

## FINAL REPORT

**Geotechnical Investigation and Cofferdam Failure Assessment  
Kabinakagami River Bridge-Additional Boreholes  
HWY 11, District – New Liskeard  
G.W.P. 5411-04-00  
MTO GEOCRES No. 42F-22**

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## Part 1 Foundation Investigation

### 1.1 Introduction

This report presents the results of a geotechnical investigation carried out by Trow Associates Inc. (Trow) at the site of the failed cofferdam for the Kabinakagami River Bridge replacement. The bridge is located on Highway 11 at the Kabinakagami River, approximately 32 km west of Hearst, Ontario (GWP No. 5411-04-00).

Trow understands that the West Abutment cofferdam was designed and constructed based on the results of geotechnical investigations at the site, performed by Jacques Whitford Ltd. in 2007. It was reported that during the excavation for the West Abutment, settlement and movement of the cofferdam sheeting occurred. A subsequent geotechnical investigation, commissioned by the Contractor and performed by Terraprobe Design Ltd. in December 2008, inferred that there were inconsistencies with respect to the previously reported subsurface conditions. The purpose of this geotechnical investigation is to provide third party verification of the subsurface conditions in the area of interest. Further, a review and assessment of the design, installation procedures and sequences applied during the construction of the West Abutment cofferdam, and their impact, if any, on the reported failure, was undertaken.

The Ministry of Transportation (MTO) provided the results of the geotechnical investigations performed by Jacques Whitford and Terraprobe for comparison. For review and assessment of the installation procedures and sequences applied during the construction of the West Abutment cofferdam, MTO also provided the shoring details for construction of the West Pier and West Abutment cofferdams designed by Terraprobe Design Ltd. (Sheet No. SH1, SH2 and SH3, Revision No. 9 dated from September 15, 2008 and stamped by Terraprobe's professional engineers on August 24, 2008; and Sheet No. SH3 Revision No. 11 dated from September 15, 2008 and stamped by Terraprobe's professional engineers on December 03, 2008). The Ministry of Transportation also made available documentation pertaining to the Contractor's soil condition claim such as a letter provided by Tulloch Engineering, the Contract Administrator, dated April 30, 2009; a letter provided by LEA Consulting Ltd. and Jacques Whitford Stantec Ltd. dated May 08, 2009; and a Memorandum provided by MTO dated May 19, 2009.

The site specific geotechnical investigation consisted of test borings, borehole logging, and field and laboratory testing. The boreholes were strategically located around the West Abutment cofferdam, close to the previously drilled boreholes to verify the subsurface conditions at the same locations reported by previous investigations, and to provide good coverage of the area encompassing the cofferdam. The factual results of the geotechnical investigation are presented in this part of the report.

## **1.2 Site Description and Geological Setting**

### **1.2.1 Site Description**

Kabinakagami River Bridge is located on Highway 11, approximately 32 km west of Hearst, Ontario. It crosses the Kabinakagami River. The site plan is shown on Drawing No. 1 in Appendix B. Photographs of the site are attached in Appendix A.

The existing bridge at the Kabinakagami River is a five span structure approximately 107 m long and 10 m wide. The bridge is oriented in an east-west direction and conveys one westbound lane and one eastbound lane of Highway 11 over the Kabinakagami River. Highway 11 at the Kabinakagami River area is generally built on embankments, so it is generally higher than the surrounding grade. Drainage for Highway 11 is provided by ditches located along the sides of the highway, which are sloped to drain towards the Kabinakagami River.

The Ministry of Transportation (MTO) planned to replace the existing bridge structure at the Kabinakagami River with a new bridge structure. It was planned that the new structure would be constructed to the south of the existing structure and would include the construction of a permanent realignment of Highway 11.

At the time of Trow's geotechnical investigation, the construction of the new bridge had already commenced. Piers 1 and 2 had been completed, while the East and West Abutments were partially constructed. It is understood that the construction was delayed due to the cofferdam failure and the Contractor's claim for discrepancy in soil conditions at the Kabinakagami River Bridge site.

The Ministry of Transportation provided to Trow the results of the geotechnical investigations performed at the same site by Jacques Whitford Ltd. in 2007 and Terraprobe Design Ltd. in December 2008. According to Jacques Whitford's investigation, on the west side of the river bedrock was encountered between Elevations of 220.9 m and 226.7 m, while on the east side of the river, bedrock was encountered much shallower at Elevations in the range 236.0 m and 244.2 m. The bedrock outcrop was observed on the east riverside, several meters north of the existing bridge. The overburden is fluvial deposits laid down by the Kabinakagami River.

### **1.2.2 Geological Setting**

According the Ministry of Northern Development and Mines, Maps 2518 (Sacrificial Geology of Northern Ontario, 1987) and 2543 (Bedrock Geology of Ontario, East-Central Sheet, 1991), the site is located in the boundary between a clay-silt deposit and a till deposit underlain by Metasedimentary bedrock. The clay-silt deposit is mapped as glaciolacustrine deposit, while the till deposits is noted as unsorted mixture of boulders, sand, silt and clay sized particles. The Metasedimentary Rock Group comprised of

argillite, slate, marble, chert, wacke, arkos, iron formation and minor metavolcanic rock intrusions.

## 1.3 Investigation Procedures

### 1.3.1 Field Program

The fieldwork for this investigation was performed between June 24, 2009 and July 01, 2009. The fieldwork consisted of drilling eight (8) sampled boreholes (KB-09-01 through KB-09-08) and installing of five (5) piezometers in KB-09-04, KB-09-06, KB-09-07 and KB-09-08. Boreholes KB-09-01, KB-09-03, KB-09-06 and KB-09-08 were strategically located close to previously drilled boreholes by Jacques Whitford and Terraprobe to provide comparative information at locations of where apparent inconsistency exists. The remaining holes were located around the failed cofferdam to provide good coverage of the subject site to facilitate the appropriate information gathering and assessment. Local removal of surface rock fill was done to facilitate drilling. The boreholes were approximately 1.5 m to 8 m apart, and between 12.8 m and 16.5 m deep. The site plan and borehole locations are shown on Drawing No. 1 in Appendix B.

All boreholes were advanced using a Bombardier mounted CME-55 drill rig, equipped with a hollow stem auger (4-1/4" HAS) and standard soil sampling equipment. They were drilled by a specialist drilling contractor, Marathon Drilling.

From the drilling program, Standard Penetration Tests (SPT) and sampling of soil materials using a 51 mm OD split-spoon sampler were performed at 0.75 m intervals to identify changes in material type, cohesive and non-cohesive materials and 'soft' ground conditions within the critical foundation zones of the structure. Sampling and testing procedures were in accordance with ASTM D1586. This consists of freely dropping a 63.5 kg hammer a vertical distance of 0.76 m to drive a 51 mm OD split-spoon sampler into the ground. The number of blows of the hammer required to drive the sampler into the relatively undisturbed ground by a vertical distance of 0.30 m is recorded as SPT 'N' value of the soil and this gives an indication of the consistency or the relative density of the soil deposit.

In addition, selected, relatively undisturbed, 51 mm diameter "Shelby" tube samples were obtained in cohesive deposits. Field vane testing was also completed in the boreholes throughout the cohesive soils to measure the *in-situ* undrained shear strength of the soils. The field vane used had dimensions of 154 mm long and 67 mm diameter. The torque was measured by using calibrated scale on a lever arm threaded to the drill rods. The field vane testing was conducted in accordance with ASTM D2573-08.

All fieldwork was supervised by a member of Trow's engineering staff who directed the drilling and sampling operations, logged the factual borehole data in accordance with the

MTO Soils Classification System for foundation reports, and retrieved soil samples for subsequent laboratory testing and identification. All of the recovered soil samples were placed in moisture-proof bags and returned to Trow’s Thunder Bay and Brampton laboratories for additional visual, textual and olfactory examination and for selected laboratory testing.

Following completion of the boreholes, water level measurements were obtained from the boreholes in accordance with Ministry of Transportation guidelines. Piezometers were installed in Boreholes KB-09-04, KB-09-06, KB-09-07 and KB-09-08 to permit monitoring of groundwater levels at the site at different depths. After completion, boreholes were sealed with bentonite/cement slurry in accordance with Ontario Regulation 903. Holes with piezometers will be similarly decommissioned.

Details of the soil strata encountered in the boreholes are included in attached logs in Appendix C, and plotted on the profiles included in Drawings No. 2 through 6 in Appendix B.

The locations of the boreholes were established by Trow personnel and referenced to the existing cofferdam structure, as shown in Drawing No. 1, Appendix B. The ground surface elevation of the borehole locations were surveyed by Trow personnel. The boreholes were surveyed to the relative benchmark located on the south side of the West Abutment of the existing Kabinakagami River Bridge, with reported Geodetic Elevation of 245.949 m.

### **1.3.2 Laboratory Testing**

All samples returned to the laboratory were subjected to detailed visual examination and classification. The laboratory testing program included moisture content determination of all samples (LS-701) and routine classification testing of approximately 25% of the selected soil samples. The routine testing included grain size distribution (LS-702) and Atterberg limits (LS-703/704). In addition, two undisturbed, “Shelby” tube cohesive samples were subjected to laboratory unconfined compression tests (ASTM D2166).

The laboratory test results are provided on the attached borehole logs in Appendix C. The results of the grain size analyses, Atterberg limits and unconfined compression tests are presented in Appendix D.

## **1.4 Subsurface Conditions**

The subsurface conditions encountered during the field investigation are summarized on the attached borehole logs in Appendix C. The “Explanation of Terms Used in Report” preceding the borehole logs (Appendix C) forms an integral part of and should be read in conjunction with this report.

Based on boring logs data obtained during this geotechnical investigation, five cross-section soil profiles were determined showing the stratigraphy of the site in different directions and locations relative to the cofferdam as shown on Drawing No.1 in Appendix B. The cross-section soil profiles are shown on Drawings No. 2 through 6, Appendix B.

In general, the stratigraphic sequence at the site consisted of silty sand fill, upper silt, silty clay, lower silt, clayey silt, silty sand/sandy silt/sand and sandy silt (till). However, as shown on the cross-section profiles, the pattern of layers was vertically and spatially variable. This spatial and vertical soil variability is common in a fluvial soil deposit due to random depositional processes over geological time periods.

A summary of the soil and groundwater conditions encountered in the boreholes is provided below.

#### **1.4.1 Silty Sand and Sand Fill**

In all boreholes silty sand and/or sand fill was encountered at the ground surface. The silty sand fill was found in boreholes drilled at the east side (KB-09-01, KB-09-02, KB-09-03) and south side (KB-09-05) of the cofferdam. The sand fill was encountered in the western boreholes KB-09-06, KB-09-07 and KB-09-08, while both silty sand and sand fill was encountered in KB-09-04. The thickness of the silty sand fill was between 1.1 m and 2.3 m. The sand fill was from 0.9 m to 1.4 m thick.

The composition of this layer was silt and sand with some gravel. The fill was brown in colour, moist to wet. Based on the “N” value from the Standard Penetration Tests, the compactness of the silty sand and sand fill was assessed as loose.

#### **1.4.2 Peat**

A layer of peat was encountered underlying the fill material in Boreholes KB-09-01 and KB-09-02 at depth of approximately 1.1 m (Elevation 241.5 m) and 1.2 m (Elevation 241.7 m), respectively. The thickness of the layer was 0.5 m in KB-09-01 and 0.1 m in KB-09-02.

#### **1.4.3 Upper Sandy Silt**

Beneath the silty sand fill and peat at the east side of the cofferdam, there is a sandy silt layer as indicated in Boreholes KB-09-01, KB-09-02 and KB-09-03. The thickness of the sandy silt was between 0.9 m (KB-09-01) and 1.9 m (KB-09-02). At these borehole locations, the layer extended to depth up to 3.1 m, which corresponds to approximate Elevation of 239.7 m.

The upper sandy silt has a trace of organic material and was brown in colour. It was frozen up to the depth of 2.2 m (approximate Elevation 240.5 m) measuring SPT “N” values from 20 to 35. Measured SPT “N” values afterward were much lower, between 4



and 6, indicating that the sandy silt became looser with depth, and/or the upper level was influenced by frost.

#### 1.4.4 Upper Silt

A layer of silt was encountered underlying the fills or upper sandy silt in all boreholes. The silt was encountered beneath silty sand and sand fills in Boreholes KB-09-04, KB-09-05, KB-09-06, KB-09-07 and KB-09-08 at depths of in the range of approximately 0.9 m to 2.3 m, elevations of approximately 242.2 m to 240.6 m. The thickness of the silt at these locations ranged from approximately 1.5 m to 3.1 m. The same layer of the silt was also encountered underlying the sandy silt in Boreholes KB-09-01, KB-09-02 and KB-09-03 at depths between 2.6 m and 3.1 m, elevations of approximately between 240.2 m and 239.7 m. The thickness was between 0.8 m (KB-09-03) and 2.0 m (KB-09-01).

The silt contained trace to some fine sand, and trace gravel and clay. It also contained trace organics. Upper silt was brown in colour, and generally wet. Based on “N” values obtained from the SPTs, the compactness of the silt was very loose to compact.

Laboratory testing performed on selected samples consisted of moisture content and grain size distribution tests. The test results are as follows:

Moisture Content:

- 19% to 23.5%

Grain Size Distribution:

- 0% gravel;
- 2% to 23% sand;
- 72% to 92% silt; and
- 5% to 8% clay.

The results of the moisture content and grain size distribution tests are provided on the Record of Borehole sheets in Appendix C. The results of the grain size distribution tests on the upper silt layer are provided on Figure 1 in Appendix D.

#### 1.4.5 Silty Clay

Beneath the upper silt, a stratum of silty clay was encountered in all boreholes. The silty clay was encountered at a depth of approximately 4.0 m below existing grade (approximate Elevation 239.5 m) in the boreholes located west of the cofferdam (KB-09-04 through KB-09-08). In the boreholes east of the cofferdam (KB-09-01, KB-09-02 and KB-09-03) the silty clay was encountered at a depth between 3.8 m (approximate Elevation 239.2 m) and 4.6 m (approximate Elevation 238.2 m). The thickness of the layer varied from 0.6 m in the area of the north-west corner of the cofferdam (KB-09-06) to 2.3 m in the area of the south-east corner of the cofferdam (KB-09-03 and KB-09-02).

The silty clay extended to depths of between 4.6 m (KB-09-06; approximate Elevation 237.9 m) and 6.9 m (KB-09-02; approximate Elevation 235.9 m) below ground.

The silty clay was grey in colour, moist to wet. It was varved with clayey silt. The individual layers or laminations varied in thickness from a few millimeters to a few centimeters, but in general were about one centimeter thick. The portions of clay and clayey silt varied also, but in general the clay portion dominated.

SPT “N” values within the silty clay encountered in the boreholes ranged from 1 to 4 indicating very soft to firm material.

Field vane tests were performed to examine undrained shear strengths of the silty clay. The results of the *in-situ* field vane tests measured in boreholes are shown on the Record of Borehole sheets in Appendix C. The measured values of the undrained shear strength ranged from 38 kPa to 55 kPa. The undrained shear strengths of two samples measured in the unconfined compression tests were 35.4 kPa (from KB-09-01 at Elevation 236.4 m) and 31.7 kPa (from KB-09-08 at Elevation 238.2 m). Sensitivity ranged from 1.4 to 2, indicating the silty clay is low to medium sensitive.

Laboratory testing performed on selected samples consisted of moisture content, grain size distribution, Atterberg limits and unconfined compression tests. The test results are as follows:

Moisture Content:

- 22% to 35%

Grain Size Distribution:

- 0% gravel;
- 3% to 4% sand;
- 49% to 78% silt; and
- 19% to 48% clay.

Atterberg Limits:

- Liquid Limits: 21% to 34.2%
- Plastic Limits: 15.2% to 17.2%.

Unconfined Compression:

- Undrained Shear Strength: 31.7 kPa and 35.4 kPa

The results of the moisture content, grain size distribution, Atterberg limits and unconfined compression tests are provided on the Record of Borehole sheets in Appendix C. The results of the grain size distribution tests on the silty clay are provided on Figure 2 in Appendix D. The results of the Atterberg limits tests are provided on Figure 8 in

Appendix D. The results of two unconfined compression tests are shown on Figure 11, Appendix D.

#### **1.4.6 Lower Silt**

Silt was encountered underlying the silty clay in all boreholes. The lower silt layer was encountered at depths in the range of approximately 4.6 m to 6.9 m, elevations of approximately 239.0 m (KB-09-04) to 235.9 m (KB-09-02). The thickness of the lower silt was variable ranging from approximately 2.9 m to 3.8 m with the thickest silt deposit encountered in Borehole KB-09-04. This layer extended up to Elevations of approximately 235.2 m (KB-09-04) and 232.9 m (KB-09-02).

The layer consisted predominately of silt with thin seams of grey clay and a trace of fine sand. Low-plastic silt was generally brown and wet. Based on the “N” values (1-14) obtained from the SPTs, the compactness of the lower silt was considered to be very loose to compact.

Laboratory testing performed on selected samples consisted of moisture content, grain size distribution and Atterberg limits tests. The test results are as follows:

Moisture Content:

- 15% to 23%

Grain Size Distribution:

- 0% gravel;
- 0% to 1% sand;
- 89% to 94% silt; and
- 6% to 10% clay.

Atterberg Limits:

- Liquid Limits: 22.1%
- Plastic Limits: 20.2%.

The result of the moisture content tests, grain size distribution and Atterberg limits tests are provided on the Record of Borehole sheet in Appendix C. The results of the grain size distribution tests on the lower silt are provided on Figure 3 in Appendix D. The results of the Atterberg limits tests are provided on Figure 9 in Appendix D.

#### **1.4.7 Clayey Silt**

Underlying the lower silt, the boreholes drilled at the east and south sides of the cofferdam (KB-09-01, KB-09-02, KB-09-03 and KB-09-05) encountered a layer of brown, moist clayey silt. The clayey silt was encountered at depths of in the range of

approximately 8.5 m (KB-09-05; approximate Elevation 234.1 m) to 9.9 m (KB-09-02; approximate Elevation 232.9 m). The thickness of the clayey silt ranged from approximately 0.5 m (KB-09-02) to 1.0 m (KB-09-05).

The clayey silt contained trace gravel and trace to some sand. Standard penetration resistance “N” values ranged from 2 to 10 suggesting soft to stiff consistency of the clayey silt.

Laboratory testing performed on selected samples consisted of moisture content, grain size distribution and Atterberg Limits tests. The test results are as follows:

Moisture Content:

- 16% to 19%

Grain Size Distribution:

- 0% gravel;
- 31% sand;
- 44% silt; and
- 25% clay.

Atterberg Limits:

- Liquid Limits: 22.4%
- Plastic Limits: 12.7%.

The results of the moisture content, grain size distribution and Atterberg limits tests are provided on the Record of Borehole sheets in Appendix C. The results of the grain size distribution tests on the clayey silt are provided on Figure 4 in Appendix D. The results of the Atterberg limits tests are provided on Figure 10 in Appendix D.

#### **1.4.8 Lower Brown Sandy Silt**

A layer of brown sandy silt was encountered underlying the clayey silt in KB-09-01 and KB-09-03, the boreholes drilled at the east side of the cofferdam. The lower brown sandy silt was encountered at depths of approximately 9.9 m (KB-09-03) and 10.4 m (KB-09-01) below ground, corresponding to Elevations of approximately 232.9 m and 232.4 m, respectively. The thickness of the layer was 0.9 m in KB-09-01 and 1.5 m in KB-09-03. It extended to depths of 11.3 m (approximate Elevation 231.5 m) in KB-09-01, and 11.4 m (approximate Elevation 231.4 m) in KB-09-03.

The lower brown sandy silt was also encountered in Boreholes KB-09-06 and KB-09-07 at the west side of the cofferdam. A 0.5 thick layer of brown sandy silt was encountered beneath the silt in Borehole KB-09-06 at the 7.9 m depth (approximate Elevation 235.6 m). The brown sandy silt was also encountered underlying the grey sandy silt till in KB-

09-07 at the depth of 14.2 m, corresponding to Elevation of approximately 229.2 m. Borehole KB-09-07 was terminated in that layer at a depth of approximately 16.5 m, Elevation of approximately 226.9 m.

The results of the grain size distribution tests showed that the layer consisted of almost equal amounts of silt (45%) and sand (42-43%) and small amounts of gravel (4-5%) and clay (8%). This layer was brown in colour, moist to wet.

Based on the “N” value from the Standard Penetration Tests, the compactness of the sandy silt was assessed as compact.

Laboratory testing performed on selected samples consisted of moisture content and grain size distribution tests. The test results are as follows:

Moisture Content:

- 10% to 12%

Grain Size Distribution:

- 4% to 5% gravel;
- 42% to 43% sand;
- 45% silt; and
- 8% clay.

The result of the moisture content and grain size distribution tests are provided on the Record of Borehole sheet in Appendix C. The results of the grain size distribution tests on the lower brown sandy silt are also provided on Figure 5 in Appendix D.

#### **1.4.9 Silty Sand**

Grey silty sand materials were encountered underlying the lower silt in Boreholes KB-09-04 at the depth of about 8.4 m (approximate Elevation 235.2 m), as well as, in Boreholes KB-09-02 and KB-09-05 below the clayey silt at depths of 10.4 m (approximate Elevation 232.4 m) and 9.5 m (approximate Elevation 233.5 m), respectively. These silty sand materials were also encountered in KB-09-06 below the sandy silt at the depth of 8.4 m (approximate Elevation 235.1 m) and in Borehole KB-09-07 below the sand at the depth of 9.1 m (approximate Elevation 234.2 m). In Borehole KB-09-04, the silty sand was encountered again at the depth of 9.8 m (approximate Elevation 233.8 m) after a 0.7 m thick sand layer. The upper and lower silty sand layers in KB-09-04 were approximately 0.7 m and 0.9 m thick, respectively. The thickness of the silty sand in KB-09-02, KB-09-05, KB-09-06 and KB-09-07 was 1.8 m, 1.2 m, 1.5 m and 0.8 m, respectively.

This cohesionless soil layer generally contained silt and fine to medium grained sand, trace gravel and clay, and was wet. Based on the “N” values obtained from the SPTs, the compactness of the silty sand was very loose to compact.

Laboratory testing performed on selected samples consisted of moisture content and grain size distribution tests. The test results are as follows:

Moisture Content:

- 10% to 15%

Grain Size Distribution:

- 6% gravel;
- 53% sand;
- 37% silt; and
- 4% clay.

The results of the moisture content and grain size distribution tests are provided on the Record of Borehole sheet in Appendix C. The results of the grain size distribution tests on the silty sand are also provided on Figure 6 in Appendix D.

#### **1.4.10 Sand**

Grey sand was encountered underlying the lower silt in Borehole KB-09-07 and the silty sand in Borehole KB-09-04. The sand was encountered at depths of about 8.4 m and 9.1 m, corresponding to Elevations of approximately 235.2 m and 234.4 m, in Boreholes KB-09-07 and KB-09-04, respectively. The sand was approximately 0.7 m thick in both boreholes.

The sand was fine to coarse grained with trace silt and gravel. It was wet. Based on the “N” values obtained from the SPTs, the compactness of the sand was very loose.

Laboratory testing performed on selected samples consisted of moisture content tests. The test results are as follows:

Moisture Content:

- 16% to 19%

The results of the moisture content tests are provided on the Record of Borehole sheets in Appendix C.

#### **1.4.11 Lower Grey Sandy Silt**

Grey sandy silt was encountered in Borehole KB-09-08 beneath the silt at a depth of 9.1 m (approximate Elevation 234.0) and in Borehole KB-09-06 beneath the sandy silt till at

a depth of 14.3 m (approximate Elevation 229.2 m). The thickness of this sandy silt layer was 6.1 m in KB-09-08 and 0.9 m in KB-09-06. Very dense silt was encountered underlying the grey sandy silt in KB-09-06, where the borehole was terminated at a depth of about 15.9 m (Elevation 227.7 m). The grey sandy silt in KB-09-08 was underlain by sandy silt till.

The grey sandy silt contained trace gravel and clay, and was moist to wet. Some cobbles may be present in KB-09-08, based on interpretation during drilling.

Based on the “N” value from the Standard Penetration Tests, the compactness of the grey sandy silt was variable ranging from loose to dense.

Laboratory testing performed on selected samples consisted of moisture content and grain size distribution tests. The test results are as follows:

Moisture Content:

- 10% to 12%

Grain Size Distribution:

- 6% gravel;
- 44% sand;
- 45% silt; and
- 5% clay.

The results of the moisture content and grain size distribution tests are provided on the Record of Borehole sheet in Appendix C. The results of the grain size distribution tests on the lower grey sandy silt are also provided on Figure 7 in Appendix D.

#### **1.4.12 Sandy Silt Till**

Sandy silt till was encountered in all boreholes at depths in the range of approximately 9.9 m to 15.2 m below existing grade, elevations in the range of approximately 233.6 m to 227.9 m. The till ranged in thickness from approximately 2.1 m to 4.5 m. All boreholes except KB-09-06 and KB-09-07 were terminated in the sandy silt till stratum at depths in the range of approximately 12.8 m to 15.9 m, corresponding to elevations of approximately 230.7 m to 227.0 m.

The sandy silt till contained trace to some gravel and trace clay. It was grey in colour, and typically moist. The presence of cobbles and/or boulders throughout the till is inferred from interpretation during drilling.

Based on the “N” value from the Standard Penetration Tests, the compactness of the sandy silt till was variable ranging from loose to dense.

Laboratory testing performed on selected samples consisted of moisture content tests. The test results are as follows:

Moisture Content:

- 9% to 12%

The results of the moisture content are provided on the Record of Borehole sheet in Appendix C.

### 1.4.13 Groundwater

Information regarding the groundwater levels at the site was obtained by measuring the water levels in the open boreholes after completion of drilling and by piezometers installed in Boreholes KB-09-04, KB-09-06, KB-09-07 and KB-09-08. The measured groundwater levels are shown on the borehole logs. The groundwater levels encountered in the boreholes are also shown in Table 1.1.

Table 1.1 Groundwater levels recorded at the site

| Borehole Number<br>[Top Elevation (m)] | Date of Drilling | Depth of Piezometer (m)<br>[Bottom Elevation (m)] | Groundwater Level<br>Depth Below Existing Grade (m)<br>[Elevation (m)] |                |                |
|--|------------------|---|--|----------------|----------------|
|  |                  |   | 06/29/2009   | 06/30/2009     | 07/01/2009     |
| <b>KB-09-01</b><br>[242.8]             | 07/01/2009       | Open Borehole                                     | -  | -              | 2.1<br>[240.7] |
| <b>KB-09-02</b><br>[242.8]             | 06/30/2009       | Open Borehole                                     | -  | 1.9<br>[240.9] | -              |
| <b>KB-09-03</b><br>[242.8]             | 06/29/2009       | Open Borehole                                     | 1.9<br>[240.9]   | -              | -              |
| <b>KB-09-04*</b><br>[243.5]            | 06/28/2009       | 3.7<br>[239.8]                                    | 1.2<br>[242.3]   | 1.2<br>[242.3] | 1.1<br>[242.4] |
| <b>KB-09-05</b><br>[242.9]             | 07/01/2009       | Open Borehole                                     | -  | -              | 2.1<br>[240.8] |
| <b>KB-09-06*</b><br>[243.5]            | 06/27/2009       | 9.8<br>[233.7]                                    | 2.3<br>[241.2]   | 2.0<br>[241.5] | 2.0<br>[241.5] |
| <b>KB-09-07*</b><br>[243.4]            | 06/25/2009       | 3.4<br>[240.0]                                    | 1.0<br>[242.4]   | 1.0<br>[242.4] | 0.8<br>[242.6] |
|  | 06/25/2009       | 9.1<br>[234.3]                                    | 2.1<br>[241.3]   | 1.8<br>[241.6] | 1.7<br>[241.7] |
| <b>KB-09-08*</b><br>[243.1]            | 06/26/2009       | 3.4<br>[237.9]                                    | 0.6<br>[242.5]   | 0.4<br>[242.7] | 0.4<br>[242.7] |

\* - piezometer

To measure water levels in the two water bearing units, separated by the low-permeable silty clay layer identified during the drilling, piezometers were installed in boreholes at different depths. Three piezometers approximately 3.4 m to 3.7 m deep were installed in KB-09-04, KB-09-07 and KB-09-08, respectively, to monitor groundwater levels in the



upper (shallow) water bearing unit in the sandy fills and loose upper silt above the silty clay layer. Two piezometers approximately 9.1 m and 9.8 m deep were installed in KB-09-07 and KB-09-06, respectively, to monitor groundwater levels in the lower (deep) water bearing unit located in the lower silty sand and sand material beneath the silty clay layer. The piezometers comprise a 50-mm PVC pipe with at least 1.5 m long slotted screen embedded in a sand pack and bentonite seals above and below the sand pack. The screened section was fully advanced in the shallow water bearing unit. The water levels in these piezometers were measured several times during the investigation program, and the results are summarized in Table 1.1.

As can be seen in Table 1.1, the groundwater levels in the upper water bearing unit at the west side of the cofferdam measured in the shorter piezometers were at elevations in range of approximately 242.4 m to 242.6 m, while the groundwater levels in this water bearing unit at the east side of the cofferdam (the river side) measured in the open boreholes were at elevations between 240.7 m and 240.9 m. At the time of the investigation the water surface elevation of the Kabinakagami River was approximately 240.4 m (July 01, 2009). It is anticipated from Terraprobe's shoring drawings (Sheet No. SH3 from 15 September 2008) that the elevation of the bottom of the cofferdam was approximately 239.5 m. The presence of the cofferdam influences groundwater levels in the vicinity.

Comparing the results of the measurements in the upper and lower water bearing units, it is notable that the groundwater levels measured in the lower water bearing unit were about 0.9 m lower than the levels measured in the upper water bearing unit, inferring a downward vertical hydraulic gradient. It is also observed that water in piezometers installed in the lower water bearing unit rose above the interface of the deep permeable sandy soil layer and the low-permeable silty clay layer.

Seasonal variations in the water level should be anticipated, with higher levels occurring during wetter periods of the year (such as spring snow melt and late fall) and lower levels during drier periods.

## **1.5 Closure**

A soil investigation is a limited sampling of a site. The information is collected at specific borehole locations and can be extrapolated to an approximate limited area around the borehole. The extent of the limited area depends on the variability of the soil and groundwater conditions as influenced by geological processes and the construction activities. Should any conditions at the site be encountered which differ from those reported at the test locations, Trow requires that Trow will be notified immediately in order to allow reassessment of our recommendations. It may then be necessary to carry out additional field work and analyses.

