

**FOUNDATION INVESTIGATION AND DESIGN REPORT
PAYS PLAT RIVER BRIDGE REPLACEMENT
HIGHWAY 17, DISTRICT OF THUNDER BAY, ONTARIO
G.W.P. 6071-09-00, SITE #48C-20**

Geocres Number: 42D-38

Report to

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained during a foundation investigation conducted at the site of the proposed replacement of the Pays Plat River Bridge on Highway 17, in the Thunder Bay District, Ontario.

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

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

A foundation investigation was previously carried out at the site for the existing Pays Plat River and Pays Plat Creek bridges. The factual data from the archive foundation report (Foundation Investigation, Pays Plat River and Creek Bridge Sites; Trow, Soderman and Associates, February 12, 1958; Geocres No. 42D-008) is provided in Appendix D for information purposes.

2 SITE DESCRIPTION

The bridge site is located on Highway 17 approximately 56 km southeast of Nipigon or 6.0 km northwest of Rossport. The existing bridge is a six span structure with a total span length of 73.2 m and a width of 11.4 m (including a steel deck sidewalk added along the north side) as indicated on the contract drawings prepared for bridge rehabilitation in July 1998. The existing approach embankments vary in height from 4 m at the abutments to 2-3 m in a distance of approximately 15 m away from the abutments.

The Pays Plat River flows southerly into the Lake Superior through a broad flat valley. The land surrounding the site is treed with residences located to the east of the bridge. A small church and cemetery are located to the north of the west approach, and a sheet pile wall lines the river's edge below the cemetery. At the bridge location, Highway 17 travels in a predominantly northwest to southeast

direction along the north edge of Lake Superior. Photographs of the bridge and surrounding area are presented in Appendix C.

The site lies within the physiographic region known as the Wawa Subprovince of the Superior Province of the Canadian Shield. Based on Ontario Geological Survey (OGS) Map 2518, titled “Surficial Geology of Northern Ontario”, dated 1987, the site is located in an area of “the mainly glaciofluvial deposits, including shallow water, glaciolacustrine and glaciomarine deposits”. Based on OGS Map 2545, titled “Bedrock Geology of Ontario”, dated 1991, the bedrock is of the Archean age and consists of intrusive rocks, mainly massive to foliated granodiorite and granite.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing at this site were carried out in two stages. Between June 21 and July 6, 2013, four boreholes designated Boreholes PPR-01 to PPR-04 were drilled at the abutments and approaches for the then-proposed rehabilitation of the bridge, and were advanced to depths ranging from 10.1 to 32.1 m below existing highway grade. Subsequently between April 21 and 25, 2015, Boreholes PPR-05 and PPR-06 were drilled through the bridge deck to depths of 33.7 and 33.0 m near the proposed pier locations for the replacement bridge. Dynamic cone penetration tests were advanced approximately 4 m west and east of Boreholes PPR-02 and PPR-03, respectively, to supplement the sampled borehole information.

Details of the drilling program, including borehole locations, drilling depths, and completion details are summarized in Table 3.1 below.

Table 3.1 – Details of Boreholes

Location	Boreholes	Drilling and Coring Depth/ Base of Hole Elevation (m)	Completion Details
West Approach	PPR-01	15.8 / 170.7	Borehole backfilled with bentonite holeplug to 0.6 m, concrete mix to 0.1 m then asphalt to surface.
West Abutment	PPR-02	27.6 / 158.8	Standpipe piezometer consisting of 19 mm diameter Schedule 40 PVC pipe with a 3 m slotted screen installed.
West Pier	PPR-05	33.7* / 152.8	Borehole backfilled with bentonite holeplug and cuttings to river bottom. Bridge deck patched with quickset ready mix concrete.
East Pier	PPR-06	33.0* / 153.5	Borehole backfilled with bentonite holeplug and cuttings to river bottom. Bridge deck patched with quickset ready mix concrete.
East Abutment	PPR-03	32.1 / 154.5	Standpipe piezometer consisting of 19 mm diameter Schedule 40 PVC pipe with a 3 m slotted screen installed.
East Approach	PPR-04	10.1 / 176.5	Borehole backfilled with bentonite holeplug to 0.6 m, concrete to 0.1 m then asphalt cold patch to surface.

* Depth below bridge deck surface.

The locations of the boreholes are shown on the attached Borehole Locations and Soil Strata Drawing included in Appendix G.

All boreholes were advanced using a CME55 truck-mounted drill rig in combination with hollow stem augers and NW casing/coring methods. Samples of the encountered soils were obtained from the boreholes at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths using MTO Standard “N” size vane and a calibrated torque wrench.

A member of Thurber’s technical staff supervised the drilling and sampling operations on a full time basis. The supervisor logged the boreholes and processed the recovered soil and rock samples for transport to Thurber’s laboratory for further examination and testing. The ground surface elevations at the borehole locations were obtained from the drawings provided by MMM.

Groundwater conditions in the open boreholes were observed during the drilling operations. Standpipe piezometers consisting of 19 mm PVC pipe with a slotted screen were installed in Boreholes PPR-02 and PPR-03. Following the final water level reading, the piezometers were decommissioned in general accordance with MOE Regulation 903.

4 LABORATORY TESTING

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

5 DESCRIPTION OF SUBSURFACE CONDITIONS

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

An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions.

In general, the subsurface stratigraphy encountered below the existing embankment fill and riverbed at the site consists of cohesionless glaciofluvial sands and silts overlying a cohesive glaciolacustrine clay deposit, underlain by a lower cohesionless silt layer and sand to sand and gravel deposits. Bedrock was encountered in one borehole drilled in the river channel.

Descriptions of the individual strata are presented below.

5.1 Asphalt and Concrete

Asphalt pavement was encountered in Boreholes PPR-01 to PPR-04. The thickness of the asphalt ranged from 65 to 115 mm. Boreholes PPR-02 and PPR-03 were advanced through the approach slabs and encountered 200 and 330 mm of concrete beneath the asphalt layer. Boreholes PPR-05 and PPR-06, which were advanced through the bridge deck, encountered 300 mm of concrete.

5.2 Embankment Fill

Embankment fill was encountered below the asphalt and approach slabs in Boreholes PPR-01 to PPR-04. The fill consists of gravelly sand with occasional cobbles. In Boreholes PPR-02 and PPR-03, located in the immediate vicinity of the abutments, the fill extended to depths of 2.7 and 4.0 m (Elev. 183.7 and 182.6), respectively. In Boreholes PPR-01 and PPR-04, located approximately 15 m away from the abutments, the fill extended to depths of 1.2 and 3.0 m (Elev. 185.3 and 183.6).

SPT 'N' values recorded in the embankment fill ranged from 19 to 86 blows per 0.3 m penetration, indicating a compact to very dense relative density. One value of 100 blows for 0.125 m penetration was also obtained. The higher SPT 'N' values are probably indicative of the presence of cobbles.

Moisture contents of the fill materials ranged from 2 to 25%, typically 10 to 20%.

The results of grain size analyses conducted on fill samples are provided on the Record of Borehole sheets in Appendix A, and are illustrated in Figure B1 of Appendix B. The results are also summarized below:

Gravel %	20 to 46
Sand %	49 to 70
Silt and Clay %	5 to 10

5.3 Sands and Silts

A cohesionless deposit of sands and silts was encountered in all boreholes either below the embankment fill or below the river channel. The deposit typically consisted of silty sand to sand and silt, however the composition locally varied from sand, trace silt, to silt, trace sand. In Borehole PPR-06 advanced in the river, a 0.5 m thick layer of organic silt and sand was encountered on the river bottom.

The thickness of the deposit ranged from 8.0 to 9.3 m, with the lower boundary sloping down from 9.8 m depth (Elev. 176.7) in Borehole PPR-01 on the west side of the river to 13.3 m depth (Elev. 173.3) in Borehole PPR-03 on the east side of the river. The sand and silt was interrupted by a 1.6 m thick layer of silty clay below 7.2 m depth in Borehole PPR-01. Borehole PPR-04 located on the east approach was terminated in this deposit at a depth of 10.1 m (Elev. 176.5).

SPT 'N' values recorded in this deposit varied from zero (Weight of Rod to Weight of Hammer) to 24 blows per 0.3 m of penetration, indicating a very loose to compact relative density. Natural moisture contents ranged between 18% and 58% with the majority of values being between 22% and 35%.

The results of grain size analyses conducted on samples of the upper cohesionless deposit are provided on the Record of Borehole sheets in Appendix A, and are illustrated in Figure B2 and B3 of Appendix B. The results of the grain size analyses are summarized below:

	<u>Silt</u>	<u>Silty Sand/Sand & Silt</u>	<u>Sand</u>
Gravel %	0	0	0 to 3
Sand %	19	47 to 67	76 to 91
Silt %	72	29 to 45	
Clay %	9	4 to 9	6 to 24

5.4 Silty Clay to Clay

A layer of grey to greyish brown silty clay to clay underlies the upper cohesionless deposit in all boreholes, except in Borehole PPR-04. The deposit, where fully penetrated, was between 8.0 and 11.6 m thick with the lower boundary encountered at depths of 18.7 to 24.4 m (Elev. 167.7 to 162.1). Borehole PPR-01 was terminated in this deposit at 15.8 m depth (Elev. 170.7). Stratification, varving and occasional sand and silt seams were noted in this deposit.

SPT 'N' values recorded in the silty clay/clay varied between zero blows per 0.3 m penetration (Weight of Rod to Weight of Hammer) to 5 blows per 0.3 m of penetration. Field vane shear tests (VST) measured undrained shear strengths ranging from 22 to 48 kPa, with the majority of values between 25 and 30 kPa. Based on the SPT and VST data, the consistency of the deposit varied from soft to firm.

The sensitivity of the deposit, calculated as a ratio of undisturbed strength to remoulded strength, ranged from 2 to 5.5, however typically being 2 to 3, suggesting that the silty clay/clay is of normal sensitivity.

The results of grain size analyses conducted on samples of the clay are provided on the Record of Borehole sheets in Appendix A, and are illustrated in Figures B4 and B5 of Appendix B. The results are summarized as follows:

Gravel %	0
Sand %	0 to 5
Silt %	19 to 60
Clay %	35 to 81

The results of Atterberg Limits testing conducted on samples of the silty clay/clay are provided on the Record of Borehole sheets in Appendix A and are illustrated on the Plasticity Charts

(Figures B8 and B9). Liquid limits typically ranged from 41 to 55 and the plasticity index typically ranged from 21 to 32, indicating medium to high plasticity of the deposit. Single samples obtained liquid limits of 33 and 65, and corresponding plasticity indices of 13 and 39, indicating respective low and high plasticity.

Natural moisture contents of the silty clay ranged from 23% to 55 %, typically 35% to 55%.

5.5 Lower Silt

In Boreholes PPR-02, PPR-03, PPR-05 and PPR-06, the silty clay/clay is underlain by a layer of silt with trace to some clay and sand. The silt layer was 2.0 to 6.4 m thick, and extended to depths ranging from 20.7 to 28.7 m (Elev. 165.7 to 157.8).

SPT ‘N’ values recorded in the silt layer ranged from 7 to 23 blows per 0.3 m penetration, indicating a loose to compact relative density. Natural moisture contents were measured to be between 19 and 32%.

The results of grain size analyses conducted on samples of the deposit are provided on the Record of Borehole sheets in Appendix A and are plotted in Figure B6 of Appendix B. The results are summarized below:

Gravel %	0
Sand %	0 to 11
Silt %	74 to 82
Clay %	8 to 26

5.6 Silty Sand to Sand and Gravel

A deposit of grey/brown silty sand to sand and gravel was encountered below the lower silt layer in Boreholes PPR-02, PPR-03, PPR-05 and PPR-06. Typically this deposit becomes coarser with depth, comprising sand to silty sand with trace to some gravel in the upper part, and sand and gravel with trace silt below this upper zone. Occasional cobbles and boulders were noted in this deposit.

The deposit was fully penetrated in Borehole PPR-05, where it was 1.9 m thick and extended to bedrock at 30.6 m depth (Elev. 155.9). Boreholes PPR-02, PPR-03 and PPR-06 were advanced 4.5 to 6.9 m into this deposit, and terminated at depths of 27.6 to 33.0 m (Elev. 158.8 to 153.5).

The deposit was typically very dense as indicated by SPT ‘N’ values ranging from 59 blows per 0.3 m of penetration to 105 blows per 0.05 m penetration. Lower N values of 17 and 6 blows per 0.3 m of penetration were measured in Borehole PPR-05; these values probably result from hydraulic disturbance of the soil, as “blow back” was observed in the drill casing during drilling at that depth.

Natural moisture contents of 7% to 22% were measured in samples of this deposit.

The results of grain size analyses conducted on samples of this deposit are provided on the Record of Borehole sheets in Appendix A and are plotted in Figure B7 of Appendix B. The results are summarized as follows:

	<u>Silty Sand</u>	<u>Sand</u>	<u>Sand & Gravel</u>
Gravel %	9	4 to 10	51
Sand %	55	76 to 93	37
Silt %	25		
Clay %	11	3 to 14	12

5.7 Bedrock

Bedrock was encountered below the silty sand in Borehole PPR-05 at a depth of 30.6 m (Elev. 155.9).

The bedrock was classified as a granitic gneiss and consisted of red and pink granite incorporated into greyish black gneiss. In the recovered rock cores, the rock was fresh with occasional fractured zones noted. The measured Total Core Recovery (TCR) was 100% for both core runs, and the Rock Quality Designation (RQD) ranged from 96% to 98%, indicating excellent rock quality. Fracture Index (FI) values between 0 and 6 were obtained for the recovered rock cores.

The unconfined compressive strength (UCS) of the rock, estimated from the results of point load tests conducted on the rock core samples, ranged from 89 to 140 MPa (average for each run), indicating a strong to very strong intact rock. The point load test results are included on the Record of Borehole PPR-05 sheet in Appendix A. The point load test sheets with details of the testing and photographs of the rock core are enclosed in Appendix B.

5.8 Water Levels

Water levels in the boreholes were observed during the drilling operations and upon completion of drilling. Water was used during the drilling and coring operations, and therefore the water levels measured on completion may not reflect prevailing groundwater levels at the site.

Standpipe piezometers were installed in Boreholes PPR-02 and PPR-03 to monitor groundwater levels after drilling. The water levels measured in the open boreholes and in the piezometers are summarized in Table 5.1.

Table 5.1: Water Level Measurements

Borehole Number	Date	Water Level (Depth/Elev.) in metres	Comments
PPR -01	June 21, 2013	4.8 / 181.7	Water level on completion of drilling. Borehole open to 15.8 m depth.
PPR-02	July 5, 2013	2.5 / 183.9	Water level in open borehole.
	May 2, 2014	3.8 / 182.6	Water level in piezometer; piezometer sealed at 22.7 m depth.
PPR-03	July 6, 2013	2.8 / 183.8	Water level in open borehole.
	May 2, 2014	3.5 / 183.1	Water level in piezometer; piezometer sealed at 21.9 m depth.
PPR-04	June 21, 2013	3.4 / 183.2	Water level on completion of drilling. Borehole open to 10.1 m depth.
PPR-05	April 25, 2015	183.0	Water level in the river.
PPR-06	April 23, 2015	183.0	Water level in the river.

The preliminary General Arrangement drawing indicates the following water levels in Pays Plat River:

Elev. 182.6 – April 2011

Elev. 183.8 - high water level, from drawing dated February 1958.

