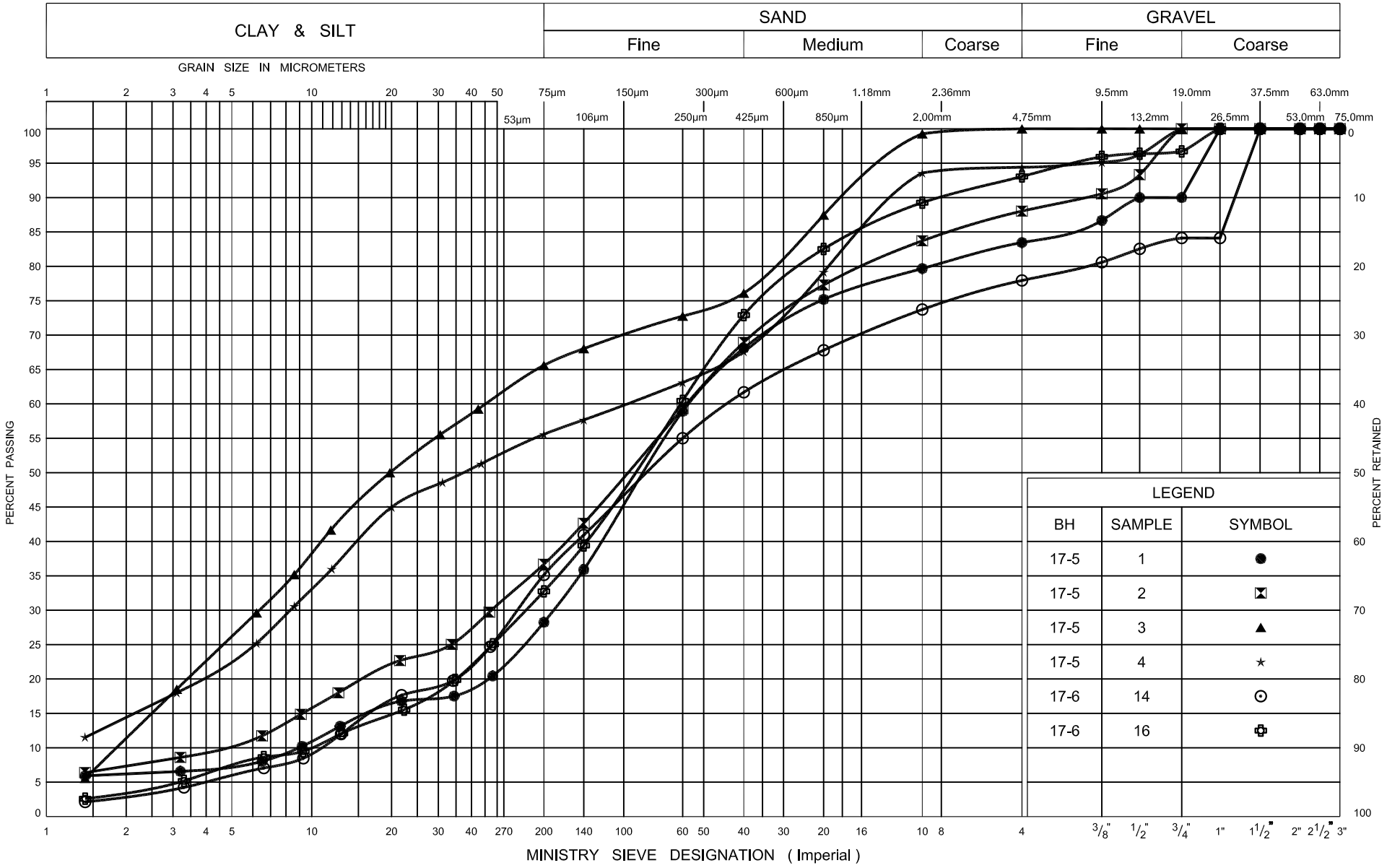
Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

SAND TO SILTY SAND, trace to some gravel, trace clay

FIG No.	GS 17-4B
HWY	11
MnDOT No.	02047
G.W.P. No.	6046-08-00

UNIFIED SOIL CLASSIFICATION SYSTEM



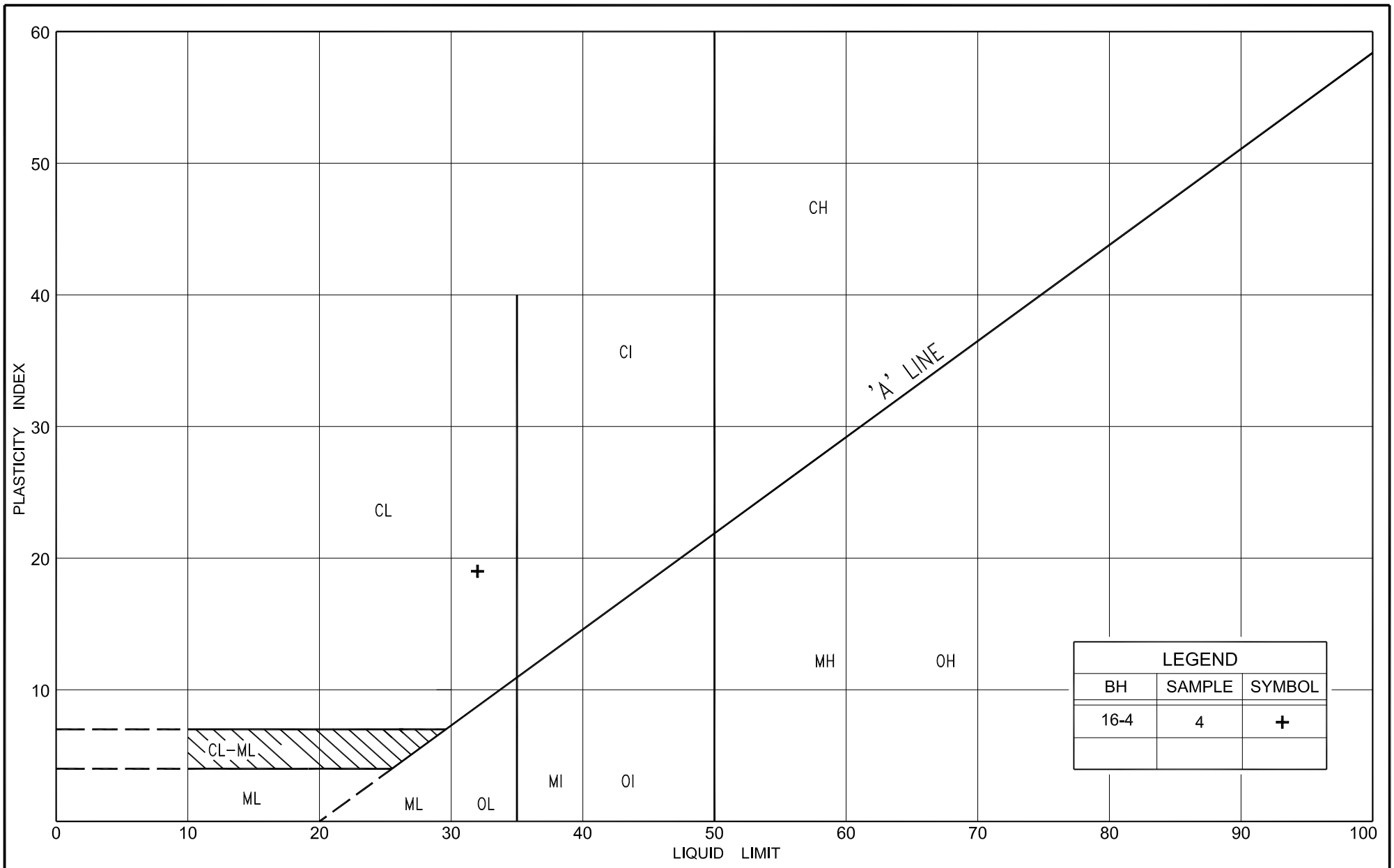
LEGEND		
BH	SAMPLE	SYMBOL
17-5	1	●
17-5	2	⧓
17-5	3	▲
17-5	4	★
17-6	14	⊙
17-6	16	✿

Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

SAND TO SILTY SAND, trace to some gravel, trace clay

FIG No.	GS 17-4C
HWY	11
MnDOT No.	02047
G.W.P. No.	6046-08-00

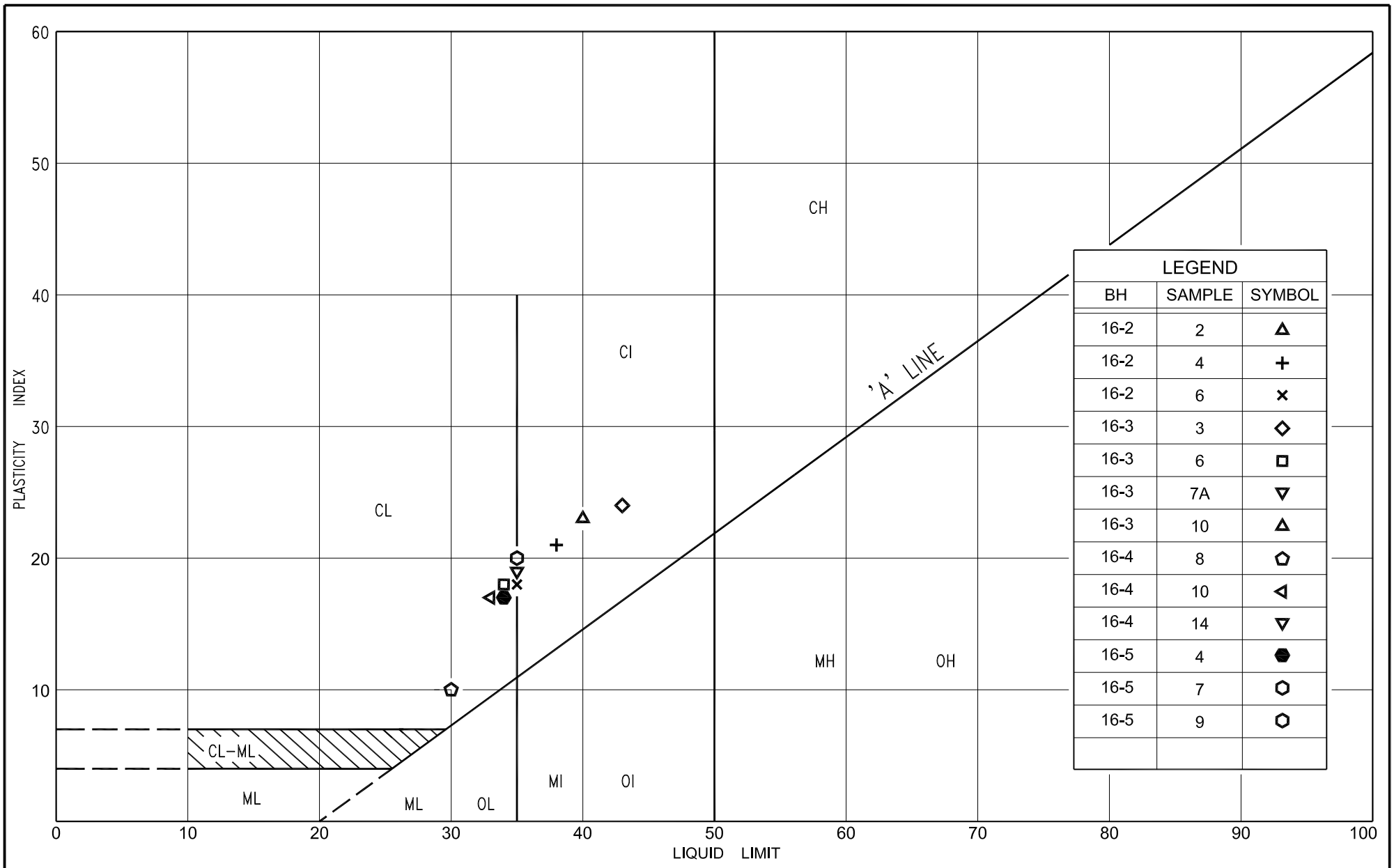


Ontario

PLASTICITY CHART

CLAYEY SILT, some sand (CL)
(FILL)