## Part 2 Engineering Discussion and Recommendations

### 2.1 Introduction

The following subsections address assessment of subsurface conditions in the area of the failed cofferdam for the West Abutment of the Kabinakagami River Bridge replacement. The results of this investigation are compared with the previous reported results of two geotechnical investigations performed by Jacques Whitford Ltd. in 2007 and Terraprobe Design Ltd. in December 2008. Stability analyses including toe kick-out, piping, basal heave and liquefaction potential analyses were completed, and the results are included in this report. A review and assessment of the design, installation procedures and sequences applied during the construction of the West Abutment cofferdam (using information supplied), and their impact, are included as well. Where possible, the physical dimensions of installed systems compared with initial designs are considered, noting that the current in situ conditions reflect the status after remedial works and further examination may be required to confirm or obtain pertinent data.

This part of the report addresses the following key issues:

- Background and site stratigraphy
- Assessment of the subsurface conditions and any noted inconsistencies in the reported information from documentation generated by Jacques Whitford, Terraprobe and in this report prepared by Trow.
- Assessment of the cofferdam design carried out by Terraprobe on behalf of the Contractor, that was based on the conditions reported by Jacques Whitford.
- Commentary on the impact of subsurface conditions identified by the Trow investigation.
- Review and assessments of the installation procedures and sequences applied, and the impact, if any, on the reported failure based on information provided and obtained.
- Comments and conclusions pertaining to the above issues.

## 2.2 Background

### 2.2.1 General

Kabinakagami River Bridge is located on Highway 11, approximately 32 km west of Hearst, Ontario. It crosses the Kabinakagami River. The site plan is shown on Drawing No. 1 in Appendix B. Photographs of the site are included in Appendix A.

The existing bridge at the Kabinakagami River is a five span structure with steel girders supporting a reinforced concrete deck. It is approximately 107 m long and 10 m wide. The bridge is oriented in an east-west direction and conveys one westbound lane and one eastbound lane of Highway 11 over the Kabinakagami River. It is reported that the structure was constructed in 1942, and that, the northern half of the bridge deck was replaced in 2002. The existing bridge structure is most likely supported on a combination of shallow and deep foundations. The East Abutment and Pier 4 are likely supported by shallow foundations placed on bedrock. The West Abutment and Piers 1, 2, and 3 are likely supported by deep foundations. Highway 11 at the Kabinakagami River area is generally higher than the surrounding lands. It is built on shallow embankments with wide gravel shoulders.

The Ministry of Transportation (MTO) planned to replace the existing bridge structure at the Kabinakagami River with a new bridge structure. The new structure is planned to be constructed to the south of the existing structure and includes the construction of a permanent realignment of Highway 11. It was reported that the new bridge would be a three span (30 m - 41 m -30 m) bridge constructed with pre-cast pre-stresses concrete girders and a reinforced concrete deck. Finished grade at the East and West Abutments would be at Elevations of approximately 249 m and 247.7 m, respectively. It is understood that the new bridge was planned to be supported by a combination of shallow and deep foundations. The East Abutment and East Pier of the replacement bridge structure was designed be founded on spread footings resting on the underlying bedrock, while the West Abutment and West Pier would be supported on piles driven to bedrock. The underside of the pile caps at the West Abutment and West Pier would be at Elevations of approximately 240.5 m and 236.8 m, respectively. The underside of the footings for the East Abutment and East Pier were designed to be at Elevations of approximately 241.4 m and 236.0 m, respectively.

The bridge was designed and constructed based on the results of geotechnical investigations at the site performed by Jacques Whitford Ltd. in 2007.

It was reported that the realigned highway would be approximately 1.3 km in total length and extend from Sta. 22+900 to Sta. 24+200. The realigned section would be approximately 10 m wide and would likely be constructed on shallow embankments. The embankment at the East Abutment would be approximately 3 m to 3.5 m high, and the embankment at the West Abutment would be approximately 4 m to 4.5 m high.

In 2008 the construction of the new bridge was in progress. However, in November 2008, during construction of the West Abutment, the cofferdam failed and the construction was delayed.

After the failure, in December 2008, the Contractor commissioned additional borehole investigations by Terraprobe and based on the results, contended that the borehole soil data shown in the Contract Documents was significantly different than what was actually encountered in the site during the sheet pile and H-pile installation. The Contractor claimed that the existing soil conditions had contributed to problems encountered during the cofferdam installation and to its failure.

To verify the subsurface conditions and clarify discrepancies, MTO engaged Trow Associates Inc. (Trow) to perform additional geotechnical investigations in the vicinity of the failed cofferdam, results of which are presented in this report. The boreholes were strategically located around the West Abutment cofferdam, close to the previously drilled boreholes to facilitate comparison and to provide good coverage of the area.

### **2.2.2 MTO Supplied Information**

The Ministry of Transportation (MTO) provided the results of the geotechnical investigations performed at the site of the West Abutment cofferdam for the Kabinakagami River Bridge replacement by Jacques Whitford in 2007, before the cofferdam failure and Terraprobe in 2008, after the cofferdam failure. The complete Foundation Investigation and Design Report of Jacques Whitford dated January 15, 2008 and the borehole logs of Terraprobe were provided. MTO also provided the shoring details for construction of the West Pier and West Abutment cofferdams designed by Terraprobe Design Ltd. (i.e. Terraprobe Dwgs Job 9-08-3018-1; Sheet No. SH1, SH2 and SH3, Revision No. 9 dated from September 15, 2008 and stamped by Terraprobe's professional engineers on August 24, 2008; and Sheet No. SH3 Revision No. 11 dated from September 15, 2008 and stamped by Terraprobe's professional engineers on December 03, 2008). MTO also made available documentation pertaining to the Contractor's soil condition claim such as a letter provided by Tulloch Engineering, the Contract Administrator, dated April 30, 2009; a letter provided by LEA Consulting Ltd. and Jacques Whitford Stantec Ltd. dated May 08, 2009; and a Memorandum provided by MTO dated May 19, 2009.

It is understood that shoring and cofferdams for the abutments and piers of the new Kabinakagami River Bridge were designed by Terraprobe based on the results of geotechnical investigations at the site performed by Jacques Whitford in 2007. According to shoring details for construction of the West Abutment (Terraprobe Dwgs – Job 9-08-3018-1, Sheet No. SH1, SH2 and SH3), the cofferdam was 15.5 m long by 7.4 m wide. The top of the cofferdam was designed to be at Elevation of approximately 244.6 m. The sheet piles as parts of the cofferdam were design to be embedded into the soil up to the Elevation of approximately 237.0 m. The excavation level inside the cofferdam was planned to be completed at Elevation of 239.5 m. The Elevation of the existing

ground was approximately 243.6 m, while the groundwater level was estimated to Elevation 243.0 m. The shoring drawing Sheet No. SH3, Revision No. 9, dated from September 15, 2008 and stamped by Terraprobe's professional engineers on August 24, 2008, shows the design of the cofferdam with only one top strut (waler), while Sheet No. SH3, Revision No. 11, dated from September 15, 2008 and stamped by Terraprobe's professional engineers on December 03, 2008, shows the design of cofferdam with two struts, top and bottom struts.

As mentioned above, during construction of the West Abutment the cofferdam failed. A chronological order of cofferdam failure events was reported by Tulloch Engineering in their letter dated April 30, 2009. This record is presented below:

*“October 24, 2008 - Miller's sub-contractor commenced with installation of the sheet piling for the West Abutment cofferdam. During this time, the West Pier cofferdam was being de-watered and excavated to the required elevation for the tremie plug. It is noted that Miller's order of operations were contrary to what was described for the shoring drawings, whereas the lower waler was to be installed and excavation to the bottom was proceed at 0.5 m intervals.*

*October 29, 2008 – The West Abutment cofferdam was completed and the excavation commenced within the cofferdam. It is noted that only one top waler was installed which was according to the shoring drawings.*

*October 30, 2008 – The excavation of the West Abutment cofferdam was completed. The cross bracing for support of the walls was installed and welded into place.*

*October 31, 2008 – It was noticed in the morning that the bottom material in the northwest corner of the West Abutment cofferdam rose slightly. The material visually consisted of grayish saturated clay with a sponge effect when walked on. The H-pile installation within the West Abutment cofferdam commenced this day.*

*November 1, 2008 – It was observed that the walls of the West Abutment were showing an inward movement, especially near the bottom. Miller's sub-contractor decided to install a second waler closer to the bottom of the cofferdam.*

*November 2, 2008 – Distress in the soils (cracking and sinkholes) were observed within adjacent limits surrounding the cofferdam. Miller's site foreman elected to suspend operations at the West Abutment until further notice.*

*November 4, 2008 – Ministry of Labour was on-site and issued a stop-work order for entire west side. Jacques Whitford representative was also on-site to assess soil conditions.*

*November 25 and 26, 2008 – Remedial work performed to brace the cofferdams. The item work of installing the H-piles at the West Abutment commenced this day.”*

## **2.3 Site Stratigraphy**

The detailed stratigraphy of the site is shown on five cross-section soil profiles attached in Appendix B. As can be seen, the subsurface conditions encountered at the site are variable in spatial and vertical directions, which is common in a fluvial soil deposit due to random depositional processes in a river vicinity.

The stratigraphy of the area around the failed cofferdam generally consisted of several units of loose to compact sandy and silty soils and soft to firm, low plastic silty clay overlaying a dense glacial till. It was reported by Jacques Whitford that the bedrock was encountered at Elevations in the range of approximately 220.9 m and 226.7 m.

Groundwater information obtained during drilling and measuring the water levels in the open boreholes after completion of drilling, and by piezometers, suggested that two significant groundwater permeable units encountered on the site: (i) an upper, shallow water bearing stratum located beneath the ground surface in the sandy fills and loose upper silt, and (ii) a lower, deep water bearing stratum located beneath the low-permeable silty clay. The groundwater monitoring program showed that the groundwater levels in the upper (shallow) water bearing unit at the west side of the cofferdam measured in the piezometers were at Elevations in range of approximately 242.4 m to 242.6 m at the time of this investigation, while the groundwater levels in this water bearing unit at the east side of the cofferdam (the river side) measured in the open boreholes were at elevations between 240.7 m and 240.9 m. The groundwater elevations measured in the lower (deep) water bearing unit were around 241.7 m. At the time of the investigation (July 1, 2009), the water level in the Kabinakagami River was approximately 240.4 m.

## **2.4 Comparison of Geotechnical Investigation Results**

### **2.4.1 Discussion of Investigation Results**

Comparisons of the soil conditions at the defined locations of the West Abutment cofferdam as investigated by Jacques Whitford, Terraprobe and Trow were performed in this project and the results are presented on Drawings No. 7 and 8, Appendix B. Drawings No. 7 and 8 show subsurface conditions west and east of the cofferdam, respectively. Drawing No. 7 includes information from Trow's Boreholes KB-09-08, KB-09-07, KB-09-06 and KB-09-04, Jacques Whitford's Borehole KB-06-3, and Terraprobe's Boreholes KB-06-5A and KB-06-3A. Drawing No. 8 includes information from Trow's Boreholes KB-09-01, KB-09-02 and KB-09-03, Jacques Whitford's Borehole KB-06-2, and Terraprobe's Boreholes KB-06-4A and KB-06-2A.



As can be seen on Drawing No.7, Appendix B, the results of all geotechnical investigations compared show that loose sandy and silty soils were encountered at the ground surface. A stratum of silty clay was encountered underlying silt and sand materials at the Elevation of approximately 239.5 m in Trow's and Terraprobe's boreholes. However, the reported thickness of this layer is different in these two reports. Trow reported that the thickness of the silty clay layer varied from 0.6 m to 1.5 m (Trow's KB-09-08, KB-09-07, KB-09-06 and KB-09-04), while the thickness of this layer is less in the Terraprobe's borehole logs. It was approximately 0.8 m thick in the area west of the cofferdam (Terraprobe's KB-06-5A and KB-06-3A). The silty clay layer was not identified in the Jacques Whitford's boring (KB-06-3) at that side of the cofferdam.

Undrained shear strengths of the silty clay measured *in-situ* and reported in the geotechnical investigation reports by Jacques Whitford, Terraprobe and Trow were somewhat different. Jacques Whitford noted that the undrained shear strength of 40 kPa was measured in the silty clay layer encountered in Borehole KB-06-2 at Elevation 238.5 m by a field vane test. Terraprobe reported on its borehole logs a range of vane undrained shear strength values between 20 and 36 kPa. This difference in soil strength measured before and one month after the failure could be attributable, at least in part, to soil disturbance during the failure. The *in-situ* measured values of the undrained shear strengths measured by Trow seven months after the failure ranged from 38 kPa to 55 kPa. Trow reported, as well, that the undrained shear strengths of two samples measured in the unconfined compression tests were 35.4 kPa (from KB-09-01 at Elevation 236.4 m) and 31.7 kPa (from KB-09-08 at Elevation 238.2 m).

Similar layers were encountered in Trow's and Terraprobe's boreholes at the south-west corner of the cofferdam. Silt was encountered immediately below the silty clay followed by a layer of sandy silt and sandy silt till at that location. The thicknesses of these layers again do not exactly concur in these two reports.

In Trow's and Terraprobe's borehole logs at the north-west corner of the cofferdam, where the failure occurred, there are some discrepancies. Terraprobe borehole KB-06-3A did not encounter a silty sand and sand deposit which was encountered in Trow's Boreholes KB-09-07, KB-09-06 and KB-09-04 at Elevations between 234.1 m and 232.9 m. At that location the Terraprobe's borehole log described a layer of sandy silt and clayey silt. On the other hand, the Jacques Whitford's Borehole KB-06-3 located between Trow's Boreholes KB-09-07 and KB-09-06 identified the presence of the sand deposit at the same elevation. Below this layer, glacial till was encountered in all boreholes compared.

Drawing No. 8 in Appendix B, shows that sandy and silty soils were encountered at the ground surface of the east side of the cofferdam in all boreholes compared. A stratum of silty clay was encountered underlying silt and sand materials at Elevations in the range of approximately 239.0 m to 238.2 m in all boreholes as well. However, the thickness of this layer was somewhat different in these three reports. Trow reported that the thickness of the silty clay layer in those locations varied from 2.1 m to 2.3 m (in range of

approximate Elevations 239.0 m and 236.1 m; Trow's KB-09-03, KB-09-02, and KB-09-01). In Terraprobe's report the thickness of this layer ranged from 2 m to 3 m (from approximate Elevation 239.0 m to 236.0 m; Terraprobe's KB-06-4A and KB-06-2A), while in Jacques Whitford's report it was reported that the thickness of the silty clay in the south-east corner of the cofferdam was 5.5 m (from approximate Elevation 239.0 m to 233.5 m; Jacques Whitford's KB-06-2).

In all boreholes drilled at the south-east corner of the cofferdam (Jacques Whitford's KB-06-2, Terraprobe's KB-06-4A and Trow's KB-09-03), an approximately 2 to 3 m thick layer of silt was encountered underlying the silty clay. However, some discrepancies in reported soil conditions deeper along the drilled boreholes are evident. For instance, Jacques Whitford's Borehole KB-06-2 did not identify any clayey and/or sandy layer below the silt, while both Trow's KB-09-03 and Terraprobe's KB-06-4A boreholes drilled at the nearby locations identified presence of a 1 to 2 m thick clayey silt layer followed by sandy silt and sand, respectively. Trow's Borehole KB-09-02 drilled approximately 6 m north from KB-09-03 also encountered a sandy layer at the same elevation. It is worthy to note that the identified sandy silt layer in Trow's KB-09-03 contained almost equal amounts of sand and silt sized particles (around 43%), which makes this layer more permeable, comparing with other silt units.

Comparison of two boreholes drilled at the north-east corner of the cofferdam, Trow's KB-09-01 and Terraprobe's KB-06-2A, showed that both soil investigations identified similar soil types along the boreholes except below Elevation 233 m. Below Elevation 233 m, Trow identified a 0.6 m thick clayey silt followed by a 2.4 m thick sandy silt and sandy silt till, while Terraprobe identified only sandy silt till below the silt.

It is noted that the "N" values in Trow's Boreholes KB-09-06 and KB-09-7 for the loose lower silt and sand layers (Elevation approximately between 237 m to 233 m), measured after the cofferdam failure, were somewhat lower than those measured in Jacques Whitford's Borehole KB-06-3 before the failure. This observation can be explained by possible disturbance of the area and/or inherent variability in SPT testing.

It should be noted that a deep water bearing stratum located at approximate Elevation 235 m below the low-permeable silty clay, was encountered at the site (see Subsection 1.4.13). Trow installed two piezometers into the deep water bearing stratum to monitor groundwater levels below the low-permeable silty clay layer, while three piezometers were installed, as well, to monitor groundwater levels above the low-permeable silty clay layer. The deep piezometers measured a hydraulic pressure head of about 6.3 m, corresponding to Elevation of 241.7 m. The shallow piezometers measured a hydraulic pressure of about 3.1 m, corresponding to Elevation 242.6 m. Jacques Whitford and Terraprobe did not report the installations of piezometers or standpipes. Jacques Whitford identified ground water levels based on the split spoon sampler during drilling. Details of Terraprobe's ground water records are limited to notes on their Borehole logs.



## 2.4.2 Summary of Deviations

The following assessments are made following a review of pertinent documentation of subsurface conditions as developed by Jacques Whitford, Terraprobe and Trow:

- The site is undertaken by complex/variable deposits reflective of the geological setting. Variations in composition occur over relative short distances both horizontally and vertically (refer to typical sections attached Drawings No. 2 to 6, Appendix B).
- The documentation of subsurface stratigraphies illustrated discrepancies among the reports/records presented by Jacques Whitford, Terraprobe and Trow. These discrepancies are highlighted on the attached Drawings No. 7 and 8, Appendix B. On these drawings, records from Jacques Whitford and Terraprobe are superimposed on pertinent stratigraphic profiles developed from information obtained by Trow. Key discrepancies are:
  - (a) Jacques Whitford did not identify the silt clay layer in their KB-06-3 near the north-west corner of the cofferdam near Elevation 239 m. This layer was identified by Terraprobe and Trow, although thickness and levels differ slightly (refer Drawing No. 7, Appendix B).
  - (b) Jacques Whitford identified a thicker layer of silty clay extending to below Elevation 234 m in the south-east corner. Terraprobe and Trow borings in the vicinity identified the material below Elevation 237 m as silt (refer to Drawing No. 8, Appendix B).
  - (c) Terraprobe did not identify a thin layer of sand near Elevation 234 m in their Borehole KB-06-3A (north-west corner), while both Jacques Whitford and Trow documented this layer (refer to Drawing No.7, Appendix B).
  - (d) Trow identified two water bearing strata separated by the low-permeable silty clay layer (an upper and lower water bearing strata) with possible different groundwater regimes. Both Jacques Withford and Terraprobe reported only one water bearing stratum.

In making the above comparisons, it is important to note that the information provided by Jacques Whitford, was developed as part of the foundation investigation for the bridge replacement structure where the typical number of boreholes and sampling intervals normally undertaken for such investigations would be the expected standard of care. Both Terraprobe and Trow undertook their respective investigation programs after a failure event (i.e. in a forensic mode). Accordingly, these test programs would be expected to be more detailed, with more attention geared to specific differentiation.

## 2.5 Assessment of Original Terraprobe Cofferdam Design

An assessment of the original cofferdam design carried out by Terraprobe on behalf of the Contractor, which was based on the conditions reported by Jacques Whitford, was performed in this report. Stability analyses related to kick-out at the toe of the sheetpiling wall, basal stability analyses (piping and heave) and liquefaction potential analyses, were completed for the original cofferdam design. The shoring system design provided by Terraprobe includes sheet piles extending to a depth of 7.6 m (Elevation 237 m) with a strut at Elevation 243.6 m, i.e., 1m below the top of sheetpiling wall (the shoring details for construction of the West Pier and West Abutment cofferdams, Sheet No. SH3, designed by Terraprobe Design Ltd., dated on September 15, 2008).

### 2.5.1 Stability Analyses

The stability analyses related to kick-out at the toe of the sheetpiling wall consider two cases to account for the natural variability of soil strata over the site. *Case 1* and *Case 2* are chosen to represent two typical soil strata at the north-west corner and at the south-east corner of the cofferdam, according to Jacques Whitford's borehole logs.

- *Case 1* - The deposit soil consists of silt, according to Jacques Whitford's KB-06-3. Within *Case 1* two sub-cases, *Case 1a* and *Case 1b* were distinguished. *Case 1a* considers the Elevation of ground surface of 244.1 m reported on KB-06-3 by Jacques Whitford, while *Case 1b* takes into account the average Elevation of ground surface of 243.6 m identified on Terraprobe's shoring drawing, Sheet No. SH3, Cross-section A. In both cases, the ground water level at Elevation 242.6 m was assumed (Jacques Whitford's KB-06-3).
- *Case 2* - The deposit soil consists of silt above the excavation bottom, and silty clay between the excavation bottom and the sheet pile tip, according to the soil strata in Jacques Whitford's KB-06-2. The ground water level at Elevation 242.6 m was assumed (Jacques Whitford's KB-06-3).

Soil parameters utilized in this analysis include: bulk soil unit weight,  $\gamma$ , effective friction angle for silt,  $\phi'$ , and undrained shear strength for silty clay,  $c_u$ . The unit weights of silt and silty clay were taken as 18 kN/m<sup>3</sup> and 20 kN/m<sup>3</sup>, respectively, according to the Foundation Investigation and Design Report by Jacques Whitford. The effective friction angle for silt was taken as 28 degree as recommended in Jacques Whitford's Geotechnical Report. The note shown on Terraprobe's drawings of design shoring systems suggests that the effective friction angle for silt was taken as 32 degree for their design of sheet piles. The design undrained shear strength for silty clay of 50 kPa was recommended by Jacques Whitford in their Foundation Investigation and Design Report, and that value was considered in these stability analyses. However, the undrained shear strength ranged from 20 kPa to 55 kPa as measured by Terraprobe and Trow afterwards. Considering these variations in the reported soil parameters, a parameter sensitivity study

was performed for this assessment to evaluate the reliability of the stability results with respect to the uncertainty of soil parameters measured from *in-situ* and/or lab tests. In this study, four (4) different effective friction angles for silt (i.e. 25, 28, 32 and 35 degrees) and four (4) different undrained shear strengths for clay (i.e. 20, 30, 40, and 50 kPa) were selected and used in the assessments.

These stability analyses used the approach recommended in the Canadian Foundation Engineering Manual (CFEM) (Chapters 24 and 26, 4<sup>th</sup> Edition). Figures 1, 2 and 3 in Appendix E show the geometry, earth stress distribution, and forces and moment arms for *Case 1a*, *Case 1b* and *Case 2*, respectively.

### *Case 1a*

Figure 1a in Appendix E shows the geometry used for *Case 1a* analyses. From the figure, the excavation is 5.1 m below the top of sheeting (Elevation 244.6 m), the exterior grade is taken as Elevation 244.1 m, the embedment depth of the sheet pile is 2.5 m, and the strut is at a depth of 1.0 m below the top of sheetpiling wall. The exterior groundwater surface is set at Elevation 242.6 m and a surcharge of 12 kPa is applied. The following parameters were used in this analysis:

$$\gamma = 18 \text{ kN} / \text{m}^3$$

$$\phi' = 28^\circ$$

$$c' = 0$$

$$K_a = K'_a = 0.36$$

$$K_p = K'_p = 2.77$$

Figures 1b and 1c, Appendix E, shows schematically stress distributions, and forces and corresponding moment arms about the strut for *Case 1a*, respectively. The calculated forces and moment arms are summarized in Table 2.1.

*Table 2.1 Case 1a - Summary of magnitudes of the forces and moment arms*

| Force           |          | Moment Arm      |        |
|-----------------|----------|-----------------|--------|
| F1              | 2.98 kN  | x <sub>1</sub>  | 0.23 m |
| F2              | 10.83 kN | x <sub>2</sub>  | 0.55 m |
| F3              | 125.2 kN | x <sub>3</sub>  | 4.15 m |
| F4              | 70.89 kN | x <sub>4</sub>  | 5.77 m |
| F <sub>1w</sub> | 47.14 kN | x <sub>1w</sub> | 3.07 m |
| F <sub>2w</sub> | 38.01 kN | x <sub>2w</sub> | 4.93 m |

where  $F_1$ ,  $F_2$ ,  $F_3$ , and  $F_4$  are the effective earth forces acting on the sheet piles, as shown in Figure 1c, Appendix E. The water pressure force acting on the sheet piles is divided into two segments - above and below the excavation bottom - which are represented by  $F_{1w}$  and  $F_{2w}$ , respectively.

The strut force ( $S_1$ ) is calculated by satisfying horizontal force equilibrium:

$$\sum F = F_1 + F_2 + F_3 + F_{1w} + F_{2w} - F_4 - S_1 = 0$$

Solving this equation for  $S_1$ , the strut force is

$$S_1 = 153.3 \text{ kN}$$

A factor of safety (FS) is defined by calculating the ratio of resisting and acting moments.

The resisting moment about the strut is

$$M_r = \sum F \cdot X = F_1 \cdot X_1 + F_4 \cdot X_4 = 410 \text{ kN}\cdot\text{m}$$

The acting/driving moment about the strut is

$$M_d = \sum F \cdot X = F_2 \cdot X_2 + F_3 \cdot X_3 + F_{1w} \cdot X_{1w} + F_{2w} \cdot X_{2w} = 858 \text{ kN}\cdot\text{m}$$

Therefore, the factor of safety for **Case 1a** is

$$FS = \frac{M_r}{M_d} = 0.48$$

### **Case 1b**

Figure 2a in Appendix E shows the geometry used for *Case 1b* analyses. The geometry for *Case 1b* is similar to that for *Case 1a*. The only difference is the elevation of the exterior ground surface grade. In *Case 1b* the exterior ground surface grade is taken as Elevation 243.6 m. The exterior groundwater surface at Elevation 242.6 m and a surcharge of 12 kPa was applied as well. The same soil parameters and procedures used in *Case 1a* were used in the *Case 1b* analysis.

Figures 2b and 2c, Appendix E, shows schematically stress distributions, and forces and corresponding moment arms about the strut for *Case 1b*, respectively. The calculated magnitudes of the forces and moment arms are summarized in Table 2.2.

Table 2.2 Case 1b - Summary of magnitudes of the forces and moment arms

| Force                    |                 | Moment Arm |
|--------------------------|-----------------|------------|
| F1 0 kN                  | x <sub>1</sub>  | 0 m        |
| F2 7.58 kN               | x <sub>2</sub>  | 0.57 m     |
| F3 107.0 kN              | x <sub>3</sub>  | 4.20 m     |
| F4 70.89 kN              | x <sub>4</sub>  | 5.77 m     |
| F <sub>1w</sub> 47.14 kN | x <sub>1w</sub> | 3.07 m     |
| F <sub>2w</sub> 38.01 kN | x <sub>2w</sub> | 4.93 m     |

where F1, F2, F3, and F4 are the effective earth forces acting on the sheet piles, as shown in Figure 2c, Appendix E. Again, the water pressure forces acting on the sheet piles are represented by  $F_{1w}$  and  $F_{2w}$ .

Solving the equation for S1 presented above in Case 1a, the strut force for Case 1b is calculated as

$$S1 = 128.9 \text{ kN}$$

Then, the resisting moment about the strut is

$$M_r = \sum F \cdot X = F1 \cdot X_1 + F4 \cdot X_4 = 409 \text{ kN}\cdot\text{m}$$

The acting/driving moment is

$$M_d = \sum F \cdot X = F2 \cdot X_2 + F3 \cdot X_3 + F_{1w} \cdot X_{1w} + F_{2w} \cdot X_{2w} = 786 \text{ kN}\cdot\text{m}$$

Therefore, the factor of safety for **Case 1b** is

$$FS = \frac{M_r}{M_d} = 0.52$$

## **Case 2**

Figure 3a in Appendix E shows the geometry for Case 2 which is the same as that in Case 1a. Again, the excavation is 5.1 m below the top of sheeting (Elevation 244.6 m), the exterior ground surface grade is taken as Elevation 244.1 m, the embedment depth of the sheet pile is 2.5 m, the strut is at a depth of 1.0 m below the top of sheeting, the exterior groundwater surface is set at Elevation 242.6 m, and a surcharge of 12 kPa is applied.

In this case, a silty clay layer presents between the excavation bottom and the sheet pile tip. The undrained shear strength,  $c_u$ , of this silty clay layer used for the analyses is 50

kPa as recommended by Jacques Whitford. The engineering parameters for the silt layer were kept same as those in *Case 1a*.

The stress distributions on the sheet pile above the excavation bottom are all same as those in *Case 1a*. The stress below the excavation bottom is

$$\sigma_p - \sigma_a = q_p K_p + 2c_u \sqrt{K_p} - (q_a K_a - 2c_u \sqrt{K_a}) = 4c_u - q_a = 105.2 \text{ kPa}$$

where  $q_a$  is the total vertical stress at the excavation bottom level behind excavation face (in the active zone), while  $q_p$  is the total vertical stress at the excavation bottom which is equal zero. Cohesive clay ( $\phi = 0$ ) has  $K_a = K_p = 1$ . Figure 3b, Appendix E, shows the stress distributions in details.

Figure 3c, Appendix E, shows the forces and the corresponding moment arms about the strut level. The magnitudes of the forces and moment arms are summarized in Table 2.3.

*Table 2.3 Case 2 - Summary of magnitudes of the forces and moment arms*

| Force           |           | Moment Arm      |        |
|-----------------|-----------|-----------------|--------|
| F1              | 2.98 kN   | x <sub>1</sub>  | 0.23 m |
| F2              | 10.83 kN  | x <sub>2</sub>  | 0.55 m |
| F3              | 57.86 kN  | x <sub>3</sub>  | 2.68 m |
| F4              | 263.00 kN | x <sub>4</sub>  | 5.35 m |
| F <sub>1w</sub> | 47.14 kN  | x <sub>1w</sub> | 3.07 m |

where F1, F2, F3, and F4 are the earth forces acting on the sheet piles, as shown in Figure 3c, Appendix E. The water pressure force acting on the sheet piles above the excavation bottom is represented by  $F_{1w}$ .