The water level in the river and groundwater levels are expected to fluctuate seasonally and are subject to precipitation patterns, and therefore may vary from the levels presented herein.

5.9 Previous Foundation Investigation

A foundation investigation was previously carried out at the site for the existing Pays Plat River and Pays Plat Creek bridges. The factual data from the archive foundation report (Foundation Investigation, Pays Plat River and Creek Bridge Sites; Trow, Soderman and Associates, February 12, 1958; Geocres No. 42D-008) is provided in Appendix D for information purposes. The approximate locations of the previous boreholes are included on the Borehole Locations and Soil Strata Drawing in Appendix G.

In general, the subsurface stratigraphy encountered during the previous investigation is consistent with that encountered during the current study, comprising a sand layer overlying clay, underlain by a layer of sand to silt. A 1.5 to 2.4 m thick transitional zone comprising layers of sand and clayey silt is noted between the upper sand deposit and the underlying clay.

6 MISCELLANEOUS

Eastern Ontario Diamond Drilling supplied the drill rigs and conducted the drilling, sampling and in-situ testing operations. Truck-mounted CME #55 drill rigs were used for the duration of the investigation.

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

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

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data in the factual report and provides geotechnical recommendations to assist the design team in selecting and designing a suitable foundation system for the proposed replacement bridge.

At present, Highway 17 crosses the Pays Plat River on a six span structure with a total length of 73.2 m and a width of 11.4 m. Based on the archive design drawings dated 1958, each bridge abutment is supported on twelve piles, comprising two rows of five 12 inch (0.3 m) O.D. steel pipe piles plus an additional pile at the back end of each wingwall. The pipe piles were to be driven closed-end to Elev. 162.1 and filled with concrete. The front row of piles are battered at 1H:5V. The pile cut-off elevations are 183.2 and 183.0 at the east and west abutments, respectively, and 185.4 and 185.3 at the east and west wingwalls, respectively.

Each pier comprises a pile bent of five 16 inch (0.4 m) O.D. steel piles. The pipe piles were to be driven closed-end to Elev. 162.1 and filled with reinforced concrete. The approximate pile cut-off elevations range from 184.8 to 185.0.

The approach embankments vary in height from approximately 4 m at the abutments to 2-3 m in a distance of approximately 15 m away from the abutments. The existing road grade at the bridge is at approximate Elev. 186.4 at the west abutment to Elev. 186.6 at the east abutment.

The preliminary General Arrangement drawing dated March 2015 indicates that the replacement bridge will be a three span structure with span lengths of 23.5, 31.0 and 23.5 m, a total length of 78.0 m, and a width of 15.8 m. The abutments and piers will be supported on steel H-piles. The new abutments will be positioned behind the existing abutments.

The road grade at the west abutment will be raised by approximately 500 mm, to Elev. 187.0. The road grade at the east abutment will not be significantly revised. The existing embankments will be widened on both sides to accommodate the wider bridge and a sidewalk on the north side.

The discussion and recommendations presented in this report are based on information provided by MMM and on the factual data obtained in the course of this investigation. The existing MTO foundation report (Geocres No. 42D-008, dated 1958) prepared for this bridge site was reviewed to supplement the factual information obtained during the current investigation.

8 STRUCTURE FOUNDATIONS

In general, the embankment fill is underlain by an 8.0 to 9.3 m thick deposit of very loose to compact silts and sands extending to depths of 9.8 to 13.3 m, underlain by an 8.0 to 11.6 m thick layer of soft to firm clay to silty clay. The clay in turn overlies a loose to compact silt layer, followed by very dense deposits of silty sand to sand and gravel encountered at depths of 20.7 to 28.7 m (Elev. 165.7 to 157.8). Bedrock comprising granitic gneiss was encountered at 30.6 m depth (Elev. 155.9) in one borehole.

The normal water level in Pays Plat River was indicated on the General Arrangement drawing at Elev. 182.6, and the high water level at Elev. 183.8. Groundwater levels were measured at 3.8 and 3.5 m depth (Elev. 182.6 and 183.1) in piezometers installed in Boreholes PPR-02 and PPR-03 on each side of the river.

Based on the subsurface conditions, several foundation options were considered for this bridge, namely

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

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

Recommendations for design of the feasible foundation alternatives are presented in the following sections together with the corresponding geotechnical design parameters. A preferred foundation alternative from a geotechnical perspective is recommended.

8.1 Spread Footings on Native Soil or Engineered Fill

The use of spread footings to support the abutments or piers is not recommended given the relatively low geotechnical resistance available in the native soils and the potential for large consolidation settlement in the underlying soft to firm cohesive deposits.

8.2 Driven H-Pile Foundations

8.2.1 Axial Resistance

The ground conditions at the site are considered to be suitable for the use of steel H-piles driven to practical refusal in the very dense sand to sand and gravel, or locally to refusal on the bedrock surface.

The recommended values of geotechnical resistances and reactions and anticipated pile tip elevations for H-piles driven to refusal in the very dense sand to sand and gravel and/or bedrock are presented in Table 8.1.

Table 8.1 – Geotechnical Resistances and Reactions for HP310x110 and HP360x132

Foundation Element	Relevant Borehole	Pile Tip Elev. (m)	Factored Geotechnical Resistance at ULS per pile (kN)		Geotechnical Reaction at SLS per pile (kN)	
			HP 310x110	HP 360x132	HP 310x110	HP 360x132
West Abutment	PPR-02	160.0	1600	1800	1400	1600
West Pier	PPR-05	155.9*				
East Pier	PPR-06	155.0				
East Abutment	PPR-03	155.0				

* Bedrock elevation in Borehole PPR-05. Bedrock was not encountered in the other boreholes.

The actual pile tip elevations may vary during installation and should be controlled as described in Section 8.2.3 Pile Installation.

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

8.2.2 Pile Tips

Pile tip protection is recommended for driven H-piles to prevent pile damage when setting the piles in the very dense founding strata, where cobbles and boulders were encountered, or on the bedrock surface. The tips of all driven H-piles should be fitted with pile tip protection from an approved manufacturer such as Skyline Steel, Titus Steel (Standard H-point) or similar.

8.2.3 Pile Installation

Pile installation should be in accordance with OPSS 903.

Pile driving should be controlled in accordance with Standard Drawing SS103-11 (Hiley Formula) and an ultimate pile resistance to be specified by the designer. The Hiley formula need not be used until the piles are within 2.0 m of the design pile tip elevation. The appropriate pile driving note is “PILES TO BE DRIVEN IN ACCORDANCE WITH STANDARD SS 103-11 USING AN ULTIMATE RESISTANCE OF “R” kN PER PILE.” “R” should have a minimum value of twice the design load at ULS.

Piles at the west pier will likely encounter refusal on the bedrock surface. As bedrock was not encountered in the remainder of the boreholes, and a sloping bedrock surface may be present, it is recommended that pile driving at the west pier be controlled as indicated above, i.e., using Hiley Formula.

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

The new piles will be installed behind the existing bridge abutments and in close proximity to the existing pile caps. The upper loose cohesionless soils and underlying soft cohesive soils are sensitive to disturbance; therefore it is important that the existing piles and pile caps are left in place.

8.2.4 Pile Lateral Resistance

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

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

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

where

z	=	depth of embedment of pile (m)
D	=	pile width or diameter (m)
n_h	=	coefficient related to soil density (kN/m^3)
γ'	=	effective unit weight (kN/m^3)
K_p	=	passive earth pressure coefficient

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

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

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

Where

S_u	=	undrained shear strength (kPa)
D	=	pile width or diameter in metres

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

Table 8.2 – Soil Parameters for Lateral Pile Resistance

Soil Unit	Elevation (m)		γ' (kN/m ³)*	n _h (kN/m ³)	K _p	S _u (kPa)
	Top	Bottom				
West Abutment						
Gravelly Sand Fill	GS	183.7	20	4,000	3.0	-
Silty Sand to Silt	183.7	175.7	8	2,000	3.0	-
Silty Clay to Clay	175.7	167.7	7	-	-	25
Lower Silt	167.7	165.7	9	2,500	3.0	-
Sand/Sand & Gravel	165.7	158.8	12	8,000	3.9	-
West and East Piers						
Sand/Sand & Silt	181.5	173.5	8	2,000	3.0	-
Silty Clay to Clay	173.5	163.0	7	-	-	30
Lower Silt	163.0	157.8	9	2,500	3.0	-
Silty Sand / Sand & Gravel	157.8	155.9 West 153.5 East	12	8,000	3.9	-
East Abutment						
Gravelly Sand Fill	GS	182.6	20	4,000	3.0	-
Sand and Silt	182.6	173.3	8	2,500	3.0	-
Silty Clay to Clay	173.3	163.4	7	-	-	30
Lower Silt	163.4	160.1	9	2,500	3.0	-
Sand/Sand & Gravel	160.1	154.5	12	8,000	3.9	-

* Effective unit weight provided for evaluation of the lateral resistance of piles.

For analysis, the spring constant, K_s , may be obtained from the expression:

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

where k_s = coefficient of horizontal subgrade reaction (kN/m³),
 D = pile width (m), and
 L = length (m) of the pile segment or element used in the analysis.

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

According to CHBDC Clause 6.8.7.1, Table C 6.4, the lateral resistance of an HP310x110 pile driven in those soil conditions should be limited to 110 kN at ULS and 40 kN at SLS.

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

Table 8.3 – Subgrade Reaction Reduction Factors for Pile Spacing

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

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

8.3 Downdrag

The weight of the additional fill that is proposed to raise the grade of the west approach embankment and to widen the embankments will induce consolidation of the underlying silty clay/clay deposit. As a result, downdrag forces will develop along the length of the abutment piles embedded in this deposit.

For design purposes, an unfactored downdrag load of 300 kN per pile should be used to evaluate the impact of downdrag on the abutment piles.

This downdrag load should be multiplied by a load factor of 1.25 as per CHBDC Commentary Clause C6.8.4 to obtain a factored downdrag load. In accordance with Section 6.8.4 of the CHBDC and Clause C6.8.4 of the Commentary, in the structural design of a pile, the factored downdrag load should be added to the factored permanent loads to assess the effects of downdrag. The factored dead and downdrag load should not exceed the factored structural resistance of a pile.

In geotechnical analysis of downdrag, the effect of live load should not be considered.

The location of the neutral plane for a pile or group of piles should be determined by using unfactored loads and unfactored geotechnical parameters.

8.4 Caissons / Drilled Shafts

Caisson installation at this site would have to extend through loose cohesionless soils below the groundwater table, a soft to firm cohesive clay layer, then through the compact silt and into the very dense sand to sand and gravel to achieve the required capacities. Such means as drilling mud and/or a permanent liner would be required to support the caisson sidewalls and prevent boiling at the caisson base. Inspection of the caisson base to confirm the caisson bearing stratum would not be practically possible in these conditions. The use of caissons is therefore not recommended, and this alternative has not been developed herein.

8.5 Recommended Foundation

From a geotechnical perspective and based on the subsurface conditions, steel H-piles driven into the very dense sand/sand and gravel and/or bedrock is the preferred foundation option at this site.

8.6 Frost Cover

The depth of frost penetration at this site is approximately 2.3 m. The base of pile caps, if employed, should be provided with a minimum of 2.3 m of earth cover as protection against frost action.

8.7 Impact on Existing Foundations

Piles for the replacement bridge will be driven in close proximity to the piles supporting the existing bridge. The new foundation units should be positioned to avoid encountering the existing foundations during the installation of new piles.

Archive documents indicate that the existing pipe piles were driven to Elev. 162.1, through the upper loose sand and silt, soft to firm clay, and up to 2.1 m into the lower compact silt, locally 3.6 m into very dense sand at the west abutment. In these conditions, driving of new piles in close proximity to the existing piles may result in disturbance and settlement of the existing bridge foundations. Therefore, it is recommended that a monitoring program (including establishment of adequate benchmarks outside the zone of potential influence and acquirement of baseline readings in advance of construction) be implemented for the duration of foundation construction to identify any movement of the existing structure.

Appropriate monitoring points and tolerable levels of movement should be specified by the structural designer. If movements exceed tolerable levels, the Contractor should be prepared to implement remedial measures for the existing bridge structure. Suggested wording for an NSSP for monitoring of the existing structure during pile driving has been included in Appendix F.

9 SHEET PILE WALLS

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

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

Table 9.1 – Soil Parameters for Sheet Pile Analysis

Foundation Element	Soil Unit	Elevation (m)		γ' (kN/m ³)	K_a	K_o	K_p
		Top	Bottom				
West Abutment	Fill	GS *	183.7	21	0.33	0.50	3.0
	Silty Sand/Silt	183.7	175.7	8	0.35	0.52	2.9
	Clay to Silty Clay	175.7	167.7	7	0.38	0.56	2.6
	Silt	167.7	165.7	8	0.35	0.52	2.9
East Abutment	Fill	GS *	182.6	21	0.33	0.50	3.0
	Sand/Sand and Silt	182.6	173.3	8	0.35	0.52	2.9
	Clay to Silty Clay	173.3	163.4	7	0.38	0.56	2.6
	Silt	163.4	160.1	8	0.35	0.52	2.9

* Top of sheet pile elevation varies.

The depth of sheet piles will also be governed by temporary construction conditions such as a heavy crane loading located on the approach embankments during pile driving or girder lifting. A preliminary analysis of a typical crane loading indicates that the sheet piles should be driven to a minimum tip elevation of 178.0 at the east abutment. The archive design drawings and preliminary GA drawing indicate that the river channel is deeper on the west side, and accordingly the sheet piles should be driven deeper, to Elev. 167.5 (the top of the lower silt stratum) to maintain stability of the approach under the temporary crane loading. The depth of penetration may need to be greater to provide lateral stability.

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

Driving of the sheet piles through the existing approach fill may encounter cobbles. Removal of any such obstructions may be required to install the sheeting. Any visible obstructions such as boulders and rock protection along the sides of the embankment should be removed prior to driving the sheet piles. Suggested wording for an NSSP in this regards is provided in Appendix F. Tip protection is recommended for the sheet piles.

In light of the sensitive sand and silt deposits and the underlying soft to firm clay below the water level, vibratory methods should not be used at this site to install sheet piles.

Design of the permanent sheet pile walls should consider environmental conditions such as road salts or fluctuating water levels that may cause corrosion and reduce the service life of the structure. The native soils in front of the sheet piles should be protected from river erosion so that the sheet piles do not lose lateral support.

10 APPROACH EMBANKMENTS

Based on the preliminary GA drawing and information from the designer, the existing road grade will be raised by 500 mm at the west abutment, reducing to 200 mm some 60 m towards the west. No grade raise is planned at the east abutment. The embankment will also be widened to accommodate the wider bridge with a sidewalk.

The foundation soils governing stability of the approach embankments consist of loose to compact sands and silts extending to depths of 9.8 to 13.3 m, underlain by an 8.0 to 9.9 m thick layer of soft to firm silty clay/clay.

No evidence of the embankment slope instability was observed during the field investigation. The existing embankment inclinations are relatively flat and covered by vegetation (grass and occasional shrubs). An increase of the west embankment grade by up to 500 mm is not expected to affect the embankment stability in light of the significant thickness of cohesionless sand/silt underlying the site.