FIG No.	PC-1
HWY	11
MnDOT No. 02047	G.W.P. No. 6046-08-00

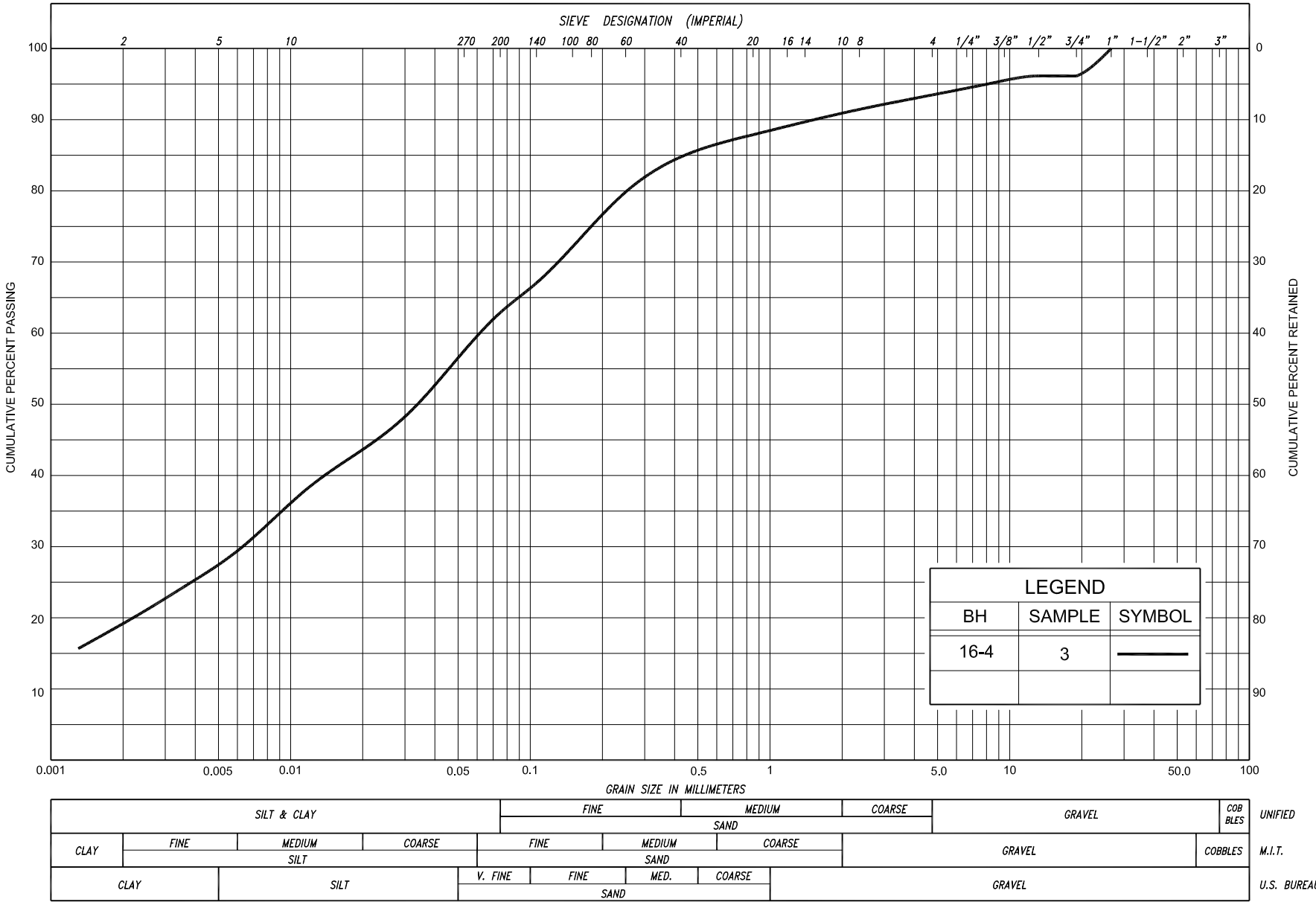


Ontario

PLASTICITY CHART

SILTY CLAY TO CLAYEY SILT, trace to some sand (CL / CI)

FIG No.	PC-2
HWY	11
MnDOT No. 02047	G.W.P. No. 6046-08-00

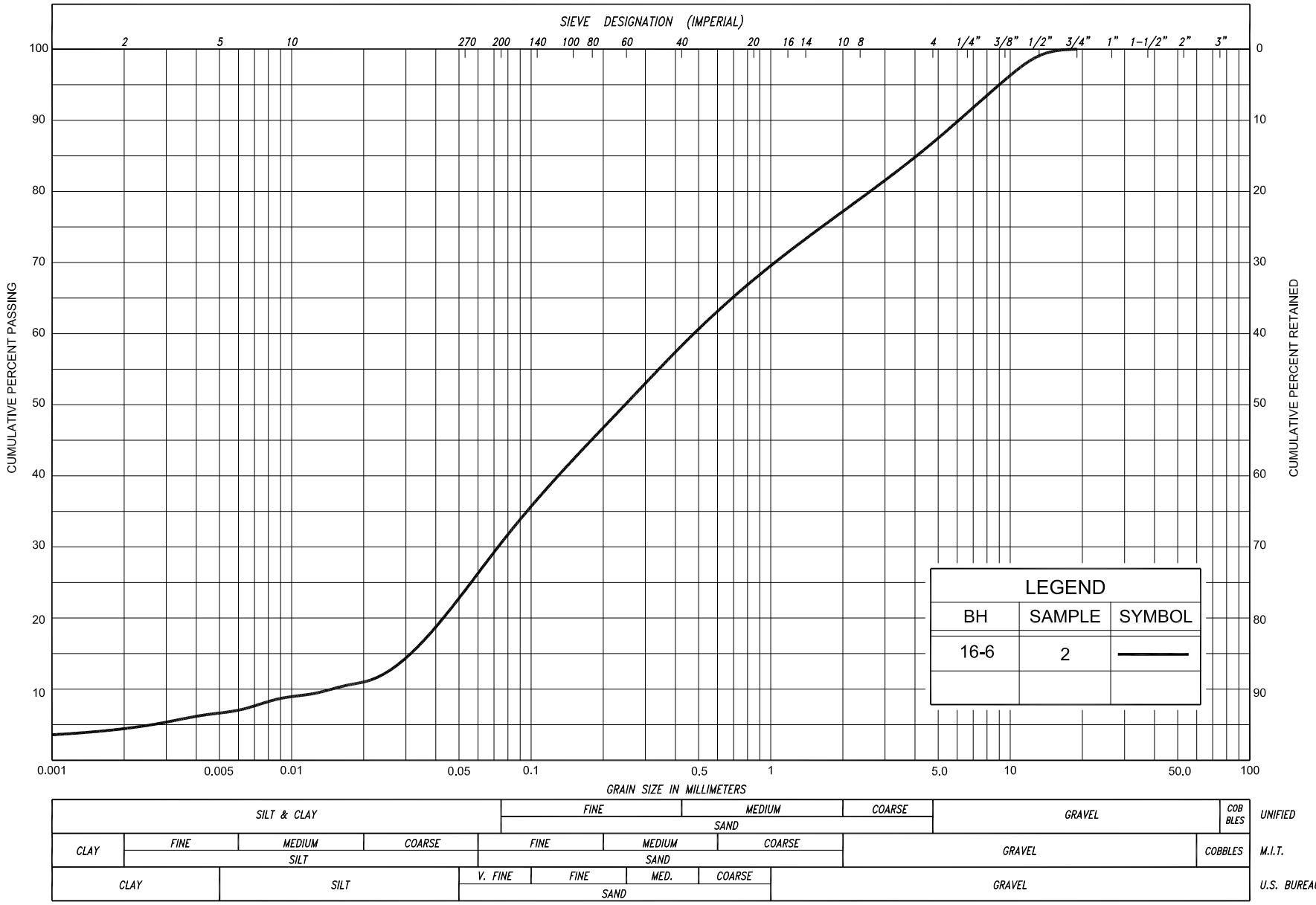


Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, some sand (CL)
(FILL)

FIG No.	GS-1
HWY	11
MnDOT No. 02047	G.W.P. No. 6046-08-00

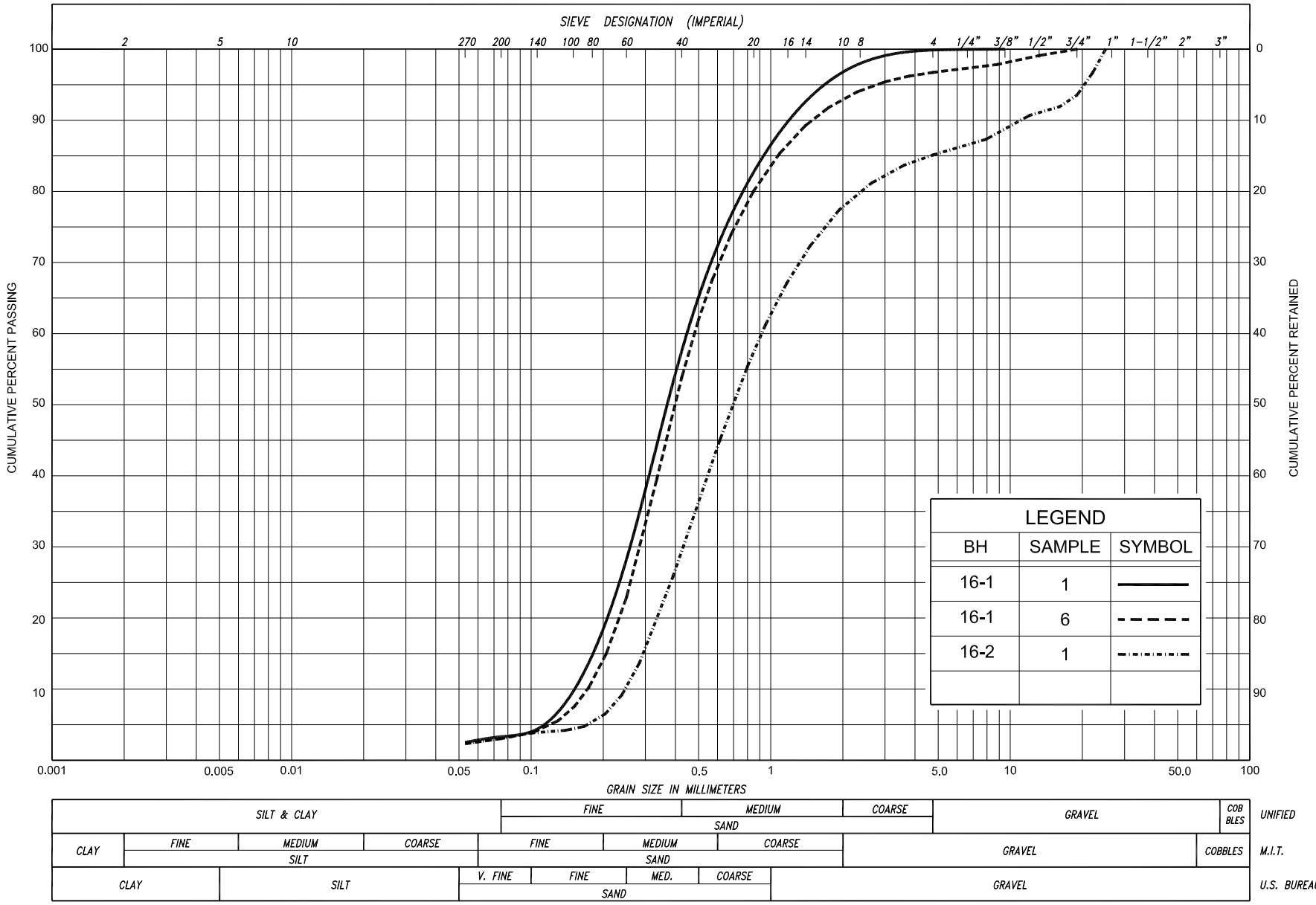


Ontario

GRAIN SIZE DISTRIBUTION

SILTY SAND, some gravel
(FILL)