The resisting moment about the strut is

$$M_r = \sum F \cdot X = F1 \cdot X_1 + F4 \cdot X_4 = 1408 \text{ kN*m}$$

The acting/driving moment is

$$M_d = \sum F \cdot X = F2 \cdot X_2 + F3 \cdot X_3 + F_{1w} \cdot X_{1w} = 306 \text{ kN*m}$$

Therefore, the factor of safety for **Case 2** is

$$FS = \frac{M_r}{M_d} = 4.61$$

### **Parameter Sensitivity Study**

The results of this parameter sensitivity study are summarized in Tables 2.4 to 2.5.

*Table 2.4a Case 1a – Results of sensitivity study*

| <i>Case 1a</i>   |      |      |      |      |
|------------------|------|------|------|------|
| $\phi'$ for silt | 25   | 28   | 32   | 35   |
| FS               | 0.40 | 0.48 | 0.62 | 0.75 |

*Table 2.4b Case 1b – Results of sensitivity study*

| <i>Case 1b</i>   |      |      |      |      |
|------------------|------|------|------|------|
| $\phi'$ for silt | 25   | 28   | 32   | 35   |
| FS               | 0.43 | 0.52 | 0.67 | 0.81 |

*Table 2.5a Case 2 - Results of sensitivity study, constant  $\phi'$  for silt= 28 degrees*

| <i>Case 2</i>                 |      |      |      |      |
|-------------------------------|------|------|------|------|
| $\phi'$ for silt              | 28   | 28   | 28   | 28   |
| Cohesion for silty clay (kPa) | 20   | 30   | 40   | 50   |
| FS                            | 0.65 | 1.10 | 2.86 | 4.61 |

*Table 2.5b Case 2 - Results of sensitivity study, constant cohesion for silty clay=30 kPa*

| <i>Case 2</i>                 |      |      |      |      |
|-------------------------------|------|------|------|------|
| $\phi'$ for silt              | 25   | 28   | 32   | 35   |
| Cohesion for silty clay (kPa) | 30   | 30   | 30   | 30   |
| FS                            | 1.04 | 1.10 | 1.20 | 1.27 |

*Table 2.5c Case 2 - Results of sensitivity study, constant cohesion for silty clay=50 kPa*

| <i>Case 2</i>                 |      |      |      |      |
|-------------------------------|------|------|------|------|
| $\phi'$ for silt              | 25   | 28   | 32   | 35   |
| Cohesion for silty clay (kPa) | 50   | 50   | 50   | 50   |
| FS                            | 4.33 | 4.61 | 5.00 | 5.36 |

As can be seen from the tables, the results of the sensitivity analyses suggest that the original cofferdam design for the excavation in the sandy silt (Jacques Whitford's KB-06-3) was not safe with only one strut. The factor of safety for toe kick-out was less than 1.0 in all cases. On the other hand, the factor of safety against sheet pile toe kick-out in the soil deposit consisting of layers of silt and silty clay (Jacques Whitford's KB-06-2) was above 1.0 (if  $c_u \geq 30$  kPa) indicating more favorable soil conditions for sheet pile stability. The results of the analyses show also that the differences in the values of the factor of safety for two different ground surface elevations, Elevation 244.1 m reported by Jacques Whitford (KB-06-3) and Elevation 243.6 m reported by Terraprobe (Shoring Dwg Sheet No. SH3, Cross-section A) are small and do not materially affect the conclusions. However, the lower exterior ground surface grade taken from the shoring drawing is non conservative, and less likely to be the case in practice, noting the recorded ground surface elevations of Terraprobe borings drilled in the area after the failure event.

### 2.5.2 Assessment of Potential for Basal Failure in the Cofferdam

Since excavation for the failed cofferdam was carried out below groundwater levels, instability of the base could potentially result from the differential hydrostatic pressures. Factors which influence these problems are depth of penetration of sheeting, the head of water and the size of the excavation, and these factors are included in most theoretical studies of the flow of water into sheeted excavations. However, these studies were mostly concerned with homogeneous soil conditions, and are, therefore, of limited applicability at this site.

Many case studies (Bridge Pier Excavation, Toronto, Ontario; Bridge Pier Excavation, Ghost River, Ontario; Pumphouse Excavation, N. Toronto, Ontario; etc.)<sup>1</sup> show that the most important factors influencing the stability of the excavation base are the groundwater and detailed soil conditions at the site. For example, the presence of coarse sand layers under excess hydrostatic pressure makes flow in fine material more nearly vertical and generally increases seepage gradients in the fine layer compared to the homogeneous soil condition. It is recommended in practice, that when the fine/coarse layer interface is at a depth below the sheeting tips greater than the width of the excavation, then the case of a homogeneous sand stratum applies. However, as the fine/coarse layer interface approaches the sheeting tips more critical conditions will result and the head necessary to cause piping decreases to a very low value. Where the permeability ratio  $k_t/k_b^2$  is large (more than 10), the critical head sufficient for failure is equivalent to the submerged weight of column of soil between the interface and the bottom of excavation.

As shown on Drawings No. 7 and 8, Attachment B, a stratum of soft to firm, varved, silty clay was identified at the site for the West Abutment of the new Kabinakagami River Bridge by all investigators (Jacques Whitford, Terraprobe and Trow). This stratum was identified by Terraprobe and Trow in all boreholes drilled around the failed cofferdam. As mentioned in Subsection 2.4.1, a 5.5 m thick silty clay layer was reported in Jacques Whitford's KB-06-2 at Elevation from 239.0 m to 233.5 m at the east side of the

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1 Milligan, V. and Lo, K.Y. (1970) Observations on some basal failures in sheeted excavations. Canadian Geotechnical Journal, Vol. 7, No. 2, pp 136-144.

2  $k_t$  and  $k_b$  are hydraulic conductivities of the top and bottom layer, respectively



cofferdam, while no silty clay was identified in KB-06-3 at the west side of the cofferdam. The distance between these two boreholes is approximately 12 m, as shown in Drawing No.1 Appendix B. Assuming Jacques Whitford's records were correct, in Trow's opinion it is reasonable to assume a transition thickness of silty clay layer between these two boreholes, that varies from about 5.5 m (east side) to zero west of the cofferdam. Noting sample intervals, it is possible that a relatively thin layer of silty clay may have been missed during sampling for Borehole KB-06-3.

Trow and Terraprobe identified the stratum of varved, silty clay about 0.6 m (area of the north-west side of the cofferdam) to 3 m (area of the south-east side of the cofferdam) thick underlain by loose silt at the site, which in some cases, contained pervious layers of sand. The thickness of these sandy layers varied from a fraction of a centimeter to 2 m recorded at the north-west side of the cofferdam by Trow. Based on these findings it is reasonable to estimate that the fine/coarse layer interface in the area of the north-west corner of the cofferdam, where the first signs of instability appeared, was at Elevation of approximately 235.4 m. The sheeting tip was at Elevation 237 m. Therefore, a depth below sheeting tips was 1.6 m, which is lower than the width of excavation (~7.4 m). This suggests that method of analyses for potential seepage using a homogeneous sand stratum should not be applied in this case.

In this report foundation basal heave stability in the cofferdam for the West Abutment of the new Kabinakagami River Bridge was reviewed, and potential for a basal failure in the cofferdam was assessed. In the assessment, the two most critical cases were studied to evaluate the potential for a basal failure:

- (i) Excavation in a sandy silt layer ( $k_r \sim 10^{-6}$  m/s; estimated using grain-size data) overlaying a sand layer ( $k_b \sim 10^{-4}$  m/s; estimated using grain-size data) (Jacques Whitford's KB-06-03; see Drawing No. 7) – **Potential for piping in the sandy silt** which is relatively permeable (drained condition)
- (ii) Excavation in a silty clay layer ( $k_r \sim 10^{-9}$  m/s; estimated using grain-size data) overlaying a sand layer ( $k_b \sim 10^{-4}$  m/s; estimated using grain-size data) (see Drawing No.7) – **Potential for basal heave in the silty clay** which is low permeable (undrained condition). This is considered to be the more likely condition based on a review of all subsurface data available.

### 2.5.2.1 Potential for Piping in Sandy Silt Below the Excavation

Figure 2.1 shows the stratigraphy considered to assess the potential for piping in the case the excavation for the cofferdam occurred in a sandy silt layer overlaying a sand layer. The soil condition assumed in this case is that there was not the low permeable silty clay layer in the examined area. The groundwater conditions in the area of the excavation just prior to failure are difficult to determine, so it is assumed that the groundwater level was between Elevation 241.7 m and 242.6 m (reported in all geotechnical reports). The bulk unit weight of native sand and silt,  $\gamma$ , is assumed to be equal to 18 kN/m<sup>3</sup> (from the Foundation Investigation and Design Report by Jacques Whitford).

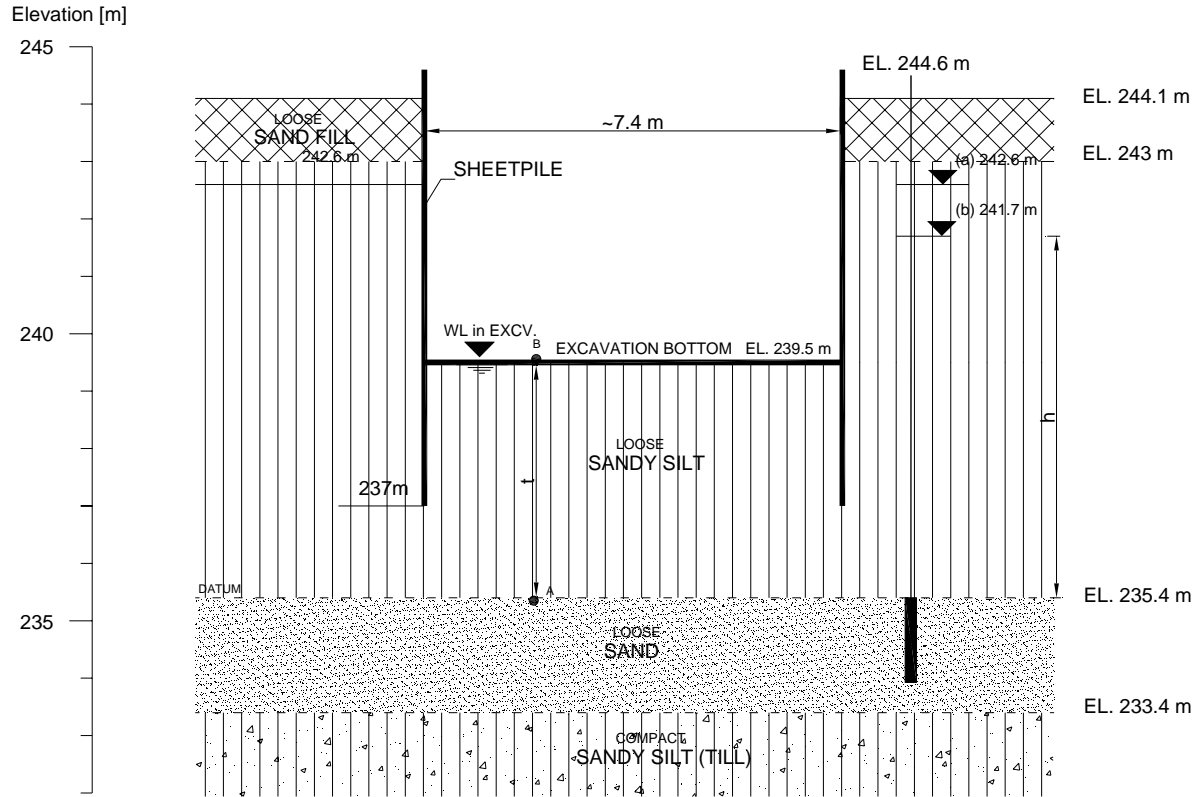


Figure 2.1. Cofferdam excavation in sandy silt overlaying a sand layer (Jacques Whitford's KB-06-3)

Failure due to piping may be expected when the hydraulic gradient becomes close to critical hydraulic gradient,  $i_{cr}$ . Using the relationship below, it was estimated that the  $i_{cr}$  in the sandy silt is approximately 0.84.

$$i_{cr} = \frac{\gamma'}{\gamma_w} = \frac{\gamma - \gamma_w}{\gamma_w} = \frac{18 - 9.81}{9.81} = 0.84$$

The hydraulic gradient,  $i$ , across the sandy silt layer beneath the bottom of the excavation (between points A and B) was estimated by:

$$i = \frac{\Delta h_t}{t} = \frac{h_A - h_B}{t}$$

Factor of safety against piping may be expressed as:

$$FS = \frac{i_{cr}}{i}$$

Table 2.6 presents the summary of the calculation for the potential of piping. As can be seen, the factor of safety against piping for the given hydro-stratigraphic conditions is between 1.12 and 1.5 suggesting the potential for piping failure in the cofferdam. The Canadian Foundation Engineering Manual (CFEM) requires a minimum factor of safety of 1.2 against base instability for basal heave in layered soils which consist of soft to medium stiff cohesive soils and loose sand (CFEM, 4<sup>th</sup> Edition; Section 26.11.1.3; Pg. 411) or/and 1.43 against base heave of layered soils due to water pressures confined by intervening low permeability soils (CFEM, 4<sup>th</sup> Edition; Section 22.3.1.1; Pg. 341). The table also illustrates the sensitivity of the actual groundwater level to the factor of safety.

*Table 2.6. Summary of calculation for assessment of the potential for piping in the sandy silt below the excavation*

| Elevation of Groundwater in Piezometers | Total Hydraulic Head in Point A $h_A$ (m) | Total Hydraulic Head in Point B $h_B$ (m) | Thickness of Sandy Silt Layer $t$ (m) | Hydraulic Gradient $i$ | Critical Hydraulic Gradient $i_{cr}$ | FS   |
|---|---|---|---------------------------------------|------------------------|--------------------------------------|------|
| (a) 242.6 m                             | 7.2                                       | 4.1                                       | 4.1                                   | 0.75                   | 0.84                                 | 1.12 |
| (b) 241.7 m                             | 6.3                                       | 4.1                                       | 4.1                                   | 0.54                   | 0.84                                 | 1.5  |

### 2.5.2.2 Potential for Basal Heave of the Excavation in Silty Clay

Figure 2.2 shows the stratigraphy considered to assess the potential for basal heave of the bottom of the excavation if the cofferdam is excavated in a silty clay layer overlaying loose silt and sand layers. At the site, the silty sand layer was approximately 0.6 to 2.3 m thick. Again, it is assumed that the groundwater level was between Elevation 241.7m and 242.6 m. The bulk unit weight,  $\gamma$ , is assumed to be equal to 18 kN/m<sup>3</sup> for native sand and silt, and 20 kN/m<sup>3</sup> for silty clay (from the Foundation Investigation and Design Report by Jacques Whitford).

For this case it is not recommended to use the critical hydraulic gradient to calculate a factor of safety against basal heave because of the undrained response in this soil. The factor of safety could be estimated as

$$FS = \frac{\text{weight of soil}}{\text{uplift pressure in water bearing soil}} = \frac{\gamma}{\gamma_w h}$$

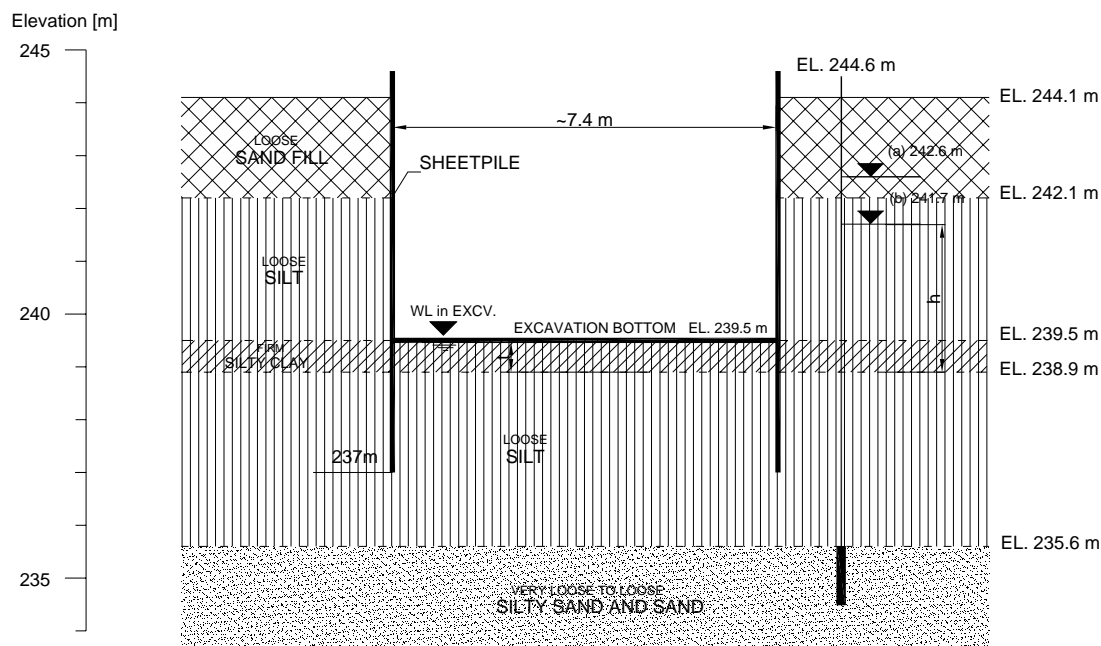


Figure 2.2 Cofferdam excavation in silty clay with lower more permeable silt and sand

Table 2.7 summarizes the results of analyses.

Table 2.7. Summary of calculation for assessment of the potential for basal heave of the excavation in silty clay

| Elevation of Groundwater in Piezometers | Hydraulic Pressure Head Above Bottom of Silty Clay Layer $h$ (m) | Thickness of Silty Clay Layer $t$ (m) | FS   | Minimum Thickness of Silty Clay Layer for FS=1.2 or [1.43]* $t_{min}$ (m) | Maximum Hydraulic Pressure Head Allowable During Excavation for FS=1.2 or [1.43]* $h_{max}$ (m) <sub>r</sub> |
|---|--|---------------------------------------|------|---|--|
| (a) 242.6 m                             | 3.7  | 0.6                                   | 0.33 | 2.2 [2.6]   | 1.0 [0.85]   |
| (b) 241.7 m                             | 2.8  | 0.6                                   | 0.44 | 1.6 [2.0]   | 1.0 [0.85]   |

\* - FS as required in CFEM

The results presented in the table above show that the factor of safety for basal heave is below 1.0 indicating that the 0.6 m thick silty clay layer was not thick enough to prevent basal heave of the excavation (*This is consistent with observations after the failure, refer to records from Tulloch Engineering*). It appears that the thickness of the silty clay layer should be more than 1.6 m (to satisfy the CFEM requirement of  $FS=1.2$  against base instability for basal heave in layered soils which consist of soft to medium stiff cohesive soils and loose sand (CFEM, 4<sup>th</sup> Edition; Section 26.11.1.3; Pg. 411)) or 2.0 m (to satisfy the CFEM requirement of  $FS=1.43$  against base heave of layered soils due to water pressures confined by intervening low permeability soils (CFEM, 4<sup>th</sup> Edition; Section 22.3.1.1; Pg. 341)) to avoid the potential of basal heave. If the silty clay layer below the excavation bottom was 0.6 m thick, the maximum hydraulic pressure head allowable during excavation should not exceed the Elevation of 239.9 m to satisfy the CFEM requirement of  $FS=1.2$  or 239.75 m to satisfy the CFEM requirement of  $FS=1.43$ . To allow safe excavation of the cofferdam, the weight of soil/material at the base should be increased, and/or the level of the hydraulic head in the water bearing soil should be lowered.

It should be observed that the Foundation Investigation and Design Report provided by Jacques Whitford recommended the following measures. It is noted:

*"The design of shoring will need to account for basal heave due to flow of water beneath the sheet piling. Basal heave and seepage should be controlled by extending the shoring below the proposed excavation depth and placing a working mat of concrete, i.e., tremie concrete or a mud mat, at the base of the excavation. Dewatering should be carried out from within the shoring. Should the geometry of the foundations preclude the use of tremie concrete to control groundwater flow, dewatering the excavation with well points could be achieved by installing a second set of sheet piles around the first set and installing the well points between the two sets of sheet piles."*

### 2.5.3 Liquefaction Potential Analysis

Liquefaction in this analysis refers to a sudden loss in strength of soil due to cyclic/vibrational loading effects. The loss arises from a tendency for soil to contract under cyclic/vibrational loading, and such contraction may lead to an increase of excess pore water pressure and decrease of effective stress. As a result, the strength reduces to zero and the soil behaves as a heavy liquid.

As shown in the cross-sections, Appendix B, silty clay and lower silt layers dominate in the passive zone of the cofferdam. Consequently, the liquefaction responses of these two layers are critical for the cofferdam stability. Thus, this liquefaction potential assessment will focus on silty clay and lower silt layers.

Silty clay and lower silt are classified as fine-grained soils. As shown in the grain size distribution analysis, they have a significant portion (over 95%) of fines passing through #200 sieve.

To delineate liquefaction susceptibility of the fine-grained soils, this report adopted the empirical criteria that recommended in the Canadian Foundation Engineering Manual (CFEM, 4<sup>th</sup> Edition; Chapter 6; Pg. 111):

- (1)  $w/w_L \geq 0.85$  and  $I_p \leq 12$ : Susceptible to liquefaction or cyclic mobility
- (2)  $w/w_L \geq 0.80$  and  $12 \leq I_p \leq 20$ : Moderately susceptible to liquefaction
- (3)  $w/w_L < 0.80$  or  $I_p \geq 20$ : No liquefaction or cyclic mobility

Based on the above criteria, two evaluation charts (see Figure 2.3 and 2.4) were made to assess the liquefaction potential of silty clay and lower silt, based on the Atterberg limit tests by Trow. Figure 2.3 shows four (4) data points for silty clay on the liquefaction assessment chart. It can be seen that one data point falls in the liquefaction susceptible zone, one in the non-liquefaction zone, and two in the moderate liquefaction zone. It appears that the silty clay layer is, in general, “moderately susceptible” to liquefaction. Figure 2.4 shows that lower silt is “susceptible” to liquefaction.

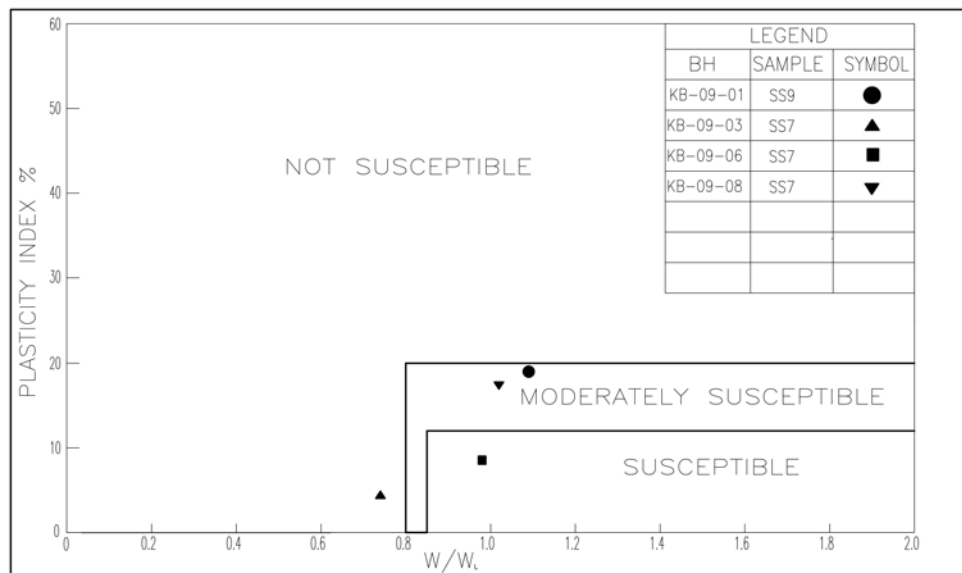


Figure 2.3 Liquefaction assessment on silty clay (data from Trow)

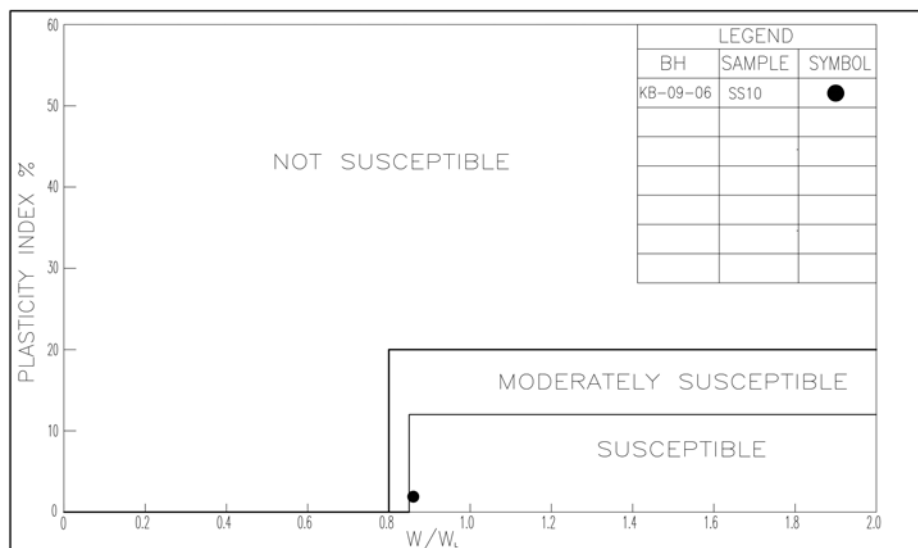


Figure 2.4 Liquefaction assessment on lower silt (data from Trow)

In addition, Figure 2.5 evaluates liquefaction potential of silty clay based on data from Jacques Whitford and Terraprobe, suggesting that silty clay is “moderately susceptible” or “susceptible” to liquefaction. This is consistent with the assessment based on the test results from Trow.

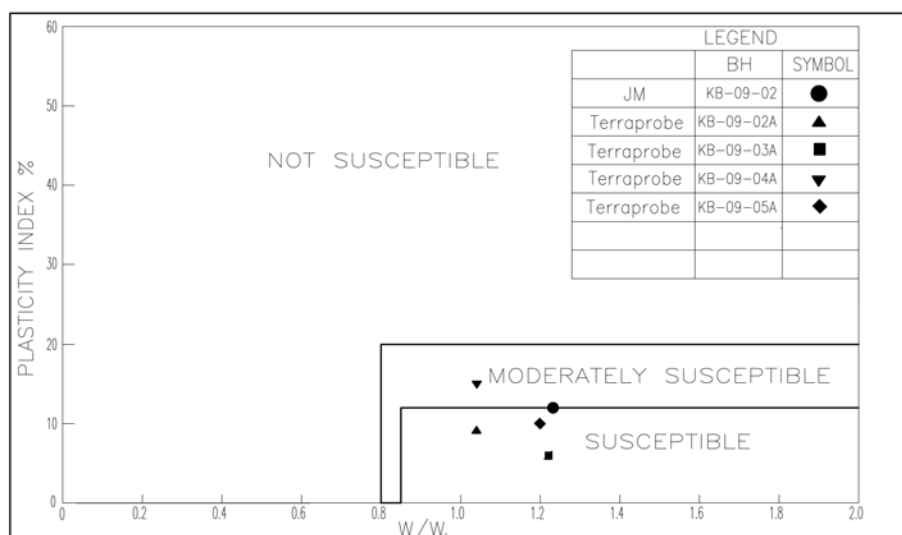


Figure 2.5 Liquefaction assessment on silty clay (data from Jacques Whitford and Terraprobe)

As a conclusion, the silty clay and lower silt are susceptible to liquefaction under vibration loads. Thus, the vibration introduced by the pile-driving might lead to a significant loss of strength in silty clay and lower silt layers. Consequently, the factor of safety of the cofferdam stability could decrease due to pile-driving.

#### **2.5.4 Conclusions**

The available Jacques Whitford's subsurface data provided significant evidence of the complex stratigraphy typical of the geological setting at the site. Notwithstanding any local inconsistencies, it is assumed that the shoring designer would have developed designs to accommodate the worst case condition identified by subsurface information at specific locations (i.e., individual borings) or a reasonable interpretation of the data as it might influence the entire structure. The assessment of the cofferdam design carried out by Terraprobe on behalf of the Contractor, which was based on the conditions reported by Jacques Whitford, shows the following:

- The results of the stability analyses suggest that the original cofferdam designed by Terraprobe and installed in the soil strata reported by Jacques Whitford was not stable with only one top strut.
- The results of stability analyses for piping in sandy silt show that piping failure in the cofferdam is possible in the area of the north-west corner assuming a sandy silt layer overlaying a more permeable sand layer (soil condition in Jacques Whitford's KB-06-3).
- Stability analyses show that the silty clay layer was not thick enough to prevent basal heave of the excavation bottom at the north-west side of the cofferdam.
- Liquefaction potential analysis suggests that both silty clay and lower silt encountered on the site have a potential to liquefaction under vibration loads.
- A cofferdam design with a second level of strut would address the stability issue provided that structural requirements are met. However, the base heave/piping elements will still need to be addressed by suitable groundwater control and/or extending sheeting depth further below the base of excavation.

It is noted from the Contract Drawings prepared by LEA Consulting Ltd. that the Foundation Investigation and Design Report prepared by Jacques Whitford for this project was available for viewing by the Contractor and his Designer.



## **2.6 Review and Assessment of Installation Procedures and Sequences Applied During the Construction**

### **2.6.1 Summary of Installation Procedures and Sequences**

The information on this aspect consists only of the report provided by Tulloch Engineering sections of which are included in Subsection 2.2.2. As outline in Subsection 2.2.2, installation of the sheet piling for the West Abutment cofferdam commenced on October 24, 2008. Excavation within the cofferdam started 5 days after. It is noted that only one top strut (waler) was installed in accordance with the shoring drawings. Based on information provided excavation was taken to final grade at approximately 4.5 m depth within two days. The cross bracing for support of the walls was installed and welded into place. It is not clear whether the bracing was installed as per instructions in the shoring drawings or whether this was completed after excavation to full depth. The latter would infer that the sheeting would have been acting as a cantilever for the full height of excavation for a period of time until the bracing was installed. The next day it was noticed that the base of excavation heaved in the area of the north-west corner. However, the H-pile installation within the West Abutment cofferdam proceeded that day. It was not reported that tremie concrete or a mud mat was placed at the base of the excavation to control seepage, as it was recommended in the Jacques Whitford's Final Geotechnical Report. The day after, it was observed that the wall of the cofferdam moved in towards the excavation at the level of the base. Consequently, it was decided to install a second strut (waler) closer to the bottom of the cofferdam. Distresses in the soils (cracking and sinkholes) were observed within adjacent limits surrounding the cofferdam. No further foundation piles were driven until remedial work was executed to brace the cofferdam.