Placement of additional fill to widen the embankment is expected to result in settlements of the underlying soils. It is expected that the settlements in the sands and silts immediately underlying the embankments will occur during construction. Some consolidation settlement of the silty clay/clay deposits underlying the site will also occur. Based on computations using Terzaghi one-dimensional consolidation theory, the primary consolidation settlements are estimated to be in the order of 40 mm for a widening of 2 m and a grade raise of up to 500 mm. The noted settlement will largely occur as differential settlement between the existing embankment and the new widened section.

It is expected that some portion of this settlement will be induced immediately after the fill placement and the remainder will largely occur within the first year after construction, however, long term deformation between the existing and the new part of the embankment should be anticipated and may require long-term maintenance after construction. To minimize differential settlements after construction, consideration could be given to scheduling widening of the embankment for the beginning of the contract, nominal surcharging of the widened portion of the embankment, and delaying paving for as long as practical.

Construction of the embankment widening should be in accordance with OPSS.PROV 206. Any topsoil/organic deposits encountered within the footprint of the widening should be stripped from the plan limits of the proposed works and the subgrade soils should be proof-rolled. In order to minimize the differential settlement between the existing embankment slope and the newly placed embankment fill, the new fill should be keyed into the existing embankment side slope per the requirements of OPSD 208.010 (Benching the Earth Slopes). The slopes for the earth fill embankment should be no steeper than 2 horizontal to 1 vertical (2H:1V).

All granular material should meet the specifications of OPSS.PROV 1010. Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS 501.

11 SCOUR AND EROSION PROTECTION

Erosion protection, such as rock protection as per the requirements of OPSS 511, should be provided along any soil surfaces that may be in contact with the river flow, to at least 0.5 m above the design high water level. In particular, erosion protection should be provided in front of the sheet pile walls to maintain lateral support of the walls.

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

12 LATERAL EARTH PRESSURES

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

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

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

K = coefficient of lateral earth pressure

γ = unit weight of retained soil

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

q = value of any surcharge (kPa)

Earth pressure coefficients for backfill to the abutment wall are dependent on the material used as backfill. Typical values are given in Table 12.1.

Table 12.1 – Coefficients of Lateral Earth Pressure (K)

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

* For wing walls.

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

The factors in Table 12.1 are “ultimate” values and require certain movements for the respective conditions to be mobilized. The values to use in design can be estimated from Figure C6.16 in the Commentary to the Canadian Highway Bridge Design Code (CHBDC).

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I or III, or at a depth of 1.7 m for Granular A or Granular B Type II.

13 SEISMIC CONSIDERATIONS

The following seismic parameters should be used for design:

- Velocity Related Seismic Zone 0
- Zonal Velocity Ratio 0.00
- Acceleration Related Seismic Zone 0
- Zonal Acceleration Ratio 0.00
- Peak Ground Acceleration 0.011 g

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

In accordance with Clause 4.6.4 of the CHBDC, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. For the design of retaining walls under seismic loading, the coefficients of horizontal earth pressure in Table 13.1 may be used:

Table 13.1 – Earth Pressure Coefficient for Earthquake Loading

Earth Pressure Coefficient (K) for Earthquake Loading				
Loading Condition	Granular A or Granular B Type II $\phi = 35^\circ$; $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I or Type III $\phi = 32^\circ$; $\gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active (K_{AE})*	0.28	0.40	0.31	0.48
Passive (K_{PE})	3.7	-	3.2	-
At Rest (K_{OE})**	0.44	-	0.49	-

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

** After Woods (1973).

Based on soil types and field test data, the upper and lower silts at the site are susceptible to liquefaction or cyclic mobility (CFEM, 4th Edition). However, considering the low seismic activity in the area (acceleration related seismic zone of zero), liquefaction of the foundation soils is not a concern.

14 EXCAVATION AND DEWATERING

The proposed abutments will be installed behind and in close proximity to the existing bridge abutments. Excavation for removal of the existing abutments and wing walls is expected to be carried out within the existing approach fills. Provided the work is not carried out during a period of unusually high water levels, the excavation is expected to remain above the river water level.

All excavations should be carried out in accordance with the requirements of the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the existing fill above the water table may be classified as Type 3 soil and as Type 4 soil below the water level. Flatter slopes may be required at locations where water seepage affects surficial stability.

It is recommended that removal of the existing abutment walls not extend below the river water level to avoid the need for cofferdams and dewatering during excavation and the possible environmental impacts on the river water quality. Abutment and wingwall removal should be limited to the minimum depth required.

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

The selection of the method of excavation and equipment is the responsibility of the Contractor. Provision should be made for handling of pavement materials, potential obstructions in the fill, and cobbles/boulders. Special equipment may be required for removal of the existing abutments to the required levels.

Roadway protection will be required during various stages of construction. Roadway protection should be provided in accordance with OPSS 539 and designed for Performance Level 2. The design of roadway protection is the responsibility of the Contractor and all shoring should be designed by a Professional Engineer experienced in such designs.

15 CONSTRUCTION CONCERNS

Potential construction concerns include, but are not limited to:

- Driving of H-piles and sheet piles for the replacement bridge may potentially cause settlement of the existing bridge during staged construction. It is recommended that settlement monitoring of the existing bridge be carried out for the duration of pile driving. The Contractor should be prepared with appropriate equipment on site to maintain the grade of the existing bridge within acceptable tolerance.
- Installation of the sheet piles may encounter resistance in the fill due to the presence of cobbles. The Contractor should allow for removal of any such obstructions. Vibratory methods must not be used to install sheet piles at this site.
- The existing piles and pile caps should be left in place to minimize disturbance to the loose to compact, cohesionless sands and silts deposit and soft clay/silty clay underlying the site.

- The sequence of H-pile and sheet pile installation should be carefully considered to avoid pile alignment problems.
- The Contractor's selection of construction equipment and methodology should include assessment of the capability of the subgrade soils to support the proposed construction equipment and any temporary structures or fill (i.e. as a pad for crane support). Site conditions may limit the type of equipment suitable for use. The design and safety of any temporary works is the responsibility of the Contractor. Recommended wording for an NSSP addressing this issue is provided in Appendix F.

16 CLOSURE

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

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Review Principal



Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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



4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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

 Water Level
 Shear Strength Determination by Pocket Penetrometer

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

EXPLANATION OF ROCK LOGGING TERMS


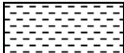



ROCK WEATHERING CLASSIFICATION

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

DISCONTINUITY SPACING

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

SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

STRENGTH CLASSIFICATION

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

TERMS

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

UNIFIED SOILS CLASSIFICATION

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

RECORD OF BOREHOLE No PPR-01

1 OF 2

METRIC

WP# 6071-09-00 LOCATION Pays Plat River Bridge N 5 416 135.6 E 263 747.6 ORIGINATED BY GA
HWY 17 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2013.06.21 - 2013.06.21 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				w _P w w _L				
								20 40 60 80 100				20 40 60				
186.5	GROUND SURFACE															
0.0 0.1	ASPHALT: (65mm)															
	Gravelly SAND Compact to Dense Brown Moist (FILL)		1	SS	19		186									
185.3			2	SS	30											
1.2	SAND and SILT, trace clay Loose Brown to Grey Wet						185									
			3	SS	15											
			4	SS	13		184									
			5	SS	6											
							183								0 47 45 8	
							182									
			6	SS	4											
							181									
			7	SS	6		180								0 50 42 8	
179.3																
7.2	Silty CLAY, varved Firm Grey Moist						179									
			8	SS	4											
							178									
177.7																
8.8	SAND and SILT, trace clay Loose Grey Moist						177									
			9	SS	8											
176.7																
9.8	Silty CLAY, varved															

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC

SOIL PROFILE						DYNAMIC CONE PENETRATION RESISTANCE PLOT SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE	 WATER CONTENT (%) PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT w _p w w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES	GROUND WATER CONDITIONS	ELEVATION SCALE				
			NUMBER	TYPE	"N" VALUES				
	Continued From Previous Page								
	Silty CLAY , varved Soft to Firm Grey Moist								
			10	SS	2				
			11	SS	2				
			12	SS	2				
			13	SS	4				
170.7 15.8	END OF BOREHOLE AT 15.8m. BOREHOLE OPEN TO 15.8m AND WATER LEVEL AT 4.8m ON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.6m, CONCRETE TO 0.1m THEN ASPHALT PATCH TO SURFACE.								

RECORD OF BOREHOLE No PPR-02

1 OF 3

METRIC

WP# 6071-09-00 LOCATION Pays Plat River Bridge N 5 416 140.0 E 263 759.9 ORIGINATED BY ES
 HWY 17 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.07.05 - 2013.07.05 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
186.4	GROUND SURFACE							20 40 60 80 100							
0.0	ASPHALT: (65mm)							20 40 60 80 100							
0.1	CONCRETE: (200mm)							20 40 60 80 100							
0.2	Gravelly SAND, trace silt, occasional cobbles Compact to Very Dense Brown Moist (FILL)		1	SS	44		186								
			2	SS	23		185								30 65 5 (SI+CL)
	Cobbles at 2.3m depth		3	SS	100/ 0.125		184								
183.7															
2.7	SAND and SILT to Silty SAND, trace clay Compact to Very Loose Brown to Grey Wet		4	SS	12		183								
			5	SS	2		182								
			6	SS	4		181								
			7	SS	4		180								0 67 29 4
177.7			8	SS	3		178								
8.7	SILT, trace sand Very loose Grey Moist						177								

Continued Next Page

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

METRIC

SOIL PROFILE						SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES	SHEAR STRENGTH kPa				WATER CONTENT (%)			GR		SA	SI	CL	
						○ UNCONFINED	+ FIELD VANE			● QUICK TRIAXIAL	x LAB VANE	w _P						w
	Continued From Previous Page																	
175.7 10.7	Silty CLAY, occasional sand seams Soft to Firm Grey Moist		9	SS	1				176						0	0	44	56
			10	SS	0				175									
			1	TW					174									
			11	SS	0				173									
			12	SS	0				172									
									171									
									170									
									169									
168.0 18.4	SILT, trace clay, trace to some sand Loose Grey Moist		13	SS	1				168						0	11	81	8
									167									

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No PPR-02

3 OF 3

METRIC

WP# 6071-09-00 LOCATION Pays Plat River Bridge N 5 416 140.0 E 263 759.9 ORIGINATED BY ES
 HWY 17 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.07.05 - 2013.07.05 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL
								20	40	60	80	100	W _P	W		W _L			
Continued From Previous Page																			
165.7	SAND , trace to some gravel, trace silt, occasional cobbles and boulders Very dense Brown Moist																		
20.7																			
		14	SS	77															

ONTMT4S 1197.GPJ 2015TEMPLATE(MTO).GDT 6/12/15

RECORD OF BOREHOLE No PPR-03

1 OF 4

METRIC

WP# 6071-09-00 LOCATION Pays Plat River Bridge N 5 416 142.0 E 263 838.9 ORIGINATED BY ES
HWY 17 BOREHOLE TYPE NW Casing COMPILED BY AN
DATUM Geodetic DATE 2013.07.06 - 2013.07.06 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
186.6	GROUND SURFACE							20 40 60 80 100					
0.0	ASPHALT: (100mm)							20 40 60 80 100					
186.3	CONCRETE: (330mm)							20 40 60 80 100					
0.3	SAND and GRAVEL, occasional cobbles Compact to Dense Brown Moist (FILL)		1	SS	37		186						
			2	SS	19		185						
			3	SS	33		184					46 49 5 (SI+CL)	
			4	SS	27		183						
182.6	SAND, trace gravel, trace silt Compact to Loose Brown Wet		5	SS	14		182						
4.0			6	SS	9		181					3 91 6 (SI+CL)	
179.4	SAND and SILT, trace clay Loose Grey Wet		7	SS	5		179						
7.2			8	SS	5		178						
							177						

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No PPR-03

2 OF 4

METRIC

WP# 6071-09-00 LOCATION Pays Plat River Bridge N 5 416 142.0 E 263 838.9 ORIGINATED BY ES
 HWY 17 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.07.06 - 2013.07.06 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
	Continued From Previous Page													
173.3			9	SS	8									0 56 37 7
174			10	SS	5									
173	Silty CLAY Soft to Firm Grey Moist		11	SS	3									0 0 21 79
172			1	TW										
170			12	SS	0									
169														
168			13	SS	0									
167														

Continued Next Page

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

RECORD OF BOREHOLE No PPR-03

3 OF 4

METRIC

WP# 6071-09-00 LOCATION Pays Plat River Bridge N 5 416 142.0 E 263 838.9 ORIGINATED BY ES
 HWY 17 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.07.06 - 2013.07.06 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
	Continued From Previous Page													
163.4	Occasional silt seams		14	SS	5									
23.2	SILT, trace clay, trace to some sand Compact Grey Moist		15	SS	15									0 11 81 8
160.1	SAND, trace to some gravel, occasional cobbles and boulders Very dense Grey Moist		16	SS	59									10 76 14 (Si+CL)
26.5			17	SS	100									
157.1	SAND and GRAVEL, occasional cobbles Very Dense				0.075									
29.5														

Continued Next Page

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

ONTMT4S 1197.GPJ 2015TEMPLATE(MTO).GDT 6/12/15

METRIC

[illegible]

RECORD OF BOREHOLE No PPR-04

1 OF 2

METRIC

WP# 6071-09-00 LOCATION Pays Plat River Bridge N 5 416 146.4 E 263 851.2 ORIGINATED BY GA
 HWY 17 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2013.06.21 - 2013.06.21 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL				
186.6	GROUND SURFACE						186									20	70	10 (SI+CL)					
0.0	ASPHALT: (115mm)																						
0.1	Gravelly SAND, occasional cobbles Dense to Very Dense Brown Moist (FILL)		1	SS	50																		
			2	SS	84																		
			3	SS	50																		
			4	SS	86																		
183.6																							
3.0	SAND, some silt to silty, occasional wood fibres Compact to Loose Grey Wet		5	SS	14																		
			6	SS	15																		
			7	SS	6																		
			8	SS	24																		
			9	SS	23																		

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No PPR-04

2 OF 2

METRIC

WP# 6071-09-00 LOCATION Pays Plat River Bridge N 5 416 146.4 E 263 851.2 ORIGINATED BY GA
HWY 17 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2013.06.21 - 2013.06.21 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
176.5 10.1	Continued From Previous Page END OF BOREHOLE AT 10.1m. BOREHOLE OPEN TO 10.1m AND WATER LEVEL AT 3.4m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.6m, CONCRETE TO 0.1m THEN ASPHALT PATCH TO SURFACE.													