FIG No.	GS-2
HWY	11
MnDOT No. 02047	G.W.P. No. 6046-08-00

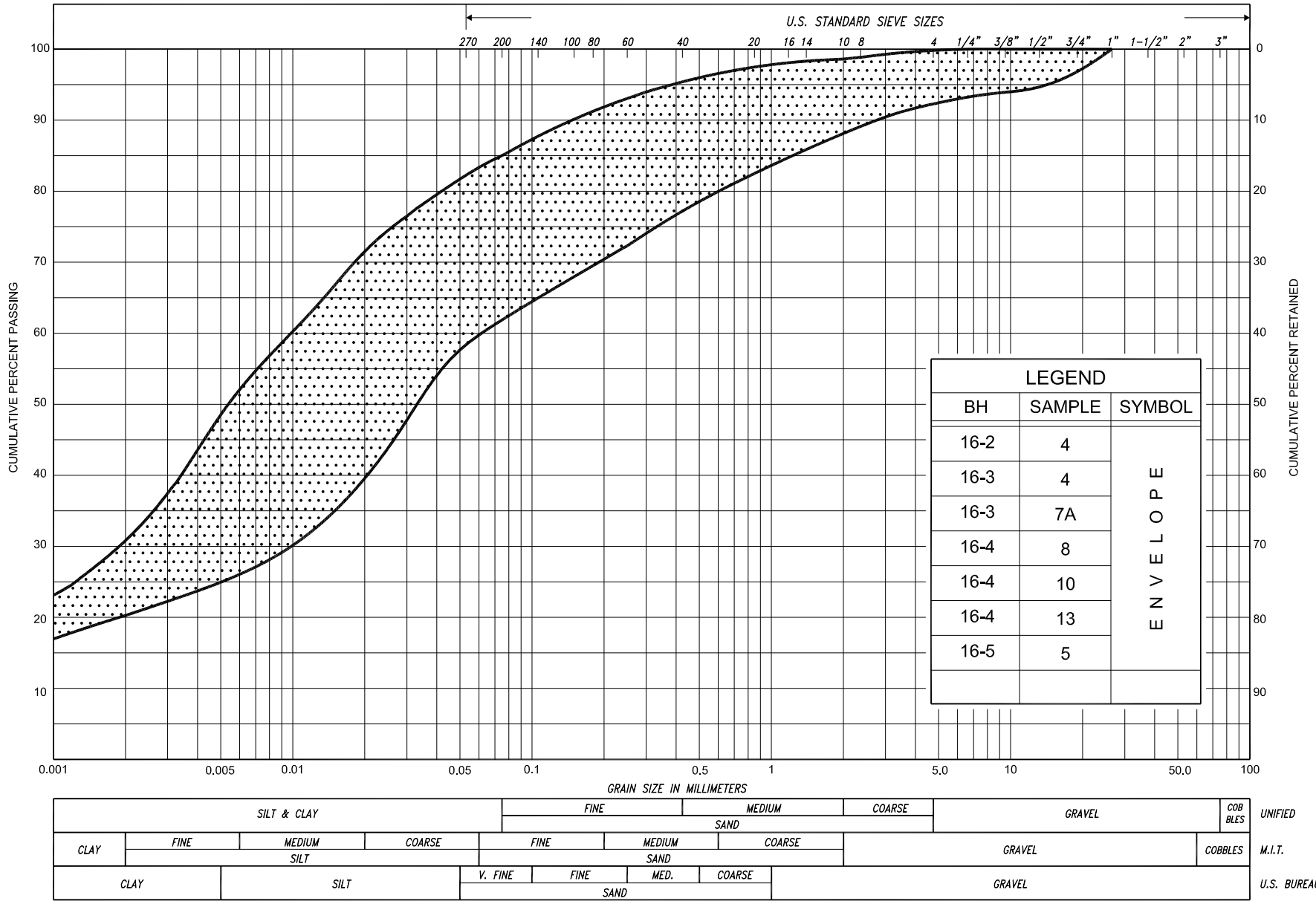


Ontario

GRAIN SIZE DISTRIBUTION

SAND, trace to some gravel, trace silt

FIG No.	GS-3
HWY	11
MnDOT No. 02047	G.W.P. No. 6046-08-00

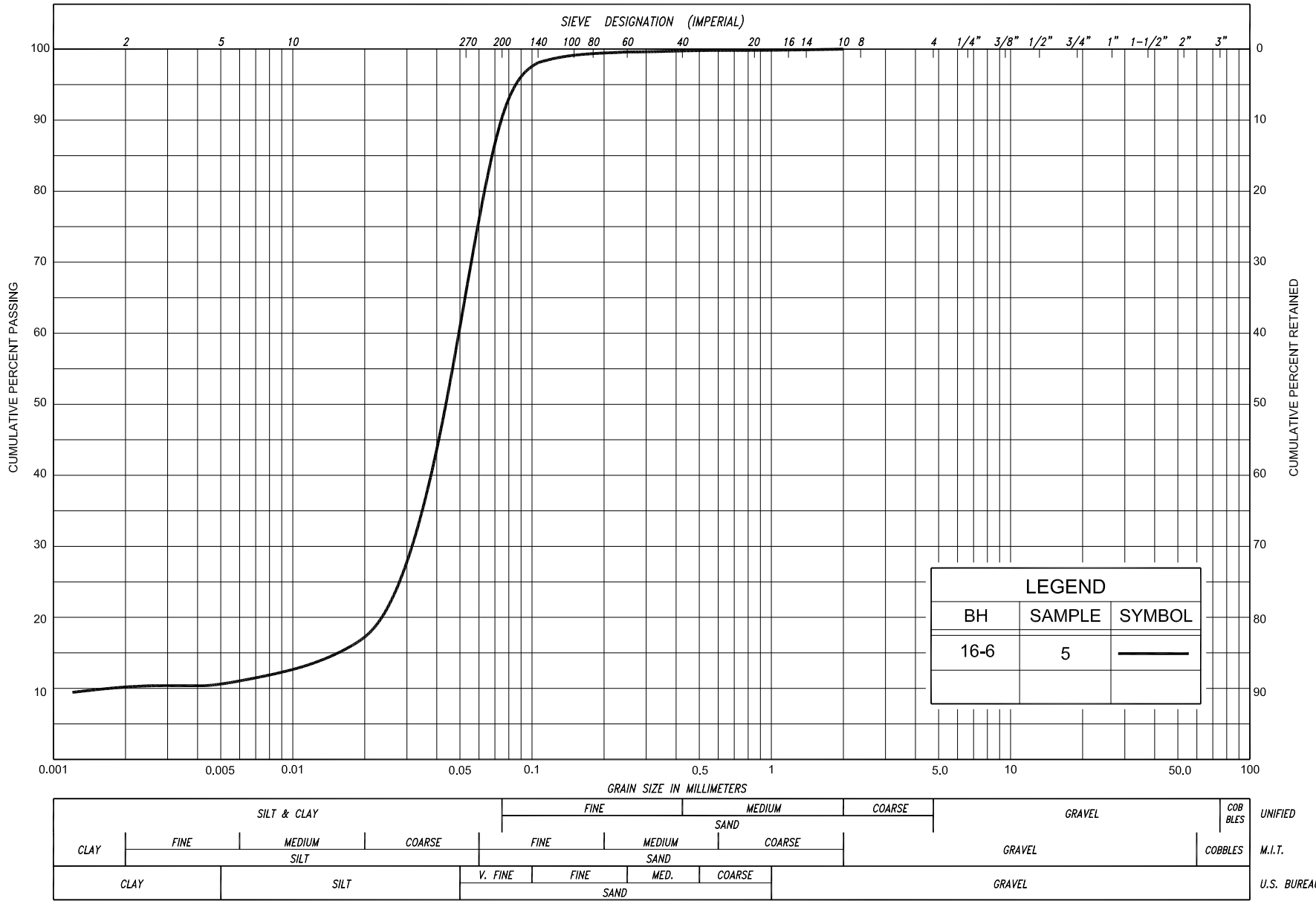


Ontario

GRAIN SIZE DISTRIBUTION

SILTY CLAY TO CLAYEY SILT, trace to some sand (CI)

FIG No.	GS-4
HWY	11
MnDOT No. 02047	G.W.P. No. 6046-08-00

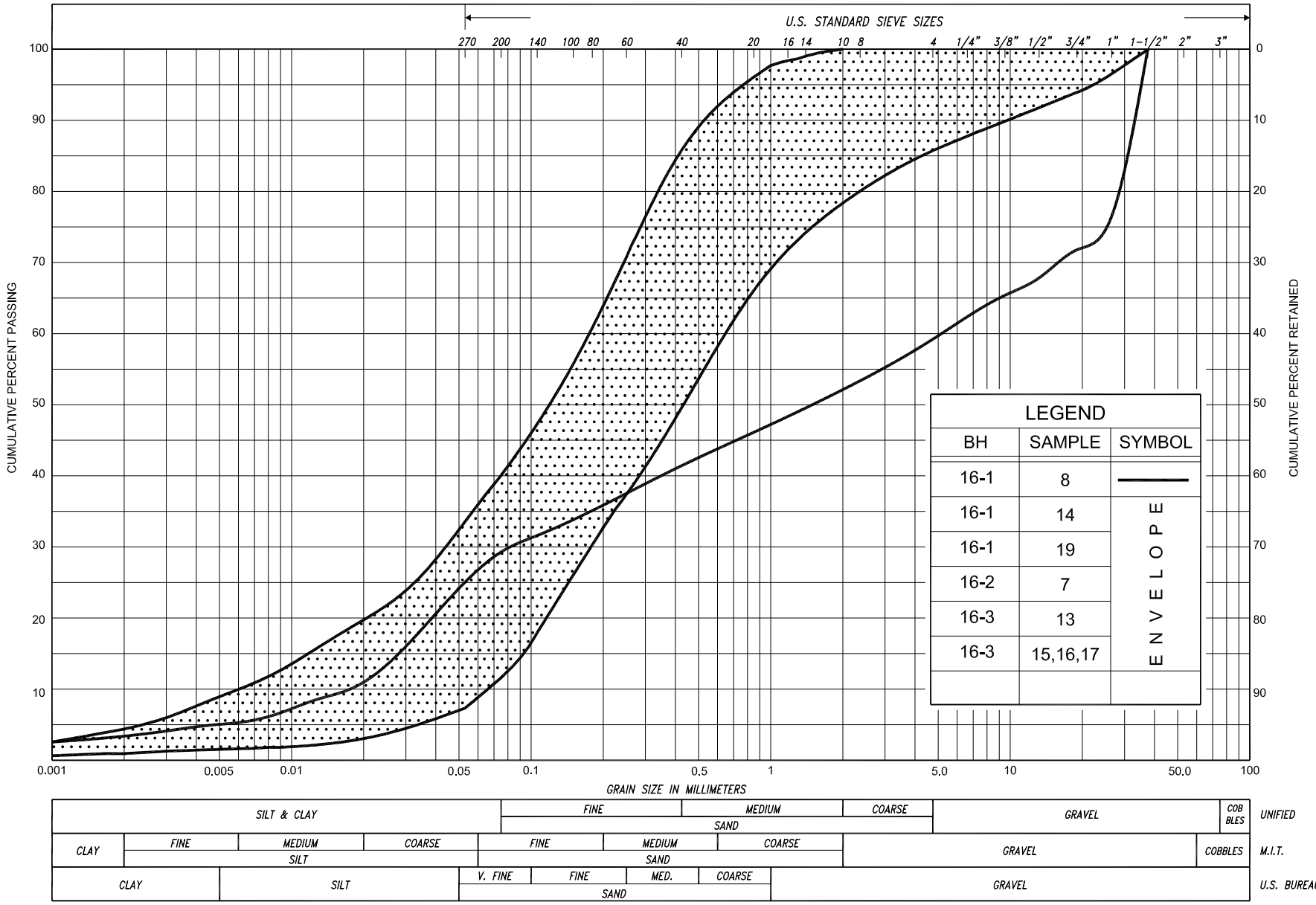


Ontario

GRAIN SIZE DISTRIBUTION

SILT, trace to some clay, trace sand

FIG No.	GS-5
HWY	11
MnDOT No. 02047	G.W.P. No. 6046-08-00



Ontario

GRAIN SIZE DISTRIBUTION

SAND TO SILTY SAND, trace to some gravel, trace clay

FIG No.	GS-6
HWY	11
MnDOT No. 02047	G.W.P. No. 6046-08-00

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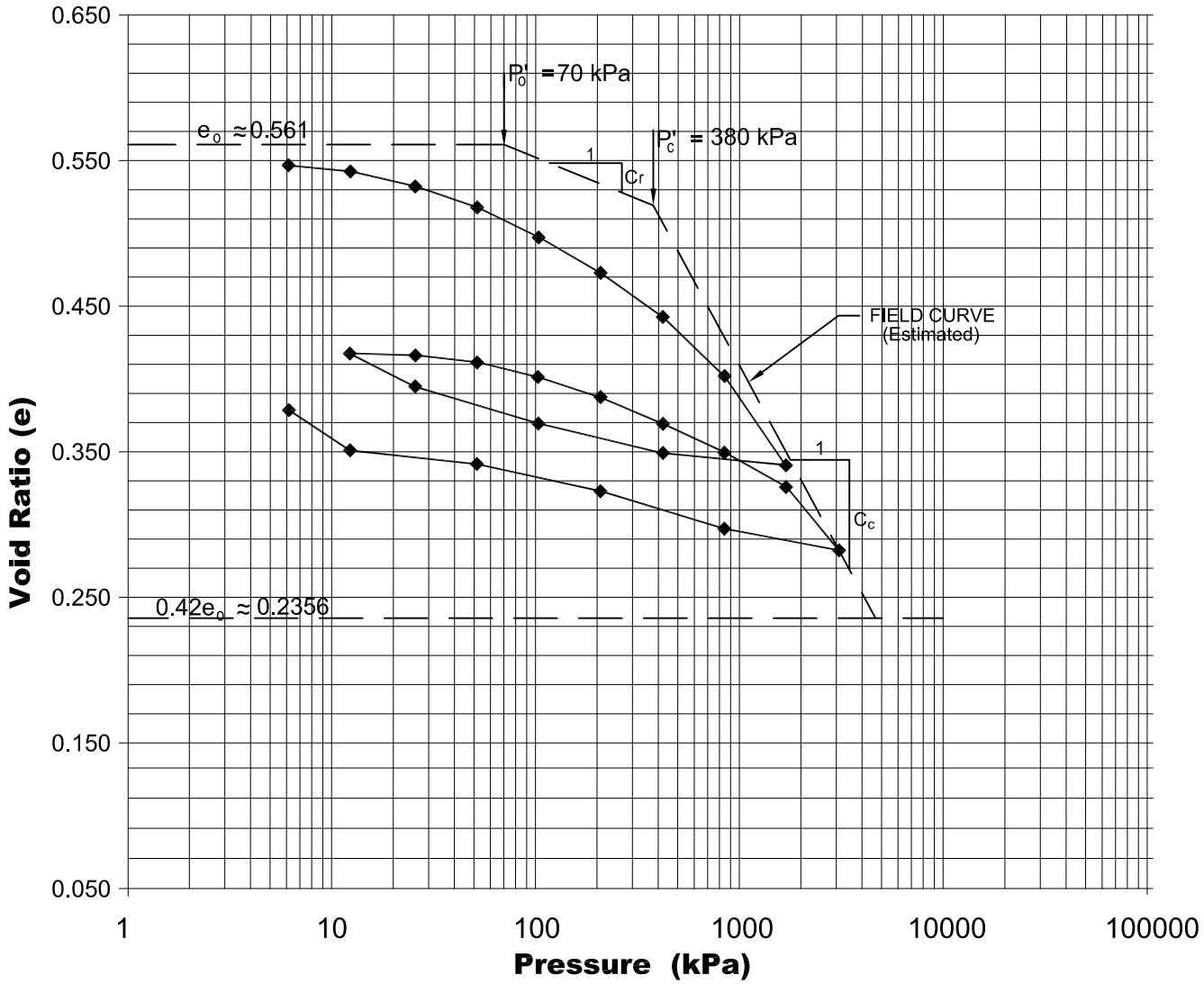
Laboratory Consolidation Test Results

Mn TH 72 / Highway 11
Baudette / Rainy River Bridge
Minnesota / Ontario

Borehole 17-6, Sample 8A, Depth 6.9 - 7.5 m (22'-6" - 24'-6")

Void Ratio versus Log of Pressure



SOIL TYPE:			MnDOT No.: 02047
e_o = 0.561	P'_0 = 70 kPa	W_L = 38	FIGURE: RR-C-1
W_o = 21%	P'_c = 380 kPa	W_P = 17	HIGHWAY: 11
γ = 20.5 kN/m^3	C_c = 0.11	PI = 21	BAUDETTE/RAINY RIVER BRIDGE
	C_r = 0.056		G.W.P. No. 6046-08-00

APPENDIX D

Soil Sample Photographs

Photograph P4 – Cobbles and Gravel within the Sand to Silty Sand Deposit in Borehole 17-3.

Photograph P5 – Sandy Silt Till Cores Retrieved from Borehole 17-3. Note the Granite/Granodiorite Boulder at a Depth of about 36 m (118 ft.).

Photograph P6 – A Core Box of Granite and Granodiorite Cobbles Retrieved from Borehole 17-6 at a Depth of 26 m (85 ft.).

APPENDIX E

Rock Core Photographs

Rock Core Descriptions

Point Load Test Results

Unconfined Compressive Strength Test Result

Photograph P7 – A Rock Core from Borehole 17-1 at a Depth of 28 m (92 ft.).

Photograph P8 – A Rock Core from Borehole 17-1 at a Depth of 31 m (102 ft.)