### **2.6.2 Conclusions**

Considering the installation procedures and sequences applied during construction of the West Abutment cofferdam as reported to Trow, the following issues are deemed relevant:

- It is possible that the Contractor excavated to full depth without installation of any strut support, contrary to the sequence directive in the design shoring drawings. This would add to the potential for cofferdam distress.
- It is not readily apparent from the design drawings what specific seepage or dewatering measures or hydrostatic head control were required for this cofferdam. No measures were instituted by the Contractor.
- It is not apparent whether the Contractor requested Terraprobe representatives to attend the site for field review for this cofferdam in accordance with the Note 'K' of the shoring drawings.

- Trow has not been able to independently verify the actual depth of excavation and length of sheeting installed.

## 2.7 Final Comments and Conclusions

Final comments and conclusions of the assessments performed in this report are listed as follows:

### (A) Soil Discrepancies

The investigation has identified discrepancies in the reported subsurface stratigraphy amongst the submissions from Jacques Whitford, Terraprobe and Trow. These discrepancies are highlighted on the attached Drawings No. 7 and 8 and summarized in Subsections 2.4.2 of this report. Key differences in the information reported by Jacques Whitford and Terraprobe relative to the Trow investigation are as follows:

- (A1) Jacques Whitford did not identify the silty clay layer near Elevation 239 m in the north-west section of the cofferdam (refer to Jacques Whitford's KB-06-3).
- (A2) Jacques Whitford reported a thicker layer of silty clay extending to below elevation 234 m in the south-east corner (refer to Jacques Whitford's KB-06-2).
- (A3) Terraprobe did not identify sand near Elevation 234 m in their Borehole KB-06-3A (north-west corner).
- (A4) Groundwater regime at the site identified was less detailed in the Jacques Whitford and Terraprobe documentations compared to Trow records. Here it is noted that groundwater measurements recorded by Trow were carried out after the installation of the cofferdam.

In making comparisons, it is important to note that the information provided by Jacques Whitford was carried out as part of a foundation investigation for supporting the bridge design with the associated standard of care expected for such assignments. Terraprobe and Trow undertook, in essence, 'forensic' investigations (i.e. after a failure event) where programs would be expected to be more detailed and geared to specific differentiation. Further, the stratigraphic sequences at the site are complex, with vertical and spatial variability over relatively short distances that are typical of the fluvial geologic setting. The nature of the materials in these sequences ranges from low-permeable silty clay to sand with much higher level of permeability. The groundwater level is near grade level and the site is quite close to the river. Standard borings may not fully determine requirements for groundwater control in these layered deposits below the groundwater level. Carefully controlled tests using pumped and observation wells would better defined the complex groundwater regime and yield the quantitative data on groundwater

volumes, pressure and relationships that are necessary to adequately engineer construction dewatering approaches and systems.

### **(B) Suitability of the Original Terraprobe Cofferdam Design**

Assessments of the original subsurface information provided by Jacques Whitford and the cofferdam design proposed for the West Abutment by Terraprobe have yielded the general conclusions listed below. It is assumed that the Terraprobe design would have been developed to accommodate the worst case conditions identified in subsurface data provided by Jacques Whitford and a reasonable interpretation of the specific data as it might impact the entire structure. It is noted that the Foundation Investigation and Design Report was available for viewing.

- (B1) Results of stability analysis undertaken by Trow using the Terraprobe cofferdam design and data supplied by Jacques Whitford indicate that the cofferdam was not stable with an adequate factor of safety when analyzed in accordance with procedures provided in the Canadian Foundation Engineering Manual (CFEM).
- (B2) There are differences in some of the selected design parameters compared with those recommended by Jacques Whitford. Some of these assumptions are less conservative.
- (B3) A cofferdam with two levels of struts would address the stability from toe kick-out provided that the structural requirements in the struts and sheets are met.
- (B4) The base heave/piping elements would need to be addressed by hydraulic pressure relief, control and/or extension of the sheeting below the excavation base.
- (B5) Some susceptibility of the subsoil to liquefaction should have reasonably been anticipated by the Designer and suitable accommodations made in the design and construction.

### **(C) Impact of Installation Procedures and Sequences**

Based on reported construction approach and sequences the following items are considered pertinent:

- (C1) Based on the diary records from Tulloch Engineering, it appears that the excavation was undertaken to full depth prior to installation of the bracing. This would add to the potential for cofferdam distress.

- (C2) The Contractor did not employ any measures for hydraulic pressure relief and seepage control. It is not clear what specific measures, if any, were required by the shoring designer.

In summary, the results of Trow's investigations have identified some material differences in subsurface conditions compared to those reported by Jacques Whitford and used for initial design of the West Abutment cofferdam. In Trow's opinion the design was not adequate for the most critical conditions reported by Jacques Whitford. Further, some recommendations and comments provided in the Jacques Whitford design report appear to have been missed or not accommodated in the design. The level of field review by Terraprobe for this installation is not certain. Some reported installation processes and sequences would exacerbate the situation with respect to cofferdam stability.

Trow has assessed the actual situation for the West Abutment shoring system with a single level of bracing for the worst case scenario based on Trow's boreholes and can conclude:

- The Terraprobe design without positive dewatering would not prevent basal heave.
- The Terraprobe design was not safe for toe kick-out.

In Trow's opinion the failure of the West Abutment cofferdam at the site occurred due to basal heave primarily in its north-west corner followed by toe kick-out. Pile driving would have aggravated the situation due to increase in excess porewater pressure during driving. This is consistent with the site observations.

### 3.0 Closure

This report has been prepared by S. Micic, Ph.D., P.Eng., assisted by G. Qu, Ph.D., and reviewed by S. Gonsalves, M.Eng., P.Eng., Designated MTO Foundation Contact. The field investigation was conducted by E. Farkas.

We trust this report is satisfactory for your purposes. Should you have any questions, please do not hesitate to contact this office.

Yours truly,

**Trow Associates Inc.**



Silvana Micic, Ph.D, P.Eng.  
Geotechnical Engineer



S.E. Gonsalves, M.Eng., P.Eng.  
Principal Engineer  
Designated MTO Foundation Contact



## **APPENDIX A**

### **Photographs**





Photograph 1: Kabinakagami River Bridge.  
On south side of Highway 11, west bank of River, looking east towards the river.  
West side of the failed cofferdam and the formwork for West Abutment.



Photograph 2: Kabinakagami River Bridge.  
On south side of Highway 11, west bank of the river, looking north.  
River bank, east side of the cofferdam.





Photograph 3: Kabinakagami River Bridge.  
On south side of Highway 11, west bank of the river, looking east.  
Piers of the new bridge.



Photograph 4: Kabinakagami River Bridge.  
On south side of Highway 11, west bank of the river.  
Inside the West Abutment cofferdam.

## **APPENDIX B**

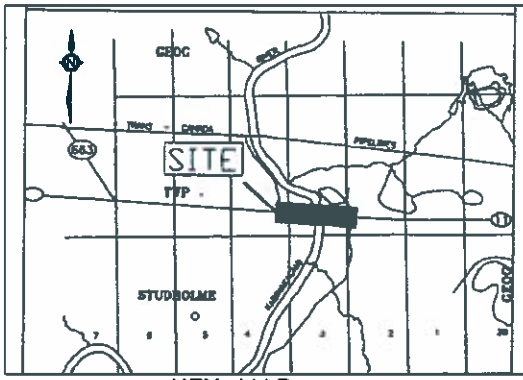
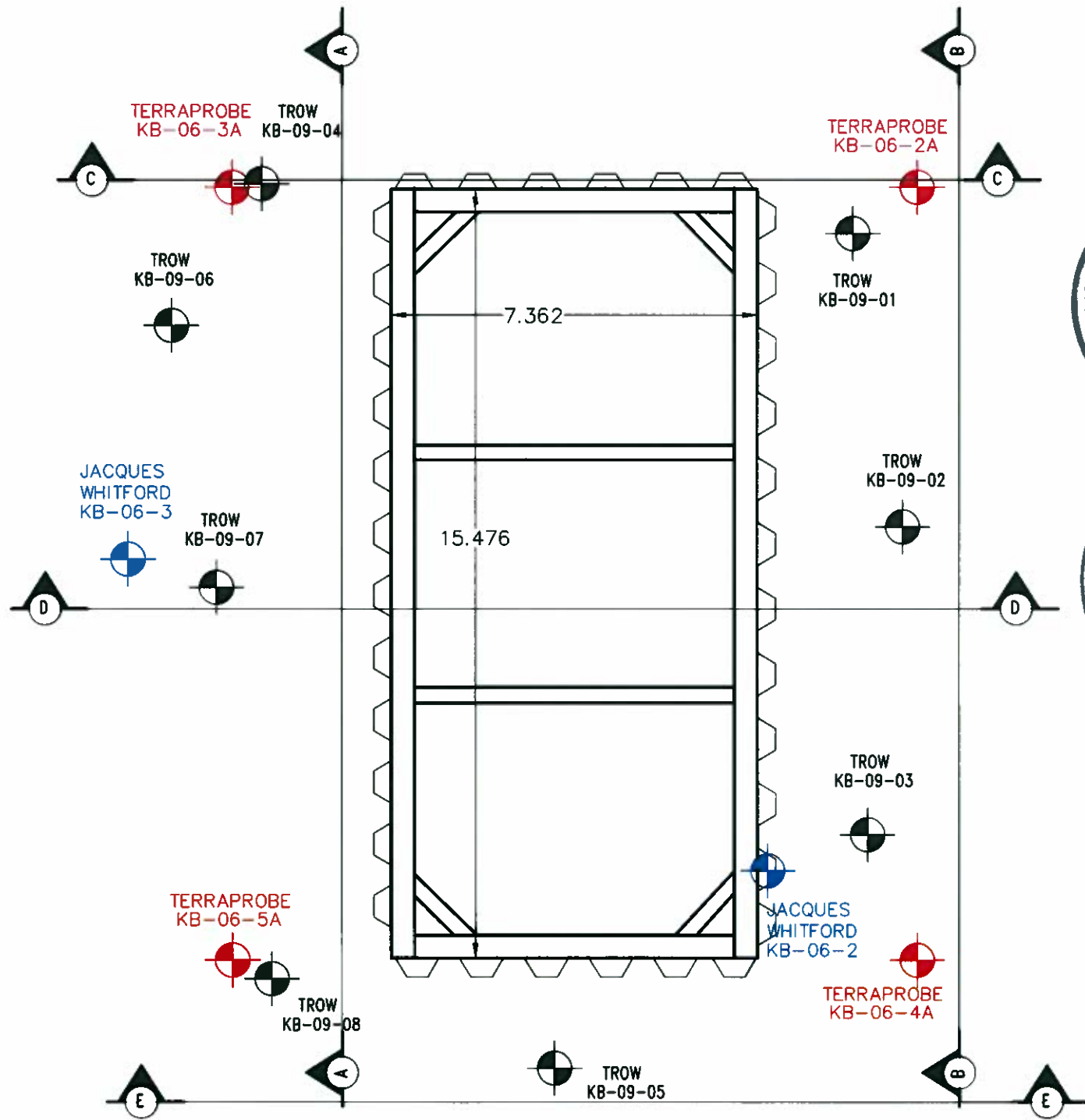
### **Drawings**

DIMENSIONS ARE IN METERS  
AND/OR MILLIMETERS  
UNLESS OTHERWISE SHOWN

GWP No. 5411-04-00  
GEOCRES No. 42F-22

Kabinakagami River  
Bridge - Additional  
Boreholes

SHEET  
1



KEY MAP  
Not to Scale

LEGEND

- Boreholes by JACQUES WHITFORD
- Boreholes by TERRAPROBE
- Boreholes by TROW

-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing to be read with subject report.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration only.
- Borehole locations are approximate.
- Borehole elevations should not be used to design building(s), or floor slab(s), or parking lot(s) grades.
- Cofferdam dimensions are as shown on Sheet SH3. Terroprobe shoring details for construction of the west abutment dated 15/Sept./2008.
- The elevation of the top of the sheetpile presented on the drawing (EL 244.6m) was taken from Terraprobe's design drawing. However, Trow measured this elevation as 243.6m on the site on 29/June/2009.
- Presented soil data from Jacques Whitford and Terroprobe geotechnical investigations are provided by the Ministry of Transportation.

| REVISIONS |    |             |
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| DATE      | BY | DESCRIPTION |
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|           |    |             |
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**Trow Associates Inc.**  
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BRAMPTON, ONTARIO, L6V 4M8  
(905) 796-3200

PROJECT TITLE AND LOCATION:  
Kabinakagami River Bridge-  
Additional Boreholes  
Highway 11, New Liskeard

DRAWING TITLE:  
SITE PLAN AND  
BOREHOLE LOCATIONS

PROJECT NO. SD000391349A  
SCALE: AS NOTED  
DATE: AUGUST 2009  
OWN.: GQ  
CHKD.: SM  
DWG. No.: 1

# SCALE

HORIZONTAL DIRECTION:  
0 2 m 4 m

VERTICAL DIRECTION:  
0 2 m 4 m

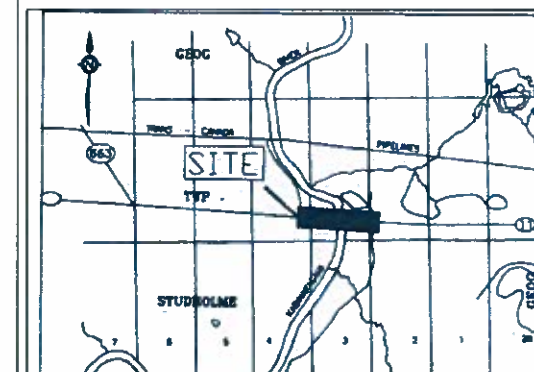


DIMENSIONS ARE IN METERS  
AND/OR MILLIMETERS  
UNLESS OTHERWISE SHOWN

GWP No. 5411-04-00  
GEOCRES No. 42F-22

Kabinakagami River  
Bridge - Additional  
Boreholes

SHEET  
2



KEY MAP  
Not to Scale

## LEGEND

- ◆ Borehole
- 'N' Blow/0.3m
- ▽ Water Level in Open Borehole
- ▽ Water Level in the shallow piezometer
- ▽ Water Level in the deep piezometer

| No.      | ELEV  | No.      | ELEV  |
|----------|-------|----------|-------|
| KB-09-04 | 243.5 | KB-09-08 | 243.1 |
| KB-09-06 | 243.5 |          |       |
| KB-09-07 | 243.5 |          |       |

## NOTES

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| REVISIONS | DATE | BY | DESCRIPTION |
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|           |      |    |             |
|           |      |    |             |
|           |      |    |             |

## SOIL STRATA SYMBOLS:



**Trow Associates Inc.**  
56 QUEEN STREET EAST, SUIT 301  
BRAMPTON, ONTARIO, L6V 4M8  
(905) 796-3200

## PROJECT TITLE AND LOCATION:

Kabinakagami River Bridge-  
Additional Boreholes  
Highway 11, New Liskeard

## DRAWING TITLE:

BOREHOLE LOCATIONS  
AND  
SOIL STRATA

## PROJECT NO.

SD000391349A

## OWN.:

GQ

## SCALE:

AS NOTED

## CHKD.:

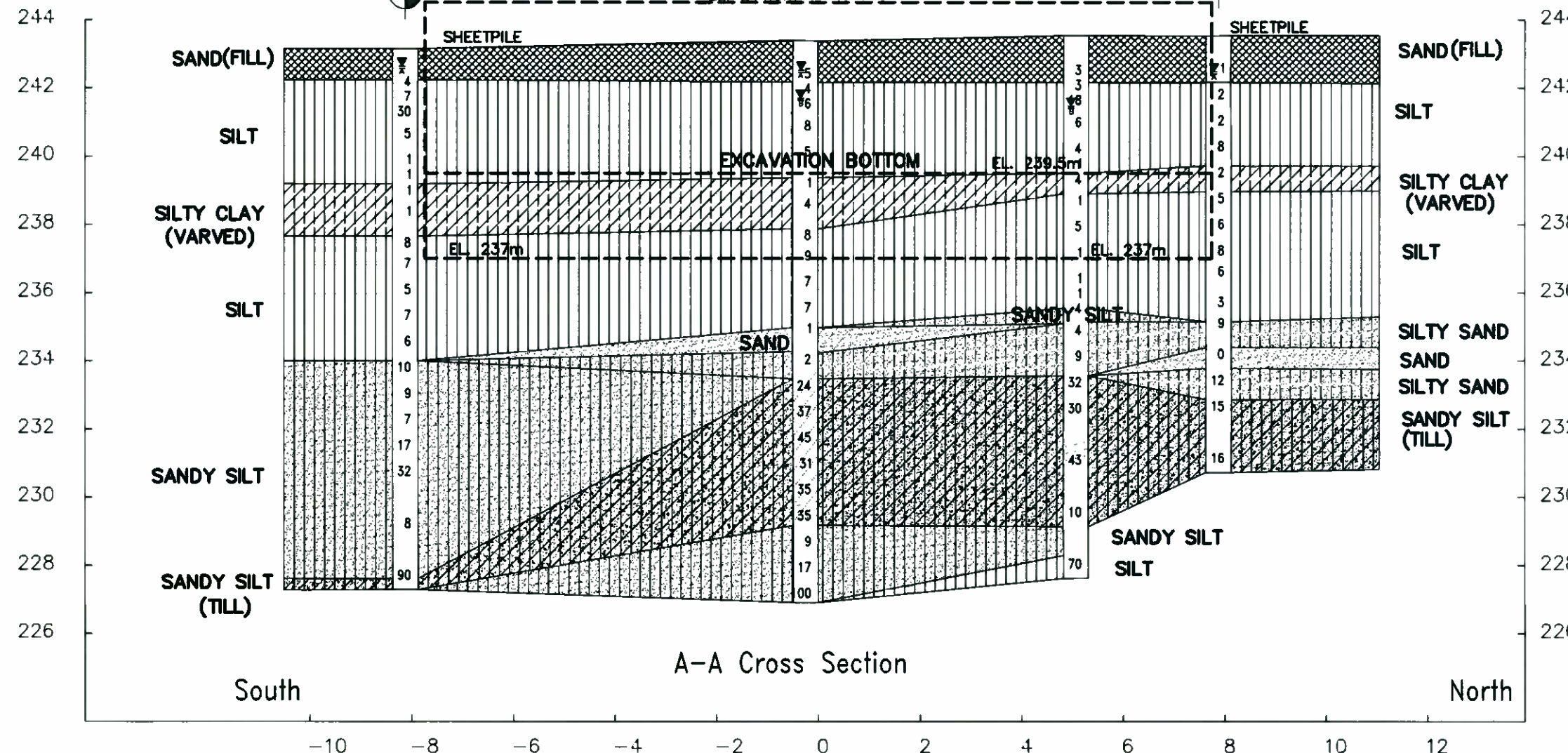
SM

## DATE:

AUGUST 2009

## DWG. No.:

2





SCALE

HORIZONTAL DIRECTION: 0 2 m 4 m  
VERTICAL DIRECTION: 0 2 m 4 m

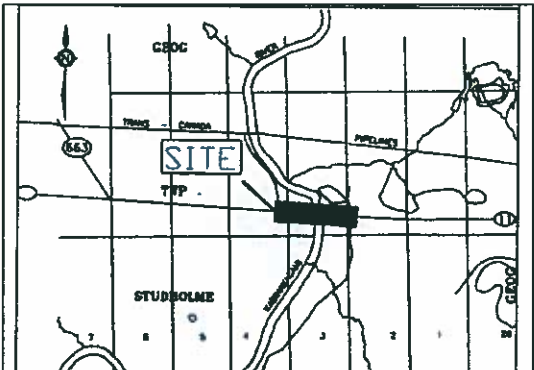
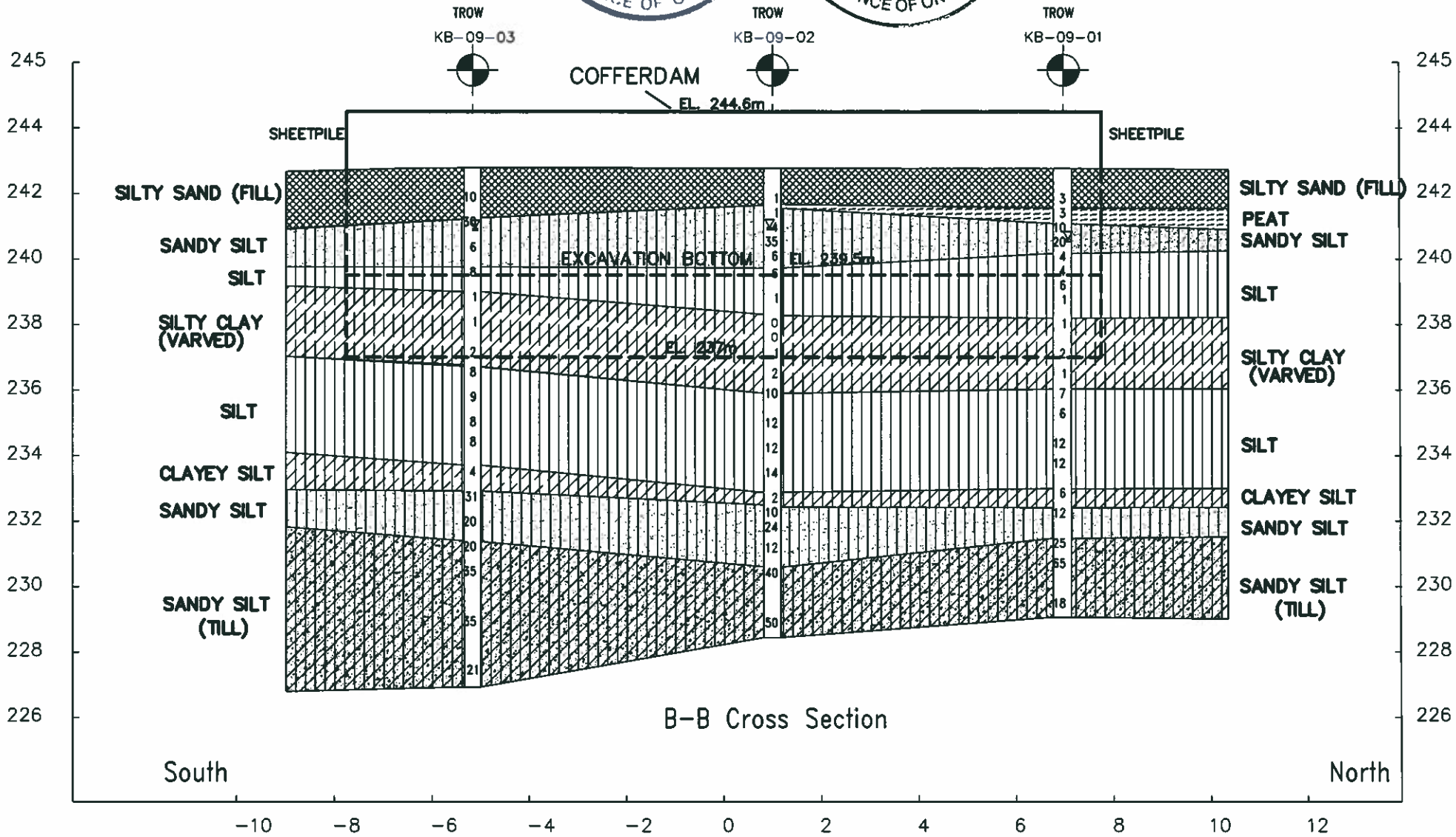


DIMENSIONS ARE IN METERS  
AND/OR MILLIMETERS  
UNLESS OTHERWISE SHOWN

GWP No. 5411-04-00  
GEOCRES No. 42F-22

Kobinakogami River  
Bridge - Additional  
Boreholes

SHEET  
3



KEY MAP  
Not to Scale

LEGEND

- Borehole
- 'N' Blow/0.3m
- Water Level in Open Borehole
- Water Level in the shallow piezometer
- Water Level in the deep piezometer

| No.      | ELEV  | No. | ELEV |
|----------|-------|-----|------|
| KB-09-01 | 242.8 |     |      |
| KB-09-02 | 242.8 |     |      |
| KB-09-03 | 242.8 |     |      |

-NOTES-

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| REVISIONS | DATE | BY | DESCRIPTION |
|-----------|------|----|-------------|
|           |      |    |             |
|           |      |    |             |
|           |      |    |             |

SOIL STRATA SYMBOLS:

- FILL
- SAND
- SANDY SILT
- SILTY CLAY
- SANDY SILT (TILL)
- PEAT
- CLAY
- SILT
- CLAYEY SILT
- SILTY SAND

**Trow Associates Inc.**  
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BRAMPTON, ONTARIO, L6V 4M8  
(905) 796-3200

PROJECT TITLE AND LOCATION:  
Kabinakogami River Bridge-  
Additional Boreholes  
Highway 11, New Liskeard

DRAWING TITLE:  
BOREHOLE LOCATIONS  
AND  
SOIL STRATA

|             |              |           |    |
|-------------|--------------|-----------|----|
| PROJECT NO. | SD000391349A | OWN.:     | GQ |
| SCALE:      | AS NOTED     | CHKD.:    | SM |
| DATE:       | AUGUST 2009  | DWG. No.: | 3  |

# SCALE

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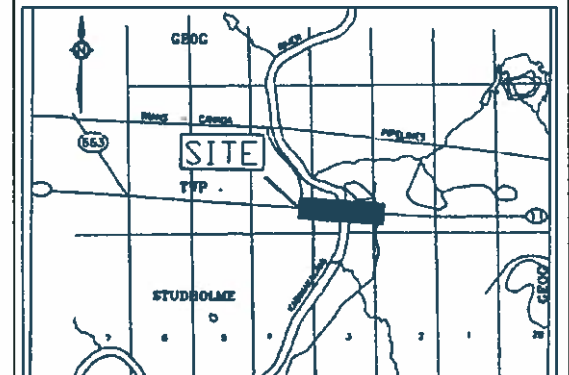
VERTICAL DIRECTION:  
0 2 m 4 m



DIMENSIONS ARE IN METERS  
AND/OR MILLIMETERS  
UNLESS OTHERWISE SHOWN

GWP No. 5411-04-00  
GEOCRES No. 42F-22  
Kabinakagami River  
Bridge - Additional  
Boreholes

SHEET  
4



KEY MAP  
Not to Scale

## LEGEND

- ◆ Borehole
- 'N' Blow/0.3m
- ▽ Water Level in Open Borehole
- ▽ Water Level in the shallow piezometer
- ▽ Water Level in the deep piezometer

| No.      | ELEV   | No. | ELEV |
|----------|--------|-----|------|
| KB-09-04 | 243.5  |     |      |
| KB-09-06 | 243.5  |     |      |
| KB-09-07 | 242.76 |     |      |

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| DATE | BY | DESCRIPTION |
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|      |    |             |
|      |    |             |
|      |    |             |

### SOIL STRATA SYMBOLS:

- FILL
- SAND
- SANDY SILT
- SILTY CLAY
- SANDY SILT (TILL)
- PEAT
- CLAY
- SILT
- CLAYEY SILT
- SILTY SAND

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BRAMPTON, ONTARIO, L6V 4M8  
(905) 796-3200

### PROJECT TITLE AND LOCATION:

Kabinakagami River Bridge-  
Additional Boreholes  
Highway 11, New Liskeard

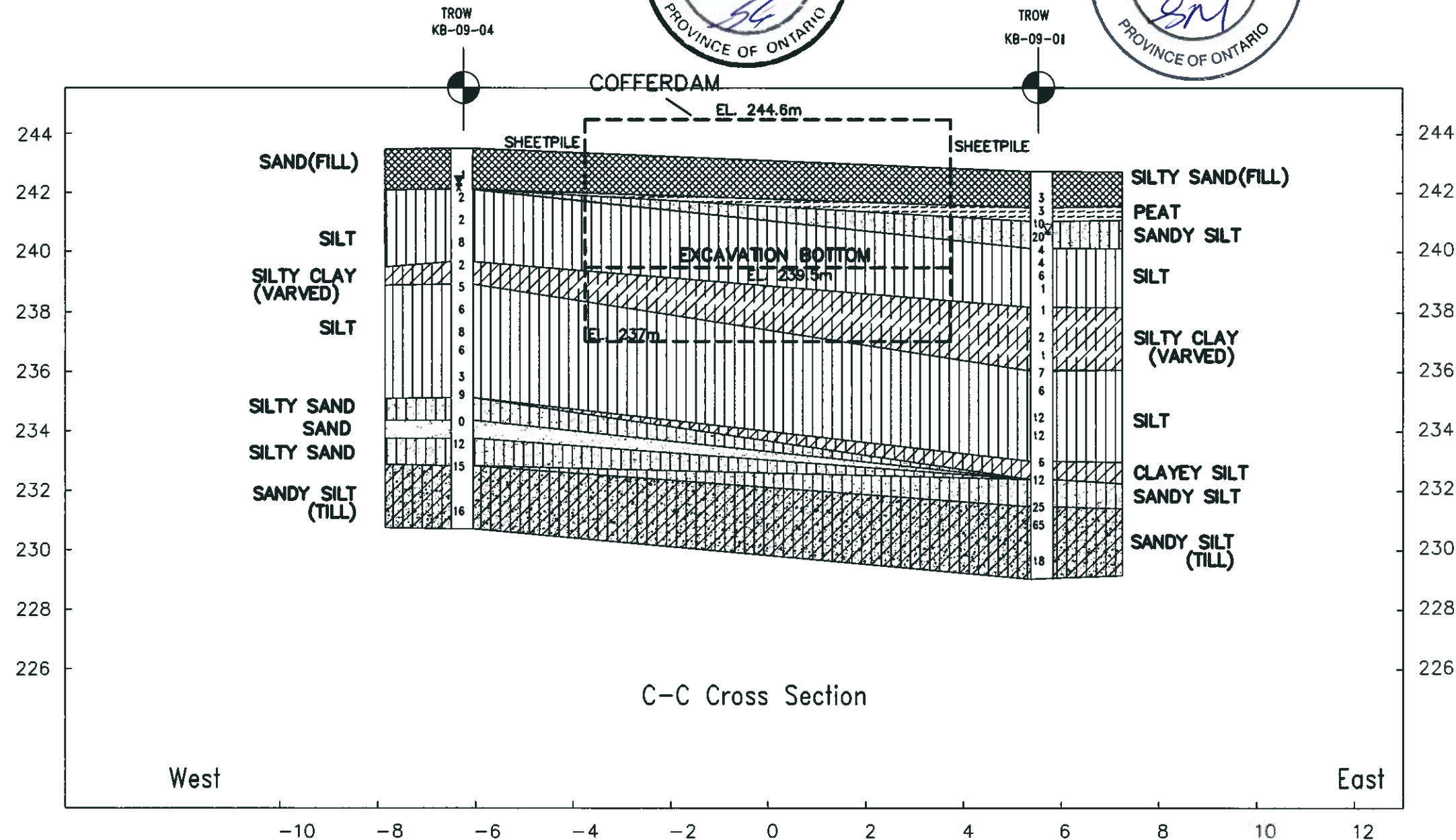
### DRAWING TITLE:

BOREHOLE LOCATIONS  
AND  
SOIL STRATA

### PROJECT NO.

SD000391349A  
SCALE: AS NOTED  
DATE: AUGUST 2009

OWN.: GQ  
CHKD.: SM  
DWG. No.: 4





# SCALE

HORIZONTAL DIRECTION:  
0 2 m 4 m

VERTICAL DIRECTION:  
0 2 m 4 m

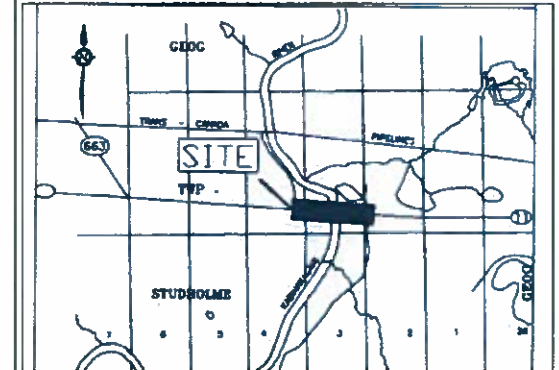


DIMENSIONS ARE IN METERS  
AND/OR MILLIMETERS  
UNLESS OTHERWISE SHOWN

GWP No. 5411-04-00  
GEOCRES No. 42F-22

Kabinakagami River  
Bridge - Additional  
Boreholes

SHEET  
5



KEY MAP  
Not to Scale

## LEGEND

- ◆ Borehole
- 'N' Blow/0.3m
- ▽ Water Level in Open Borehole
- ▲ Water Level in the shallow piezometer
- ▼ Water Level in the deep piezometer

| No.      | ELEV  | No. | ELEV |
|----------|-------|-----|------|
| KB-09-07 | 243.5 |     |      |
| KB-09-02 | 242.8 |     |      |

### -NOTES-

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REVISIONS

| DATE | BY | DESCRIPTION |
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### SOIL STRATA SYMBOLS:

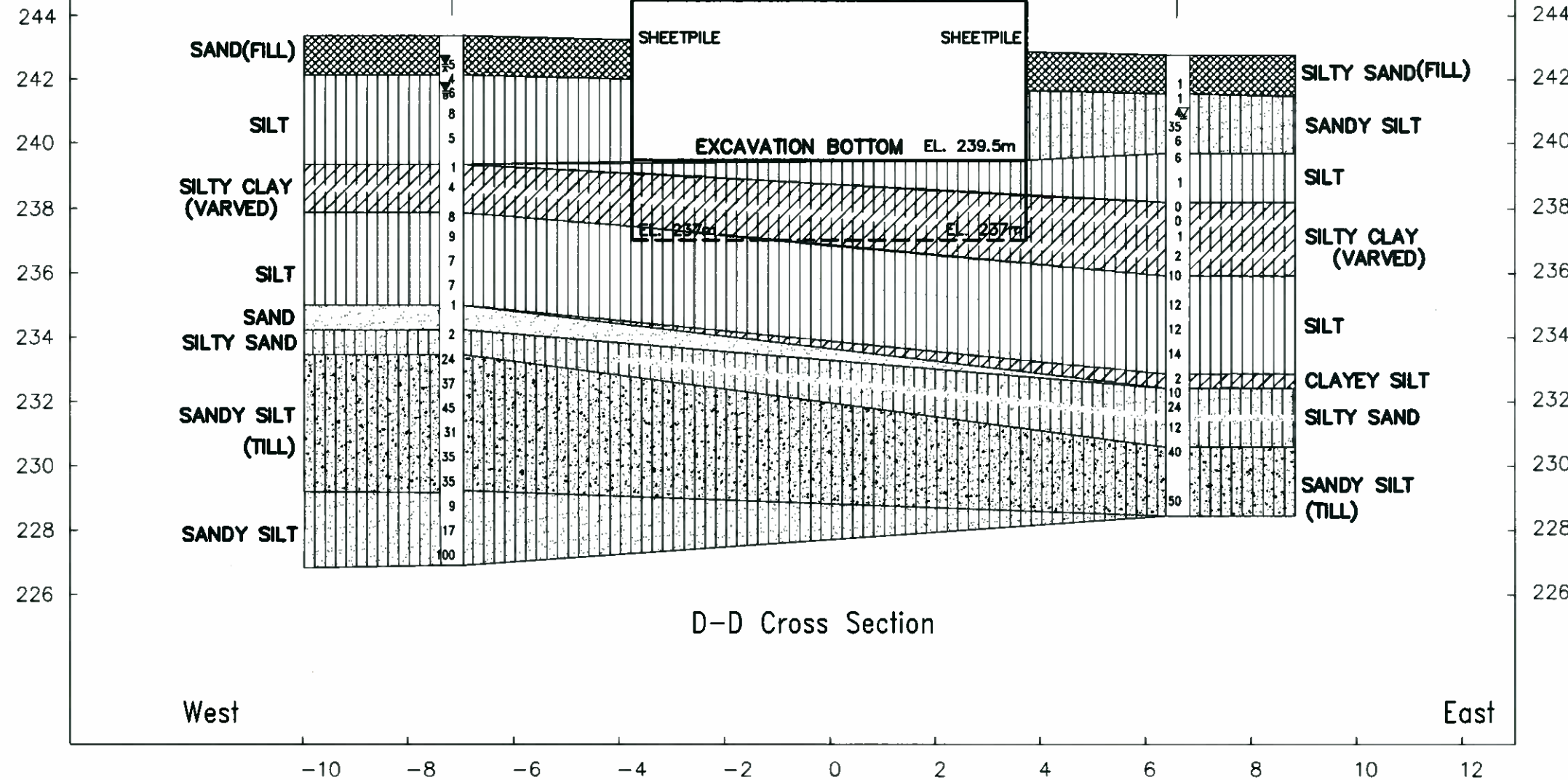
- FILL
- SAND
- SANDY SILT
- SILTY CLAY
- SANDY SILT (TILL)
- PEAT
- CLAY
- SILT
- CLAYEY SILT
- SILTY SAND

**Trow Associates Inc.**  
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BRAMPTON, ONTARIO, L6V 4M8  
(905) 796-3200

PROJECT TITLE AND LOCATION:  
Kabinakagami River Bridge-  
Additional Boreholes  
Highway 11, New Liskeard

DRAWING TITLE:  
BOREHOLE LOCATIONS  
AND  
SOIL STRATA

PROJECT NO. SD000391349A  
SCALE: AS NOTED  
DATE: AUGUST 2009  
DWN.: GQ  
CHKD.: SM  
DWG. No.: 5



D-D Cross Section



# SCALE

HORIZONTAL DIRECTION:  
0 2 m 4 m

VERTICAL DIRECTION:  
0 2 m 4 m

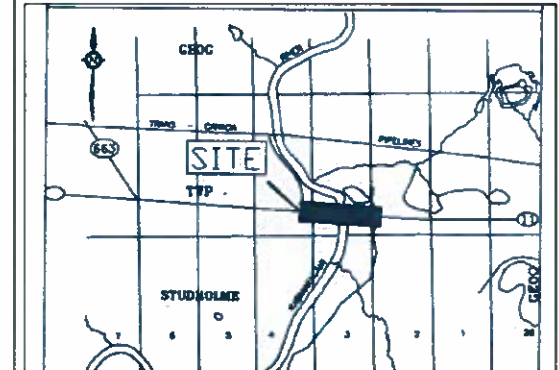


DIMENSIONS ARE IN METERS  
AND/OR MILLIMETERS  
UNLESS OTHERWISE SHOWN

GWP No. 5411-04-00  
GEOCRES No. 42F-22

Kabinakagami River  
Bridge - Additional  
Boreholes

SHEET  
6



KEY MAP  
Not to Scale

## LEGEND

- Borehole
- Blow/0.3m
- Water Level in Open Borehole
- Water Level in the shallow piezometer
- Water Level in the deep piezometer

| No.      | ELEV  | No. | ELEV |
|----------|-------|-----|------|
| KB-09-08 | 243.1 |     |      |
| KB-09-05 | 242.9 |     |      |
| KB-09-03 | 242.8 |     |      |

## NOTES

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REVISIONS

| DATE | BY | DESCRIPTION |
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|      |    |             |
|      |    |             |

## SOIL STRATA SYMBOLS:

|  |      |  |      |  |            |  |             |  |                   |
|--|------|--|------|--|------------|--|-------------|--|-------------------|
|  | FILL |  | SAND |  | SANDY SILT |  | SILTY CLAY  |  | SANDY SILT (TILL) |
|  | PEAT |  | CLAY |  | SILT       |  | CLAYEY SILT |  | SILTY SAND        |

**Trow Associates Inc.**  
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BRAMPTON, ONTARIO, L6V 4M8  
(905) 796-3200

## PROJECT TITLE AND LOCATION:

Kabinakagami River Bridge-  
Additional Boreholes  
Highway 11, New Liskeard

## DRAWING TITLE:

BOREHOLE LOCATIONS  
AND  
SOIL STRATA

## PROJECT NO.

SD000391349A

## OWN.:

GQ

## SCALE:

AS NOTED

## CHKD.:

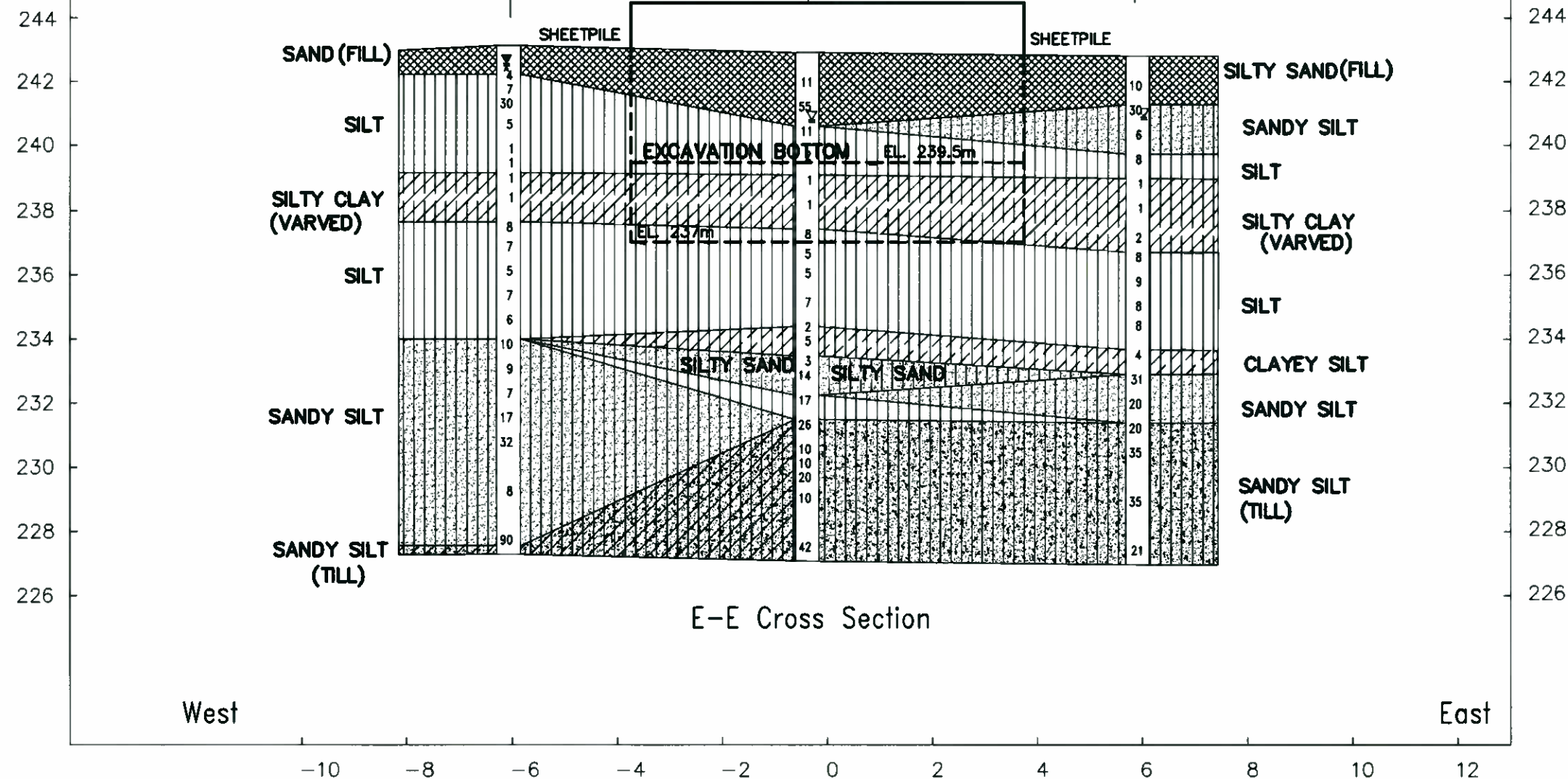
SM

## DATE:

AUGUST 2009

## DWG. No.:

6



E-E Cross Section



# SCALE

HORIZONTAL DIRECTION:  
0 2 m 4 m

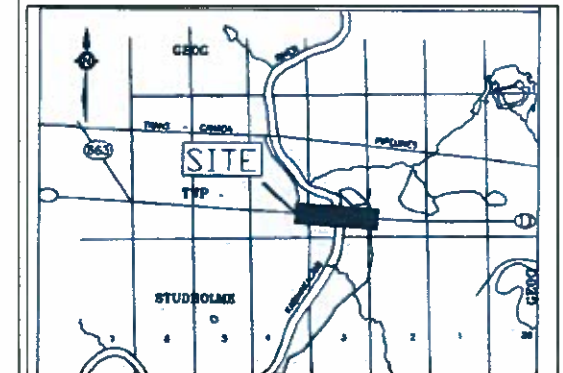
VERTICAL DIRECTION:  
0 2 m 4 m

DIMENSIONS ARE IN METERS  
AND/OR MILLIMETERS  
UNLESS OTHERWISE SHOWN

GWP No. 5411-04-00  
GEOCRES No. 42F-22

Kabinakagami River  
Bridge - Additional  
Boreholes

SHEET  
7



KEY MAP  
Not to Scale

## LEGEND

- ◆ Borehole
- ▽ Water Level from Jacques Whitford
- 'N' Blow/0.3m
- ▽ Water Level from Terraprobe
- ▽ Water Level in Open Borehole
- ▽ Water Level in the shallow piezometer
- ▽ Water Level in the deep piezometer

| No.      | ELEV  | No.      | ELEV  |
|----------|-------|----------|-------|
| KB-09-04 | 243.5 | KB-09-08 | 243.1 |
| KB-09-06 | 243.5 |          |       |
| KB-09-07 | 243.5 |          |       |

## NOTES

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is to be read with subject report.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration only.
- Borehole locations are approximate.
- Borehole elevations should not be used to design building(s), or floor slab(s), or parking lot(s) grades.
- Cofferdam dimensions are as shown on Sheet SH3, Terraprobe shoring details for construction of the west abutment dated 15/Sept./2008.
- The elevation of the top of the sheetpile presented on the drawing (EL. 244.6m) was taken from Terraprobe's design drawing. However, Trow measured this elevation as 243.6m on the site on 29/June/2009.
- Presented soil data from Jacques Whitford and Terraprobe geotechnical investigations are provided by the Ministry of Transportation.

REVISIONS

DATE BY DESCRIPTION

## SOIL STRATA SYMBOLS:

FILL SAND SANDY SILT SILTY CLAY SANDY SILT (TILL)  
 PEAT CLAY SILT CLAYEY SILT SILTY SAND

**Trow Associates Inc.**  
56 QUEEN STREET EAST, SUIT 301  
BRAMPTON, ONTARIO, L6V 4M8  
(905) 796-3200

## PROJECT TITLE AND LOCATION:

Kabinakagami River Bridge-  
Additional Boreholes  
Highway 11, New Liskeard

## DRAWING TITLE:

BOREHOLE LOCATIONS AND  
SOIL STRATA  
WITH INCORPORATED RESULTS FROM JACQUES  
WHITFORD AND TERRAPROBE SOIL  
INVESTIGATIONS

## PROJECT NO.

SD000391349A

## DWN.:

GQ

## SCALE:

AS NOTED

## CHKD.:

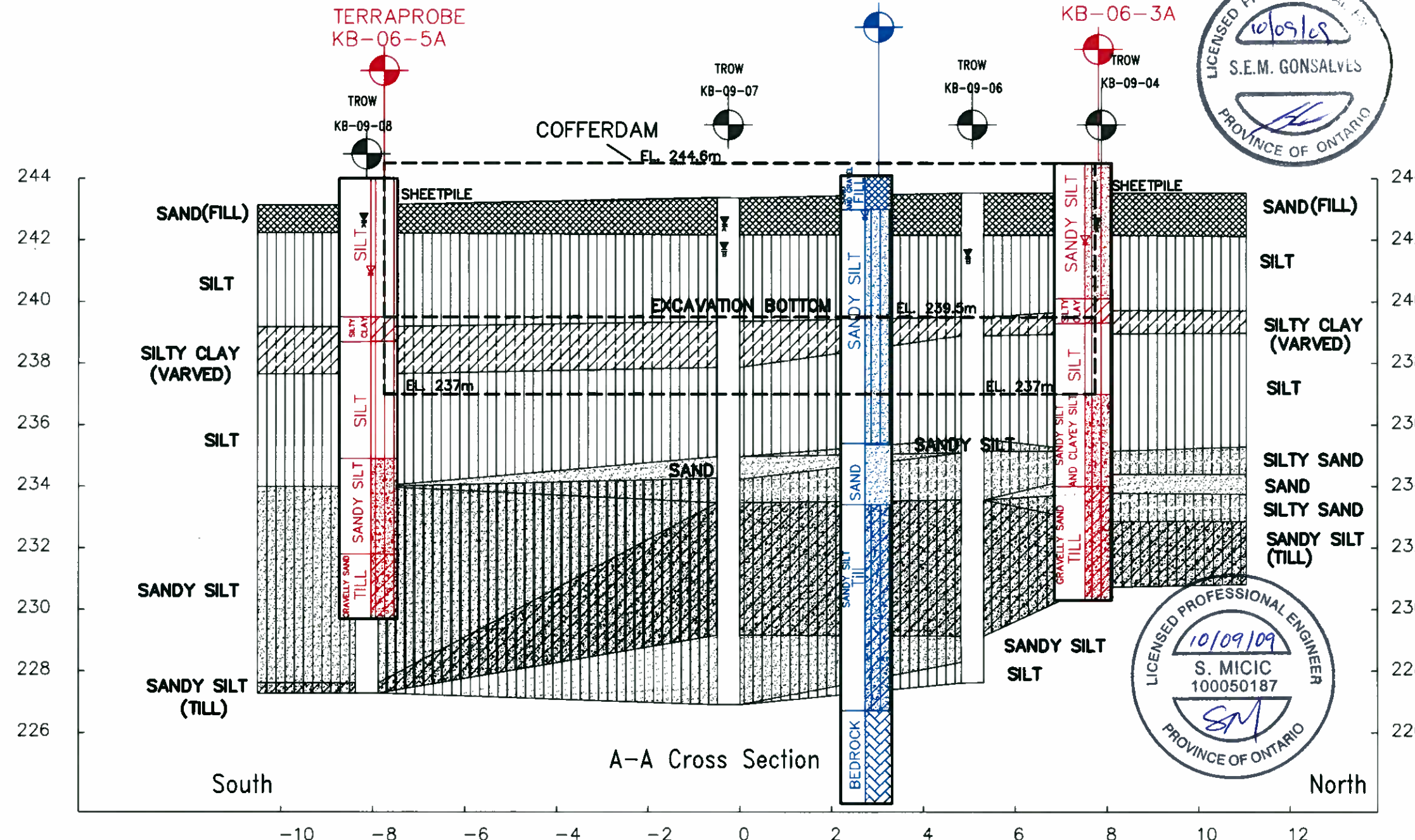
SM

## DATE:

AUGUST 2009

## DWG. No.:

7



A-A Cross Section

South

North

# SCALE

HORIZONTAL DIRECTION: 0 2 m 4 m  
VERTICAL DIRECTION: 0 2 m 4 m

JACQUES  
WHITFORD  
KB-06-2

TERRAPROBE  
KB-06-4A

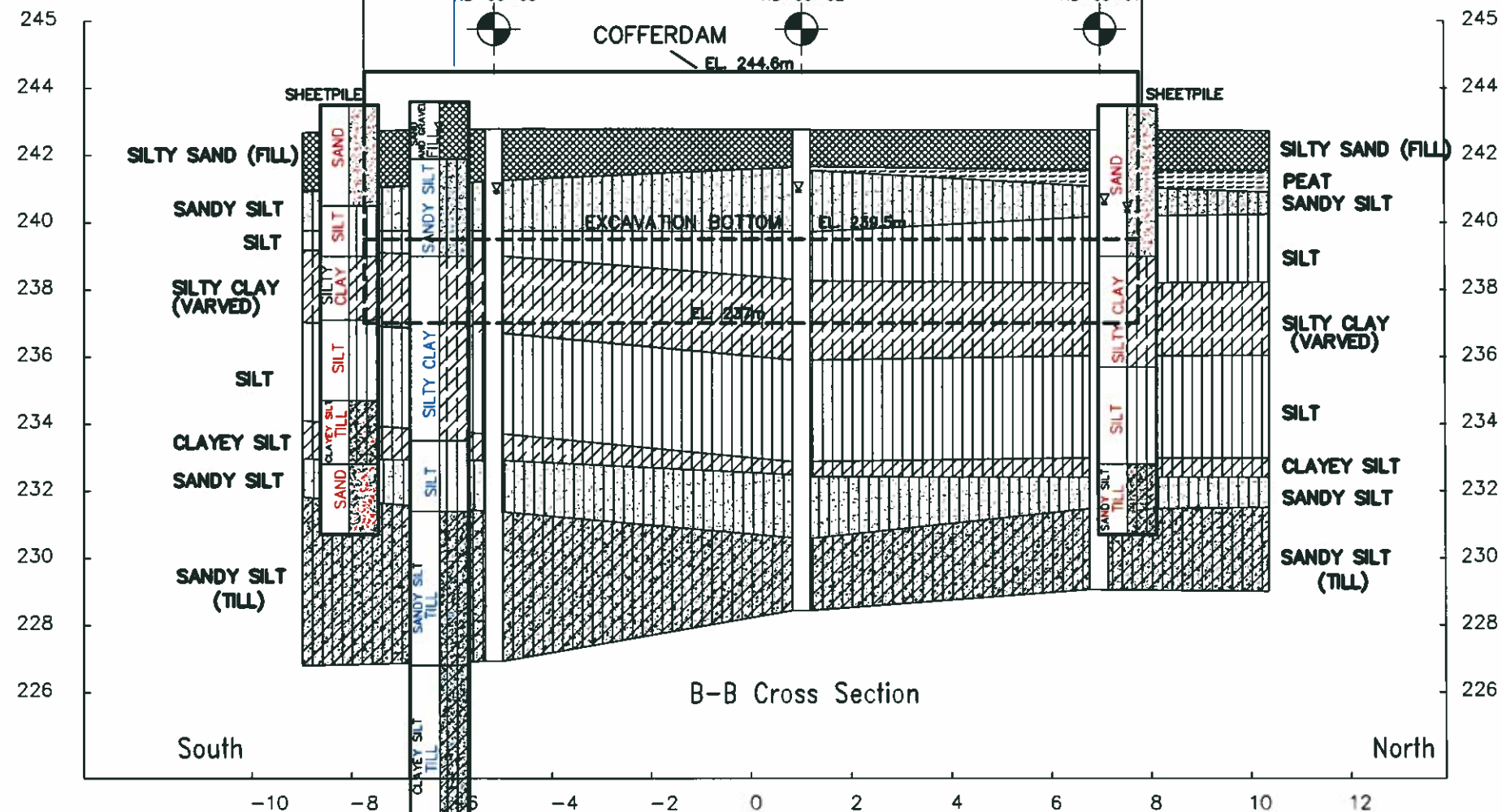
TERRAPROBE  
KB-06-2A

TROW  
KB-09-03

TROW  
KB-09-02

TROW  
KB-09-01

COFFERDAM  
EL. 244.6m



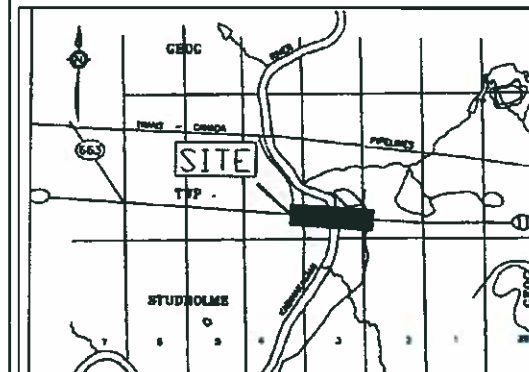
B-B Cross Section

DIMENSIONS ARE IN METERS  
AND/OR MILLIMETERS  
UNLESS OTHERWISE SHOWN

GWP No. 5411-04-00  
GEOCRES No. 42F-22

Kabinakagami River  
Bridge - Additional  
Boreholes

SHEET  
8



KEY MAP  
Not to Scale

## LEGEND

- ◆ Borehole
- ▽ Water Level from Jacques Whitford
- 'N' Blow/0.3m
- ▽ Water Level from Terraprobe
- ▽ Water Level in Open Borehole
- ▽ Water Level in the shallow piezometer
- ▽ Water Level in the deep piezometer

| No.      | ELEV  | No. | ELEV |
|----------|-------|-----|------|
| KB-09-01 | 242.8 |     |      |
| KB-09-02 | 242.8 |     |      |
| KB-09-03 | 242.8 |     |      |

### NOTES

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- This drawing is to be read with subject report.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration only.
- Borehole locations are approximate.
- Borehole elevations should not be used to design building(s), or floor slab(s), or parking lot(s) grades.
- Cofferdam dimensions are as shown on Sheet SH3. Terraprobe shoring details for construction of the west abutment dated 15/Sept./2008.
- The elevation of the top of the sheetpile presented on the drawing (EL. 244.6m) was taken from Terraprobe's design drawing. However, Trow measured this elevation as 243.6m on the site on 29/June/2009.
- Presented soil data from Jacques Whitford and Terraprobe geotechnical investigations are provided by the Ministry of Transportation.

| REVISIONS | DATE | BY | DESCRIPTION |
|-----------|------|----|-------------|
|           |      |    |             |
|           |      |    |             |
|           |      |    |             |

### SOIL STRATA SYMBOLS:

- FILL
- SAND
- SANDY SILT
- SILTY CLAY
- SANDY SILT (TILL)
- PEAT
- CLAY
- SILT
- CLAYEY SILT
- SILTY SAND

**Trow Associates Inc.**  
56 QUEEN STREET EAST, SUIT 301  
BRAMPTON, ONTARIO, L6V 4M8  
(905) 796-3200

PROJECT TITLE AND LOCATION:  
Kabinakagami River Bridge-  
Additional Boreholes  
Highway 11, New Liskeard

DRAWING TITLE:  
BOREHOLE LOCATIONS AND  
SOIL STRATA  
WITH INCORPORATED RESULTS FROM JACQUES  
WHITFORD AND TERRAPROBE SOIL  
INVESTIGATIONS

PROJECT NO. SD000391349A  
SCALE: AS NOTED  
DATE: AUGUST 2009  
DWN.: GQ  
CHKD.: SM  
DWG. No.: 8

## **APPENDIX C**

### **Borehole Logs**



## EXPLANATION OF TERMS USED IN REPORT

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

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

| $C_u$ (kPa) | 0 – 12    | 12 – 25 | 25 – 50 | 50 – 100 | 100 – 200  | >200 |
|-------------|-----------|---------|---------|----------|------------|------|
|             | VERY SOFT | SOFT    | FIRM    | STIFF    | VERY STIFF | HARD |

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

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

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

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

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

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

**JOINT AND BEDDING:**

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

## ABBREVIATIONS AND SYMBOLS

### FIELD SAMPLING

|    |                     |    |                           |
|----|---------------------|----|---------------------------|
| SS | SPLIT SPOON         | TP | THINWALL PISTON           |
| WS | WASH SAMPLE         | OS | OSTERBERG SAMPLE          |
| ST | SLOTTED TUBE SAMPLE | RC | ROCK CORE                 |
| BS | BLOCK SAMPLE        | PH | TW ADVANCED HYDRAULICALLY |
| CS | CHUNK SAMPLE        | PM | TW ADVANCED MANUALLY      |
| TW | THINWALL OPEN       | FS | FOIL SAMPLE               |

### STRESS AND STRAIN

|                                      |     |                               |
|--------------------------------------|-----|-------------------------------|
| $u_w$                                | kPa | PORE WATER PRESSURE           |
| $r_u$                                | 1   | PORE PRESSURE RATIO           |
| $\sigma$                             | kPa | TOTAL NORMAL STRESS           |
| $\sigma'$                            | kPa | EFFECTIVE NORMAL STRESS       |
| $\tau$                               | kPa | SHEAR STRESS                  |
| $\sigma_1, \sigma_2, \sigma_3$       | kPa | PRINCIPAL STRESSES            |
| $\epsilon$                           | %   | LINEAR STRAIN                 |
| $\epsilon_1, \epsilon_2, \epsilon_3$ | %   | PRINCIPAL STRAINS             |
| E                                    | kPa | MODULUS OF LINEAR DEFORMATION |
| G                                    | kPa | MODULUS OF SHEAR DEFORMATION  |
| $\mu$                                | 1   | COEFFICIENT OF FRICTION       |