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No PPR-05

2 OF 4

METRIC

WP# 6071-09-00 LOCATION Pays Plat River Bridge N 5 416 138.1 E 263 784.0 ORIGINATED BY MNW
HWY 17 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2015.04.24 - 2015.04.25 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								20 40 60 80 100	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT		
	Continued From Previous Page							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					
								WATER CONTENT (%)					
								20 40 60	W _P	W	W _L		
175.1			6	SS	9		176						
11.4	SILT, some sand, trace clay Very Loose Greyish Brown Wet		7	SS	2		175						
173.5							174						
13.0	Silty CLAY to CLAY, varved Very Soft to Soft Greyish Brown to Grey Wet		8	SS	0		173						
							172	5.5 +					
			9	SS	0		171						
							170						
			10	SS	0		169						
							168						
			11	SS	0		167						
			12	SS	0								

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No PPR-05

3 OF 4

METRIC

WP# 6071-09-00 LOCATION Pays Plat River Bridge N 5 416 138.1 E 263 784.0 ORIGINATED BY MNW
HWY 17 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2015.04.24 - 2015.04.25 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
<div><div><div>20406080100</div><div>○ UNCONFINED + FIELD VANE</div><div>● QUICK TRIAXIAL × LAB VANE</div></div><div><div><div>204060</div><div>W P W W L</div><div>WATER CONTENT (%)</div></div></div></div>													
	Continued From Previous Page												
	With lenses of silt						166						
			13	SS	0		165						0 0 38 62
164.2													
22.3	SILT , trace clay, trace sand, with varves of silty clay Compact to Loose Light and Dark Greyish Brown Wet		14	SS	15		164						0 0 74 26
							163						
			15	SS	23		162						
							161						
							160						
			16	SS	7		159						
157.8							158						
28.7	Silty SAND , trace clay, trace gravel, occasional cobbles Compact Greyish Brown Wet		17	SS	17		157						

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No PPR-05

4 OF 4

METRIC

WP# 6071-09-00 LOCATION Pays Plat River Bridge N 5 416 138.1 E 263 784.0 ORIGINATED BY MNW
HWY 17 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2015.04.24 - 2015.04.25 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa											
								20 40 60 80 100											
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE											
Continued From Previous Page							20 40 60 80 100					WATER CONTENT (%)							
155.9			18	SS	6		156										9 55 25 11		
30.6	GRANITIC GNEISS, red/pink and dark grey, occasional fractures, strong to very strong																RUN #1 TCR=100% SCR=98% RQD=96% UCS=140MPa (Average)		
			1	RUN															
			2	RUN															
152.8							154										RUN #2 TCR=100% SCR=100% RQD=98% UCS=89MPa (Average)		
33.7	END OF BOREHOLE AT 33.7m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND SLOUGH TO SURFACE. BRIDGE DECK PATCHED WITH QUICKSET CONCRETE.						153												

ONTMT4S 1197.GPJ 2015TEMPLATE(MTO).GDT 6/12/15

RECORD OF BOREHOLE No PPR-06

1 OF 4

METRIC

WP# 6071-09-00 LOCATION Pays Plat River Bridge N 5 416 143.7 E 263 813.2 ORIGINATED BY MNW
 HWY 17 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2015.04.21 - 2015.04.23 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
186.5	GROUND SURFACE													
0.0	BRIDGE DECK													
186.2														
0.3														
183.0														
3.5	ICE/WATER													
182.4														
4.1	Organic SILT and SAND, trace gravel: (FROZEN)		1	SS	36									
181.9	Dark Brown/Black Wet													
4.6	Silty SAND to SAND and SILT, trace clay Loose to Very Loose Greyish Brown Wet													
			2	SS	2									
			3	SS	5									
			4	SS	2									0 62 29 9
			5	SS	4									0 54 37 9
			6	SS	7									

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No PPR-06

2 OF 4

METRIC

WP# 6071-09-00 LOCATION Pays Plat River Bridge N 5 416 143.7 E 263 813.2 ORIGINATED BY MNW
HWY 17 BOREHOLE TYPE NW Casing COMPILED BY AN
DATUM Geodetic DATE 2015.04.21 - 2015.04.23 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL
Continued From Previous Page									20	40	60	80	100	W _p		W	W _L		
175.1			7	SS	14		176												
11.4	SILT, some sand, trace clay Loose Greyish Brown Wet		8	SS	8		175												
173.7							174												
12.8	Silty CLAY to CLAY, varved Very Soft to Soft Greyish Brown Wet		9	SS	1		173											0	5
							172												
			10	SS	0		171												
							170												
			11	SS	0		169												
							168											0	0
			12	SS	2		167												
			13	SS	0														

Continued Next Page

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

RECORD OF BOREHOLE No PPR-06

3 OF 4

METRIC

WP# 6071-09-00 LOCATION Pays Plat River Bridge N 5 416 143.7 E 263 813.2 ORIGINATED BY MNW
HWY 17 BOREHOLE TYPE NW Casing COMPILED BY AN
DATUM Geodetic DATE 2015.04.21 - 2015.04.23 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
<div><div><div>20406080100</div><div>○ UNCONFINED + FIELD VANE</div><div>● QUICK TRIAXIAL × LAB VANE</div></div><div><div>PLASTIC LIMIT</div><div>NATURAL MOISTURE CONTENT</div><div>LIQUID LIMIT</div></div><div><div>W_P</div><div>W</div><div>W_L</div></div><div>WATER CONTENT (%)</div><div><div>204060</div></div></div>													
	Continued From Previous Page												
162.1			14	SS	0		166						
24.4	SILT , trace sand, trace clay Compact Greyish Brown Wet		15	SS	2		165						
			16	SS	12		164						
			17	SS	15		163						
158.0			18	SS	62		162						
28.5	SAND and GRAVEL , trace silt, occasional cobbles Very Dense Grey Moist						161						
							160						
							159						
							158						
							157						

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No PPR-06

4 OF 4

METRIC

WP# 6071-09-00 LOCATION Pays Plat River Bridge N 5 416 143.7 E 263 813.2 ORIGINATED BY MNW
HWY 17 BOREHOLE TYPE NW Casing COMPILED BY AN
DATUM Geodetic DATE 2015.04.21 - 2015.04.23 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT							UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
								20 40 60 80 100												PLASTIC LIMIT W _P		NATURAL MOISTURE CONTENT W		LIQUID LIMIT W _L																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
	Continued From Previous Page							20 40 60 80 100							WATER CONTENT (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
			19	SS	104		156																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														

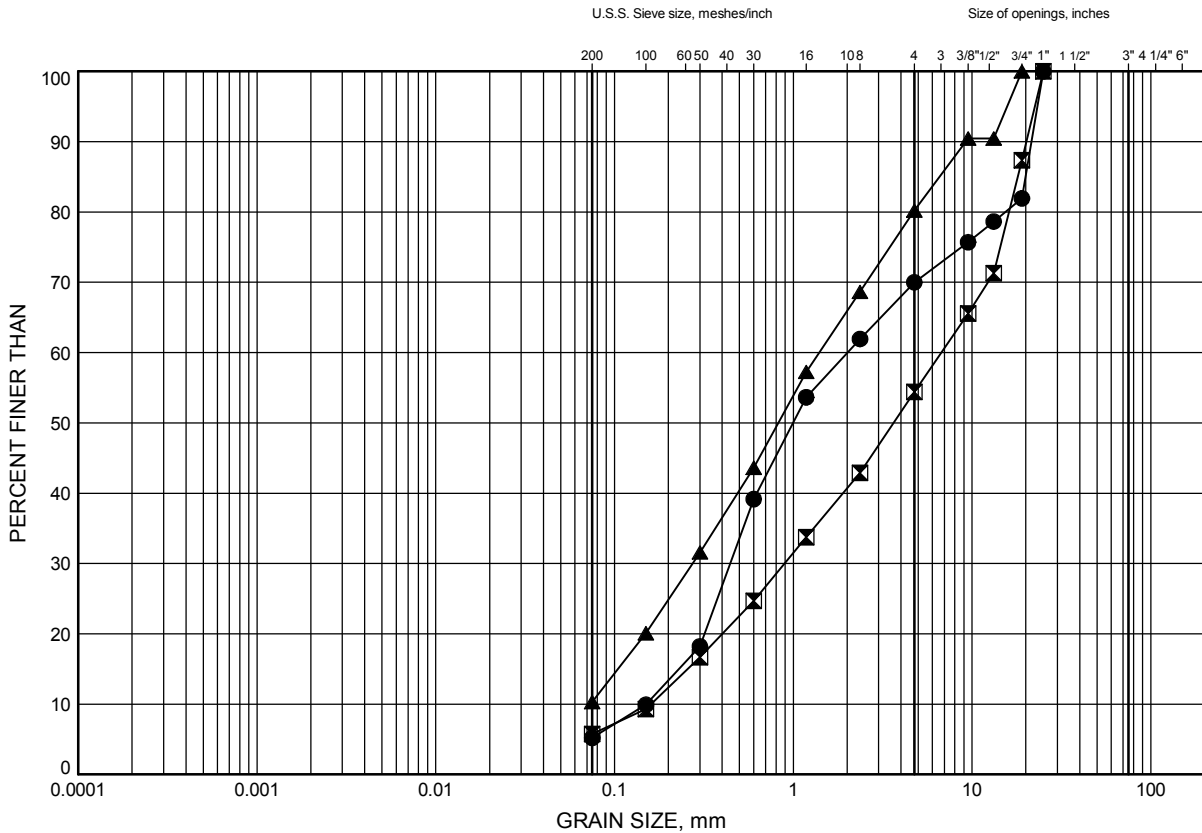
Appendix B

Laboratory Test Results

Pays Plat River Bridge
GRAIN SIZE DISTRIBUTION

FIGURE B1

GRAVELLY SAND to SAND & GRAVEL FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PPR-02	1.83	184.57
⊠	PPR-03	2.59	184.01
▲	PPR-04	1.83	184.77

Date June 2015
WP# 6071-09-00

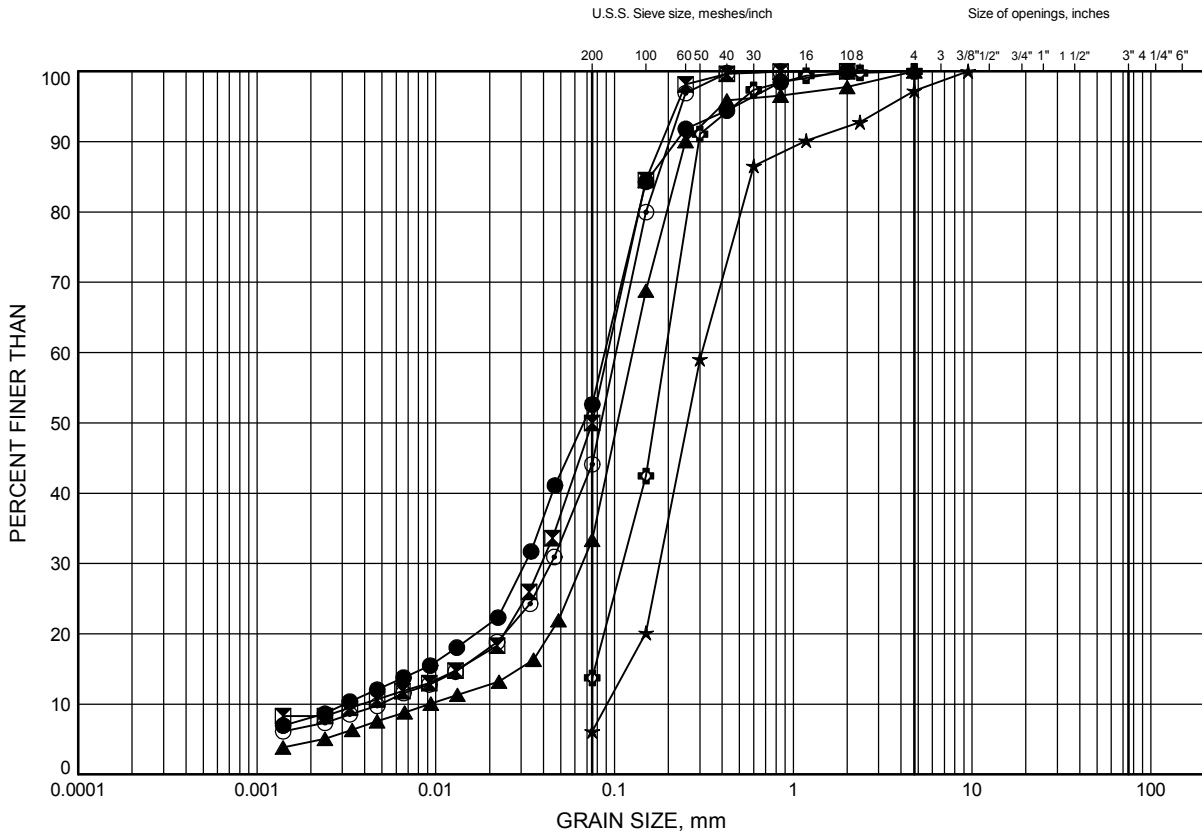


Prep'd MFA
Chkd. MRA

Pays Plat River Bridge GRAIN SIZE DISTRIBUTION

FIGURE B2

Upper SAND & SILT



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PPR-01	3.35	183.15
⊠	PPR-01	6.40	180.10
▲	PPR-02	7.92	178.48
★	PPR-03	6.40	180.20
⊙	PPR-03	10.97	175.63
⊕	PPR-04	4.88	181.72

Date June 2015
WP# 6071-09-00



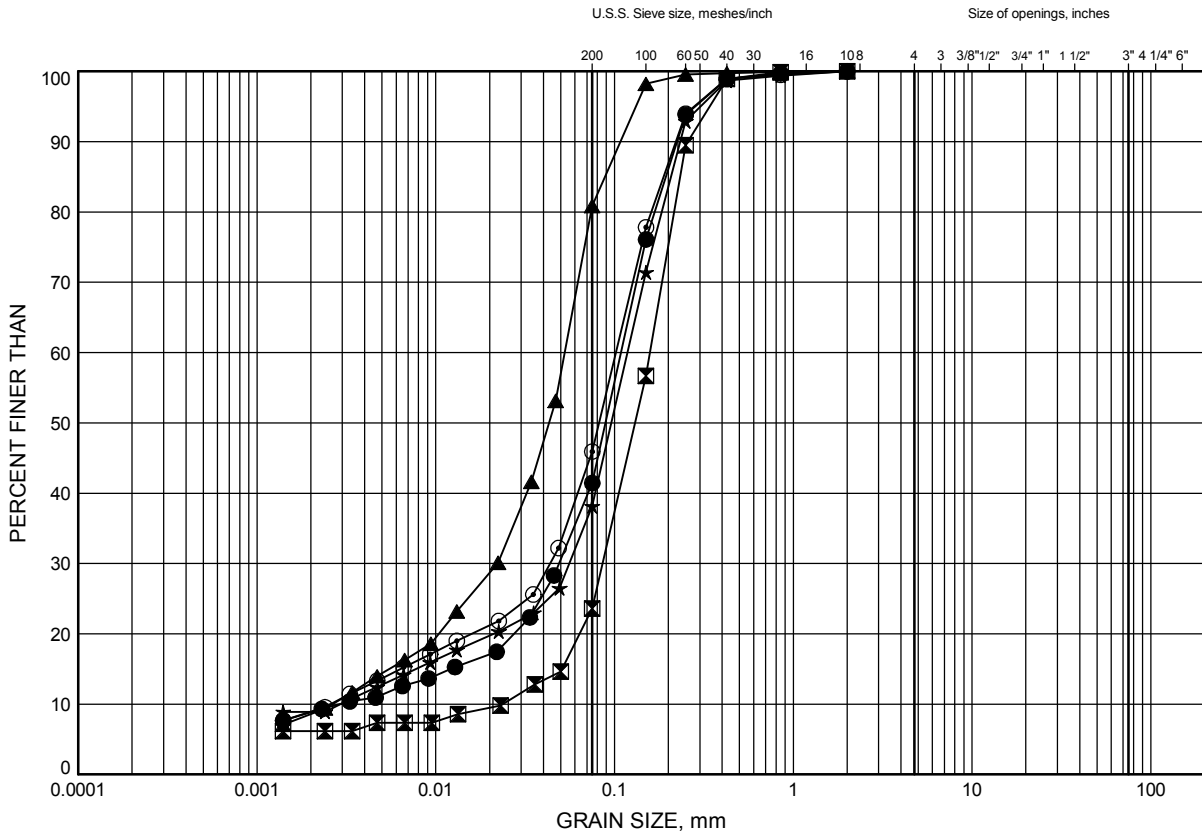
Prep'd MFA
Chkd. MRA

Pays Plat River Bridge

GRAIN SIZE DISTRIBUTION

FIGURE B3

Upper SAND & SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PPR-04	7.92	178.68
⊠	PPR-05	9.14	177.36
▲	PPR-05	12.19	174.31
★	PPR-06	7.16	179.34
⊙	PPR-06	7.92	178.58