ROCK CORE DESCRIPTIONS

BOREHOLE NO.	**SAMPLE NO. (CORE RUN)**	**DEPTH (m/ft)**	**% CR***	**% RQD***	**DESCRIPTION**
17-1	18 (1)	28.1 – 29.6 92 – 97	100% (1.52 m)	53.3% (0.81 m)	**SUPERIOR PROVINCE** **DIORITE – MONZONITE – GRANODIORITE SUITE** **GRANODIORITE** – black/white/pink; coarse grained to very coarse grained; crystalline; moderately hard; Occasional features: slight iron staining along core; pink feldspar vein at 28.47 – 28.52 m. Natural fractures: angles 20 - 50°; surface - rough/planar; infill – micaceous with chlorite/biotite, <1.0 mm thick.
17-1	19 (2)	29.6 – 31.1 97 – 102	92.1% (1.40 m)	71.7% (1.09 m)	**SUPERIOR PROVINCE** **DIORITE – MONZONITE – GRANODIORITE SUITE** **GRANODIORITE** – black/white/pink; coarse grained to very coarse grained; crystalline; moderately hard; Occasional features: slight iron staining along core. Natural fractures: angles 50°; surface – rough/planar; infill – micaceous with chlorite/biotite, <1.0 mm thick.
17-1	20 (3)	31.1 – 32.6 102 – 107	90.1% (1.37 m)	78.3% (1.19 m)	**SUPERIOR PROVINCE** **DIORITE – MONZONITE – GRANODIORITE SUITE** **GRANODIORITE** – black/white/pink; coarse grained to very coarse grained; crystalline; moderately hard; Occasional features: broken rock zone at 32.41 – 32.46 m; slight iron staining along core. Natural fractures: angles 20 - 50°; surface - rough to smooth (with thick presence of infill <5.0 mm) / planar; infill – micaceous with chlorite/biotite, <1.0 to 5.0 mm thick.
17-1	21 (4)	32.6 – 34.1 102 – 112	100.0% (1.52 m)	83.5% (1.27 m)	**SUPERIOR PROVINCE** **DIORITE – MONZONITE – GRANODIORITE SUITE** **GRANODIORITE** – black/white/pink; coarse grained to very coarse grained; crystalline; moderately hard; Occasional features: pink feldspar vein at 33.78 – 33.81 m. Natural fractures: angles 30 - 35°; surface - rough/planar; infill – micaceous with chlorite/biotite, <1.0 mm thick.

CR* - Core Recovery
RQD* - Rock Quality Designation

Logged by: Heather Racher, M.Sc.
Reviewed By: Lulseged Yimam, PhD, P.Eng.

Note: Depths are approximated where core recovery is less than 100%.

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POINT LOAD STRENGTH INDEX OF ROCK

CLIENT	Stantec Consulting Services Inc.	*PML REF*	17TF029
PROJECT	Baudette - Rainy River Crossing, MnDOT Contract No. 02047 Soil(Geo) 0	*REPORT NO*	
LOCATION	Rainy River, Ontario	*ENCLOSURE*	
		LAB NUMBER	1704124 A
		DATE TESTED	2017-10-23

POINT LOAD TESTER										
MODEL	PIL7	SERIAL NO	048A13035		CALIBRATION FACTOR		0.006534557			
SAMPLE DETAILS										
BH	17-Jan	SAMPLE NO	Rn 4	DEPTH	109-112 ft.	TYPE				
DESCRIPTION										

TEST TYPE	ORIENTATION	WIDTH (w) mm	DIAMETER (D) mm	GUAGE READING	LOAD (P) kN	D_e^2	D_e	I_s MPa	F	$I_{s(50)}$ MPa
Axial	⊥	22.00	63.32	241.00	1.575	1773.7	42.1	0.89	0.93	0.82
Axial	⊥	22.00	63.59	241.00	1.575	1781.2	42.2	0.88	0.93	0.82
Axial	⊥	19.50	63.52	255.00	1.666	1577.1	39.7	1.06	0.90	0.95
Axial	⊥	24.00	63.38	261.00	1.706	1936.8	44.0	0.88	0.94	0.83
Axial	⊥	26.50	63.31	293.00	1.915	2136.1	46.2	0.90	0.97	0.87
Axial	⊥	19.50	63.55	215.00	1.405	1577.8	39.7	0.89	0.90	0.80
Axial	⊥	22.50	63.34	220.00	1.438	1814.6	42.6	0.79	0.93	0.74
Axial	⊥	21.00	63.46	171.00	1.117	1696.8	41.2	0.66	0.92	0.60
Axial	⊥	21.50	63.49	232.00	1.516	1738.0	41.7	0.87	0.92	0.80
Axial	⊥	21.00	63.35	305.00	1.993	1693.9	41.2	1.18	0.92	1.08
Axial	⊥	25.00	63.38	197.00	1.287	2017.4	44.9	0.64	0.95	0.61
Axial	⊥	25.00	63.41	165.00	1.078	2018.4	44.9	0.53	0.95	0.51
Axial	⊥	21.50	63.31	276.00	1.804	1733.1	41.6	1.04	0.92	0.96
Axial	⊥	19.00	63.46	157.00	1.026	1535.2	39.2	0.67	0.90	0.60
Axial	⊥	19.00	63.39	191.00	1.248	1533.5	39.2	0.81	0.90	0.73
Axial	⊥	19.00	63.42	104.00	0.680	1534.2	39.2	0.44	0.90	0.40
Axial	⊥	20.00	63.37	125.00	0.817	1613.7	40.2	0.51	0.91	0.46
Axial	⊥	19.00	63.37	165.00	1.078	1533.0	39.2	0.70	0.90	0.63
Axial	⊥	18.00	63.36	133.00	0.869	1452.1	38.1	0.60	0.88	0.53
						AVERAGE AXIAL STRENGTH				**0.72**

⊥ = Perpendicular to plane of weakness ‖ = Parallel to plane of weakness

MOISTURE CONTENT

WET SAMPLE WITH TARE (g)	DRY SAMPLE WITH TARE (g)	WATER (g)	TARE (g)	DRY SAMPLE (g)	WATER CONTENT (%)
210.11	206.29	3.82	33.47	172.82	2.21
209.76	206.67	3.09	34.17	172.50	1.79
186.80	183.78	3.02	35.09	148.69	2.03
213.46	209.16	4.30	21.75	187.41	2.29
242.94	238.52	4.42	34.26	204.26	2.16
265.70	262.00	3.70	109.44	152.56	2.43
209.38	205.54	3.84	34.16	171.38	2.24
201.60	198.53	3.07	33.41	165.12	1.86
207.56	204.03	3.53	34.26	169.77	2.08
204.51	200.81	3.70	35.09	165.72	2.23
231.70	227.59	4.11	34.71	192.88	2.13
231.61	227.42	4.19	34.21	193.21	2.17
205.74	202.16	3.58	35.09	167.07	2.14
184.60	180.41	4.19	36.28	144.13	2.91
179.59	175.48	4.11	33.53	141.95	2.90
183.00	178.30	4.70	37.20	141.10	3.33
192.15	187.59	4.56	36.65	150.94	3.02
178.82	175.28	3.54	33.25	142.03	2.49
165.20	161.33	3.87	36.70	124.63	3.11
				AVERAGE MOISTURE CONTENT	**2.40**

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ROCK CORE TESTING

CLIENT	STANTEC CONSULTING SERVICES INC.	PML REF	17TF029
PROJECT	Baudette - Rainy River Crossing, MnDOT	LAB NO.	1704124-A
SAMPLE IDENTIFICATION	BH# 17-1/ SN-4/ 109'-112'	DATE SAMPLED	
		DATE TESTED	
		TESTED BY	

UNCONFINED COMPRESSIVE STRENGTH

CORE DIMENSIONS		COMPRESSIVE STRENGTH	
SPECIMEN DIAMETER (in.)	2.4853	**TEST TIME (min) (spec. 2 to 15)**	2:07
SPECIMEN LENGTH (in.)	4.118	**MAXIMUM LOAD APPLIED (kN)**	67.2
	4.115		
	4.113	**COMPRESSIVE STRENGTH (MPa)**	21.5
AVE.	4.115	**TYPE OF FAILURE**	4
SURFACE AREA (sq mm)	3130	**LENGTH TO DIAMETER RATIO (spec 2-2.5)**	1.66

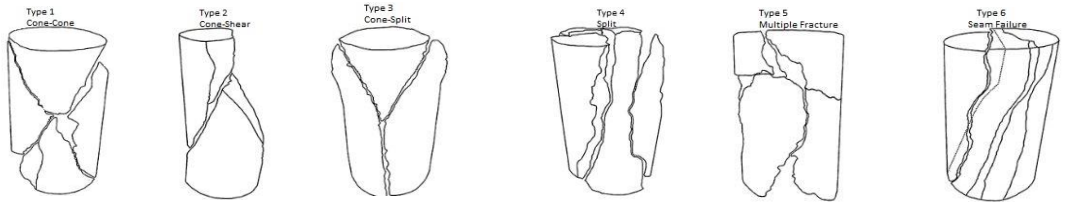
MOISTURE CONTENT

WEIGHT OF WET SAMPLE + TARE (g)	927.59
WEIGHT OF DRY SAMPLE + TARE (g)	911.64
WEIGHT OF WATER (g)	15.95
WEIGHT OF TARE (g)	108.83
WEIGHT OF DRY SAMPLE (g)	802.81
MOISTURE CONTENT (%)	2.0

UNIT WEIGHT

WEIGHT OF DRY SAMPLE IN AIR (g)	819.01
VOLUME OF SAMPLE (cu m)	0.000327
UNIT WEIGHT (kg/cu m)	2504

REMARKS



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CONSULTING ENGINEERS

ROCK CORE DIMENSIONS

CLIENT STANTEC CONSULTING SERVICES INC.
PROJECT Baudette - Rainy River Crossing, MnDOT
SAMPLE IDENTIFICATION BH# 17-1/ SN-4/ 109'-112'

PML REF 17TF029
LAB NO. 1704124-A
DATE SAMPLED
DATE TESTED Nov 9,2017
TESTED BY BM/YA

DEVIATION FROM STRAIGHTNESS

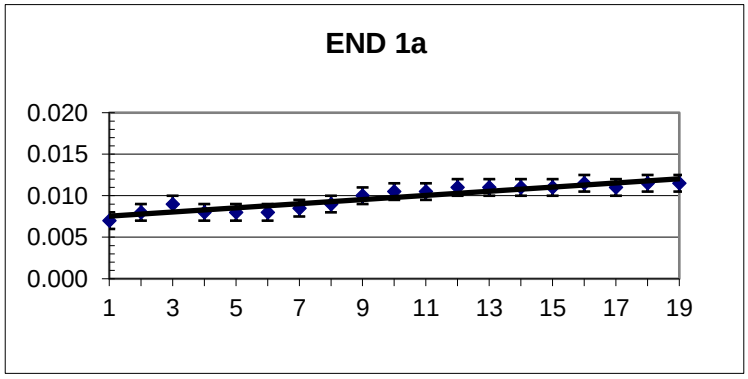
DIAL READING (IN)	TRIAL 1	TRIAL 2	TRIAL 3
MINIMUM	0.0290	0.0320	0.0380
MAXIMUM	0.0450	0.0460	0.0490
DIFFERENCE	0.0160	0.0140	0.0110
MAX DIFF.	0.016	SPEC.	0.020 max.

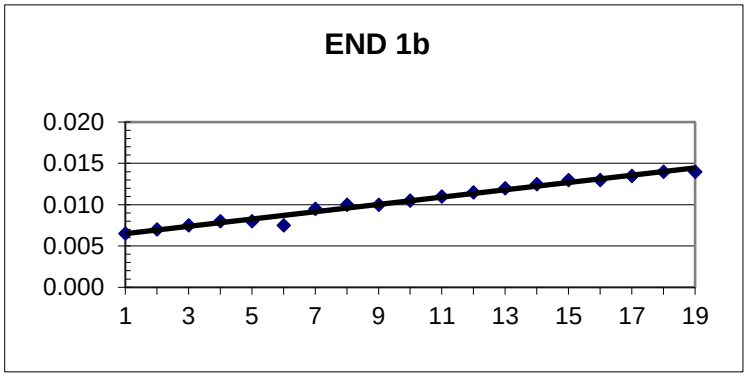
FLATNESS TOLERANCE

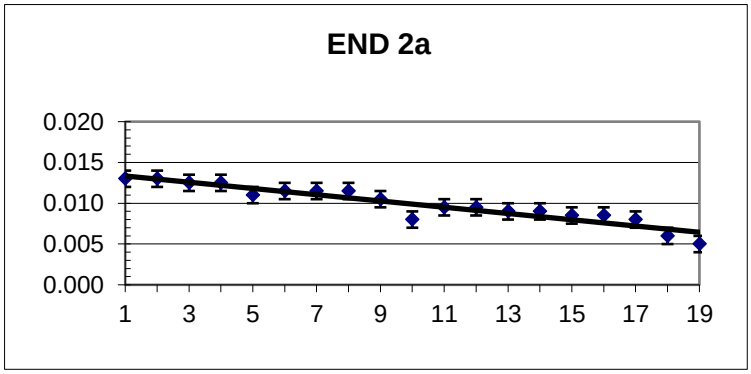
DIAL READING (IN)	END 1 SET 1	END 1 SET 2	END 2 SET 1	END 2 SET 2
RDG 1	0.0070	0.0065	0.0130	0.0135
RDG 2	0.0080	0.0070	0.0130	0.0130
RDG 3	0.0090	0.0075	0.0125	0.0115
RDG 4	0.0080	0.0080	0.0125	0.0125
RDG 5	0.0080	0.0080	0.0110	0.0120
RDG 6	0.0080	0.0075	0.0115	0.0120
RDG 7	0.0085	0.0095	0.0115	0.0120
RDG 8	0.0090	0.0100	0.0115	0.0115
RDG 9	0.0100	0.0100	0.0105	0.0105
RDG 10	0.0105	0.0105	0.0080	0.0085
RDG 11	0.0105	0.0110	0.0095	0.0120
RDG 12	0.0110	0.0115	0.0095	0.0120
RDG 13	0.0110	0.0120	0.0090	0.0120
RDG 14	0.0110	0.0125	0.0090	0.0115
RDG 15	0.0110	0.0130	0.0085	0.0115
RDG 16	0.0115	0.0130	0.0085	0.0110
RDG 17	0.0110	0.0135	0.0080	0.0110
RDG 18	0.0115	0.0140	0.0060	0.0105
RDG 19	0.0115	0.0140	0.0050	0.0105
RDG 20				

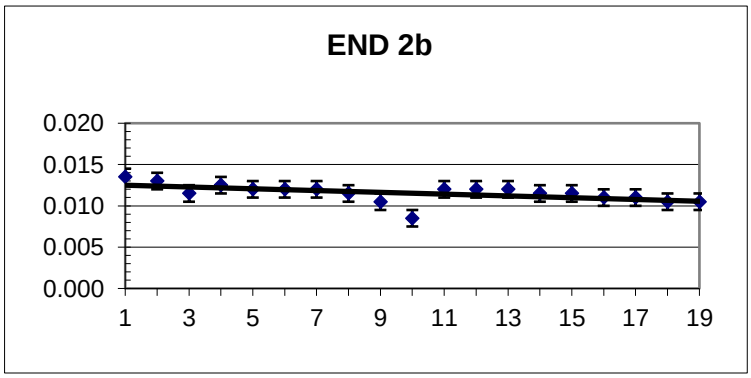
FLATNESS TOLERANCE= .001 in.