### MECHANICAL PROPERTIES OF SOIL

|                |                       |                                      |
|----------------|-----------------------|--------------------------------------|
| $m_v$          | $\text{kPa}^{-1}$     | COEFFICIENT OF VOLUME CHANGE         |
| $c_c$          | 1                     | COMPRESSION INDEX                    |
| $c_s$          | 1                     | SWELLING INDEX                       |
| $c_a$          | 1                     | RATE OF SECONDARY CONSOLIDATION      |
| $c_v$          | $\text{m}^2/\text{s}$ | COEFFICIENT OF CONSOLIDATION         |
| H              | m                     | DRAINAGE PATH                        |
| $T_v$          | 1                     | TIME FACTOR                          |
| U              | %                     | DEGREE OF CONSOLIDATION              |
| $\sigma'_{vo}$ | kPa                   | EFFECTIVE OVERBURDEN PRESSURE        |
| $\sigma'_p$    | kPa                   | PRECONSOLIDATION PRESSURE            |
| $\tau_f$       | kPa                   | SHEAR STRENGTH                       |
| $c'$           | kPa                   | EFFECTIVE COHESION INTERCEPT         |
| $\phi'$        | °                     | EFFECTIVE ANGLE OF INTERNAL FRICTION |
| $c_u$          | kPa                   | APPARENT COHESION INTERCEPT          |
| $\phi_u$       | °                     | APPARENT ANGLE OF INTERNAL FRICTION  |
| $\tau_R$       | kPa                   | RESIDUAL SHEAR STRENGTH              |
| $\tau_r$       | kPa                   | REMOULDED SHEAR STRENGTH             |
| $S_i$          | 1                     | SENSITIVITY = $c_u / \tau_r$         |

### PHYSICAL PROPERTIES OF SOIL

|                       |                        |                                |                  |      |                                       |                  |                        |  |
|-----------------------|------------------------|--------------------------------|------------------|------|---------------------------------------|------------------|------------------------|--|
| $P_s$                 | $\text{kg}/\text{m}^3$ | DENSITY OF SOLID PARTICLES     | e                | 1, % | VOID RATIO                            | $e_{\text{min}}$ | 1, %                   | VOID RATIO IN DENSEST STATE  |
| $\gamma_s$            | $\text{kN}/\text{m}^3$ | UNIT WEIGHT OF SOLID PARTICLES | n                | 1, % | POROSITY                              | $I_D$            | 1                      | DENSITY INDEX = $\frac{e_{\text{max}} - e}{e_{\text{max}} - e_{\text{min}}}$ |
| $P_w$                 | $\text{kg}/\text{m}^3$ | DENSITY OF WATER               | w                | 1, % | WATER CONTENT                         | D                | mm                     | GRAIN DIAMETER   |
| $\gamma_w$            | $\text{kN}/\text{m}^3$ | UNIT WEIGHT OF WATER           | $s_r$            | %    | DEGREE OF SATURATION                  | $D_n$            | mm                     | N PERCENT – DIAMETER   |
| $P$                   | $\text{kg}/\text{m}^3$ | DENSITY OF SOIL                | $w_L$            | %    | LIQUID LIMIT                          | $C_u$            | 1                      | UNIFORMITY COEFFICIENT   |
| $\gamma'$             | $\text{kN}/\text{m}^3$ | UNIT WEIGHT OF SOIL            | $w_p$            | %    | PLASTIC LIMIT                         | h                | m                      | HYDRAULIC HEAD OR POTENTIAL  |
| $P_d$                 | $\text{kg}/\text{m}^3$ | DENSITY OF DRY SOIL            | $w_s$            | %    | SHRINKAGE LIMIT                       | q                | $\text{m}^3/\text{s}$  | RATE OF DISCHARGE  |
| $\gamma_d$            | $\text{kN}/\text{m}^3$ | UNIT WEIGHT OF DRY SOIL        | $I_p$            | %    | PLASTICITY INDEX = $(w_L - w_p)$      | v                | $\text{m}/\text{s}$    | DISCHARGE VELOCITY   |
| $P_{\text{sat}}$      | $\text{kg}/\text{m}^3$ | DENSITY OF SATURATED SOIL      | $I_L$            | 1    | LIQUIDITY INDEX = $(w - w_p) / I_p$   | i                | 1                      | HYDRAULIC GRADIENT   |
| $\gamma_{\text{sat}}$ | $\text{kN}/\text{m}^3$ | UNIT WEIGHT OF SATURATED SOIL  | $I_C$            | 1    | CONSISTENCY INDEX = $(w_L - w) / I_p$ | k                | $\text{m}/\text{s}$    | HYDRAULIC CONDUCTIVITY   |
| $P'$                  | $\text{kg}/\text{m}^3$ | DENSITY OF SUBMERGED SOIL      | $e_{\text{max}}$ | 1, % | VOID RATIO IN LOOSEST STATE           | j                | $\text{kN}/\text{m}^2$ | SEEPAGE FORCE  |
| $\gamma'$             | $\text{kN}/\text{m}^3$ | UNIT WEIGHT OF SUBMERGED SOIL  |                  |      |                                       |                  |                        |  |

# RECORD OF BOREHOLE No KB-09-01

1 OF 1

METRIC

W.P. 5411-04-00 LOCATION KABINAKAGAMI RIVER BRIDGE - WEST ABUTMENT ORIGINATED BY E.F.  
 DIST NEW LISK. HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS COMPILED BY D.T.  
 DATUM GEODETIC DATE 09.06.30 - 09.07.01 CHECKED BY D.C./D.G.

| SOIL PROFILE  |  |            | SAMPLES |      |            | GROUND WATER<br>CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |  | PLASTIC LIMIT<br>NATURAL<br>MOISTURE<br>CONTENT<br>LIQUID LIMIT |  | UNIT<br>WEIGHT<br><br>γ<br><br>kN/m³ | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%) |
|---------------|--|------------|---------|------|------------|----------------------------|-----------------|---|--|---|--|--------------------------------------|---|
| ELEV<br>DEPTH | DESCRIPTION  | STRAT PLOT | NUMBER  | TYPE | "N" VALUES |                            |                 | SHEAR STRENGTH kPa                          |  | WATER CONTENT (%)   |  |                                      |   |
|               |  |            |         |      |            |                            |                 | 20 40 60 80 100                             |  | 10 20 30  |  |                                      | GR SA SI CL                                       |
| 242.8         |  |            |         |      |            |                            |                 |   |  |   |  |                                      |   |
| 0.0           | <b>SILTY SAND (FILL)</b> -very loose, brown, moist, with silt, some gravel, trace clay, fuel odours  |            | 1       | AS   |            |                            |                 |   |  |   |  |                                      |   |
| 241.5         |  |            | 2A      | SS   | 3          |                            |                 |   |  |   |  |                                      |   |
| 1.2           |  |            | 2B      | SS   | 3          |                            |                 |   |  |   |  |                                      |   |
| 241.1         | <b>PEAT</b> - frozen, dark brown, roots & rootlets   |            | 3A      | SS   | 10         |                            |                 |   |  |   |  |                                      |   |
| 1.7           | -becoming soft, moist, some silt & fine sand   |            | 3B      | SS   | 20         |                            |                 |   |  |   |  |                                      |   |
| 240.2         | <b>SANDY SILT (ML)</b> - frozen to ~2.2m depth, greyish brown, fine grained, occ. organic  |            | 4A      | SS   | 4          |                            |                 |   |  |   |  |                                      |   |
| 2.6           | <b>SILT (ML)</b> - loose, brown, wet, with very fine sand, occ. organics   |            | 4B      | SS   | 4          |                            |                 |   |  |   |  |                                      |   |
|               | - very loose, grey, wet, some clay, seams of grey clay, trace fine sand  |            | 5       | SS   | 6          |                            |                 |   |  |   |  |                                      | 23 72 5   |
|               |  |            | 6       | SS   | 1          |                            |                 |   |  |   |  |                                      |   |
| 238.2         |  |            |         |      |            |                            |                 |   |  |   |  |                                      |   |
| 4.6           | <b>SILTY CLAY (CL)</b> - firm, grey, wet, occ. seams of silt, trace fine sand  |            | 7       | SS   | 1          |                            |                 |   |  |   |  |                                      |   |
|               |  |            | 8       | VANE |            |                            |                 |   |  |   |  |                                      |   |
|               |  |            | 9       | SS   | 2          |                            |                 |   |  |   |  |                                      | 3 55 42   |
|               |  |            | 10      | TW   |            |                            |                 |   |  |   |  |                                      |   |
| 236.1         |  |            |         |      |            |                            |                 |   |  |   |  |                                      |   |
| 6.7           | <b>SILT (ML)</b> - loose, brown, wet, seam of grey clay, occ. fine sand<br>- becoming loose to compact near bottom   |            | 11      | SS   | 7          |                            |                 |   |  |   |  |                                      |   |
|               |  |            | 12      | SS   | 6          |                            |                 |   |  |   |  |                                      |   |
|               |  |            | 13      | SS   | 12         |                            |                 |   |  |   |  |                                      | 1 89 10   |
|               |  |            | 14      | SS   | 12         |                            |                 |   |  |   |  |                                      |   |
| 233.0         |  |            |         |      |            |                            |                 |   |  |   |  |                                      |   |
| 9.8           | <b>CLAYEY SILT (CL)</b> - firm, brown, moist, trace sand & gravel  |            | 15      | SS   | 6          |                            |                 |   |  |   |  |                                      |   |
| 232.4         | <b>SANDY SILT (ML)</b> - compact, brown, moist, trace gravel   |            | 16      | SS   | 12         |                            |                 |   |  |   |  |                                      | 4 43 45 8   |
| 10.4          |  |            |         |      |            |                            |                 |   |  |   |  |                                      |   |
| 231.5         | <b>SANDY SILT TILL (ML)</b> - compact, grey, moist, trace to some gravel<br>- becoming very dense, trace clay at depth   |            | 17      | SS   | 25         |                            |                 |   |  |   |  |                                      |   |
| 11.3          |  |            | 18      | SS   | 65         |                            |                 |   |  |   |  |                                      |   |
|               |  |            |         |      |            |                            |                 |   |  |   |  |                                      |   |
|               |  |            |         |      |            |                            |                 |   |  |   |  |                                      |   |
|               |  |            | 19      | SS   | 18         |                            |                 |   |  |   |  |                                      |   |
| 229.0         |  |            |         |      |            |                            |                 |   |  |   |  |                                      |   |
| 13.7          | <b>End of Borehole (Auger Refusal)</b>   |            |         |      |            |                            |                 |   |  |   |  |                                      |   |
|               | <b>NOTES:</b><br>1. This drawing is to be read with the subject report and project number as presented above.<br>2. Interpretation assistance by Trow is required before use by others.<br>3. BH caved to 3.0m depth.<br>4. Date of W.L.=July 1/09.<br>5. About 0.6m rockfill removed prior to drilling.<br>6. Borehole is plugged by bentonite. |            |         |      |            |                            |                 |   |  |   |  |                                      |   |

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ONL\_MOT\_09143A-KABINAKAGAMI BRIDE V6 PWP.GPJ ON\_MOT.GDT 09/08/14

# RECORD OF BOREHOLE No KB-09-02

1 OF 1

METRIC

W.P. 5411-04-00 LOCATION KABINAKAGAMI RIVER BRIDGE - WEST ABUTMENT ORIGINATED BY E.F.  
 DIST NEW LISK. HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS COMPILED BY D.T.  
 DATUM GEODETIC DATE 09.06.29 - 09.06.30 CHECKED BY D.C./D.G.

| SOIL PROFILE  |  |            | SAMPLES |      |            | GROUND WATER<br>CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT              |  |  |  |  | PLASTIC NATURAL LIQUID<br>LIMIT MOISTURE CONTENT LIMIT |  |  | UNIT<br>WEIGHT<br>$\gamma$<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%)<br>GR SA SI CL |
|---------------|--|------------|---------|------|------------|----------------------------|-----------------|--|--|--|--|--|--|--|--|---|--|
| ELEV<br>DEPTH | DESCRIPTION  | STRAT PLOT | NUMBER  | TYPE | "N" VALUES |                            |                 | SHEAR STRENGTH kPa                                       |  |  |  |  | WATER CONTENT (%)                                      |  |  |   |  |
|               |  |            |         |      |            |                            |                 | ○ UNCONFINED + FIELD VANE<br>● QUICK TRIAXIAL x LAB VANE |  |  |  |  | w <sub>p</sub> w w <sub>L</sub>                        |  |  |   |  |
|               |  |            |         |      |            |                            |                 | 20 40 60 80 100  |  |  |  |  |  |  |  |   |  |
| 242.8         |  |            |         |      |            |                            |                 |  |  |  |  |  |  |  |  |   |  |
| 0.0           | <b>SILTY SAND (FILL)</b> - loose, brown, moist, some gravel, with silt, some wood, occ. cobble, fuel odour   |            | 1       | AS   |            |                            | 242             |  |  |  |  |  |  |  |  |   |  |
| 241.7         |  |            | 2A      | SS   | 1          |                            |                 |  |  |  |  |  |  |  |  |   |  |
| 241.6         | <b>PEAT</b> - dark brown, frozen   |            | 2B      | SS   | 1          |                            |                 |  |  |  |  |  |  |  |  |   |  |
| 1.2           | <b>SANDY SILT (ML)</b> - frozen, brown, some oxidation, fine grained, trace peat   |            | 2C      | SS   | 4          |                            |                 |  |  |  |  |  |  |  |  |   |  |
|               | - loose, wet from 2.3m depth   |            | 3       | SS   | 35         |                            | 241             |  |  |  |  |  |  |  |  |   |  |
|               |  |            | 4       | SS   | 6          |                            | 240             |  |  |  |  |  |  |  |  |   |  |
| 239.7         |  |            |         |      |            |                            |                 |  |  |  |  |  |  |  |  |   |  |
| 3.1           | <b>SILT (ML)</b> - loose, brown, wet, some oxidation, marbling, trace fine sand  |            | 5       | SS   | 6          |                            | 239             |  |  |  |  |  |  |  |  |   |  |
|               | - becoming very loose, grey, some interbedded grey clay from 3.8m depth  |            | 6       | SS   | 1          |                            |                 |  |  |  |  |  |  |  |  |   |  |
| 238.2         |  |            |         |      |            |                            | 238             |  |  |  |  |  |  |  |  |   |  |
| 4.6           | <b>SILTY CLAY (CL-ML)</b> - firm, grey, wet  |            | 7A      | SS   | 0          |                            |                 |  |  |  |  |  |  |  |  |   |  |
| 237.7         | <b>SILT</b> - very loose, grey, wet, occ. seam of grey clay  |            | 7B      | SS   | 0          |                            |                 |  |  |  |  |  |  |  |  |   |  |
| 5.0           |  |            | 8       | VANE |            |                            |                 | 1.75   |  |  |  |  |  |  |  |   |  |
| 237.1         |  |            |         |      |            |                            | 237             |  |  |  |  |  |  |  |  |   |  |
| 5.6           | <b>SILTY CLAY (CL-ML)</b> - firm, grey, wet, occ. pebble   |            | 9       | SS   | 1          |                            |                 |  |  |  |  |  |  |  |  |   |  |
| 236.7         |  |            |         |      |            |                            | 236             |  |  |  |  |  |  |  |  |   |  |
| 6.1           | <b>SILTY CLAY / SILT</b> - firm brown silty clay, loose wet silt, interbedded  |            | 10      | SS   | 2          |                            |                 |  |  |  |  |  |  |  |  |   |  |
| 235.9         |  |            |         |      |            |                            | 235             |  |  |  |  |  |  |  |  |   |  |
| 6.9           | <b>SILT (ML)</b> - loose to compact, brown, wet, seam of grey clay   |            | 11      | SS   | 10         |                            |                 |  |  |  |  |  |  |  |  |   |  |
|               |  |            | 12      | SS   | 12         |                            | 234             |  |  |  |  |  |  |  |  |   |  |
|               |  |            | 13      | SS   | 12         |                            |                 |  |  |  |  |  |  |  |  |   |  |
|               |  |            | 14      | SS   | 14         |                            | 233             |  |  |  |  |  |  |  |  |   |  |
| 232.9         |  |            |         |      |            |                            |                 |  |  |  |  |  |  |  |  |   |  |
| 9.9           | <b>CLAYEY SILT (CL)</b> - soft to stiff, brown, moist, trace sand & gravel   |            | 15A     | SS   | 2          |                            | 232             |  |  |  |  |  |  |  |  |   |  |
| 232.4         |  |            | 15B     | SS   | 10         |                            |                 |  |  |  |  |  |  |  |  |   |  |
| 10.4          | <b>SILTY SAND (SM)</b> - compact, grey, wet, with silt, trace gravel, fine to med. grained (See Note 5)  |            | 16      | SS   | 24         |                            | 231             |  |  |  |  |  |  |  |  |   |  |
|               |  |            | 17      | SS   | 12         |                            |                 |  |  |  |  |  |  |  |  |   |  |
| 230.6         |  |            | 18      | AS   |            |                            | 230             |  |  |  |  |  |  |  |  |   |  |
| 12.2          | <b>SANDY SILT TILL (ML)</b> - dense, grey, moist, trace to some gravel, trace clay   |            | 19      | SS   | 40         |                            |                 |  |  |  |  |  |  |  |  |   |  |
|               | - dense to very dense from 12.8m depth   |            |         |      |            |                            | 229             |  |  |  |  |  |  |  |  |   |  |
| 228.4         |  |            | 20      | SS   | 50         |                            |                 |  |  |  |  |  |  |  |  |   |  |
| 14.3          | <b>End of Borehole</b>   |            |         |      |            |                            |                 |  |  |  |  |  |  |  |  |   |  |
|               | <b>NOTES:</b><br>1. This drawing is to be read with the subject report and project number as presented above.<br>2. Interpretation assistance by Trow is required before use by others.<br>3. BH caved to 2.0m depth<br>4. Date of W.L.=June 30/09.<br>5. Blow up of sand (~0.3m) and water (~4m) inside augers at depth of about 11.5m.<br>6. About 0.6m rockfill removed prior to drilling.<br>7. Borehole is plugged by bentonite |            |         |      |            |                            |                 |  |  |  |  |  |  |  |  |   |  |

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ONL\_MOT\_09143A-KABINAKAGAMI BRIDE V6 PWP.GPJ ON\_MOT.GDT 09/08/14



# RECORD OF BOREHOLE No KB-09-03

1 OF 1

METRIC

W.P. 5411-04-00 LOCATION KABINAKAGAMI RIVER BRIDGE - WEST ABUTMENT ORIGINATED BY E.F.  
 DIST NEW LISK. HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS COMPILED BY D.T.  
 DATUM GEODETIC DATE 09.06.28 - 09.06.29 CHECKED BY D.C./D.G.

| SOIL PROFILE  |  |            | SAMPLES |      |            | GROUND WATER<br>CONDITIONS | ELEVATION<br>SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |  | PLASTIC<br>LIMIT<br>W <sub>p</sub> | NATURAL<br>MOISTURE<br>CONTENT<br>W | LIQUID<br>LIMIT<br>W <sub>L</sub> | UNIT<br>WEIGHT<br>γ | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%) |
|---|--|------------|---------|------|------------|----------------------------|--------------------|---|--|------------------------------------|-------------------------------------|-----------------------------------|---------------------|---|
| ELEV<br>DEPTH   | DESCRIPTION  | STRAT PLOT | NUMBER  | TYPE | "N" VALUES |                            |                    | SHEAR STRENGTH kPa                          |  |                                    |                                     |                                   |                     |   |
| 242.8   |  |            |         |      |            |                            |                    | 20 40 60 80 100                             |  |                                    |                                     |                                   |                     |   |
| 0.0   | <b>SILTY SAND (FILL)</b> - loose, brown, moist, some gravel, bits of wood, fuel odours<br>- very loose & wet to 1.1m depth |            | 1       | AS   |            |                            | 242                |   |  |                                    |                                     |                                   |                     |   |
| 241.3   | - frozen, trace peat, roots, bits of wood, some gravel   |            | 2       | SS   | 10         |                            |                    |   |  |                                    |                                     |                                   |                     |   |
| 1.5   | <b>SANDY SILT (ML)</b> - frozen, brown, some oxidation, mostly fine grained<br>- loose at depth                            | 3          | SS      | 30   |            |                            | 241                |   |  |                                    |                                     |                                   |                     |   |
| 239.8   |  | 4          | SS      | 6    |            |                            | 240                |   |  |                                    |                                     |                                   |                     |   |
| 3.1   | <b>SILT (ML)</b> - loose, brown, wet, trace fine sand & clay   | 5          | SS      | 8    |            |                            | 239                |   |  |                                    |                                     |                                   |                     | 2 92 6  |
| 239.0   |  | 6          | SS      | 1    |            |                            | 238                |   |  |                                    |                                     |                                   |                     |   |
| 3.8   | <b>SILT/CLAY</b> - very loose/soft, brown, grey, wet, interbedded with clay  | 7          | SS      | 1    |            |                            | 237                |   |  |                                    |                                     |                                   |                     |   |
| 238.2   |  | 8          | SS      | 2    |            |                            | 236                |   |  |                                    |                                     |                                   |                     |   |
| 4.6   | <b>SILTY CLAY (CL-ML)</b> - firm, grey, wet  | 9          | SS      | 8    |            |                            | 235                |   |  |                                    |                                     |                                   |                     | 1 92 7  |
| 237.3   |  | 10         | SS      | 9    |            |                            | 234                |   |  |                                    |                                     |                                   |                     |   |
| 5.5   | <b>SILT/CLAY</b> - very loose to firm, brown/grey, wet, slightly layering  | 11         | SS      | 8    |            |                            | 233                |   |  |                                    |                                     |                                   |                     | 31 44 25  |
| 236.7   |  | 12         | SS      | 8    |            |                            | 232                |   |  |                                    |                                     |                                   |                     |   |
| 6.1   | <b>SILT (ML)</b> - loose, brown, wet, seams of grey clay, trace gravel, varved (10-20mm layers)                            | 13         | SS      | 4    |            |                            | 231                |   |  |                                    |                                     |                                   |                     | 5 42 45 8   |
| 233.7   |  | 14         | SS      | 31   |            |                            | 230                |   |  |                                    |                                     |                                   |                     |   |
| 9.1   | <b>CLAYEY SILT (CL)</b> - firm, brown, moist, with sand  | 15         | SS      | 20   |            |                            | 229                |   |  |                                    |                                     |                                   |                     |   |
| 232.9   |  | 16         | SS      | 20   |            |                            | 228                |   |  |                                    |                                     |                                   |                     |   |
| 9.9   | <b>SANDY SILT (ML)</b> - compact, brown, wet, trace gravel   | 17         | SS      | 35   |            |                            | 227                |   |  |                                    |                                     |                                   |                     |   |
| 231.4   |  | 18         | SS      | 35   |            |                            |                    |   |  |                                    |                                     |                                   |                     |   |
| 11.4  | <b>SANDY SILT TILL (ML)</b> - compact, brown, moist, trace gravel & clay<br>- brown to grey near bottom                    | 19         | SS      | 21   |            |                            |                    |   |  |                                    |                                     |                                   |                     |   |
| 227.0   |  |            |         |      |            |                            |                    |   |  |                                    |                                     |                                   |                     |   |
| 15.9  | <b>End of Borehole</b>   |            |         |      |            |                            |                    |   |  |                                    |                                     |                                   |                     |   |
| <b>NOTES:</b><br>1. This drawing is to be read with the subject report and project number as presented above.<br>2. Interpretation assistance by Trow is required before use by others.<br>3. BH caved to 2.1m depth.<br>4. Date of W.L.=June 29/09.<br>5. About 0.6m rockfill removed prior to drilling.<br>6. Borehole is plugged by bentonite. |  |            |         |      |            |                            |                    |   |  |                                    |                                     |                                   |                     |   |

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE















ONL\_MOT\_09143A-KABINAKAGAMI BRIDE V6 PWP.GPJ ON\_MOT.GDT 09/08/14

# RECORD OF BOREHOLE No KB-09-04

1 OF 1

METRIC

W.P. 5411-04-00 LOCATION KABINAKAGAMI RIVER BRIDGE - WEST ABUTMENT ORIGINATED BY E.F.  
 DIST NEW LISK. HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS COMPILED BY D.T.  
 DATUM GEODETIC DATE 09.06.27 - 09.06.28 CHECKED BY D.C./D.G.

| SOIL PROFILE  |   |   | SAMPLES |      |            | GROUND WATER<br>CONDITIONS  | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |    |    | PLASTIC<br>LIMIT<br>w <sub>p</sub> | NATURAL<br>MOISTURE<br>CONTENT<br>w | LIQUID<br>LIMIT<br>w <sub>L</sub> | UNIT<br>WEIGHT<br>γ | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%) |                   |  |  |
|---|---|---|---------|------|------------|---|-----------------|---|----|----|------------------------------------|-------------------------------------|-----------------------------------|---------------------|---|-------------------|--|--|
| ELEV<br>DEPTH   | DESCRIPTION   | STRAT PLOT  | NUMBER  | TYPE | "N" VALUES |   |                 | SHEAR STRENGTH kPa                          |    |    |                                    |                                     |                                   |                     |   | WATER CONTENT (%) |  |  |
|   |   |   |         |      |            |   |                 | ○ UNCONFINED      + FIELD VANE              |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
| 243.5   |   |   |         |      |            |   | 20              | 40  | 60 | 80 | 100                                |                                     |                                   |                     |   |                   |  |  |
| 240.2   | <b>SAND (FILL)</b> - loose, brown, damp, coarse to fine grained, trace gravel & silt                        |    | 1       | AS   |            |  |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
| 0.3   |   |   | 2       | AS   |            |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
| 242.2   | <b>SILTY SAND (FILL)</b> - loose, brown, moist, trace to some gravel, coarse to fine grained                |    | 3       | SS   | 1          |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
| 1.4   |   |   | 4       | SS   | 2          |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
|   | <b>SILT (ML)</b> - loose, brown, wet, trace gravel, trace organics, some oxidation                          |    |         |      |            |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
|   |   |   | 5       | SS   | 2          |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
|   | - very loose, brown, wet from 2.3m depth  |    |         |      |            |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
|   |   |   | 6       | SS   | 8          |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
| 239.7   | - loose, brown, wet, trace clay, some oxidation, some fine sand seams                                       |    |         |      |            |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
| 3.8   |   |   | 7       | SS   | 2          |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
| 239.0   | <b>SILTY CLAY (CL)</b> - firm, brown to grey, moist   |    |         |      |            |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
| 4.6   | <b>SILT (ML)</b> - loose, brown, wet, seams of grey clay  |    | 8       | SS   | 5          |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
|   |   |   | 9       | SS   | 6          |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
|   |   |   |         |      |            |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
|   |   |   | 10      | SS   | 8          |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
|   |   |   | 11      | SS   | 6          |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
|   |   |   |         |      |            |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
|   | - trace to some clay, trace sand & gravel from 7.6m depth   |    | 12      | SS   | 3          |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
| 235.2   | <b>SILTY SAND (SM)</b> - loose, grey, wet, trace gravel, med. to fine grained                               |    | 13      | SS   | 9          |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
| 8.4   |   |   |         |      |            |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
| 234.4   | (See Note 5)  |    | 14      | SS   | 0          |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
| 9.1   |   |   |         |      |            |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
| 233.8   | <b>SAND (SP)</b> - very loose, grey, wet, trace gravel, trace silt, mostly med. to coarse sand (See Note 5) |   |         |      |            |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
| 9.8   |   |   | 15      | SS   | 12         |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
| 232.9   | <b>SILTY SAND (SM)</b> - compact, greyish brown, wet, trace gravel  |  |         |      |            |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
| 10.7  | <b>SANDY SILT TILL (ML)</b> - compact, grey, moist, trace gravel, occ. stones                               |   |         | 16   | SS         | 15  |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
| 230.7   | <b>End of Borehole</b>  |  |         |      |            |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
| 12.8  |   |   |         |      |            |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |
| <b>NOTES:</b><br>1. This drawing is to be read with the subject report and project number as presented above.<br>2. Interpretation assistance by Trow is required before use by others.<br>3. Date of W.L.=July 1/09.<br>4. Installed 20mm dia. PVC standpipe to 3.7m depth.<br>5. Blow-up of sand (~1m) and water (~3.5m) inside augers between about 8.8m to 10m depth. |   |   |         |      |            |   |                 |   |    |    |                                    |                                     |                                   |                     |   |                   |  |  |

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

# RECORD OF BOREHOLE No KB-09-05

1 OF 1

METRIC

W.P. 5411-04-00 LOCATION KABINAKAGAMI RIVER BRIDGE - WEST ABUTMENT ORIGINATED BY E.F.  
 DIST NEW LISK. HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS COMPILED BY D.T.  
 DATUM GEODETIC DATE 09.07.01 - 09.07.01 CHECKED BY D.C./D.G.