Date June 2015
WP# 6071-09-00

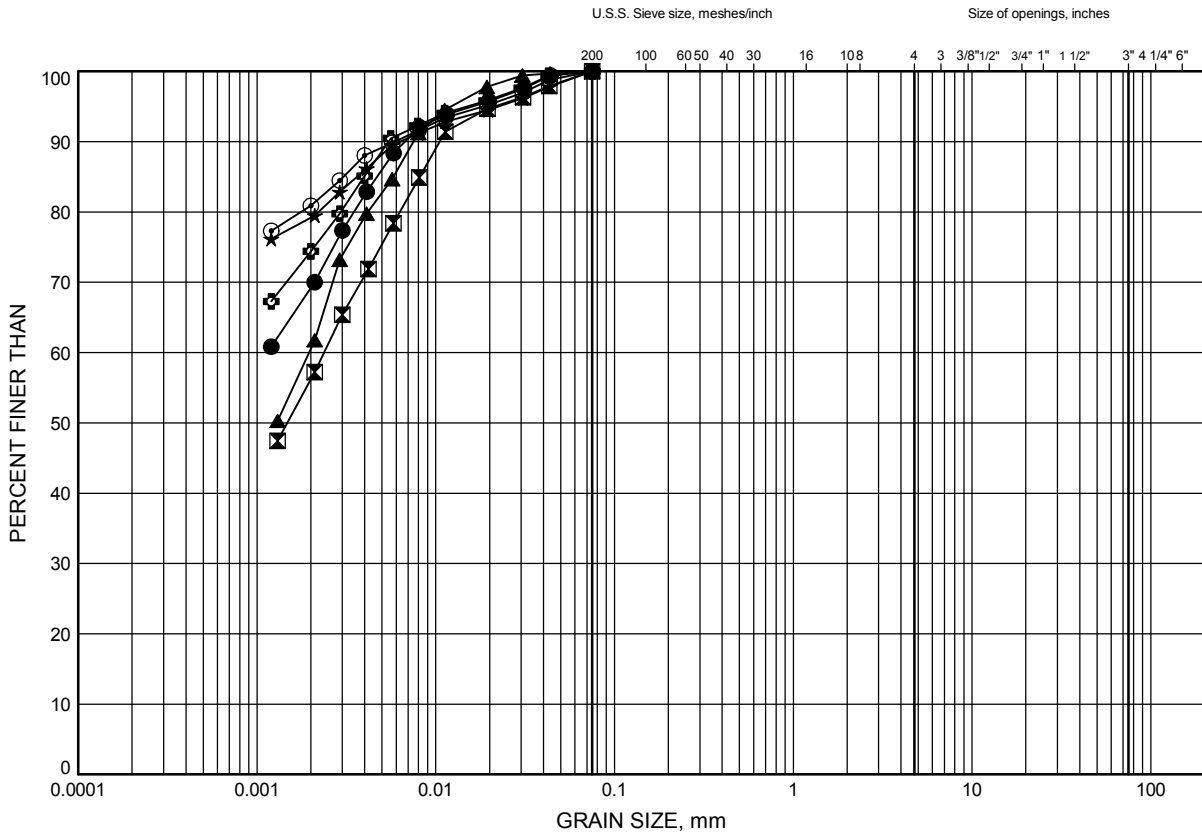


Prep'd MFA
Chkd. MRA

Pays Plat River Bridge GRAIN SIZE DISTRIBUTION

FIGURE B4

SILTY CLAY to CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PPR-01	14.02	172.48
⊠	PPR-02	10.97	175.43
▲	PPR-02	17.07	169.33
★	PPR-03	14.02	172.58
⊙	PPR-05	15.24	171.26
⊕	PPR-06	18.29	168.21

Date June 2015
WP# 6071-09-00

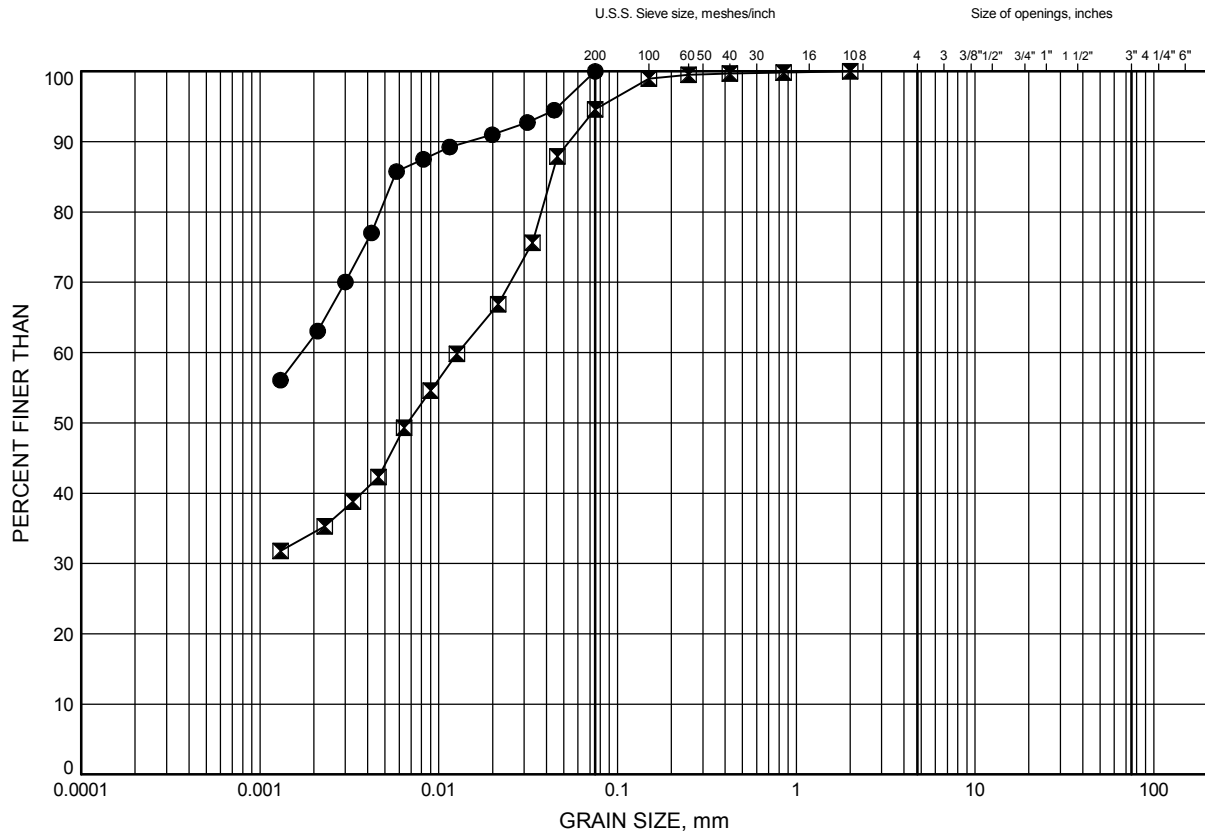


Prep'd MFA
Chkd. MRA

Pays Plat River Bridge GRAIN SIZE DISTRIBUTION

FIGURE B5

SILTY CLAY, With Silt Seams



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PPR-05	21.34	165.16
◻	PPR-06	13.72	172.78

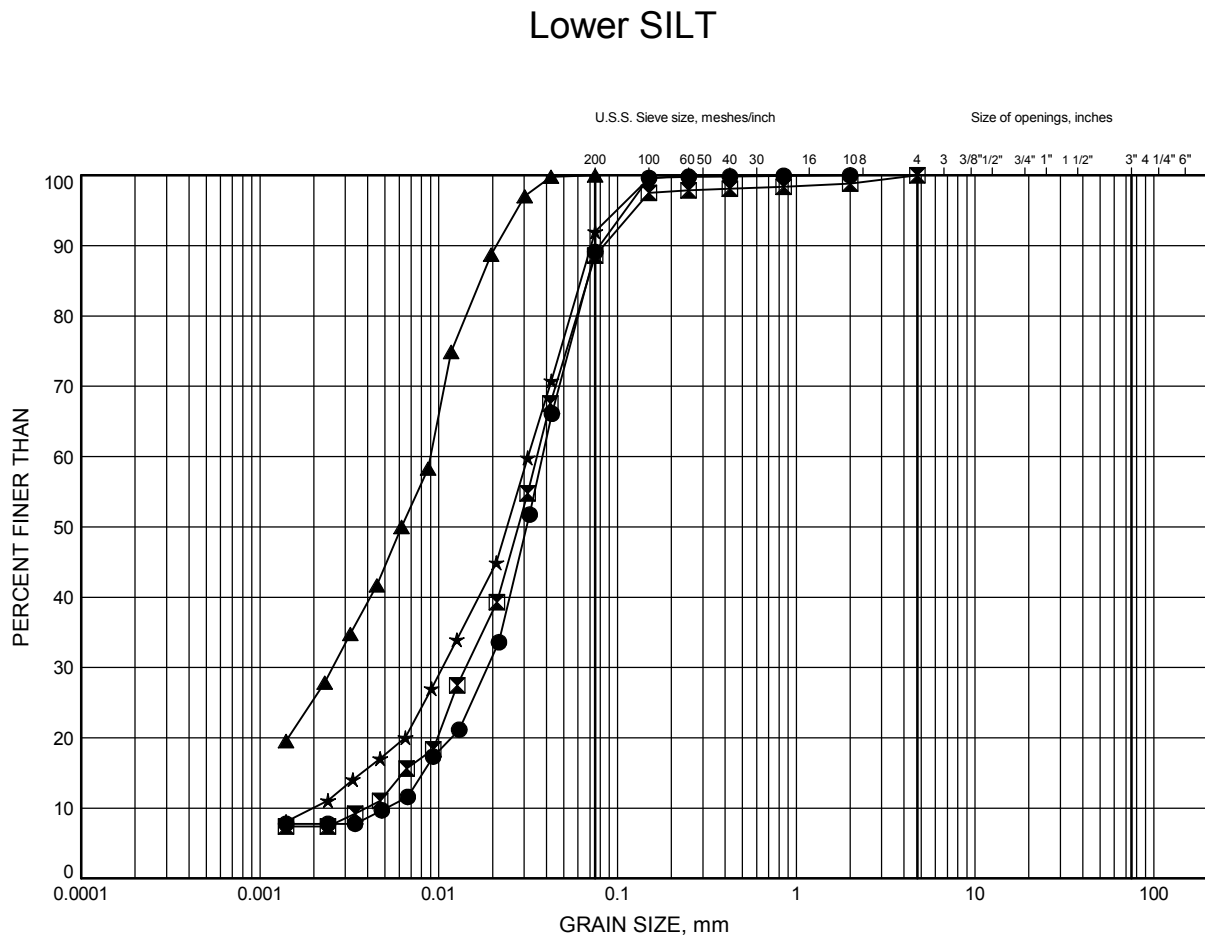
Date June 2015
WP# 6071-09-00



Prep'd MFA
Chkd. MRA

Pays Plat River Bridge GRAIN SIZE DISTRIBUTION

FIGURE B6



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PPR-02	18.59	167.81
⊠	PPR-03	24.69	161.91
▲	PPR-05	23.01	163.49
★	PPR-06	25.91	160.59

Date June 2015
WP# 6071-09-00

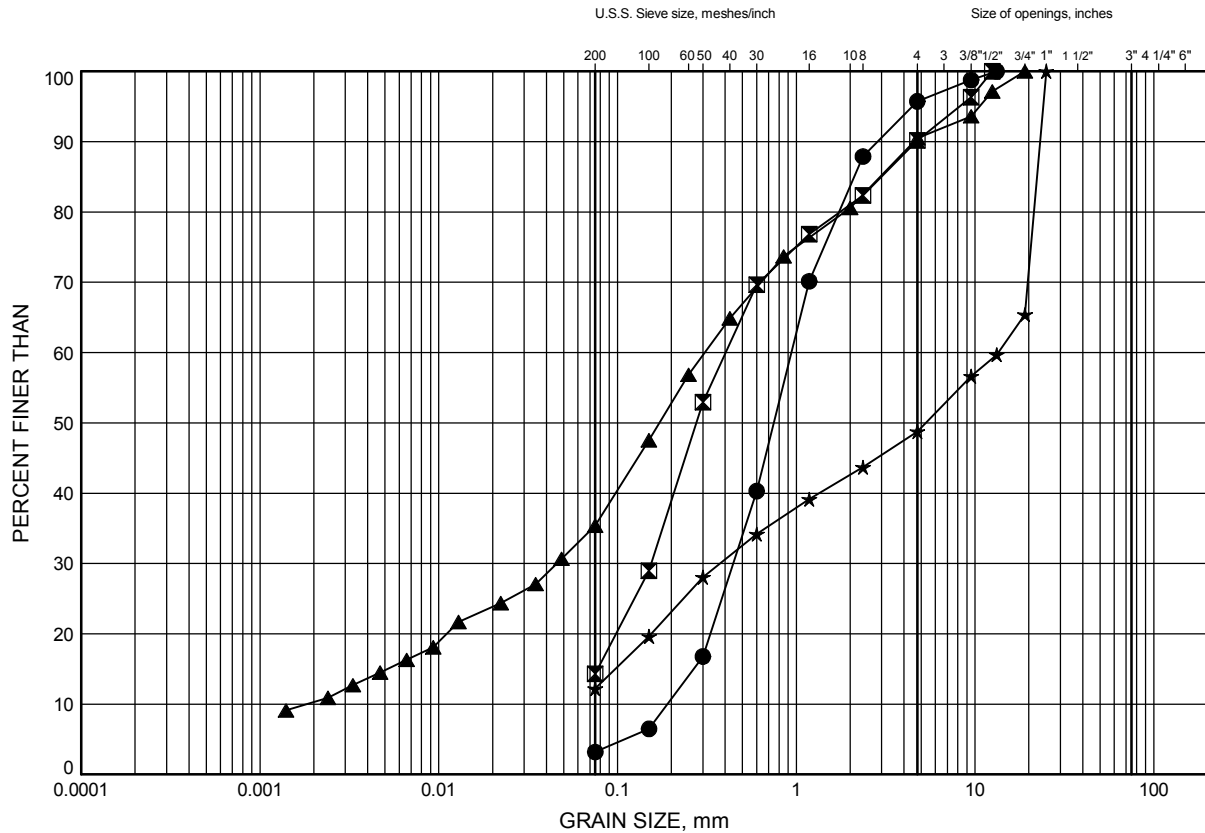


Prep'd MFA
Chkd. MRA

Pays Plat River Bridge GRAIN SIZE DISTRIBUTION

FIGURE B7

SILTY SAND to SAND & GRAVEL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PPR-02	24.59	161.81
⊠	PPR-03	27.74	158.86
▲	PPR-05	30.18	156.32
★	PPR-06	30.25	156.25