CORE DIAMETER (in.)	2.4874	2.4846	2.4839
AVE:	2.4853	PERPENDICULARITY RATIO (Specified .0043 max.)	
SLOPE OF BEST FIT LINE			
	MINIMUM	MAXIMUM	
END 1A	0.0075	0.0120	0.0018
END 2B	0.0065	0.0145	0.0032
END 2A	0.0064	0.0133	0.0028
END 2B	0.0106	0.0125	0.0008









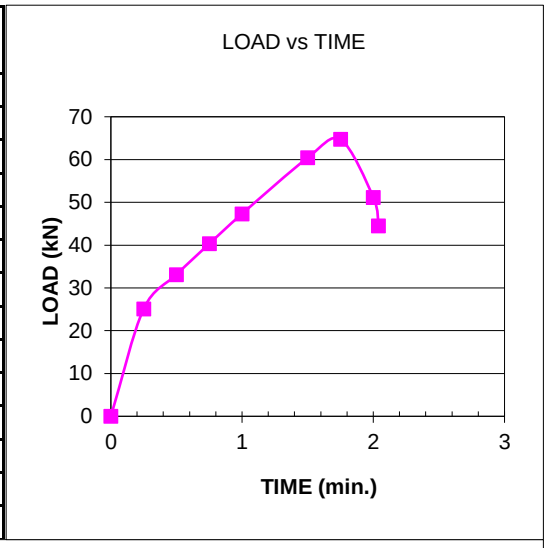
Peto MacCallum Ltd.
CONSULTING ENGINEERS

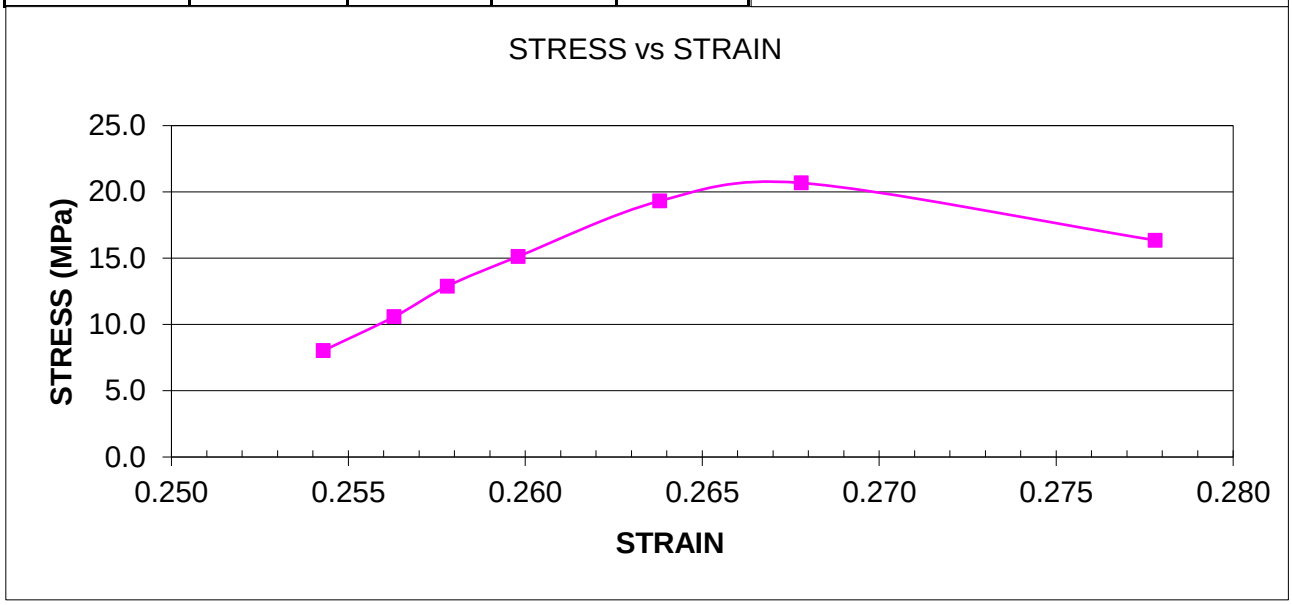
ROCK CORE TESTING

CLIENT	STANTEC CONSULTING SERVICES INC.	PML REF	17TF029
PROJECT	Baudette - Rainy River Crossing, MnDOT	LAB NO.	1704124-A
SAMPLE IDENTIFICATION	BH# 17-1/ SN-4/ 109'-112'	DATE SAMPLED	
		DATE TESTED	
		TESTED BY	

UNCONFINED COMPRESSIVE STRENGTH CURVE

TIME (min.)	DEFLECTION (in)	LOAD (kN)	STRESS (MPa)	STRAIN (mm/mm)
0	0.328	0	0	0
0.25	0.334	25.13	8.0	0.254
0.5	0.336	33.11	10.6	0.256
0.75	0.3375	40.32	12.9	0.258
1	0.3395	47.33	15.1	0.260
1.5	0.3435	60.43	19.3	0.264
1.75	0.3475	64.72	20.7	0.268
2	0.3575	51.18	16.4	0.278
2.04		44.51	14.2	





APPENDIX F

Results of Chemical Corrosivity Test

AGAT Laboratories

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
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Certificate of Analysis

AGAT WORK ORDER: 17T272311

PROJECT: 17TF029

CLIENT NAME: PETO MACCALLUM LIMITED

ATTENTION TO: Lul Yimam

SAMPLING SITE:Rainy River, Ontario

SAMPLED BY:Shane Aziz

Corrosivity Package

DATE RECEIVED: 2017-10-16 **DATE REPORTED: 2017-10-24**

		SAMPLE DESCRIPTION:		17-1 SS2	17-1 SS6	17-2 SS4	17-3 SS2	17-4 SS4	17-5 37m	17-6 SS3	17-6 SS8
		SAMPLE TYPE:		Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
		DATE SAMPLED:		2017-09-30	2017-09-30	2017-09-30	2017-09-30	2017-09-30	2017-09-30	2017-09-30	2017-09-30
Parameter	Unit	G / S	RDL	8823835	8823840	8823841	8823842	8823843	8823844	8823845	8823846
Sulfide (S2-)	%		0.05	<0.05	<0.05	0.08	<0.05	0.19	<0.05	<0.05	0.25
Chloride (2:1)	µg/g		2	22	77	4	6	4	4	14	20
Sulphate (2:1)	µg/g		2	20	31	443	88	293	73	5	205
pH (2:1)	pH Units		NA	7.95	8.27	8.17	8.50	8.27	9.34	8.58	8.24
Electrical Conductivity (2:1)	mS/cm		0.005	0.192	0.264	0.567	0.165	0.479	0.201	0.148	0.373
Resistivity (2:1)	ohm.cm		1	5210	3790	1760	6060	2090	4980	6760	2680
Redox Potential (2:1)	mV		5	148	140	151	172	167	126	153	164

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

8823835-8823846 EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil).

*Sulphide analyzed at AGAT 5623 McAdam

Certified By: Amanjot Bhela

AGAT Laboratories

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Quality Assurance

CLIENT NAME: PETO MACCALLUM LIMITED

AGAT WORK ORDER: 17T272311

PROJECT: 17TF029

ATTENTION TO: Lul Yimam

SAMPLING SITE:Rainy River, Ontario

SAMPLED BY:Shane Aziz

Soil Analysis

RPT Date: Oct 24, 2017			DUPLICATE				REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD	Method Blank	Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper
Corrosivity Package															
Sulfide (S2-)	8823841	8823841	0.08	0.08	NA	< 0.05	98%	80%	120%						
Chloride (2:1)	8824114		60	59	1.7%	< 2	108%	80%	120%	109%	80%	120%	109%	70%	130%
Sulphate (2:1)	8824114		137	141	2.9%	< 2	104%	80%	120%	107%	80%	120%	105%	70%	130%
pH (2:1)	8823322		8.14	8.09	0.6%	NA	101%	90%	110%	NA			NA		
Electrical Conductivity (2:1)	8831754		0.685	0.705	2.9%	< 0.005	97%	90%	110%	NA			NA		
Redox Potential (2:1)	8823322		130	131	0.8%	< 5	101%	70%	130%	NA			NA		

Comments: NA signifies Not Applicable.
Duplicate Qualifier: As the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

Certified By: Amanjot Bhela

AGAT Laboratories

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Method Summary

CLIENT NAME: PETO MACCALLUM LIMITED

AGAT WORK ORDER: 17T272311

PROJECT: 17TF029

ATTENTION TO: Lul Yimam

SAMPLING SITE:Rainy River, Ontario

SAMPLED BY:Shane Aziz

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Sulfide (S2-)	MIN-200-12025	ASTM E1915-09	GRAVIMETRIC
Chloride (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
Sulphate (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
pH (2:1)	INOR 93-6031	MSA part 3 & SM 4500-H+ B	PH METER
Electrical Conductivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B	EC METER
Resistivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B,SSA #5 Part 3	CALCULATION
Redox Potential (2:1)		McKeague 4.12 & SM 2510 B	REDOX POTENTIAL ELECTRODE

Peto MacCallum Ltd.
CONSULTING ENGINEERS

PART B - FOUNDATION DESIGN REPORT

for

BAUDETTE - RAINY RIVER BRIDGE REPLACEMENT
MNDOT BRIDGE NO. 39016 / MTO SITE NO. 45-110
MN TH 72 / HIGHWAY 11
MNDOT PROJECT NO. SP 3905-09
MNDOT CONTRACT NO. 02047
BAUDETTE, MINNESOTA / RAINY RIVER, ONTARIO

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Distribution:
2 cc: Stantec Consulting Services Inc. for distribution to MTO, Project Manager + 1 Digital Copy (pdf)
1 cc: Stantec Consulting Services Inc. for distribution to MTO, Foundations Section + 1 digital Copy (pdf)
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1 cc: PML Toronto

PML Ref.: 17TF029
Index No.: 018FDR
GEOCRES No.: 52D-33
December 21, 2017

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PART B – PRELIMINARY FOUNDATION DESIGN REPORT

PART B – FOUNDATION DESIGN REPORT
for
Baudette - Rainy River Bridge Replacement
MnDOT Bridge No. 39016, MTO Site No. 45-110
MN TH 72 / Highway 11
MnDOT Project No. SP 3905-09
MnDOT Contract No. 02047, GWP 6046-08-00
Rainy River, Ontario

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10. INTRODUCTION

This foundation design report provides foundation design recommendations for the Baudette - Rainy River Bridge replacement, based on the findings provided in the Foundation Investigation Report (Part A), and the preliminary foundation investigation carried out by Peto MacCallum Ltd. (PML) in 2016. The objective of this report is to provide geotechnical design parameters required for detail design and preparation of construction documents and specifications.

This report is intended for the use of Stantec Consulting Services Inc. (Stantec) on behalf of the Minnesota Department of Transportation (MnDOT) and the Ministry of Transportation of Ontario (MTO) for detail design of the Baudette - Rainy River Bridge replacement. It shall not be used or relied upon for any other purposes, or by any other parties including construction or design-build contractors. Where comments are made in this report on construction, they are provided only to highlight aspects, which could affect the design of the project. Contractors must make their own interpretation of the subsurface information based on the data provided in the Foundation Investigation Report as it may affect equipment selection, construction methods and scheduling.

11. PROJECT DESCRIPTION

11.1. Proposed Replacement Bridge

MnDOT and MTO have jointly retained Stantec to undertake the design of the proposed replacement bridge. In August, 2017 and October, 2017, Stantec has provided PML with the design drawings at the stage of 60% and 95% completion. Based on the drawings, the proposed bridge will be constructed approximately 1.0 m (3 ft.), edge to edge, away from the south side of the existing bridge. The new bridge will be a five-span structure with a total length of 411.5 m (1350 ft.) and 14.7 m (48.3 ft.) wide, and designed to accommodate two lanes of traffic and a sidewalk. The alignment will be parallel to the existing bridge with modifications to the end span configurations.

The substructure will consist of four piers (Pier 1, Pier 2, Pier 3, and Pier 4) supported by drilled shafts. Pier 1 and Pier 2 will be located on the US side of the river and Pier 3 and Pier 4 will be placed on the Canadian side. The piers for the replacement bridge will be offset at least 4 m (13 ft.) away from the piers of the existing bridge. The abutments for the new bridge will be founded on driven steel piles, and will have similar minimum offset as the piers. The approach embankments on both the US and Canadian sides will be widened on the south side with identical grade as the existing structure to accommodate the alignment of the new bridge.