| SOIL PROFILE  |   |            | SAMPLES |      |            | GROUND WATER<br>CONDITIONS | ELEVATION<br>SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |  | PLASTIC NATURAL LIQUID<br>LIMIT MOISTURE CONTENT LIMIT |  | UNIT<br>WEIGHT<br>$\gamma$<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%) |
|---------------|---|------------|---------|------|------------|----------------------------|--------------------|---|--|--|--|---|---|
| ELEV<br>DEPTH | DESCRIPTION   | STRAT PLOT | NUMBER  | TYPE | "N" VALUES |                            |                    | SHEAR STRENGTH kPa                          |  | WATER CONTENT (%)                                      |  |   |   |
| 242.9         |   |            |         |      |            |                            |                    | 20 40 60 80 100                             |  |  |  |   |   |
| 0.0           | <b>SILTY SAND (FILL)</b> - loose, brown, wet, with silt, trace to some gravel, occ. cobble or rockfill<br><br>- compact, wet from 1.0m depth  |            | 1       | AS   |            |                            | 242                |   |  |  |  |   |   |
|               |   |            | 2       | SS   | 11         |                            |                    |   |  |  |  |   |   |
|               |   |            | 3       | SS   | 55         |                            | 241                |   |  |  |  |   |   |
| 240.6         |   |            |         |      |            |                            |                    |   |  |  |  |   |   |
| 2.3           | <b>SILT (ML)</b> - compact, brown, wet, some oxidation, occ. organic<br><br>- very loose from 3.0m depth  |            | 4       | SS   | 11         |                            | 240                |   |  |  |  |   |   |
|               |   |            | 5       | SS   | 2          |                            |                    |   |  |  |  |   |   |
| 239.1         |   |            |         |      |            |                            |                    |   |  |  |  |   |   |
| 3.8           | <b>SILT to SILTY CLAY (ML-CL)</b> very loose/soft, brown to grey, wet, slightly varved (6mm layering)<br><br>- firm, grey, wet, interbedded from 4.8m depth   |            | 6       | SS   | 1          |                            | 239                |   |  |  |  |   |   |
|               |   |            | 7       | SS   | 1          |                            | 238                |   |  |  |  |   |   |
| 237.4         |   |            | 8       | VANE |            |                            |                    |   |  |  |  |   |   |
| 5.5           | <b>SILT (ML)</b> - loose, brown, wet, seams of grey clay  |            | 9       | SS   | 8          |                            | 237                |   |  |  |  |   |   |
|               |   |            | 10      | SS   | 5          |                            |                    |   |  |  |  |   |   |
|               |   |            | 11      | SS   | 5          |                            | 236                |   |  |  |  |   |   |
|               |   |            |         |      |            |                            |                    |   |  |  |  |   |   |
|               |   |            | 12      | SS   | 7          |                            | 235                |   |  |  |  |   |   |
| 234.4         |   |            | 13A     | SS   | 2          |                            |                    |   |  |  |  |   |   |
| 8.5           | <b>CLAYEY SILT (CL)</b> - firm, brown, moist, trace sand & gravel   |            | 13B     | SS   | 5          |                            | 234                |   |  |  |  |   |   |
| 233.5         |   |            |         |      |            |                            |                    |   |  |  |  |   |   |
| 9.5           | <b>SILTY SAND (SM)</b> - very loose, grey, wet, with silt, trace gravel, mostly coarse to med. grained (see note 4)   |            | 14      | SS   | 3          |                            | 233                |   |  |  |  |   |   |
|               |   |            | 15      | SS   | 14         |                            |                    |   |  |  |  |   |   |
| 232.3         |   |            |         |      |            |                            |                    |   |  |  |  |   |   |
| 10.7          | <b>SILT (ML)</b> - compact, grey, wet, with very fine sand, trace gravel  |            | 16      | SS   | 17         | 232                        |                    |   |  |  |  |   |   |
| 231.5         |   |            |         |      |            |                            |                    |   |  |  |  |   |   |
| 11.4          | <b>SANDY SILT TILL (ML)</b> - compact, grey, moist, trace gravel, trace clay  |            | 17      | SS   | 26         | 231                        |                    |   |  |  |  |   |   |
|               |   |            | 18A     | SS   | 10         |                            |                    |   |  |  |  |   |   |
|               |   |            | 18B     | SS   | 10         | 230                        |                    |   |  |  |  |   |   |
|               |   |            | 19      | SS   | 20         |                            |                    |   |  |  |  |   |   |
|               |   |            |         |      |            |                            |                    |   |  |  |  |   |   |
|               | - loose to compact, trace clay from 13.7m depth   |            | 19      | SS   | 10         | 229                        |                    |   |  |  |  |   |   |
|               |   |            |         |      |            |                            |                    |   |  |  |  |   |   |
|               | - dense, wet from 15.0m depth   |            |         |      |            | 228                        |                    |   |  |  |  |   |   |
| 227.1         |   |            | 20      | SS   | 42         |                            |                    |   |  |  |  |   |   |
| 15.9          | <b>End of Borehole</b><br><br><b>NOTES:</b><br>1. This drawing is to be read with the subject report and project number as presented above.<br>2. Interpretation assistance by Trow is required before use by others.<br>3. Date of W.L.=July 1/09.<br>4. Blow-up of sand (~1m) and water (~4m) inside augers at a depth of about 9.5m.<br>5. Borehole is plugged by bentonite. |            |         |      |            |                            |                    |   |  |  |  |   |   |

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE











ONL MOT 09143A-KABINAKAGAMI BRIDE V6 PWP.GPJ ON MOT.GDT 09/08/14

# RECORD OF BOREHOLE No KB-09-06

1 OF 1

METRIC

W.P. 5411-04-00 LOCATION KABINAKAGAMI RIVER BRIDGE - WEST ABUTMENT ORIGINATED BY E.F.  
 DIST NEW LISK. HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS COMPILED BY D.T.  
 DATUM GEODETIC DATE 09.06.27 - 09.06.27 CHECKED BY D.C./D.G.

| SOIL PROFILE  |  |   | SAMPLES |      |            | GROUND WATER<br>CONDITIONS  | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT                      |    |    | PLASTIC<br>LIMIT<br>w <sub>p</sub> | NATURAL<br>MOISTURE<br>CONTENT<br>w | LIQUID<br>LIMIT<br>w <sub>L</sub> | UNIT<br>WEIGHT<br>γ<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%)<br>GR SA SI CL |  |
|---|--|---|---------|------|------------|---|-----------------|--|----|----|------------------------------------|-------------------------------------|-----------------------------------|--|--|--|
| ELEV<br>DEPTH   | DESCRIPTION  | STRAT PLOT  | NUMBER  | TYPE | "N" VALUES |   |                 | SHEAR STRENGTH kPa   |    |    |                                    |                                     |                                   |  |  |  |
|   |  |   |         |      |            |   |                 | ○ UNCONFINED      + FIELD VANE<br>● QUICK TRIAXIAL    × LAB VANE |    |    |                                    |                                     |                                   |  |  |  |
|   |  |   |         |      |            |   |                 | WATER CONTENT (%)  |    |    |                                    |                                     |                                   |  |  |  |
| 243.5   |  |   |         |      |            |   | 20              | 40   | 60 | 80 | 100                                | 10                                  | 20                                | 30                                       |  |  |
| 0.0   | <b>SAND (FILL)</b> - loose, brown, damp, med. to fine grained, trace gravel, trace silt                    |    | 1       | AS   |            |  |                 |  |    |    |                                    |                                     |                                   |  |  |  |
|   |  |   | 2A      | SS   | 3          |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
| 242.1   |  |   | 2B      | SS   | 3          |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
| 1.4   | <b>SILT (ML)</b> - loose, brown, moist, some fine sand, trace gravel, occ. oxidation                       |    | 3       | SS   | 18         |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
|   |  |   | 4       | SS   | 6          |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
|   | - occ. stone below 3.0m depth  |   | 5A      | SS   | 4          |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
|   |  |   | 5B      | SS   | 1          |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
| 239.5   |  |   | 6       | VANE |            |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
| 4.0   | <b>SILTY CLAY (CL)</b> - firm, grey, wet, interbedded, mostly silt w/clay layers                           |    | 7       | SS   | 4          |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
| 238.9   |  |   |         |      |            |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
| 4.6   | <b>SILT (ML)</b> - loose, grey, wet, seams of grey clay, tiny black rootlets                               |    | 8       | TW   | 1          |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
|   |  |   | 9       | SS   | 5          |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
|   |  |   | 10      | SS   | 1          |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
|   | - very loose, brown, wet, trace to some clay, trace sand & gravel from 7.2m depth                          |   | 11A     | SS   | 1          |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
|   |  |   | 11B     | SS   | 1          |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
| 235.6   |  |   | 12      | SS   | 4          |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
| 7.9   | <b>SANDY SILT (ML)</b> - loose, brown, wet, trace gravel   |  | 13      | SS   | 4          |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
| 235.1   |  |   |         |      |            |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
| 8.4   | <b>SILTY SAND (SM)</b> - loose to very loose, grey, wet, coarse to fine grained, trace gravel (see note 5) |  | 14      | SS   | 9          |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
|   |  |   |         |      |            |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
| 233.6   |  |   |         |      |            |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
| 9.9   | <b>SANDY SILT TILL (ML)</b> - dense, grey, moist, trace gravel   |  | 15      | SS   | 32         |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
|   | - compact to dense from 11.0m depth  |   | 16      | SS   | 30         |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
|   | - occ. stone   |   |         |      |            |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
|   |  |   | 17      | SS   | 43         |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
|   |  |   |         |      |            |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
|   | - loose to compact, trace clay from 13.7m depth  |   | 18      | SS   | 10         |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
| 229.2   |  |   |         |      |            |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
| 14.3  | <b>SANDY SILT (ML)</b> - loose to compact, grey, moist, trace gravel, trace clay                           |  |         |      |            |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
| 228.3   |  |   |         |      |            |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
| 15.2  | <b>SILT (ML)</b> - very dense, grey, wet, trace sand   |  | 19      | SS   | 70         |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
| 227.7   |  |   |         |      |            |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
| 15.9  | <b>End of Borehole</b>   |   |         |      |            |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |
| <b>NOTES:</b><br>1. This drawing is to be read with the subject report and project number as presented above.<br>2. Interpretation assistance by Trow is required before use by others.<br>3. Date of W.L.=July 1/09.<br>4. Installed 20mm dia. PVC standpipe to 9.7m depth.<br>5. Blow-up of sand (~1m) and water (~3m) inside augers at a depth of 8.4m<br>6. A 30mm stone prevented the vane test. |  |   |         |      |            |   |                 |  |    |    |                                    |                                     |                                   |  |  |  |

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ONL MOT 09143A-KABINAKAGAMI BRIDE V6 PWP.GPJ ON MOT.GDT 09/08/14

# RECORD OF BOREHOLE No KB-09-07

1 OF 1

METRIC

W.P. 5411-04-00 LOCATION KABINAKAGAMI RIVER BRIDGE - WEST ABUTMENT ORIGINATED BY E.F.  
DIST NEW LISK. HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS COMPILED BY D.T.  
DATUM GEODETIC DATE 09.06.24 - 09.06.25 CHECKED BY D.C./D.G.

| SOIL PROFILE  |   |            | SAMPLES |      |            | GROUND WATER<br>CONDITIONS | ELEVATION<br>SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |                            |    |     |    | PLASTIC<br>LIMIT<br>w <sub>p</sub> | NATURAL<br>MOISTURE<br>CONTENT<br>w | LIQUID<br>LIMIT<br>w <sub>L</sub> | UNIT<br>WEIGHT<br>γ<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%)<br>GR SA SI CL |                   |  |  |  |  |
|---|---|------------|---------|------|------------|----------------------------|--------------------|---|----------------------------|----|-----|----|------------------------------------|-------------------------------------|-----------------------------------|--|--|-------------------|--|--|--|--|
| ELEV<br>DEPTH   | DESCRIPTION   | STRAT PLOT | NUMBER  | TYPE | "N" VALUES |                            |                    | SHEAR STRENGTH kPa                          |                            |    |     |    |                                    |                                     |                                   |  |  | WATER CONTENT (%) |  |  |  |  |
|   |   |            |         |      |            |                            |                    | ○ UNCONFINED<br>● QUICK TRIAXIAL            | + FIELD VANE<br>× LAB VANE |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
| 243.4   |   |            |         |      |            |                            | 20                 | 40  | 60                         | 80 | 100 | 10 | 20                                 | 30                                  |                                   |  |  |                   |  |  |  |  |
| 0.0   | <b>SAND (FILL)</b> - loose, brown, damp,<br>fine to med. grained, trace gravel,<br>occ. stone         |            | 1       | AS   |            |                            | 243                |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
| 242.2   | - loose to compact, moist from 0.9m<br>depth  |            | 2A      | SS   | 5          |                            | 242                |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
| 1.2   | <b>SILT (ML)</b> - loose, brown, moist to<br>wet, trace clay at depth, occ.<br>organics               |            | 2B      | SS   | 4          |                            | 241                |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
|   |   |            | 3       | SS   | 6          |                            | 240                |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
|   |   |            | 4       | SS   | 8          |                            | 239                |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
|   |   |            | 5       | SS   | 5          |                            | 238                |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
| 239.4   |   |            | 6       | VANE |            |                            | 237                |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
| 4.0   | <b>SILTY CLAY (CL)</b> - firm, grey,<br>moist, slightly varved (3mm layers)                           | 7          | SS      | 1    | 236        |                            |                    |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
|   |   | 8          | SS      | 4    | 235        |                            |                    |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
| 237.9   |   | 9          | VANE    |      | 234        |                            |                    |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
| 5.5   | <b>SILT (ML)</b> - loose, brown, wet,<br>seams of grey clay   | 10         | SS      | 8    | 233        |                            |                    |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
|   |   | 11         | SS      | 9    | 232        |                            |                    |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
|   |   | 12         | SS      | 7    | 231        |                            |                    |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
|   |   | 13         | SS      | 7    | 230        |                            |                    |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
| 235.0   |   | 14         | SS      | 1    | 229        |                            |                    |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
| 8.4   | <b>SAND (SP)</b> - very loose, grey, wet,<br>fine to med. grained, trace silt (see<br>note 5)         | 15         | SS      | 2    | 228        |                            |                    |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
| 234.2   | <b>SILTY SAND (SM)</b> - very loose,<br>grey, wet, with silt, trace gravel (see<br>note 5)            | 16         | SS      | 24   | 227        |                            |                    |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
| 9.1   | <b>SANDY SILT TILL (ML)</b> - compact<br>to dense, grey, moist, trace gravel,<br>trace clay           | 17         | SS      | 37   |            |                            |                    |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
| 233.5   |   | 18         | SS      | 45   |            |                            |                    |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
| 9.9   |   | 19         | SS      | 31   |            |                            |                    |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
|   |   | 20         | SS      | 35   |            |                            |                    |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
| 229.2   |   |            |         | SS   | 35         |                            |                    |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
| 14.2  | <b>SANDY SILT (ML)</b> - loose to<br>compact, brown, wet, trace clay,<br>trace gravel, some fine sand | 21         | SS      | 9    |            |                            |                    |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
|   | - compact to very dense<br>- compact to dense, brown, moist   | 22         | SS      | 17   |            |                            |                    |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
| 226.9   |   | 23         | SS      | 100  |            |                            |                    |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
| 16.5  | <b>End of Borehole (Refusal to Auger)</b>   |            |         |      |            |                            |                    |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |
| <b>NOTES:</b><br>1. This drawing is to be read with the<br>subject report and project number as<br>presented above.<br>2. Interpretation assistance by Trow<br>is required before use by others.<br>3. Date of W.L.=July 1/09.<br>4. Installed 20mm dia. PVC<br>standpipes (nested piezometers) to<br>3.4m (A), and 9.1m (B) depth. The<br>ground water levels were measured<br>as 0.8m depth (EL242.6m) for<br>Piezometer (A), and 1.7m depth (EL<br>241.7m) for Piezometer (B) on<br>July/01/2009.<br>5. Blow-up of sand (~1m) and water<br>(~4m) inside augers at a depth of<br>8.4m |   |            |         |      |            |                            |                    |   |                            |    |     |    |                                    |                                     |                                   |  |  |                   |  |  |  |  |

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

ONL MOT 09143A-KABINAKAGAMI BRIDE V6 PWP.GPJ ON MOT.GDT 09/08/14

# RECORD OF BOREHOLE No KB-09-08

1 OF 1

METRIC

W.P. 5411-04-00 LOCATION KABINAKAGAMI RIVER BRIDGE - WEST ABUTMENT ORIGINATED BY E.F.  
 DIST NEW LISK. HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS COMPILED BY D.T.  
 DATUM GEODETIC DATE 09.06.26 - 09.06.26 CHECKED BY D.C./D.G.

| SOIL PROFILE  |  |            | SAMPLES |       |            | GROUND WATER<br>CONDITIONS | ELEVATION<br>SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |    |     |    |     | PLASTIC NATURAL LIQUID<br>LIMIT MOISTURE CONTENT |   |                | UNIT<br>WEIGHT<br>$\gamma$<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%) |
|---------------|--|------------|---------|-------|------------|----------------------------|--------------------|---|----|-----|----|-----|--|---|----------------|---|---|
| ELEV<br>DEPTH | DESCRIPTION  | STRAT PLOT | NUMBER  | TYPE  | "N" VALUES |                            |                    | SHEAR STRENGTH kPa                          |    |     |    |     | W <sub>p</sub>                                   | W | W <sub>L</sub> |   |   |
| 243.1         |  |            |         |       |            |                            |                    | 20  | 40 | 60  | 80 | 100 |  |   |                |   |   |
| 0.0           | <b>SAND (FILL)</b> loose, brown, moist,<br>med. to fine grained, trace gravel,<br>trace silt   |            | 1       | AUGER |            |                            | 243                |   |    |     |    |     |  |   |                |   |   |
| 242.2         |  |            | 2A      | SS    | 4          |                            |                    |   |    |     |    |     |  |   |                |   |   |
| 0.9           | <b>SILT (ML)</b> - compact, brown, moist,<br>trace sand, trace organics near top,<br>some rootlets   |            | 2B      | SS    | 7          |                            | 242                |   |    |     |    |     |  |   |                |   |   |
|               |  |            | 3       | SS    | 30         |                            | 241                |   |    |     |    |     |  |   |                |   |   |
|               | - loose, brown, wet, some oxidation<br>from 2.3m depth<br>- trace clay near bottom   |            | 4       | SS    | 5          |                            | 240                |   |    |     |    |     |  |   |                |   | 5 87 8  |
|               |  |            | 5A      | SS    | 1          |                            |                    |   |    |     |    |     |  |   |                |   |   |
|               |  |            | 5B      | SS    | 1          |                            |                    |   |    |     |    |     |  |   |                |   |   |
| 239.2         | <b>SILTY CLAY (CL)</b> - firm, grey, moist   |            | 6       | VANE  |            |                            | 239                |   |    | 2.5 |    |     |  |   |                |   | 3 49 48   |
| 4.0           |  |            | 7       | SS    | 1          |                            |                    |   |    |     |    |     |  |   |                |   |   |
|               |  |            | 8       | TW    |            |                            | 238                |   |    |     |    |     |  |   |                |   |   |
| 237.7         | <b>SILT (ML)</b> - loose, brown, wet,<br>seams of grey clay  |            | 9       | VANE  |            |                            |                    |   |    | 2   |    |     |  |   |                |   |   |
| 5.5           |  |            | 10      | SS    | 8          |                            | 237                |   |    |     |    |     |  |   |                |   | 94 6  |
|               |  |            | 11      | SS    | 7          |                            |                    |   |    |     |    |     |  |   |                |   |   |
|               |  |            | 12      | SS    | 5          |                            | 236                |   |    |     |    |     |  |   |                |   |   |
|               |  |            | 13      | SS    | 7          |                            |                    |   |    |     |    |     |  |   |                |   |   |
|               | - brown/grey, trace sand & gravel,<br>trace clay from 8.4m depth   |            | 14      | SS    | 6          |                            | 235                |   |    |     |    |     |  |   |                |   |   |
| 234.0         | <b>SANDY SILT (ML)</b> - loose to<br>compact, grey, wet, trace gravel,<br>occ. stone   |            | 15      | SS    | 10         |                            | 234                |   |    |     |    |     |  |   |                |   | 6 44 45 5   |
| 9.1           |  |            | 16      | SS    | 9          |                            | 233                |   |    |     |    |     |  |   |                |   |   |
|               |  |            | 17      | SS    | 7          |                            | 232                |   |    |     |    |     |  |   |                |   |   |
|               |  |            | 18      | SS    | 17         |                            | 231                |   |    |     |    |     |  |   |                |   |   |
|               | -compact   |            | 19      | SS    | 32         |                            | 230                |   |    |     |    |     |  |   |                |   |   |
|               |  |            |         |       |            |                            |                    |   |    |     |    |     |  |   |                |   |   |
|               | -loose   |            | 20      | SS    | 8          |                            | 229                |   |    |     |    |     |  |   |                |   |   |
|               |  |            |         |       |            |                            | 228                |   |    |     |    |     |  |   |                |   |   |
| 227.8         | <b>SANDY SILT TILL</b> - very dense,<br>grey, wet, trace gravel  |            | 21      | SS    | 90         |                            |                    |   |    |     |    |     |  |   |                |   |   |
| 15.3          |  |            |         |       |            |                            |                    |   |    |     |    |     |  |   |                |   |   |
| 227.3         | <b>End of Borehole</b>   |            |         |       |            |                            |                    |   |    |     |    |     |  |   |                |   |   |
| 15.9          | <b>NOTES:</b><br>1. This drawing is to be read with the<br>subject report and project number as<br>presented above.<br>2. Interpretation assistance by Trow<br>is required before use by others.<br>3. BH caved to 7.3m depth.<br>4. Date of W.L.=July 1/09.<br>5. Installed 20mm dia. PVC<br>standpipe to 3.0m depth. |            |         |       |            |                            |                    |   |    |     |    |     |  |   |                |   |   |

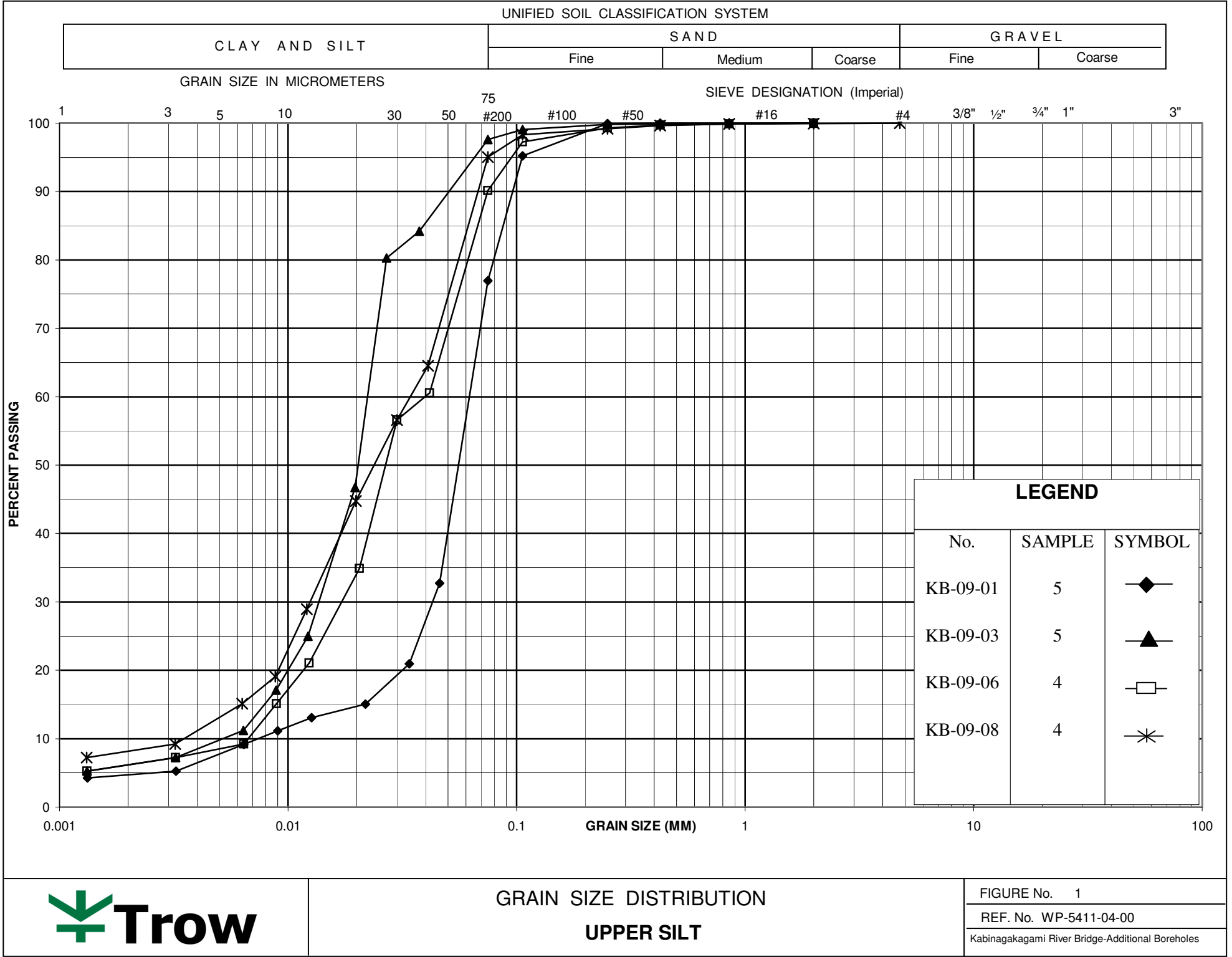
+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

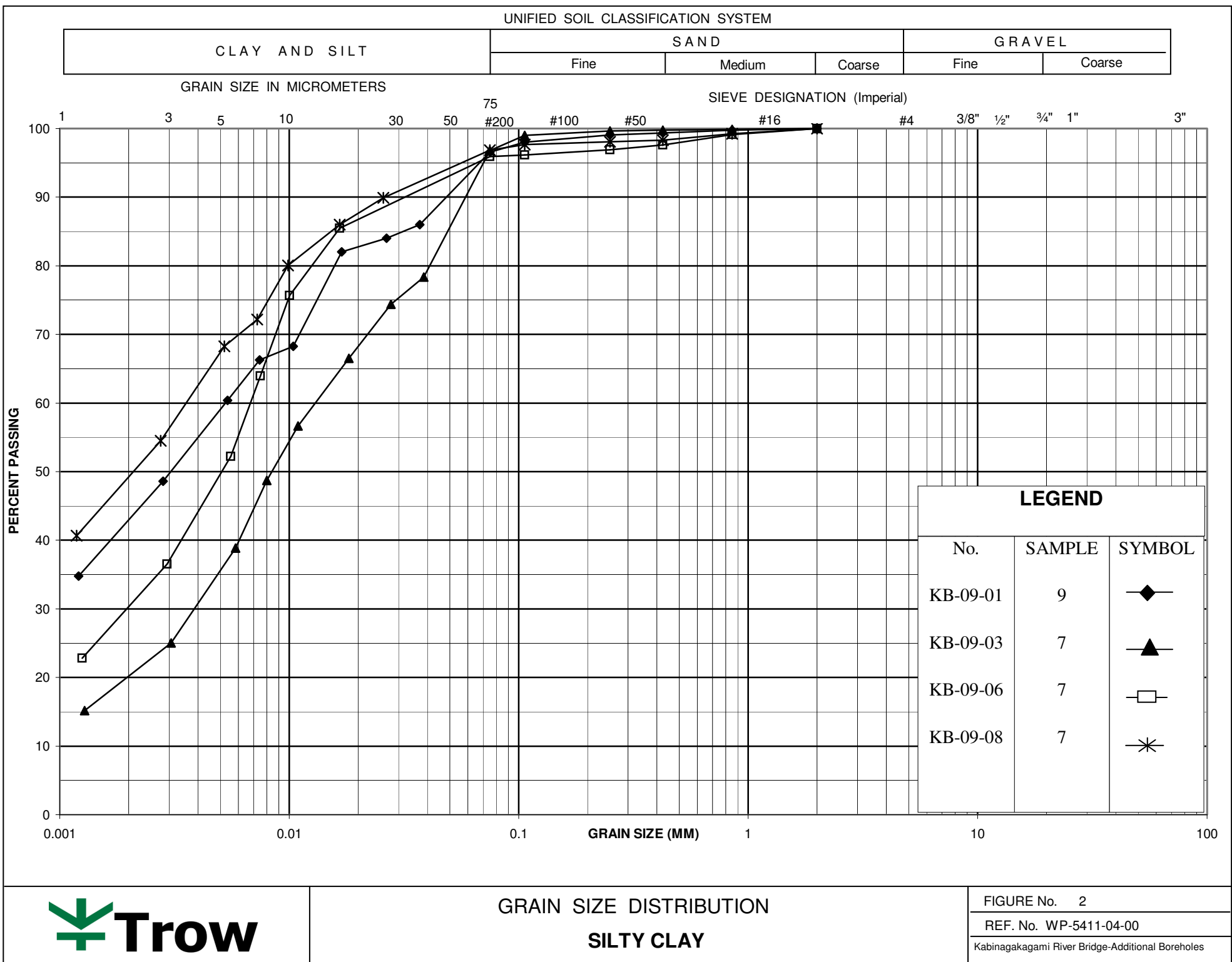
ONL\_MOT\_09143A-KABINAKAGAMI BRIDE V6 PWP.GPJ ON\_MOT.GDT 09/08/14