Date June 2015
WP# 6071-09-00

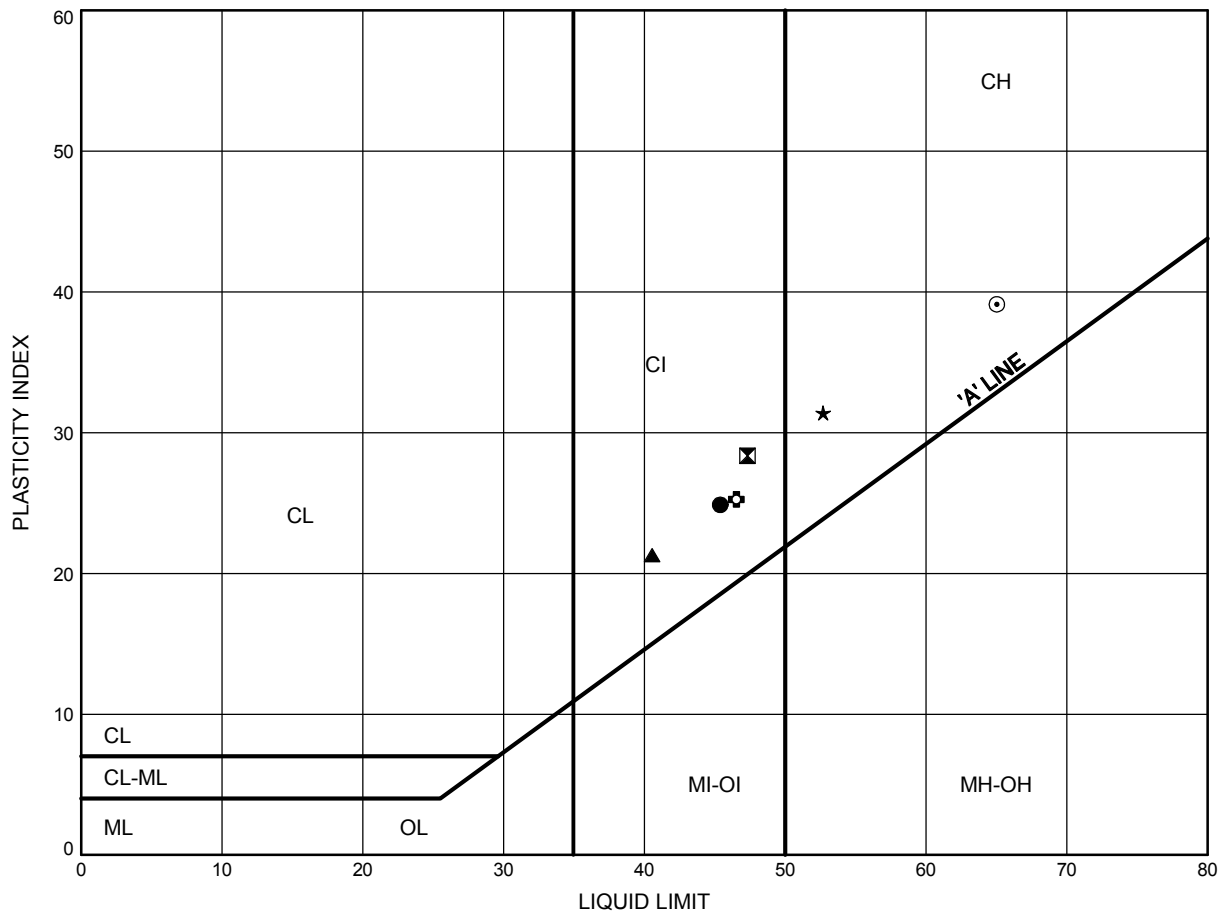


Prep'd MFA
Chkd. MRA

Pays Plat River Bridge
ATTERBERG LIMITS TEST RESULTS

FIGURE B8

SILTY CLAY to CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PPR-01	14.02	172.48
⊠	PPR-02	10.97	175.43
▲	PPR-02	17.07	169.33
★	PPR-03	14.02	172.58
⊙	PPR-05	15.24	171.26
⊕	PPR-05	21.34	165.16

Date June 2015
 WP# 6071-09-00

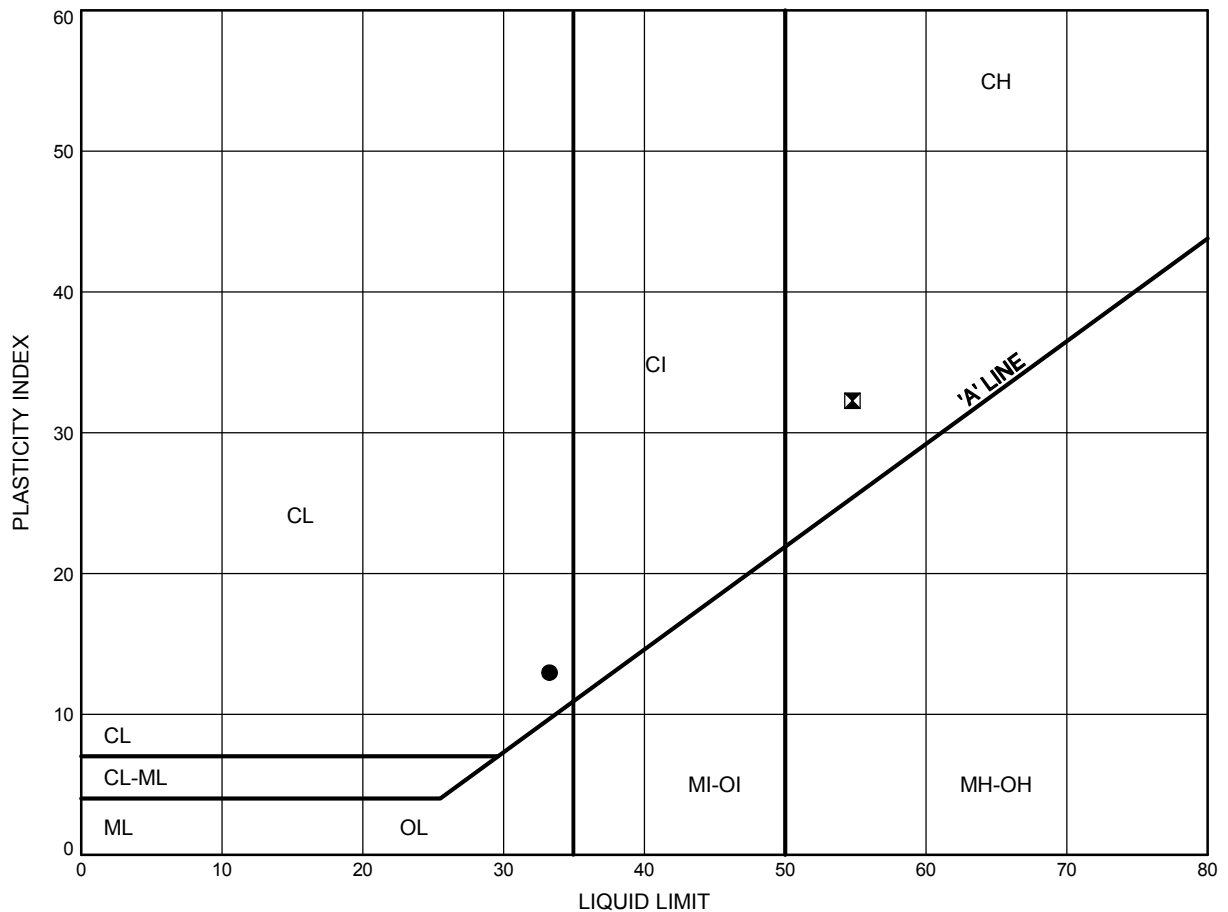


Prep'd MFA
 Chkd. MRA

Pays Plat River Bridge
ATTERBERG LIMITS TEST RESULTS

FIGURE B9

SILTY CLAY to CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PPR-06	13.72	172.78
⊠	PPR-06	18.29	168.21

Date June 2015
 WP# 6071-09-00



Prep'd MFA
 Chkd. MRA



THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

Job No : 19-1351-197

Client : MMM Group Ltd.

Project Name : Pays Plat River Bridge

Date Drilled : 25-Apr-15

Core Size : NQ BH No : PPR-05

Date Tested : 07-May-15

Tester : ISP

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	UCS (MPa)	Rock Type	Notes
1	1	31.1	D	12.3	47.2	Long	122.0		Very Strong
2	1	31.8	D	22.4	47.2	Long	222.6		Very Strong
3	1	32.1	D	7.6	47.2	Long	75.6		Strong
4	2	32.7	D	9.0	47.5	Long	88.8		Strong
5	2	33.5	D	8.9	47.3	Long	88.4		Strong
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* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

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

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

Last Modified: August 15, 2013



Photograph of Rock Core recovered from Borehole PPR-05

Appendix C

Site Photographs



Photograph 1 – Pays Plat River Bridge Looking East



Photograph 2 – Pays Plat River Bridge Looking West



Photograph 3 - South Bridge Elevation - Looking West



Photograph 4 - North Bridge Elevation - Looking West

Appendix D

Factual Data from the Previous Foundation Investigation Report Geocres No. 42D-008

TROW SODERMAN AND ASSOCIATES

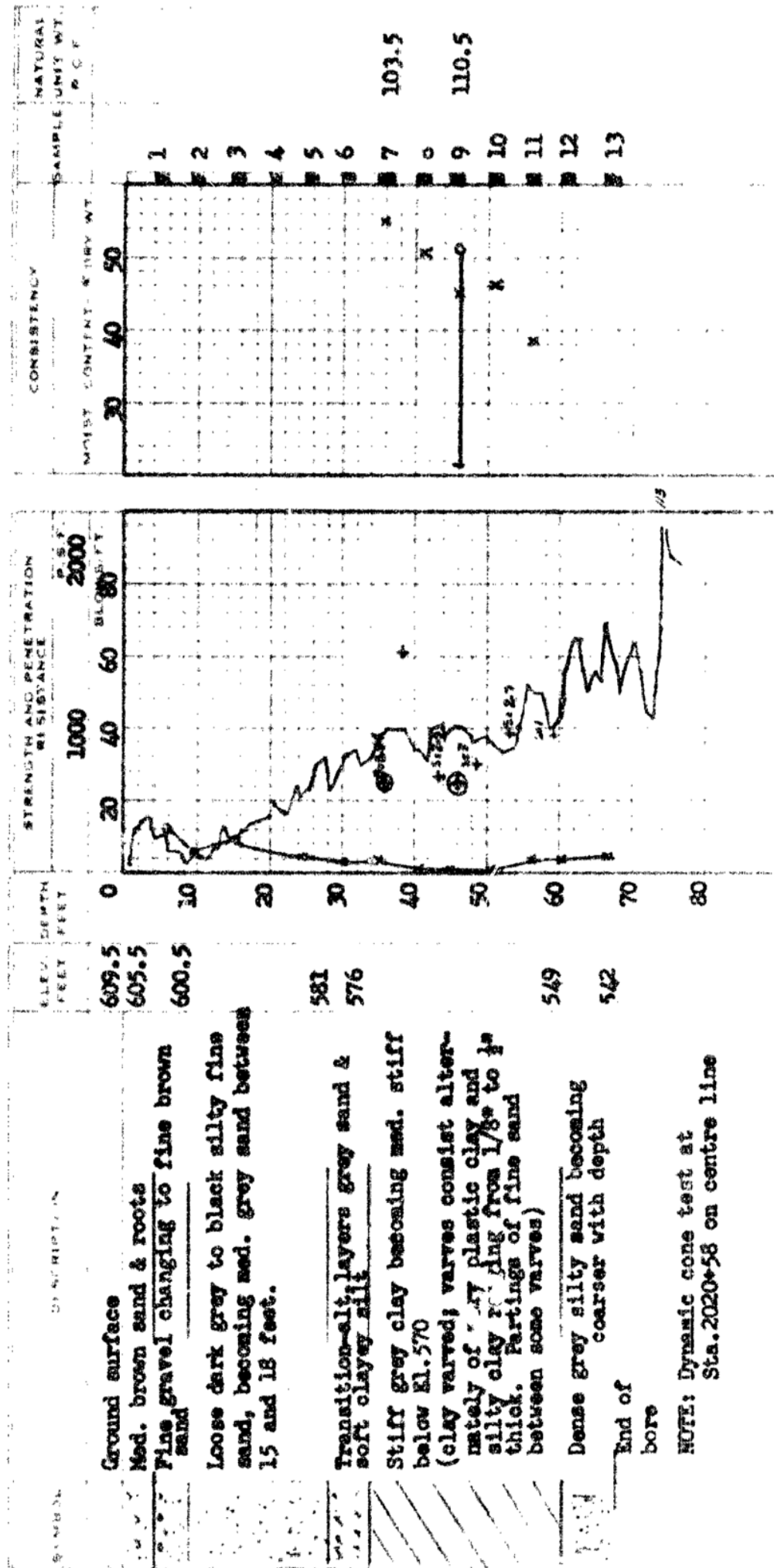
FOR INVESTIGATIONS AND SOIL MECHANICS CONSULTATION

PROJECT Pays Plat River
LOCATION Hwy. 17, near Rossport, Ont.
HOLE NO. 1 See diag. 1
HOLE ELEVATION AND DATUM 609.5

BOREHOLE NO. 1
FIELD SUPERVISOR KP
DRILLER WL
PREP WT

LEGEND

- 1. 1/4" SPLIT TUBE
- 2. SHELBY TUBE
- 3. SPLIT TUBE
- 4. DIA. CONE
- 5. CASING
- 6. SHELBY
- 7. UNCONFINED COMPRESSION (QU)
- 8. VANE TEST (C) AND SENSITIVITY (S)
- 9. NATURAL MOISTURE AND LIQUIDITY INDEX
- 10. LIQUID LIMIT
- 11. PLASTIC LIMIT



NOTE: Dynamic cone test at Sta. 2020+58 on centre line

[illegible]

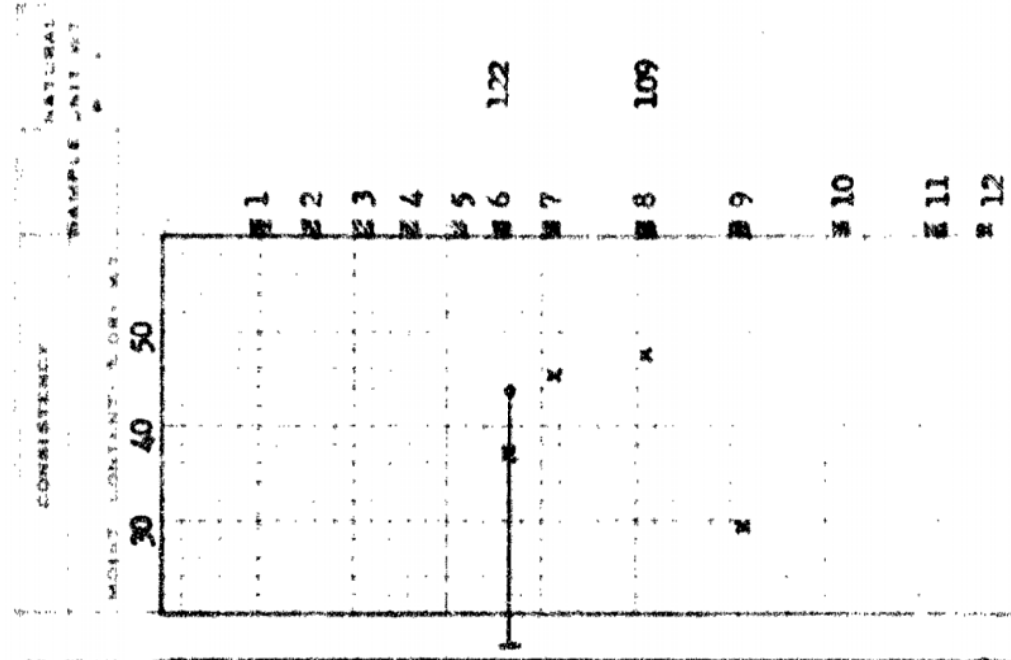
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Figure 1



CL29/J152

TROW SOOERMANN AND ASSOCIATES

Pays Platt River

Hwy.#17 near Rossport, Ont.