Drawing RR-1 in Appendix A shows the alignment of the proposed bridge relative to the location of the existing bridge, and a railway bridge located about 85 m (280 ft.) further to the north.

11.2. Foundation Conditions

In summary, the boreholes drilled in the river indicated the presence of approximately 1.2 m (3.9 ft.) to 4.6 m (15 ft.) “very loose to compact” sand layer below the river bed. The sand layer is underlain by firm to hard silty clay to clayey silt layer, with trace to some sand and trace gravel. The thickness of this layer ranged from 2.1 m (6.9 ft.) to 12.4 m (40.1 ft.), extending to El. 312.2 m (1024 ft.). The subsurface below the silty clay to clayey silt layer consisted of dense to very dense sand to silty sand glacial till deposit. This glacial till deposit contained cobbles and occasional boulders, and extends to the maximum depth of investigation of 40 m (130 ft.) or El. 283.8 m (931 ft.).

The borehole drilled recently by PML at the proposed location of Pier 1, about 30 m (100 ft.) from the river bank on the US side, encountered a bedrock at a depth of 28 m (92 ft.), or El. 296.7 m (973.4 ft). The visual examination and description of the rock cores indicate that the bedrock appears to be Diorite or Granodiorite, and appears to be an extension of the Granodiorite (Tonalite) bedrock commonly found in the region. The same type of bedrock was also found at similar depth in a borehole that was drilled by others at the abutment on the US side.

The subsurface at the abutment on the Canadian side consisted of a fill unit made up of clayey silt, with some sand and trace gravel. Beneath this material, a silty sand deposit was encountered. This silty sand deposit was underlain by a layer of silty clay to clayey silt. The lower part of the stratigraphy to the full depth of investigation of El.298.2 (978 ft.) consisted of compact to very dense

sand to silty sand till deposit. For the abutment on the US side, the borehole drilled by others indicate the presence of silty clay layers with trace to some sand followed by sandy clay and very dense silty sand deposits. Drawing RR-1 (Appendix A) presents the location of the boreholes drilled on the US side by others. The logs for these boreholes are provided in Appendix C.

The groundwater level was at El. 322.9 m (1059.4 ft.), and was observed to be the same as the water level in the river. Artesian conditions were not noted at the time of drilling.

12. FOUNDATION RECOMMENDATIONS

The design drawings at the stage of 60% and 95% completion indicate that caissons (drilled shafts) are the preferred option by MnDOT and MTO to support the piers of the replacement bridge, while driven steel pile foundations are used at the abutments. A comparison of the foundation alternatives, advantages, disadvantages, relative costs and risks/consequences was provided in the preliminary investigation and design reported prepared by PML in 2016.

12.1. Driven Steel H-Piles

According to the design drawings, HP 310x79 (12x53) steel H-piles will be used to support the foundations at the abutments. At the east abutment on the Canadian side, the geotechnical resistances provided in Table 12.1 are recommended for driven steel piles. The geotechnical resistance values are estimated at the tip elevation provided in Table 12-1, and an allowance of at least 10% should be allowed in material quantity calculations.

Table 12.1 - Recommended Axial Geotechnical Resistance Values for Driven Piles

FOUNDATION TYPE	SIZE	PILE LOCATION	MINIMUM DESIGN PILE TIP ELEVATION	ULTIMATE GEOTECHNICAL RESISTANCE
Driven Piles	HP 310x110 (12x74)	East Abutment	296 m (970 ft.)	2,500 kN (250 tons)
	HP 310x79 (12x53)		296 m (970 ft.)	2,250 kN (225 tons)

Static load tests should be conducted to verify the pile resistances used for detail design. Alternatively, piles may be driven to an elevation recommended in Table 12.1 and resistances achieved may be checked by employing the MnDOT procedure, Hiley Formula, or Pile Driving Analyser (PDA). It should be noted the pile lengths recommended on design drawings may be shorter than the tip elevations provided in Table 12.1.

The pile lengths are subject to validation by the results of the test piles. Once the test piles are driven and tested by the MnDOT procedure, the level where the required resistance is obtained should govern. If the required resistance is achieved at levels higher than those indicated in Table 12.1, there would be no need to drive piles deeper than the level obtained from the test piles.

Considering occasional cobbles encountered below about El. 310.0 m (1017 ft.), the pile tips may have to be reinforced to drive the piles through layers consisting of cobbles. Oversize tip reinforcement similar to that of OPSD 3000.100 or Titus standard model should not be used. Instead, an H-pile tip reinforcement of the type provided in Appendix G, is recommended. In addition, splices of H-piles within 6.0 m (20 ft.) below the pile cut-off should not be permitted.

As shown on design drawings, the east abutment will be supported on a pile cap, placed at El. 323.8 m (1062.3 ft.). The piles caps should be constructed below the frost depth (Refer to Section 12.7), and at the east abutment, would be placed on a silty sand layer. Since the water level in the river is constant at El. 322.9 m (1059.4 ft.), it is estimated that a “cofferdam-and-dewatering” scheme would not be required to construct the pile cap in the dry. However, if the river rises to a level that causes the pile caps to be placed underwater, or if a flowing water reaches the area during construction, a dewatering system including a cofferdam may need to be considered.

The water level during excavation should be kept at least 0.5 m (1.6 ft.) below the base by sump-pumping. The silty sand layer at the bottom of the pile cap can be susceptible to disturbance from construction traffic and flowing water. To limit the degradation of the soil and provide a working platform, a 100 mm (4 in.) concrete working slab (lean concrete) may be placed on the subgrade within four hours of preparation, inspection and approval.

12.2. Drilled Shafts

It is understood that the drilled shafts are the preferred foundation option by MTO and MnDOT to support the proposed piers. The 2.3 m (7.5 ft.) diameter drilled shafts will be installed in a group of two (2) at each pier location. The design drawings indicate that the drilled shafts at Pier 2, Pier 3 and Pier 4 will be founded at El. 290.6 m (953.5 ft.), 290.6 m (953.5 ft.) and 292.2 m (958.5 ft.), respectively. This indicates that the shafts will be placed at least about 15 m (50 ft.) into the dense to very dense sand to silty sand till deposit. At Pier 1, the drilled shafts will be socketed about 3 m (10 ft.) into the bedrock, encountered at El. 296.4 m (972.4 ft.) in Borehole 17-1.

The advantage and disadvantages of drilled shafts were discussed in the report prepared by PML in 2016. In particular, the drilled shafts will have to be constructed under 36 m (118 ft.) to 38 m (125 ft.) hydrostatic head and founded in sand to silty sand till deposits. It is understood that the contractors preferred by MnDOT have the expertise to construct the piers under these conditions and prevent disturbance to the soil at the base as well as along the sides of the shaft. In addition, there may be a loss of ground during the excavation for each shaft, which may affect the integrity of the piers supporting the existing bridge in areas where the offset is minimal, such as at Pier 2. Hence, if the drill shaft are selected to support the piers, they should be tested after construction to ensure their integrity and confirm the geotechnical resistances assumed for the design.

Further, the use of slurry to stabilize the base during the installation of drilled shafts will be a major concern in an environmentally sensitive area if not handled adequately during construction and disposal. Polymers or bentonite slurry may not be able to bring the spoils to the surface in a large diameter shaft. In case large size bailers are used to clean the base, the technique may cause disturbance to the base and lead to reduction in geotechnical resistance of the drilled-shaft.

However, since the use of drilled shafts are preferred by MnDOT and MTO based on the previous experiences and the techniques used in the USA, the ultimate geotechnical resistances provided in Table 12.2 can be utilized before factoring for design purposes.

Table 12.2 – Recommended Axial Geotechnical Resistance Values for Drilled Shafts

FOUNDATION TYPE	DIAMETER	PILE LOCATION	AVERAGE DESIGN PILE TIP ELEVATION (m)	ULTIMATE GEOTECHNICAL RESISTANCE
Drilled Shaft	2.3 m (7.5 ft.)	Pier 2, Pier 3, Pier 4	291 m (955 ft.)	30,000 kN (3,000 tons)
		Pier 1	293 m (960 ft.)	40,000 kN (4,000 tons)

The drilled shafts at the site would have to be installed in sand to silty sand till material with occasional cobbles and boulders, and at least with 7.0 m (23 ft.) high water level with strong currents. The drilled shaft will probably require a permanent liner to support the caisson walls and bentonite slurry to stabilize the sandy material. Removal of cobbles and boulders may be difficult with conventional technique and may require special equipment and/or diver's assistance. In addition, there may be environmental restrictions on the use of bentonite slurry within the river.

A wet construction method would have to be employed for the installation of drilled shafts, and visual inspection of the unexposed portion of the shaft would not be possible. Cleaning and inspection of the base would be at best very difficult. Special integrity testing methods would be required to ensure the continuity and carrying capacity of the shaft.

12.3. Geotechnical Resistance Factors

A geotechnical resistance factor of 0.4 may be used where no field testing of drilled shafts and driven piles is carried out, to obtain factored axial resistances at Ultimate Limit State (ULS) from the ultimate resistance values provided in Table 12.1 and Table 12.2. The resistance factor may be increased to 0.6 if representative static load tests are conducted at or near the corresponding location of the foundation element. A resistance factor of 0.50 may be used where the pile resistance is verified by field dynamic testing, such as the Hiley Formula or the MnDOT procedures.

The recommended geotechnical resistance factors are based on a typical degree of understanding of the project site and predictability mode of the subsurface conditions, as specified in the Canadian Highway Bridge Design Code (CHBDC), 2014.

12.4. Lateral Geotechnical Resistance

As indicated in the preliminary foundation investigation and design report prepared by PML in 2016, the design value used for lateral pile resistance should not exceed 110 kN (24.7 kips) for Factored Resistance at ULS and 80 kN (18 kips) for resistance at SLS. If greater lateral resistance is required, the option of using battered piles may be considered.

The lateral resistance within the frost penetration depth shall be ignored. If pre-drilled holes are used, the lateral resistance within the depth of pre-drilling shall not be used.

When piles that are installed in groups are subjected to lateral loads, additional design issues must be considered. Piles in a group carry unequal lateral loads, depending on their location within the group, the configuration, the spacing between piles and their diameter.

For a group of piles, the coefficient of subgrade reaction and ultimate lateral resistance may have to be reduced, based on pile spacing. The reduction factors to be used for a pile group oriented perpendicular or parallel to the direction of loading are provided in Table 12.4.

Table 12.4 – Lateral Pile Resistance Reduction Factors

PILE GROUP CONFIGURATION	PILE SPACING (CENTRE TO CENTRE)	REDUCTION FACTOR
Pile group oriented **perpendicular** to the direction of loading	1 D	0.5
	4 D	1.0
Pile group oriented **parallel** to direction of loading	3 D	0.25
	4 D	0.4
	6 D	0.7
	8 D	1.0

D = Pile Diameter

12.5. Approach Embankment

Based on the design drawings, the approach embankments on both the US and Canadian sides will be widened to accommodate the proposed bridge. The grade of the approach embankment of the existing bridge on the Canadian side is at El. 328.3 m (1077.1 ft.) and the toe is at El. 324.4 m (1064.3 ft.). Therefore, about 4.0 m (13.1 ft.) high embankment will be required to make the grade of the proposed bridge similar to that of the existing bridge and to tie into the existing highways.

Embankment widening should be designed and constructed in conformance with OPSD 203.020 (Embankments over swamp). Benching should be in conformance with OPSD 208.010 (Benching of Earth Slopes). The widened portion of the embankment, outside the existing edge of shoulders, should be preloaded for as long as possible prior to paving but at least for a period of 1 month.

Any spongy or soft area observed under the plan limits of the embankment should be sub-excavated and the excavated surface should be proof rolled and backfilled with acceptable fill material.

Riprap should be provided in accordance with OPSD 810.010 (General Riprap Layout), to protect the toe of the embankment and prevent erosion. Riprap shall be provided to a minimum height of 1.0 m (3.3 ft.) above the high flood level expected in the river.

12.5.1. Settlement

The height of the approach embankment on the Canadian side of the proposed bridge is not expected to exceed 4.0 m (13 ft.). The placement of this new fill will impose a load of about 80 kPa (11.6 psi), assuming a compacted density of 20 kN/m^3 (127.3 lb/ft^3). The result of the consolidation test conducted on a silty clay to clayey silt sample retrieved from Borehole 17-6, is given in Appendix D. The sample was taken at the depth of 7 m (22.5 ft.), El. 319.2 m (1047.2 ft.).

The consolidation test results indicate a pre-consolidation pressure of 340 kPa (49.3 psi) compared to an effective overburden pressure of 70 kPa (10.2 psi). This suggests that the silty clay to clayey silt is over consolidated. Further, the review of the borehole logs indicate that the moisture content of the silty clay to clayey silt samples were near the plastic limits. This also indicates that the silty clay to

clayey silt in the area is over consolidated and will behave like a brittle material under an imposed load and all of the settlement will result from elastic compression rather than consolidation.

Hence no major post construction settlements are expected that would exceed MTO guidelines for tolerable post paving movements (Embankment Settlement Criteria for Design, Final Draft, March 2, 2010), are expected on the Canadian side approach embankment of the proposed bridge under a fill height of about 4.0 m (13.1 ft.). Further, settlement of embankment constructed of suitable fill material will occur almost immediately after completion of fill placement. The results supports the suggestion provided earlier in the PML preliminary report, and also in the technical memorandum submitted to Stantec on October 16, 2017.

It should be noted that any spongy or soft area observed under the plan limits of the embankment of the proposed bridge should be sub-excavated before the placement of any fill and the exposed subgrade surface should be proof-rolled and backfilled with acceptable fill material. Further, embankment widening should be designed and constructed in conformance with OPSD 203.020 (Embankments over swamp, provided in Appendix A). Benching should be according to OPSD 208.010 (Benching of Earth Slopes, provided in Appendix H). In addition, the widened portion of the embankment, outside the edge of the shoulders of the existing bridge, should be preloaded for as long as possible, but at least for a period of 1 month prior to paving.

12.5.2. Slope Stability

The height of the existing approach fill is approximately 7 m (23 ft.) above the riverbed at the shoreline and the embankment itself is about 4 m (13 ft.) high. The side slopes appeared to be at an approximate gradient of 2H:1V. Hence, no instability problems are anticipated for an embankment widening constructed with a 2H:1V side slope, based on the good performance of the existing slope observed earlier and at the time of the current foundation investigation.

12.6. Retaining Walls

If the design requires the construction of retaining walls, these walls should be designed to resist the horizontal earth pressure imposed by the backfill and any surcharge load. The earth pressure for concrete structures should be computed as per Clause 6.12.2 of Canadian Highway Bridge Design Code (CHBDC, 2014). The earth pressure calculation should include maximum water level expected behind the wall. The lateral earth pressure, p (kPa), may be computed using the diagrams for equivalent fluid pressure given in CHBDC, 2014, or by employing the following equation, assuming a triangular pressure distribution:

$$p = K(\gamma h_1 + \gamma' h_2 + q) + \gamma_w h_2 + C_p + C_s$$

where
- K = Coefficient of lateral earth pressure (dimensionless)
- γ = Unit weight of backfill material above design water level (kN/m^3)
- γ' = Unit weight of submerged backfill ($\gamma - \gamma w$) material below design water level (kN/m^3)
- γw = Unit weight of water (9.8 kN/m^3, 62.4 lb/ft^3)
- $h1$ = Depth below final grade above design water level (m)
- $h2$ = Depth below design water level (m)
- q = Surcharge load (kPa)
- Cp = Compaction pressure (kPa) (Clause 6.12.3 of CHBDC, 2014)
- Cs = Earth pressure from seismic events, (kPa) (Clause 4.6.5 of CHBDC, 2014)

Ontario Provincial Standard Specifications (OPSS) Granular ‘A’ or ‘B Type II’ should be used as backfill material behind the wall and carried out based on the requirements specified in the OPSS 902 (Excavation and Backfilling of Structures). The backfill material should be placed in layers not exceeding 200 mm (8 in.) in thickness before compaction. The list of all OPSSs and Ontario Provincial Standard Drawings (OPSDs) used in this report is provided in Appendix H.

Heavy vibratory compaction equipment adjacent to retaining structures should be restricted to limit the compaction pressure described in Clause 6.12.3 of the CHBDC, 2014. The type of compaction equipment and the compaction procedure that can be used for this purpose should be in accordance with OPSS 501 (Construction Specification for Compacting).

Table 12.6 provides the recommended preliminary earth pressure coefficients for granular backfill.

Table 12.6 – Preliminary Earth Pressure Coefficients

PARAMETERS	OPSS GRANULAR A	OPSS GRANULAR B TYPE II
Internal Friction Angle, (degrees)	35	30
Unit weight, γ (kN/m^3)	22.5± 0.3	21.5 ± 0.3
Coefficient of Active Earth Pressure, K_a	0.27	0.33
Coefficient of Earth Pressure At Rest, K_o	0.43	0.5
Coefficient of Passive Earth Pressure, K_p	3.69	3

The coefficient of earth pressure “at rest” should be used for design of rigid and unyielding walls where sufficient movement of the structure wall will not be permitted. For unrestrained structures, the active earth pressure coefficient should be employed.

Adequate drainage should be provided behind retaining walls to prevent the build-up of hydrostatic pressure. A weeping tile system (OPSS 405, Construction Specification for Pipe Sub-drains, and OPSD 3190.100, Walls Retaining and Abutment Wall Drain) should be installed to minimise the build-up of hydrostatic pressure. The weeping tiles should be surrounded by a properly designed granular filter or geotextile to prevent migration of fines into the system. The drainage pipe should be placed on a positive grade.

Both reinforced concrete gravity (or cantilever) and reinforced soil system (RSS) walls are geotechnically feasible alternatives for retaining walls at the project site. The cantilever walls could be cast-in-place (CIP) or made up of precast elements. Cast-in-place concrete gravity and cantilever walls will require longer construction time and deeper excavations compared to RSS walls. However, at locations affected by the waterway, RSS walls may not be practical and could suffer damages due to wave action or constant flow of water. For these reasons, RSS walls should not be considered near the river below the known or estimated high water level.

12.7. Frost Protection

In accordance with OPSD 3090.100 (Foundation Frost Penetration Depths for Northern Ontario), a minimum of 2.2 m (7.2 ft.) earth cover is required to protect against the frost penetration in the area where the bridge is located. Frost tapers within the granular backfill should be constructed in accordance with OPSD 3101.150 (Walls Abutment, Backfill, Minimum Granular Requirement).

Equivalent thermal insulation can be provided by appropriate thickness of rigid polystyrene. Polystyrene insulation should meet requirements of National Standards of Canada, CAN/ULC-S701-05 (Standard for Thermal Insulation, Polystyrene, Boards and Pipe Covering). Appropriate thickness can be determined from manufacturer's literature.

12.8. Seismic Considerations

The Spectral and Peak Ground Accelerations (Sa(0.2) and PGA) for the project site, based on the Town of Rainy River, and for the 2% in 50 year probability of exceedance, is 0.059 and 0.035, respectively (National Building Code of Canada, 2015). The Reference Peak Ground Acceleration (PGA_{ref}) based on these Sa(0.2) and PGA values is 0.028.

The seismic site classification is based on the conditions of soils encountered in the upper 30 m (100 ft.). Based on the average SPT "N" values of the silty clay to clayey silt and sand to silty sand till, the subsurface at the site is classified as Type D for seismic design purposes, based on Clause 4.4.3.2 of CHBDC, 2014. This indicates that the risk of seismic activity affecting the bridge is low.

For the design of retaining walls, seismic loading must be taken into account in accordance with Clause 4.6.4 of CHBDC, 2014, as it can result in increased lateral earth pressure. The walls should be designed to withstand the combined lateral loading for the appropriate static pressure conditions plus the applicable seismic induced dynamic earth pressure.

12.9. Scour and Erosion Protection

The foundation investigation and design reports prepared by MnDOT and Dan Brown Associates indicated that the scour depth at the bridge piers for a 500 year and 100 year events were estimated to be as high as 8.3 m (27.3 ft.) and 7.8 m (25.6 ft.). The corresponding 500 year and 100 year scour levels are El. 308.9 m (1013.4 ft) and El. 309.4 m (1015.1 ft.). Generally, scour protection shall be provided in accordance with Clause 1.9.5 of CHBDC, 2014.

In addition to scour, work around the abutment area of the new bridge and embankment widening may expose slopes for erosion. Therefore, erosion protection measures should be provided.

The erosion protection should be constructed in accordance with OPSS 511 (Rock Protection). Erosion protection along the riverbank should extend from the anticipated high water level to the toe of the slope and a minimum distance equivalent to the riverbank across the river bottom.

If the approach embankments are composed of earth fill, they should be covered with topsoil or suitable excess earth material from swamps or muskeg areas and seeded in accordance with OPSS 802 (Construction Specification for Topsoil) and OPSS 804 (Construction Specification for Topsoil) as soon as grading is completed to prevent erosion and material degradation.

In addition to scour and erosion control, the effect of piers and abutments of the new replacement bridge on the risk of undermining the existing bridge as well as well as the railway bridge further north should be investigated during the detail design phase.

12.10. Soil Corrosion

To analyze the potential exposure of concrete to sulphate attack, representative samples from all boreholes were tested for soil corrosivity. The sample selection was based on the plan to cover all piers and abutments, as well as all soil layers and the target depth of construction. A summary of the corrosivity test results are provided in Table 8 of Part A of this report.

12.10.1. Pier 1

At the location of the proposed Pier 1, two (2) samples were taken from the silty clay to clayey silt layers encountered in the upper part of Borehole 17-1. The sulphate content of these samples range from 20 (0.002%) to 31 (0.0031%). According to Clause 4.1.1.6 of the Canadian Standards Association (CSA) standard A23.1-14, soluble sulphate concentrations less than 1000 μg/g or 0.1% indicate a low degree of sulphate attack when concrete is in contact with soil or groundwater.

The chloride contents for samples from Borehole 17-1 ranged from 22 ppm to 27 ppm, and this suggests a non-corrosive environment for buried metal or rebar. For a corrosive environment, it is generally recognised that chloride concentrations should be higher than 250 ppm. Further, high resistivity values (3790 ohm-cm to 5210 ohm-cm) was obtained for the same samples, indicating a non-corrosive environment for metals embedded within the depth of testing. In addition, a pH level of 7.95 to 8.27 was measured for these samples and this indicates a neutral soil pH environment.

12.10.2. Pier 2

The sample from Borehole 17-2 corresponds to the location of Pier 2. Based on the values provided in Table 8 of Part A of this report, this sample had a sulphate content of 443 μg/g (0.0443%). Based on CSA standard A23.1-14, the value indicated a moderate attack if concrete is exposed to the soil. Hence, for a concrete work at this location, sulphate resistance cement may be required.

The chloride contents for the sample from Borehole 17-2 is 4 ppm, and this suggests a non-corrosive environment for a metal or rebar. However, the resistivity value of 1760 ohm-cm indicates a moderately corrosive environment as it is 12% lower than the threshold of 2000 ohm-cm. In addition, a pH level of 8.17 implies a neutral soil pH environment.

12.10.3. Pier 3

The sample taken from Borehole 17-3 correspond to the location of Pier 3. Based on the values provided in Table 8 of Part A of this report, this sample had a sulphate content of 88 μg/g (0.0088%). According to CSA standard A23.1-14, this concentration indicates a low degree of sulphate attack when concrete is in contact with soil or groundwater.

The chloride contents for the sample from Borehole 17-3 is 6 ppm, and this suggests a non-corrosive environment for a metal or rebar. Similarly, a high resistivity value of 6060 ohm-cm suggests a non-corrosive environment for metals and rebar embedded within the depth of testing. In addition, a pH level of 8.50 implies a neutral soil pH environment.

12.10.4. Pier 4

At Pier 4, two (2) samples were taken from Boreholes 17-4 and 17-5. The sample from Borehole 17-4 was taken at a depth of 11.6 m (38 ft.). On the other hand, the sample from Borehole 17-5 was from the sand to silty sand till deposit retrieved from a depth of 37.1 m (121.7 ft.). The sulphate content of the sample from Borehole 17-4 is 293 μg/g (0.0293%). For the sample taken from Borehole 17-5, the sulphate content is 73 μg/g (0.0073%). According to CSA standard A23.1-14, both concentrations indicate a low degree of sulphate attack. Hence, no attack is expected when a drilled shaft concrete is in contact with the sand to silty sand till deposit or groundwater.

The chloride content for samples from Boreholes 17-3 and 17-5 is 4 ppm, and this suggests a non-corrosive environment for a metal or rebar within the depth of installation of the drill shafts. Similarly, the resistivity value increases with depth from 2090 ohm-cm to 4980 ohm-cm, and this also suggests a non-corrosive environment for metals and rebar. The pH level of 9.34 is relatively high compared to those values obtained at shallow depth, but it still suggests a neutral soil pH environment.

12.10.5. East Abutment

At the east abutment, two (2) samples were taken from Borehole 17-6 at different depths. The sulphate content of these samples range from 5 μg/g (0.0005%) to 205 μg/g (0.0205%). According to CSA standard A23.1-14, soluble sulphate concentrations less than 1000 μg/g or 0.1% indicate a low degree of sulphate attack when concrete is in contact with soil or groundwater.

The chloride contents ranged from 14 ppm to 20 ppm, and this suggests a non-corrosive environment for buried metal. Further, high resistivity values (2680 ohm-cm to 6760 ohm-cm) indicate a non-corrosive environment for metals embedded within the depth of testing. In addition, a pH level of 8.24 to 8.58 suggests a neutral soil pH environment.

Generally, no sulphate attack is expected from selected backfill materials. However, it may be advisable to test backfill material for corrosion potential if it is imported from unknown sources.

13. CONSTRUCTION CONSIDERATIONS

13.1. Staging of Construction and Monitoring Plan

PML understands that the existing bridge will remain open for traffic during construction. However, construction staging will still be required to build the approach embankments.

A monitoring plan will have to be developed and implemented during the construction of the replacement bridge to maintain the structural integrity of the existing bridge and the safety of the public. A monitoring plan should also include the protection of the safety and integrity of the railway bridge located further north and other facilities that can be affected by vibration and ground movement. The Non-Standard Special Provision (NSSP-1) provided in Appendix H, should be included in the contract document for use during construction.

13.2. Excavation

Excavation for construction of foundations at abutment location is expected to extend to a depth of about 3 m (10 ft.) below the existing grade. Embankment widening at the approach may involve partial removal of the existing 4 m (13 ft.) thick fill on the south side.

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA) and MTO Regulations for Construction Projects. The protection system for excavations should follow OPSS 539 (Construction Specification for Temporary Protection Systems), and OPSS 902 (Construction Specifications for Excavating and Backfilling – Structures).

Excavation of the soils at the project site may be carried out using conventional excavation equipment. All excavated surfaces should be kept free of frost and water during the period of construction. Runoff shall be directed away from open excavations and should not be allowed to flow into the excavation. Excavated material shall not be stockpiled on top of the excavation.

Based on the subsurface conditions encountered in Borehole 17-6, the excavations to the level of El. 323.8 m (1062.3 ft.) for the construction of the pile cap at the east abutment, will be advanced through embankment fill material and the silty sand layer. For OHSA classification purposes, the fill materials should be classified as Type 3 soils. For excavations through multiple soil layers, the side slope geometry is governed by the soil with the highest number designation.

At the approach embankment where the fill contains clayey silt materials, open excavation with a side slope of 1H:1V may not be stable. Since the existing bridge will continue to carry traffic during construction of the replacement bridge, roadway protection will be required at this location.

The design and installation of shoring for roadway protection will be the responsibility of the contractor. Shoring systems may consist of solider piles and timber lagging or sheet pile walls with struts. Shoring should be designed and installed in accordance with OPSS 539 (Construction Specification for Temporary Protection Systems) Level 2 performance.