See Dwg. 1

601

3 and 4

BOREHOLE NO.

FIELD SUPERVISOR KP

DRILLER WL

PREP WT

STRENGTH AND PENETRATION

RESISTANCE

FEET DEPTH

FEET DEPTH

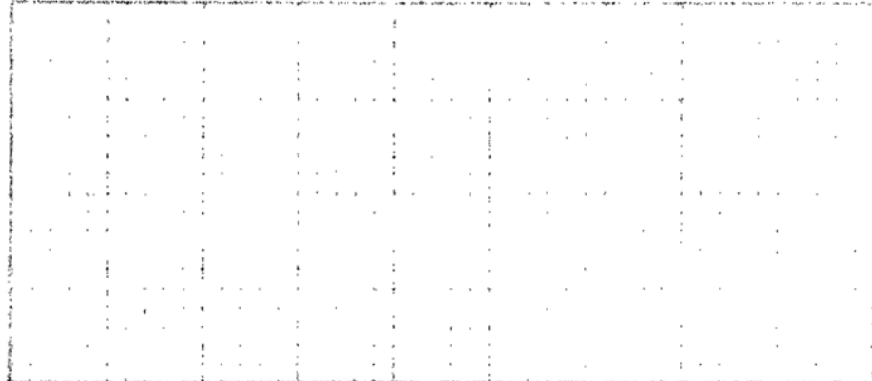
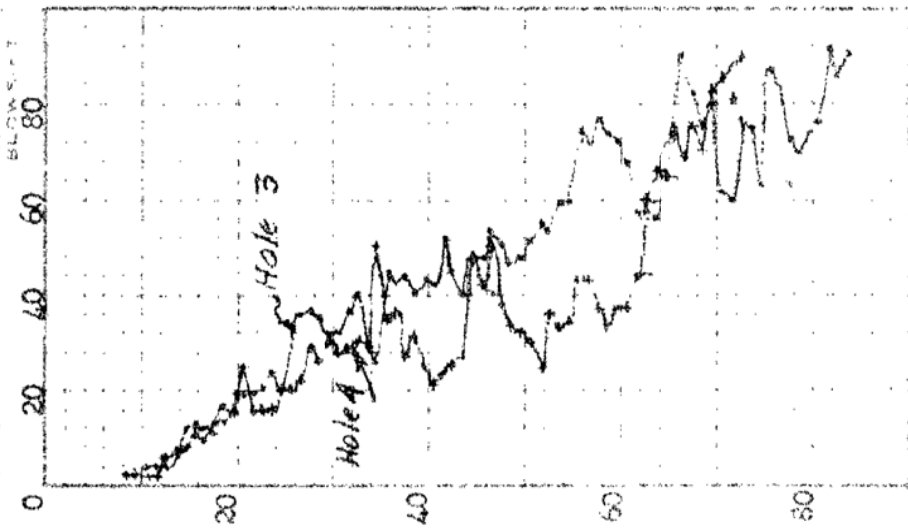
Surface of Ice

River bed

Dynamic Cone Penetration Tests only

Hole 3 = Sta. 2022+13 on centre L.

Hole 4 = Sta. 2021+80 on centre L.



CL29/J152

TROW SODERMAN AND ASSOCIATES

Pays Flat River
Highway 17 near Rossport, Ont.

See Dwg. 1

EL. 601

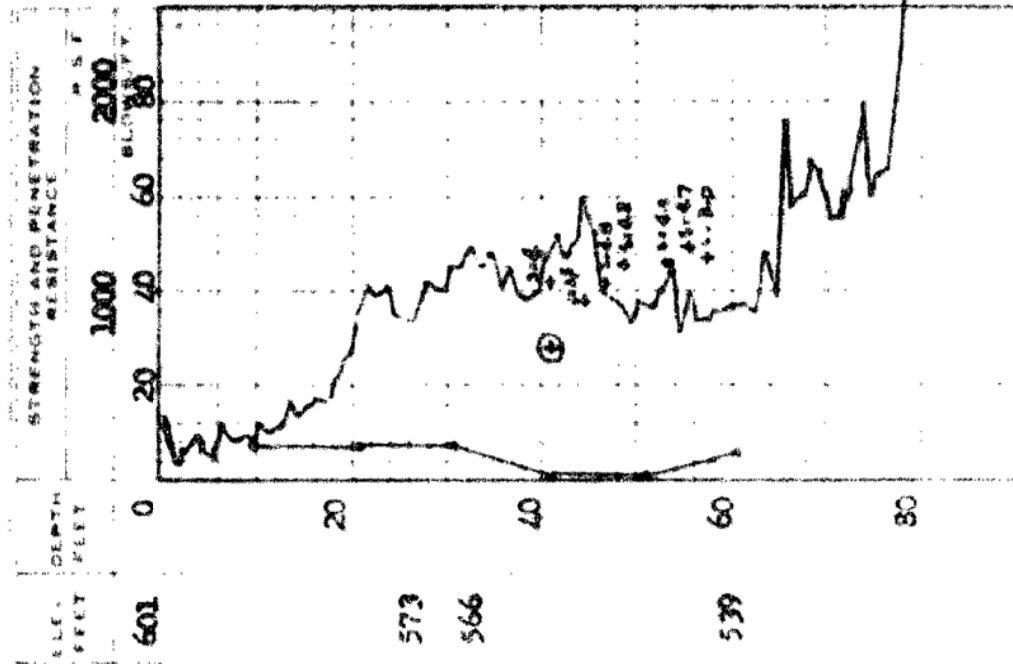
CONTINUED NO. 5
FIELD SUPERVISOR
WILLIAM M. L.
PREP WT

DRAWING NO. 5

TESTED

- 1. 100% SPLIT TUBE
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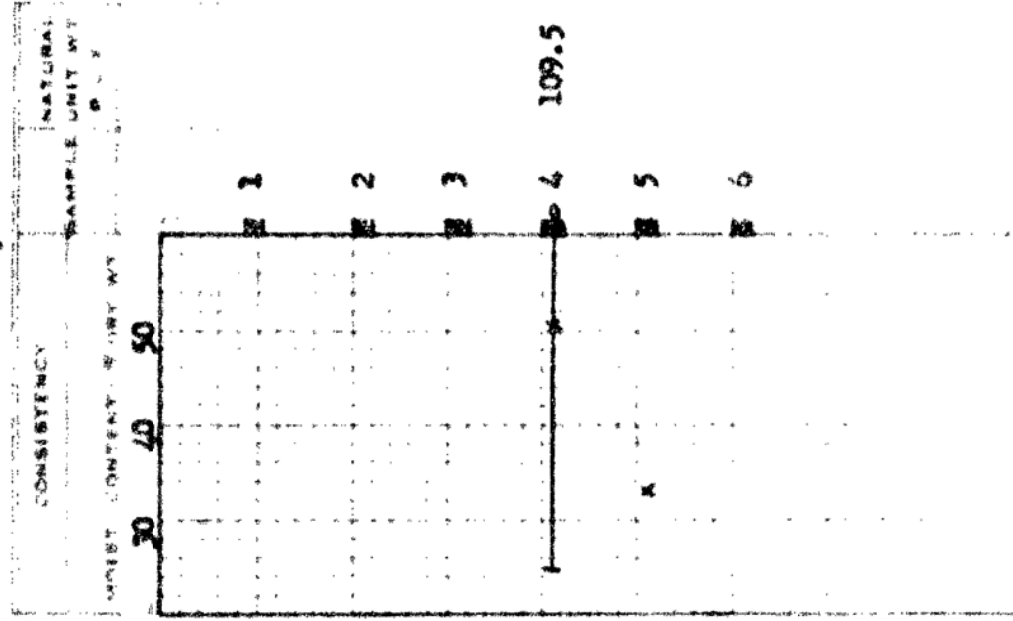
Ground surface
1 ft. topsoil & organics

Med. to coarse grey sand

Transition-Alt. layers of grey sand
and soft clayey silt

Stiff grey clay
(as in hole 1)

End of bore

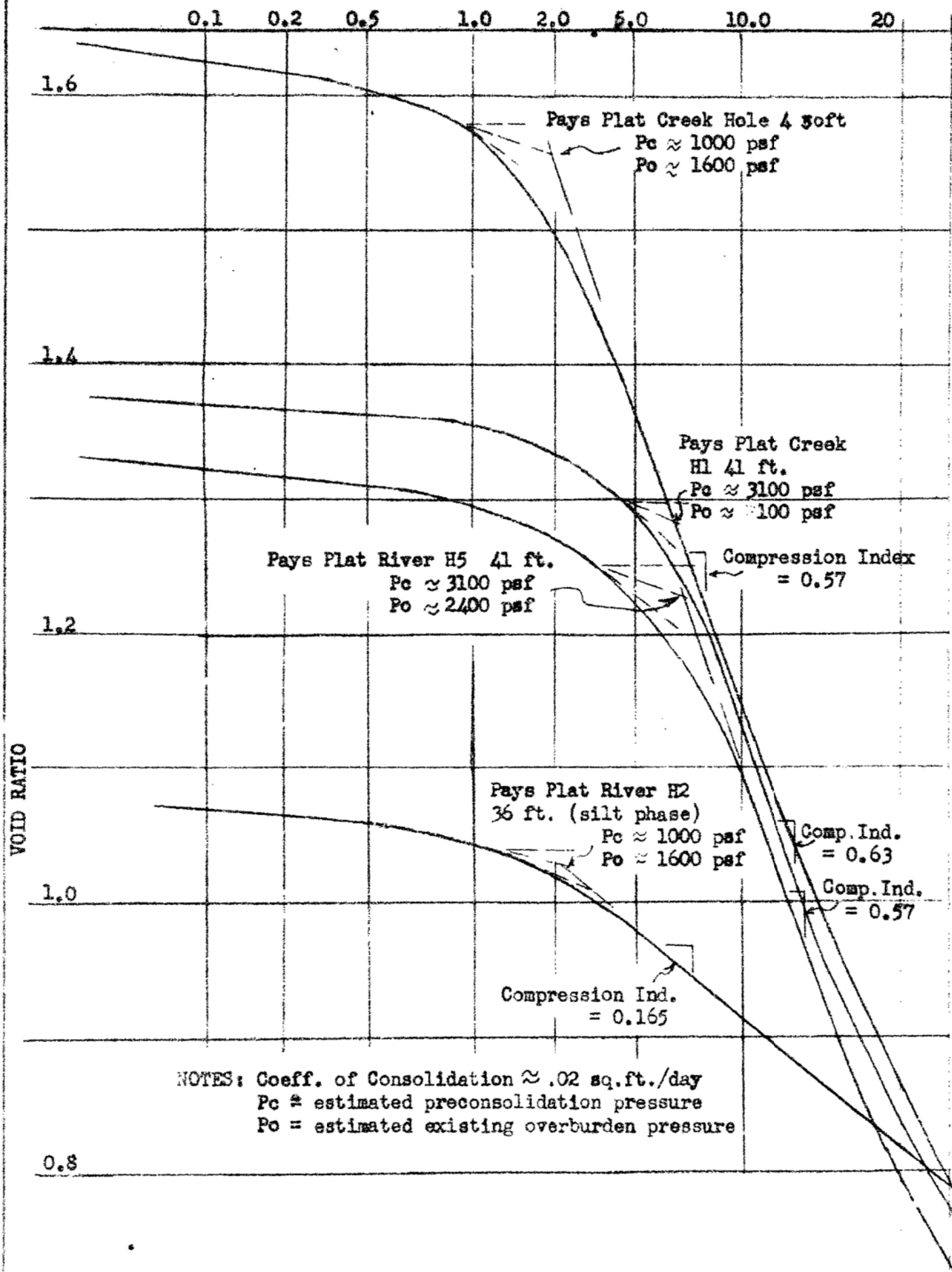


SUMMARY OF FIELD AND LABORATORY TEST MEASUREMENTS
PAYS PLAT RIVERTABLE NO. 1
C129J152

Elev. Ft.	Hole	Stand. Pene. Test Blows/ft.			Shearing P.s.f.			Resistance P.s.f.			Consistency %			Dry. Wt.			Natural Unit Weight P.c.f.			
		1	2	5	1	2	3	1	2	3	1	2	5	L.L.	P.L.	L.L.	P.L.	1	2	5
600		5																		
596		8																		
592			4	6																
588		4	4																	
584		3	6	6																
580																				
576		4	10																	
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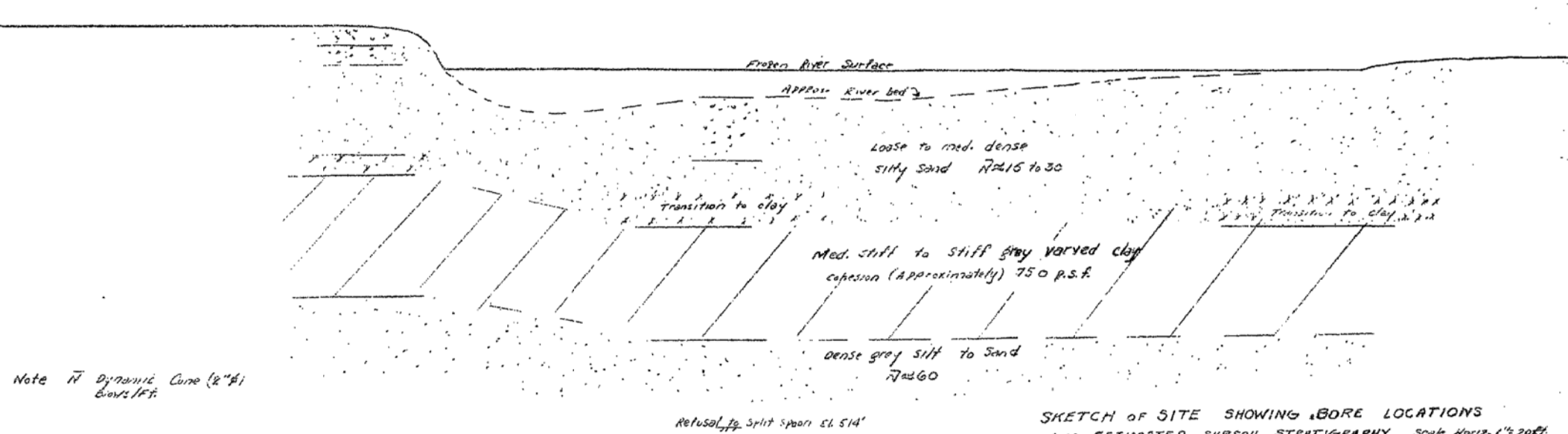
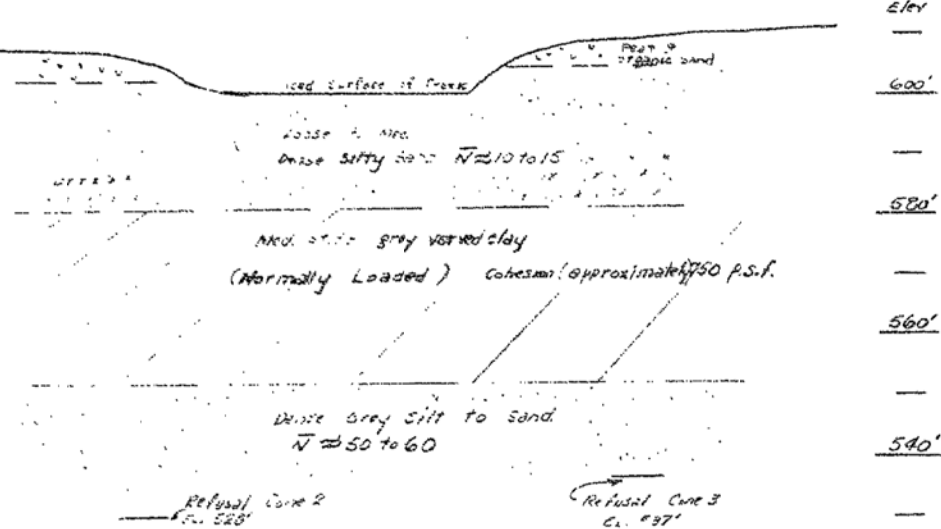
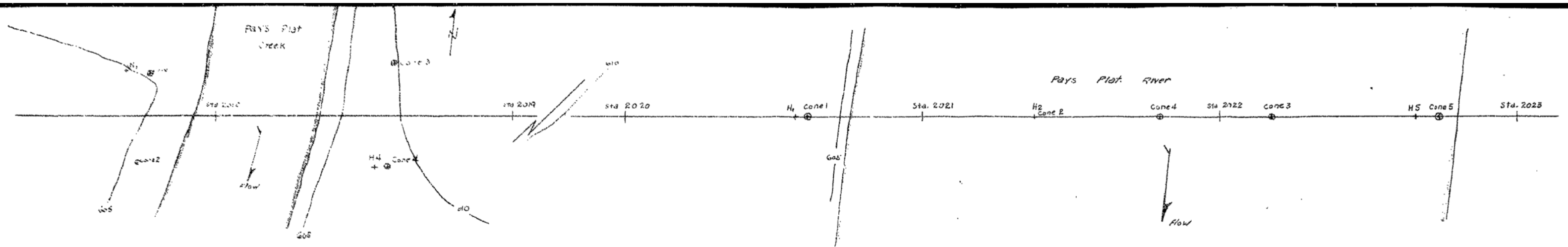
SYMBOLS

Qa - undrained triaxial test at
overburden pressure
Cq - consolidated undrained test
Wn - natural moisture content
L.L. - Liquid Limit
P.L. - Plastic Limit



REPRESENTATIVE CONSOLIDATION CURVES FOR
THE VARVED CLAY

TROW SODERMAN & ASSOCIATES



Note N Dynamic Cone (2" dia) blows/ft.

SKETCH OF SITE SHOWING BORE LOCATIONS AND ESTIMATED SUBSOIL STRATIGRAPHY Scale Horiz. 1" = 20ft. Vert. 1" = 20ft.

Appendix E

Comparison of Foundation Alternatives

COMPARISON OF FOUNDATION ALTERNATIVES

Footings on Native Soil	Footings on Engineered Fill	Driven H-Piles	Caissons
<p>Advantages:</p> <ul style="list-style-type: none"> • Ease of construction. • Lower cost than deep foundations. 	<p>Advantages:</p> <ul style="list-style-type: none"> • Generally less costly construction than deep foundation elements. • Allows use of perched abutments. • Higher geotechnical resistance than for spread footings placed directly on native soil. 	<p>Advantages:</p> <ul style="list-style-type: none"> • Piles will develop high geotechnical resistance on very dense soils. • Installation of piles could continue in freezing weather. • Allows integral abutment design. • Requires less excavation than spread footings. 	<p>Advantages:</p> <ul style="list-style-type: none"> • Higher resistances may be available for caissons than for spread footings founded in native soils. • Construction of caissons could continue in freezing weather.
<p>Disadvantages:</p> <ul style="list-style-type: none"> • Low geotechnical resistance available in native soils • Potential for significant consolidation settlement in silty clay/clay not acceptable for the structure. • Dewatering may be required, depending on depth of excavation. 	<p>Disadvantages:</p> <ul style="list-style-type: none"> • Cost of engineered fill placement. • Potential for significant consolidation settlement in silty clay/clay not acceptable for the structure. 	<p>Disadvantages:</p> <ul style="list-style-type: none"> • Higher unit costs than for spread footings. • Possibility that cobbles and/or boulders may be encountered in the fill and native deposits, obstructing pile installation. 	<p>Disadvantages:</p> <ul style="list-style-type: none"> • Relatively low capacities in native soils at shallow depths. • High cost of construction, as caissons would need to be relatively deep. • Possibility of encountering cobbles and boulders during installation. • Liners and/or drilling mud required to support caisson sidewalls and prevent base heave. • Difficulty in cleaning and inspecting bases.
NOT RECOMMENDED	NOT RECOMMENDED	RECOMMENDED	NOT RECOMMENDED

Appendix F

List of Standard Specifications and Special Provisions

- 1) The following Standard Specifications and Special Provisions are referenced in this report:

OPSS 501

OPSS 511

OPSS 539

OPSS 804

OPSS 902

OPSS 903

OPSS.PROV 1010

OPSS.PROV 206

OPSD 208.010

SS103-11 (Hiley Formula)

- 2) Recommended wording for “NSSP – Use of Heavy Construction Equipment”

The use of heavy construction equipment and in particular heavy lift cranes may be required during removal of the existing bridge and erection of the new bridge. The impact of the heavy equipment loads on the underlying sensitive soils, river banks and existing bridge foundations shall be considered during selection of the methodology and equipment employed for construction.

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

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

- Determining appropriate setbacks for heavy equipment from the river banks and existing foundations;
- Evaluating the need for preventing heavy equipment from travelling or operating on the areas adjacent to the river, possibly requiring restriction of heavy loads to the existing highway embankment platform;
- Determining the permissible ground pressure that may be applied to the foundation soils by the equipment; and
- Providing recommendations for crane pad design to distribute the crane loads without causing foundation failure.

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

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

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

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

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

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

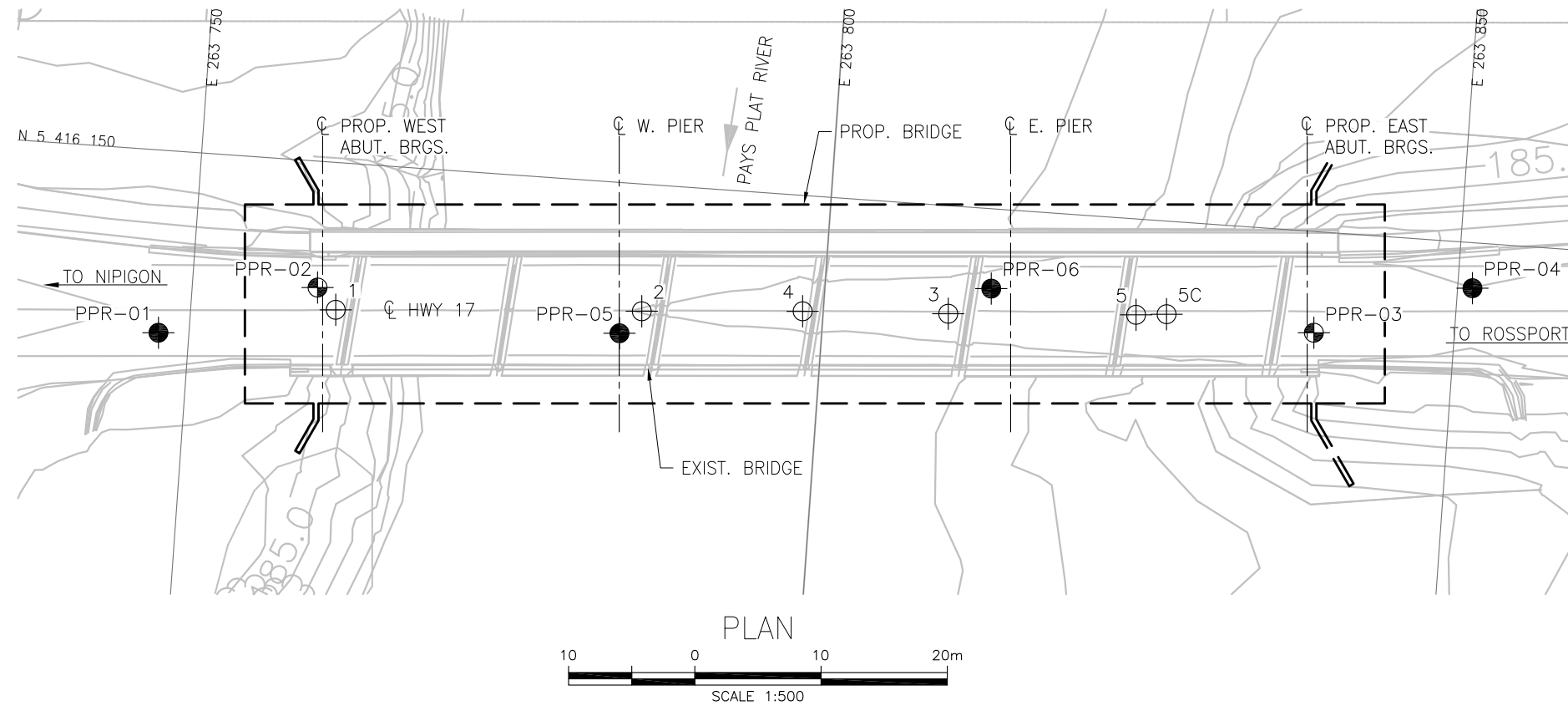
The Contract Administrator should be advised of the importance of monitoring and be required to advise the Ministry immediately if the vertical and horizontal movements exceed the specified limits.

4) Suggested wording for “NSSP – Presence of Cobbles and Boulders”

Cobbles and boulders are present within the existing embankment fill and in the sand deposit underlying the silts and clays on site. The cobbles and boulders may interfere with H-pile and sheet pile installation. The Contractor must be prepared to remove, dislodge or otherwise penetrate these obstructions to advance the piles to the specified tip elevation/resistance while meeting the specified deflection tolerances.

Appendix G

Borehole Locations and Soil Strata Drawing



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



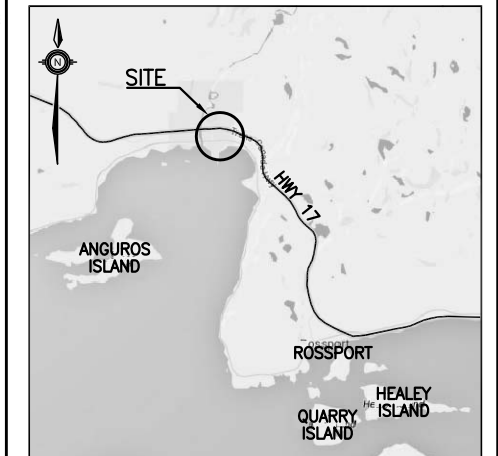
CONT No
WP No 6071-09-01

HIGHWAY 17
PAYS PLAT RIVER BRIDGE
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET








THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

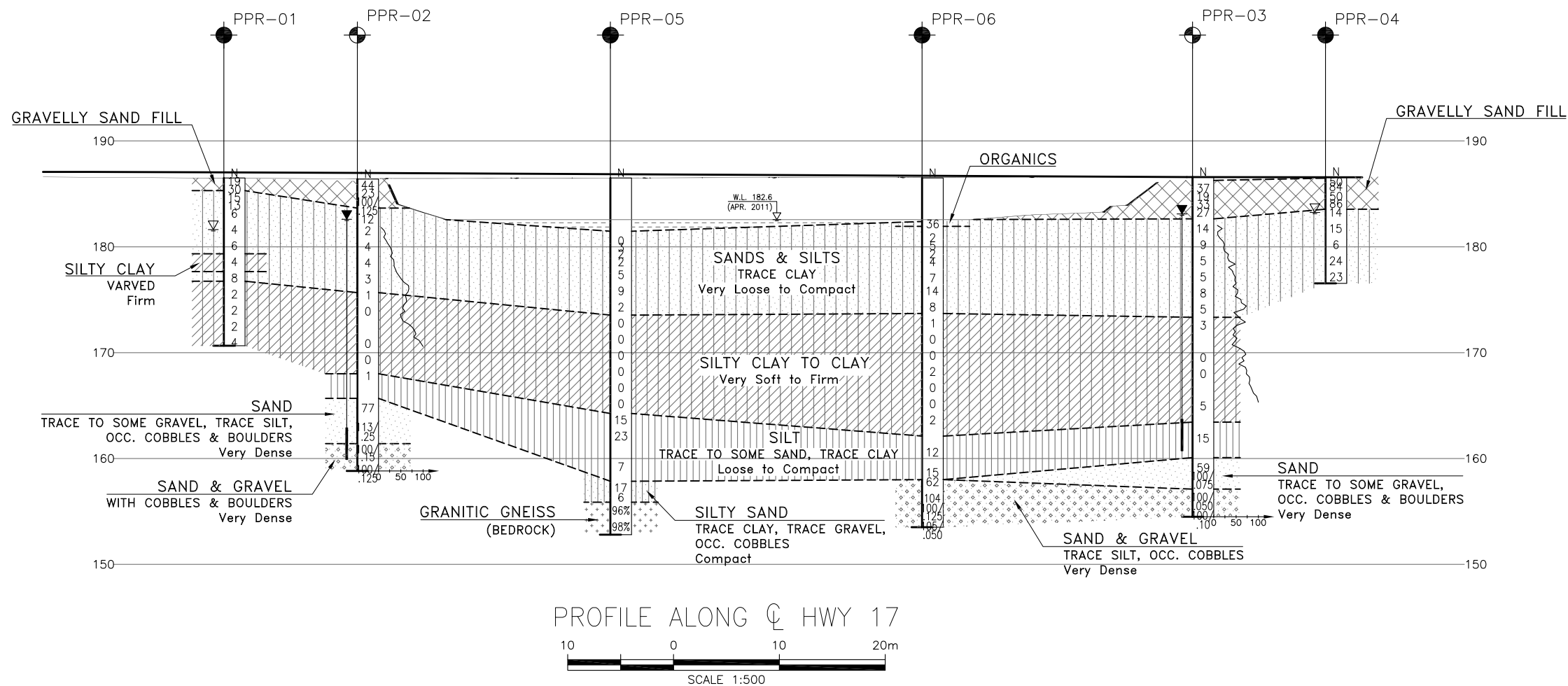
	Borehole
	Borehole & DCPT
	Borehole & DCPT From Previous Study (Geocres 42D-008)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level In Open Borehole
	Water Level In Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
PPR-01	186.5	5 416 135.6	263 747.6
PPR-02	186.4	5 416 140.0	263 759.9
PPR-03	186.6	5 416 142.0	263 838.9
PPR-04	186.6	5 416 146.4	263 851.2
PPR-05	186.5	5 416 138.1	263 784.0
PPR-06	186.5	5 416 143.7	263 813.2

-NOTES-

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

GEOCRES No. 42D-38

[illegible]