13.3. Pile Installation and Obstructions

In view of the presence of occasional cobbles and boulders below about El. 302 m (990.8 ft.), the NSSP-2 provided in Appendix H should be included in the contract document to alert the contactor. The contractor may select and use the appropriate methods and equipment to account for obstructions from cobbles or boulders during the installation of piles or liners.

13.4. Dewatering

The groundwater should be lowered a minimum of 0.5 m (1.6 ft.) below the base of excavations for construction in the dry, and the contractor should be responsible for selection, performance and detailed design of the dewatering system including a cofferdam. The dewatering system should be designed to conform to the requirements of OPSS 517 (Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation) and OPSS 518 (Construction Specification for Control of Water from Dewatering Operations). In addition to these standard specifications, the inclusion of the Special Provision for Dewatering Structure Excavations provided in Appendix H, into contract documents should be considered.

13.5. Permission to Take Water (PTTW)

In accordance with the Ontario Water Resources Act, the Water Taking and Transfer Regulation 387/04, a Permit to Take Water (PTTW) from the Ministry of Environment is required if the discharge from dewatering is greater than 50,000 L/day (13,208 gal/day). Although the requirement for this permit depends on the water tightness of the contractor's selected dewatering system, it is recommended that a PTTW be obtained due to the proximity to the river.

In addition, construction site dewatering involving between 50,000 L/day (13,208 gal/day) and 400,000 L/day (105,668 gal/day) will require registration in the Environmental Activity and Sector Registry (EASR) under water taking EASR Regulation 63/16.

14. CLOSURE

This report was prepared by Lulseged Yimam, PhD, P.Eng., and reviewed by M. Vasavithasan, M.Sc. Eng., P. Eng., Senior Engineer, Geotechnical Services. Mr. C.M.P. Nascimento, P.Eng., Principal Consultant, conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

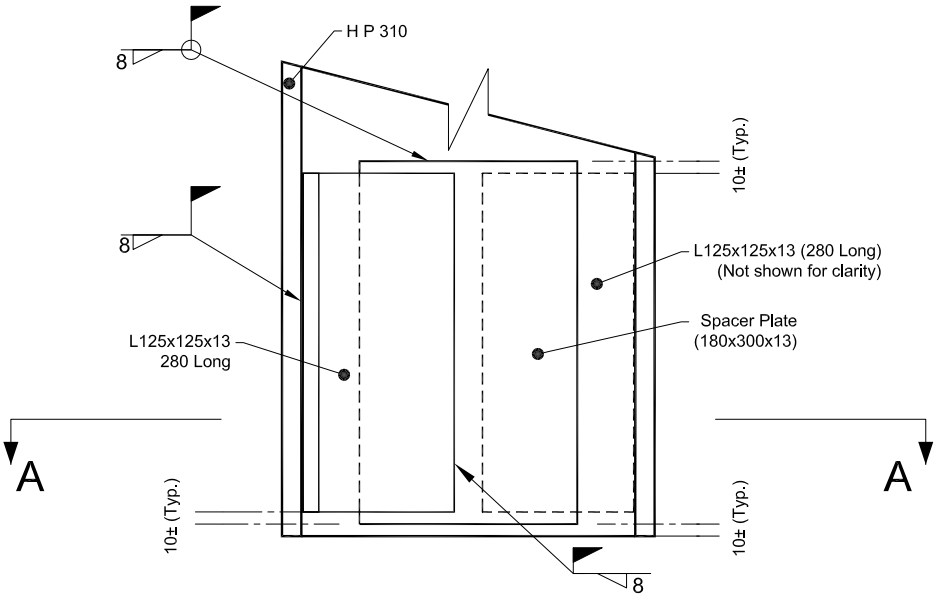
Lulseged Yimam, PhD, P.Eng.
Senior Engineer, Geotechnical Services

Carlos M.P. Nascimento, P.Eng.
Project Manager and
MTO Designated Principal Contact

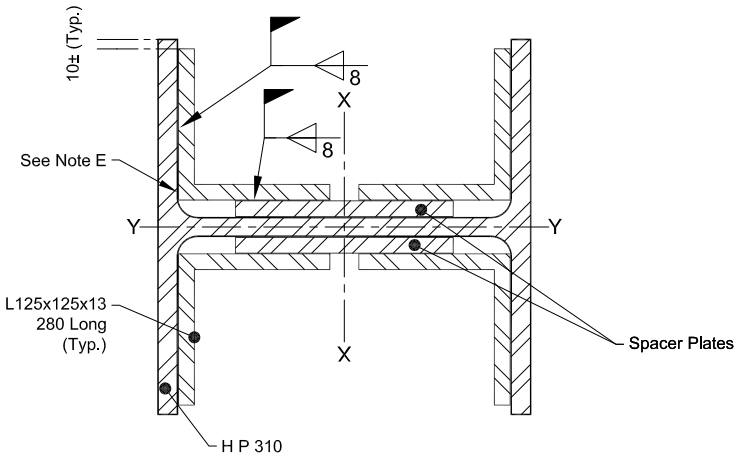
LY/MV/CN:nk

APPENDIX G

Pile Tip Reinforcement



ELEVATION



SECTION A - A

NOTES:

A. Pile tip reinforcement applies to piles HP310x79, HP310x110 & HP310x132.
B. Reinforcement steel shall be according to CSA G40.20/G40.21, Grade 300W.
C. Welding shall be according to CSA W59.
D. Spacer plate shall be 13 mm thick.
E. Chamfer corner of L-shape as required to be flat on flange.
F. Welds are symmetrical about both axis.
G. All dimensions are in millimetres unless otherwise shown.

H-PILE TIP REINFORCEMENT

BRIDGE FOUNDATION

BAUDETTE - RAINY RIVER BRIDGE

Peto MacCallum Ltd.
CONSULTING ENGINEERS

DRAWN:	CHECKED:	APPROVED:	DATE	SCALE	JOB NO.	SKETCH NO.
N.A.	M.V.	C.N.	DEC. 2017	N.T.S.	17TF029	PML-1

APPENDIX H

List of Ontario Provincial Standard Specifications (OPSS) and List of Ontario Provincial Standard Drawings (OPSD) Referenced in the Report

Non-Standard Specific Provision (NSSP)

Special Provision – Dewatering Structure Excavations

LIST OF ONTARIO PROVINCIAL STANDARD SPECIFICATIONS AND DRAWINGS REFERENCED IN THE REPORT

DOCUMENT	TITLE
OPSD 3000.100	Foundation Piles Steel H-Pile Driving Shoe
OPSS 902	Construction Specification for Excavating and Backfilling - Structures
OPSS 501	Construction Specification for Compacting
OPSS 405	Construction Specification for Pipe Sub-Drains
OPSD 3190.100	Walls, Retaining and Abutment Wall Drain
OPSD 203.020	Embankments over Swamp, Existing Slope Excavated to 1H:1V
OPSD 208.010	Benching of Earth Slopes
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.100	Foundation Frost Penetration Depth for Northern Ontario
OPSD 3101.150	Walls, Abutment, Backfill Minimum Granular Requirement
OPSS 511	Construction Specification for Rip-Rap, Rock Protection and Granular Sheeting
OPSS 802	Construction Specification for Topsoil
OPSS 804	Construction Specification for Seed and Cover
OPSS 539	Construction Specification for Temporary Protection Systems
OPSS 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS 518	Construction Specification for Control of Water from Dewatering Operations

NON-STANDARD SPECIFIC PROVISION (NSSP)

NSSP-1 – Monitoring of the Existing Bridge and Railway

The possibility of damage to the existing bridge and railway located further north due to vibration caused by pile driving activities shall be considered by the contractor during construction. Vibration of the existing railway and vibration and movement of the existing bridge should be monitored during pile driving activities. The contractor shall inform the Contract Administrator and halt pile driving activities if vibrations with a velocity greater than 50 mm/sec are measured in one of the three planes (directions), where the predominate frequency exceeds 40 Hz or if vibrations with a velocity greater than 20 mm/sec are measured in one of the three planes where the predominate frequency is below 40 Hz.

NSSP-2 – Potential for Cobbles and Boulders during Pile Driving

The Contractor shall be advised that cobbles and boulders were identified within the sand to silty sand glacial till deposit during the advancement of boreholes.

Hence, the Contractor shall allow for these obstructions during the installation of piles. If during pile driving there is evidence that a pile meets refusal on a boulder, the contractor shall inform the Contract Administrator. Piles meeting refusal on a boulder may need to be relocated, have their capacity reduced and / or require additional piles to be installed.

The contractor shall also consider the difficulties associated with the excavation for drilled shafts because of the presence of cobbles and boulders within the sand to silty sand glacial till deposit.

DEWATERING STRUCTURE EXCAVATIONS - Item No.

Special Provision

Amendment to OPSS 902, November 2010

902.02 REFERENCES

Section 902.02 of OPSS 902 is amended by the addition of the following:

Ontario Provincial Standard Specifications, Construction

OPSS 517 Dewatering
OPSS 805 Temporary Erosion and Sediment Control Measures

902.03 DEFINITIONS

Section 903.03 of OPSS 902 is amended by the addition of the following:

Automatic Transfer Switch means as defined in OPSS 517.

Cofferdam means as defined in OPSS 539.

Cut-Off Wall means as defined in OPSS 517.

Design Storm Return Period means as defined in OPSS 517.

Dewatering System means as defined in OPSS 517.

Groundwater Control System means as defined in OPSS 517.

Plug means as defined in OPSS 517.

Sediment means as defined in OPSS 517.

Sediment Control Measure means as defined in OPSS 517.

Temporary Flow Passage System means as defined in OPSS 517.

Unwatering means as defined in OPSS 517.

Vegetated Discharge Area means as defined in OPSS 517.

Waterbody means as defined in OPSS 517.

Watercourse means as defined in OPSS 517.

902.04 DESIGN AND SUBMISSION REQUIREMENTS

902.04.01 Design Requirements

902.04.01.01 Dewatering

Clause 902.04.01.01 of OPSS 902 is deleted in its entirety and replaced with the following:

A dewatering system shall be designed to control water and the flow of water into the excavation, prevent disturbance of the foundation, permit the placing of concrete in the dry, and complete the excavating and backfilling for structures work.

When the system includes temporary flow passage system, the system shall be designed, as a minimum, for a [* Designer Fill-In, See Notes to Designer] year design storm return period, and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

The dewatering system shall be according to the design requirements specified in OPSS 517.

902.04.02 Submission Requirements

Subsection 902.04.02 of OPSS 902 is deleted in its entirety and replaced with the following:

902.04.02.01 Working Drawings

Working Drawings for the dewatering system shall be according to OPSS 517.

902.04.02.02 Preconstruction Survey

When a groundwater control system by wells or a well point system will be used, a condition survey of property and structures that may be affected by the work shall be carried out. The condition survey shall include the location and condition of adjacent properties, buildings, underground structures, water wells, Utilities, and structures, within a distance of [** Designer Fill-In, See Notes to Designer] metres from the groundwater control system. In addition, all water wells used as a supply of drinking water and located within this distance shall be tested for compliance with Ontario Drinking Water Quality Standards.

Water wells within the preconstruction survey distance can be located using the website https://www.ontario.ca/environment-and-energy/map-well-records or its successor site.

Copies of the condition survey and water quality test results shall be submitted to the Contract Administrator prior to the operation of the groundwater control system.

902.04.02.03 Milestone Inspections

The Quality Verification Engineer shall witness the following Interim Inspections of the work:

a) Dewatering of excavation for structure.

b) Completion of excavation for foundation.

c) Excavation for backfill and frost tapers.

d) Backfilling.

A copy of the written permission to proceed shall be submitted to the Contract Administrator prior to commencement of the successive operation.

902.07 CONSTRUCTION

Subsection 902.07.04 of OPSS 902 is deleted in its entirety and replaced with the following:

902.07.04 Dewatering Structure Excavation

902.07.04.01 General

The dewatering systems shall be constructed and operated according to the Working Drawings.

Activation and deactivation of a temporary flow passage system, if applicable, shall be according to OPSS 517.

The dewatering system shall be continuously operational to control buoyancy forces until such forces can be resisted by backfill and structure self-weight, to keep excavations stable, to avoid erosion impacts from the release of accumulated water, and to keep the work area in the condition required to complete the associated work as specified in the Contract Documents.

When a temporary flow passage system is to remain operational through a seasonal shutdown period, the Contractor shall be responsible for any maintenance or repair costs due to the system during the seasonal shutdown period.

Temporary erosion and sediment control measures, including controlling the discharge of water, shall be according to OPSS 805. Measures not specified in OPSS 805 shall be according to the Working Drawings. Temporary erosion and sediment control measures and cover material to protect exposed soils, as required by the Working Drawings, shall be installed as soon as is practical.

Stranded fish shall be managed as specified in the Contract Documents.

Unwatering shall be carried out as necessary.
Water suspected of being contaminated as indicated by visual or olfactory observations shall be reported to the Contract Administrator.

Dewatering and temporary flow passage systems shall be discontinued in a manner that does not disturb any structure, pipeline, or flow channel. Operation of the dewatering system shall be shut down according to the procedures specified in the Working Drawings, where applicable.

902.07.04.02 Discharge of Water

The discharge of water shall be according to OPSS 517.

902.07.04.03 Monitoring

Monitoring shall be according to OPSS 517.

902.07.04.04 System Amendments

Amendments to stop any displacement, damage, soil loss or erosion due to the operation of the dewatering system shall be according to OPSS 517.

902.07.04.05 Removal

Removal of dewatering system and temporary flow passage system components shall be according to OPSS 517.

NOTES TO DESIGNER:

Designer Fill-Ins

* Fill in the design storm return period according to MTO Drainage Design Standard TW-1.

** Fill in the preconstruction survey distance as recommended by the foundation engineer.

WARRANT: Include with this standard tender item **only** on the recommendation of a foundation engineer.

CUSTODIAN: Tony Sangiuliano, MERO - Foundation Group.