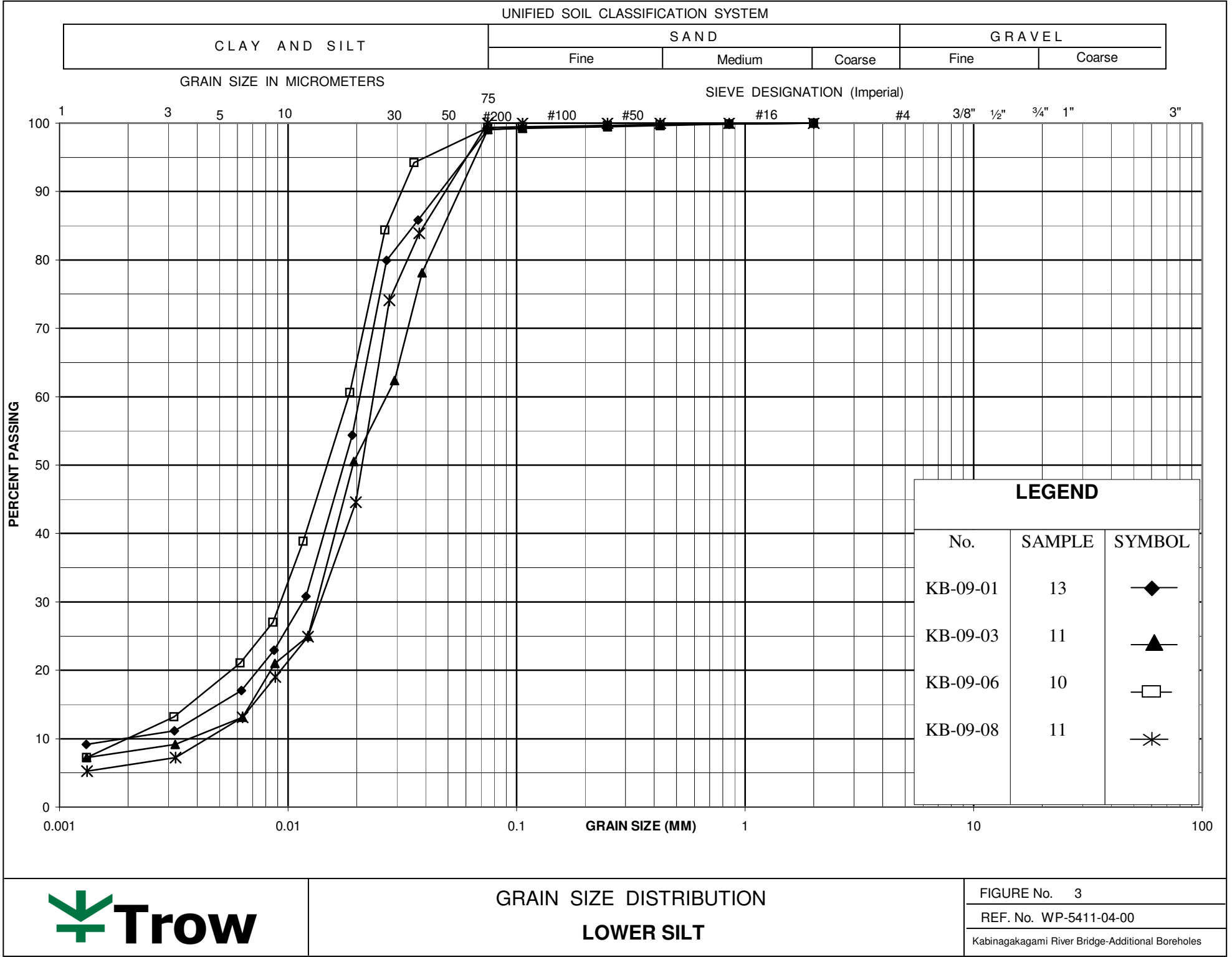
## **APPENDIX D**

### **Laboratory Data**

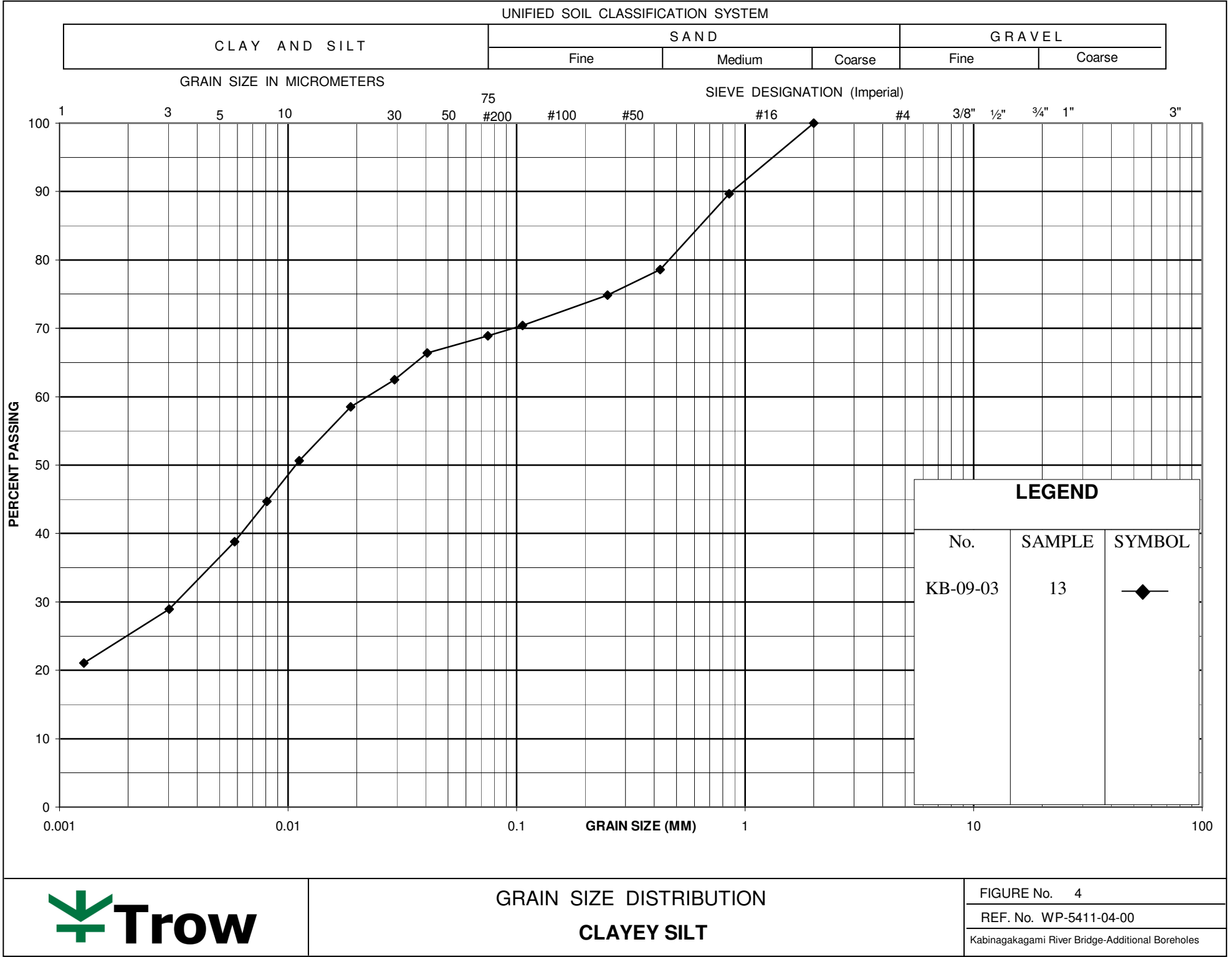


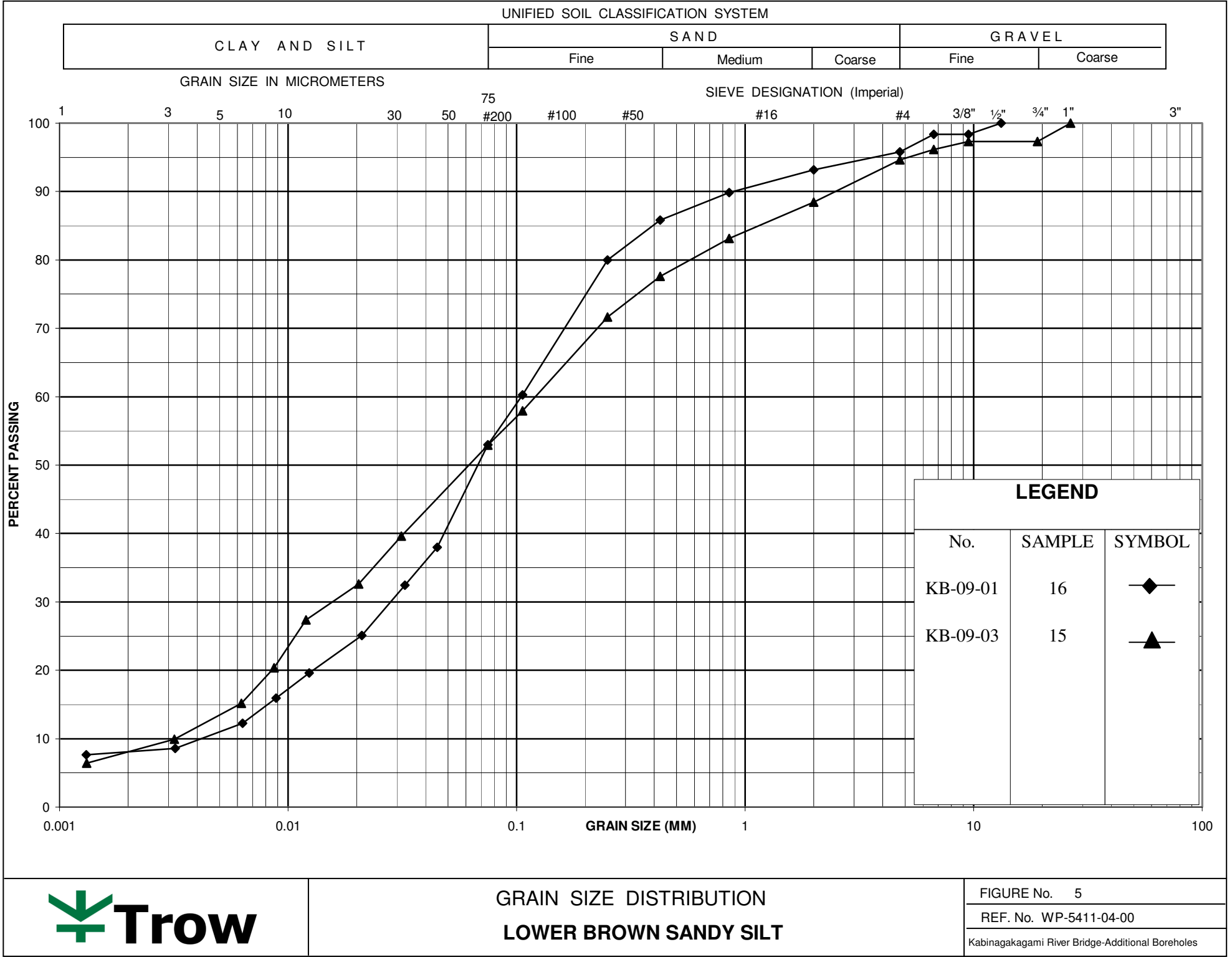




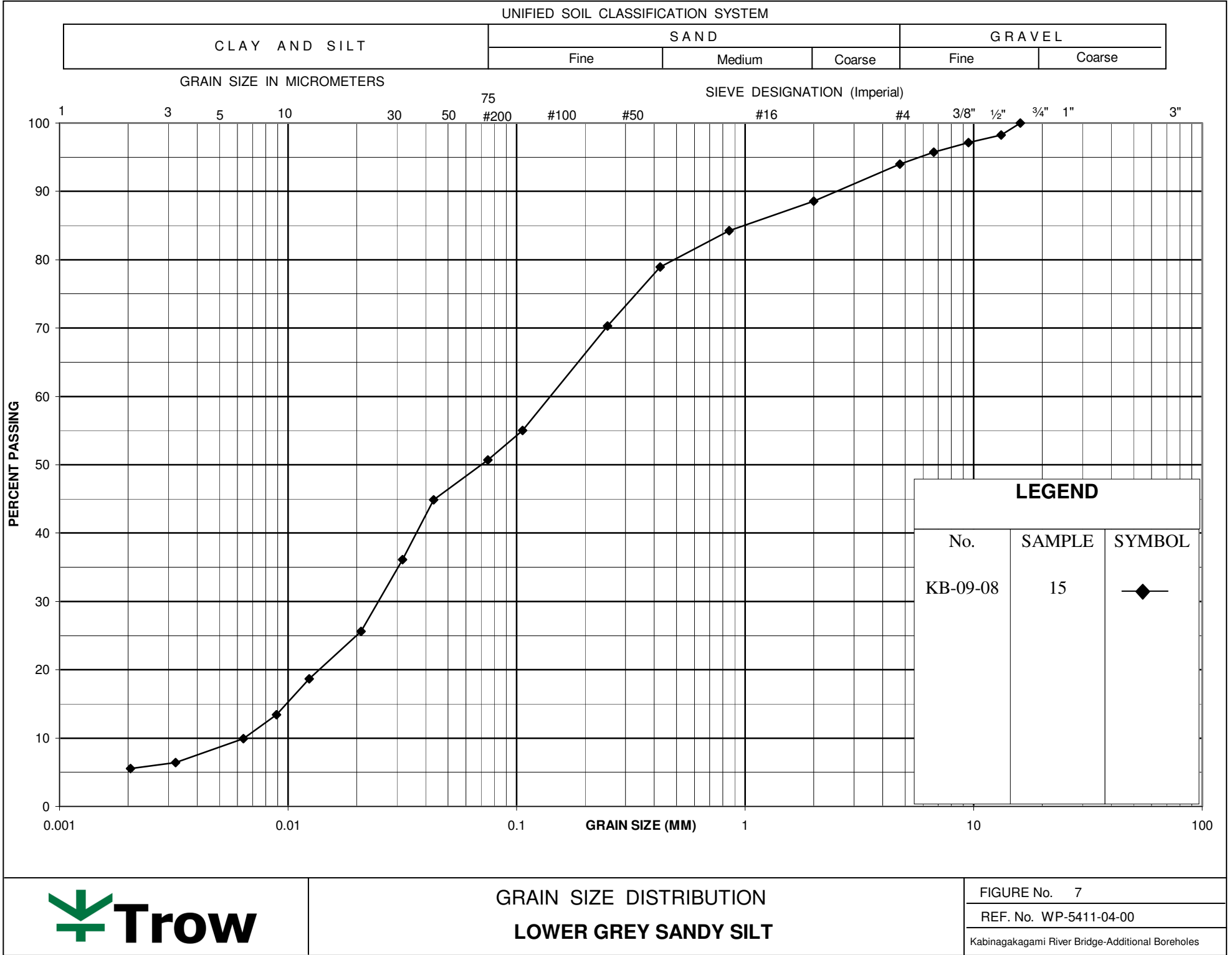


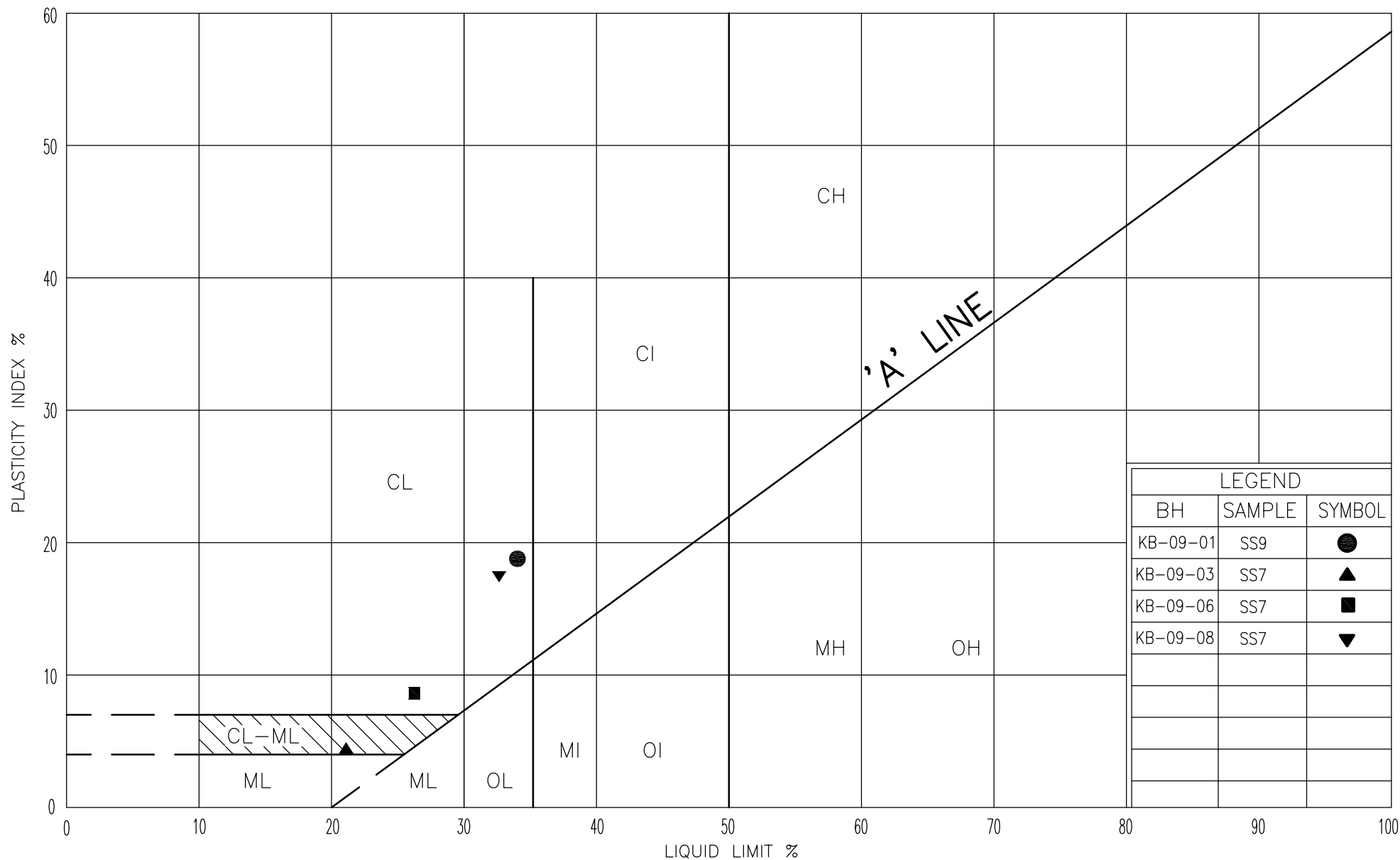
GRAIN SIZE DISTRIBUTION  
LOWER SILT











# PLASTICITY CHART SILTY CLAY, CI-ML, AND CL

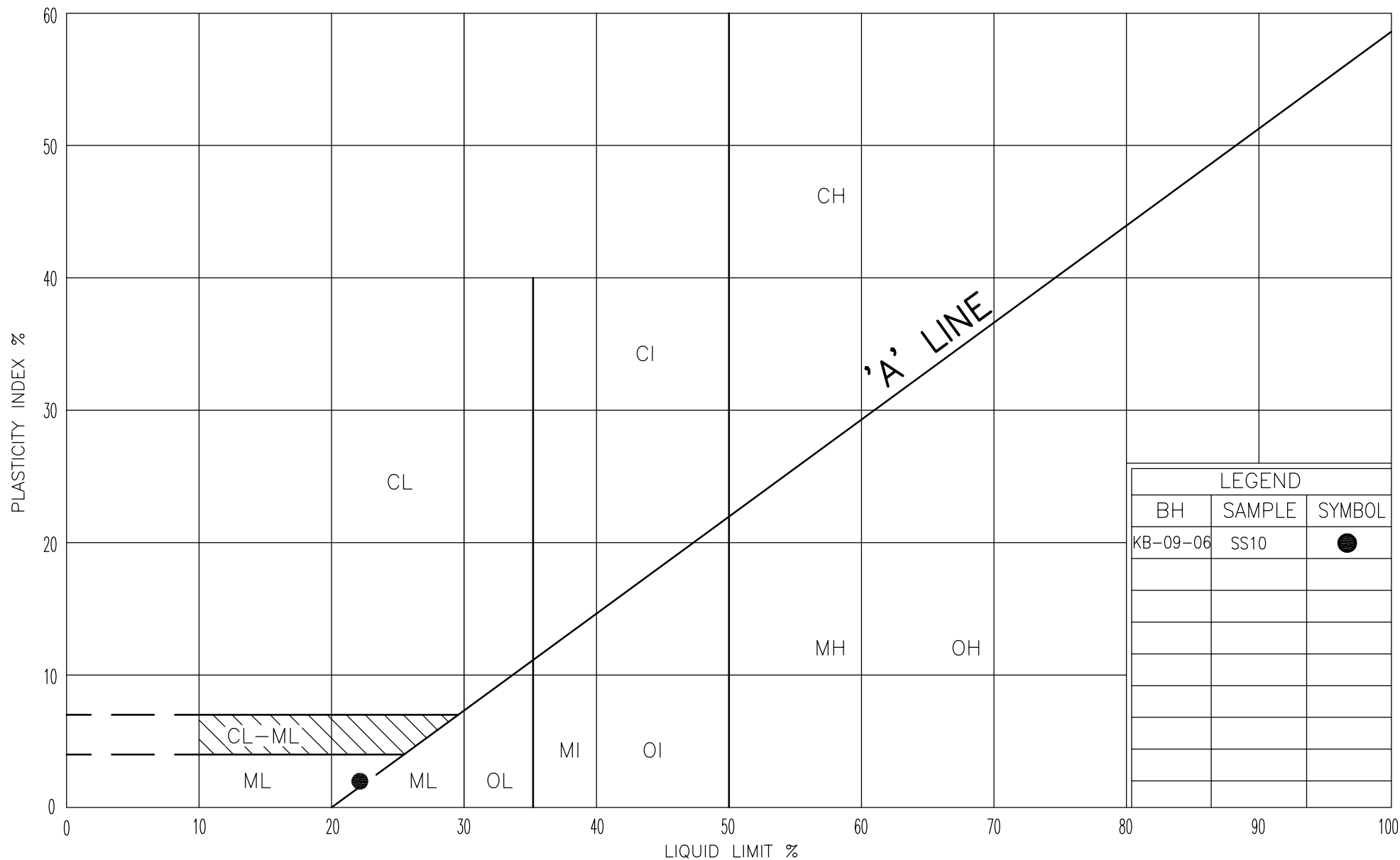
FIGURE No. 8

WO: 5411-04-00

Kabinakagami River Bridge -Additional Boreholes





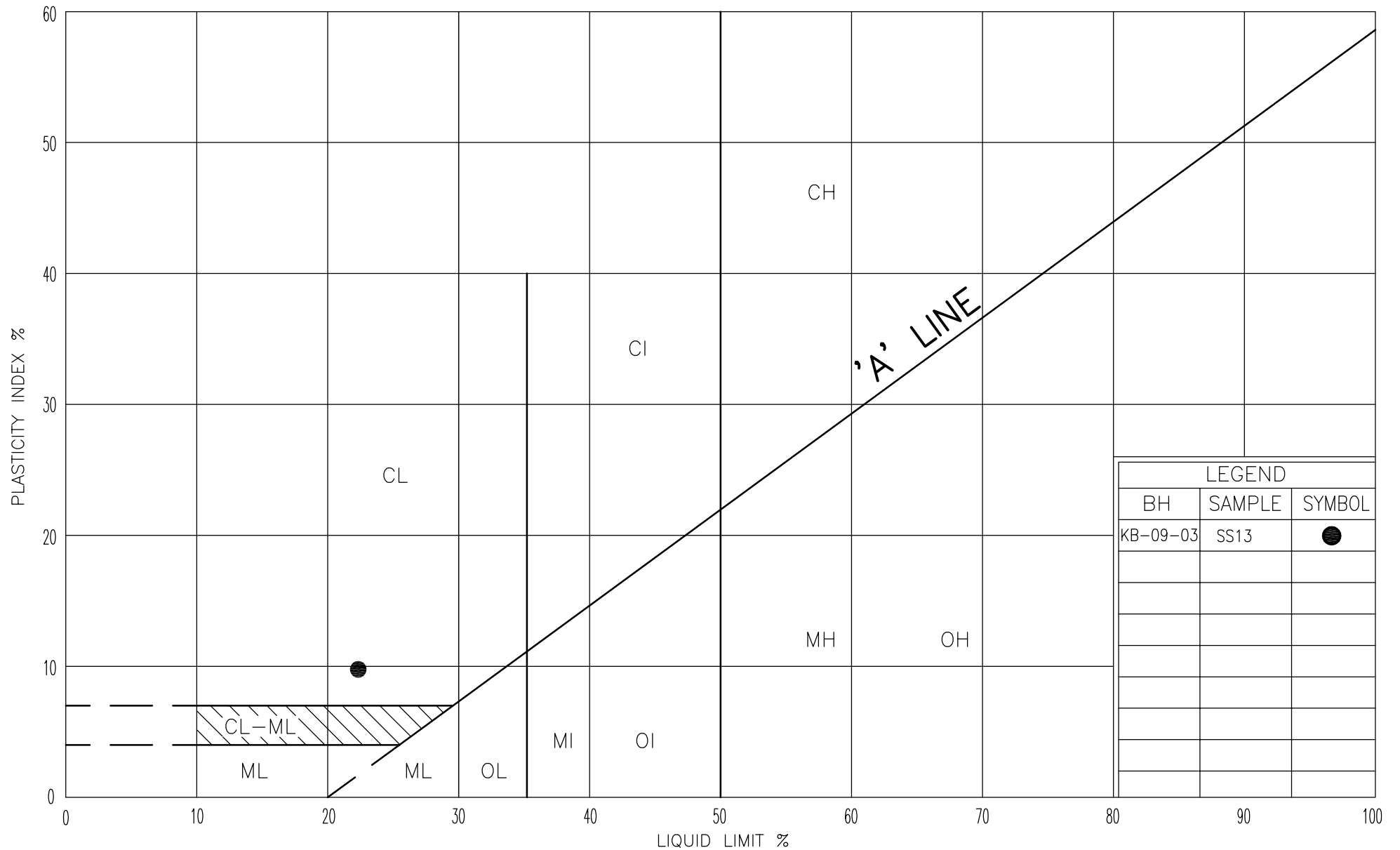


# PLASTICITY CHART LOWER SILT, ML

FIGURE No. 9

WO: 5411-04-00

Kabinakagami River Bridge -Additional Boreholes



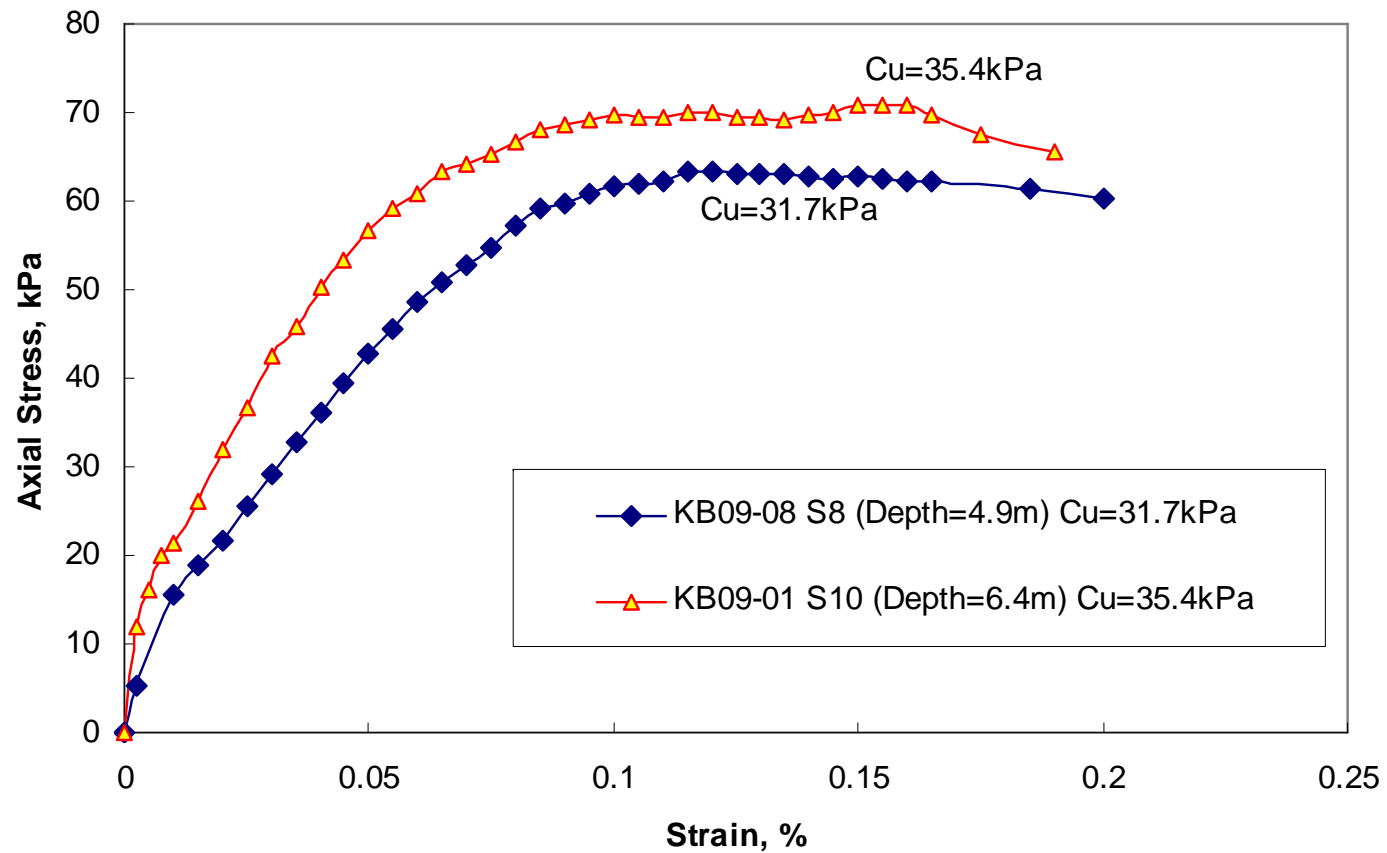
# PLASTICITY CHART CLAYEY SILT, CL

FIGURE No. 10

WO: 5411-04-00

Kabinakagami River Bridge -Additional Boreholes

## Results of Unconfined Compression Tests



### TROW Associates Inc.

56 Queen Street East, Suite 301  
BRAMPTON, ONTARIO L6V 4M8  
Tel. (905) 796-3200  
Fax. (905) 793-5533

SCALE: NTS

DATE: August 2009

DRAWN: SM

TITLE: Foundation Investigation

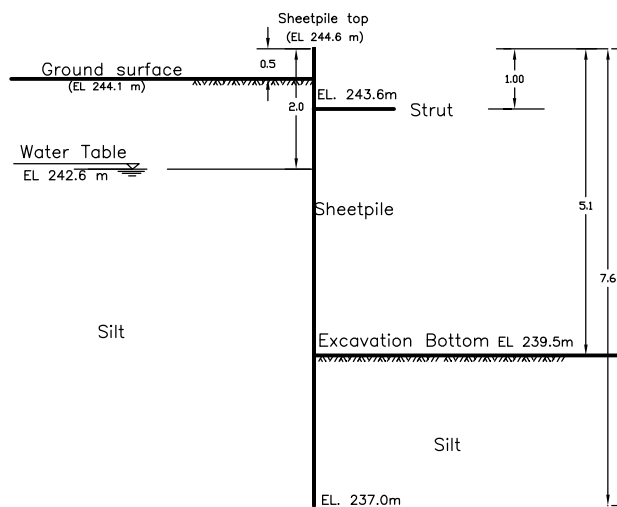
PROJECT: Kabinakagami River Bridge - Additional Boreholes

FIGURE 11

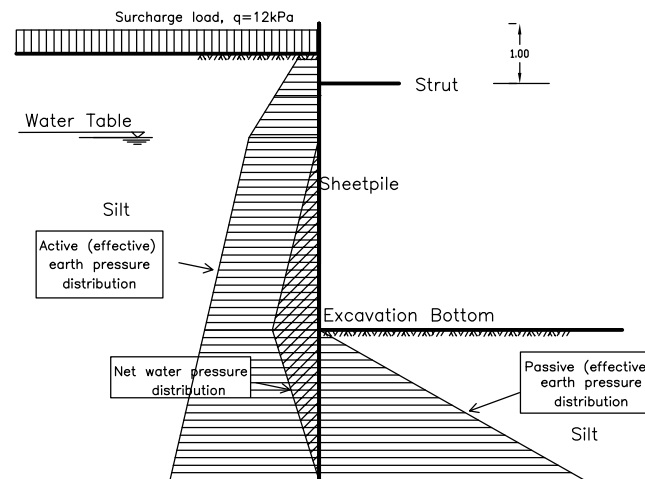
PROJECT No.  
GWP 5411-04-00

## **APPENDIX E**

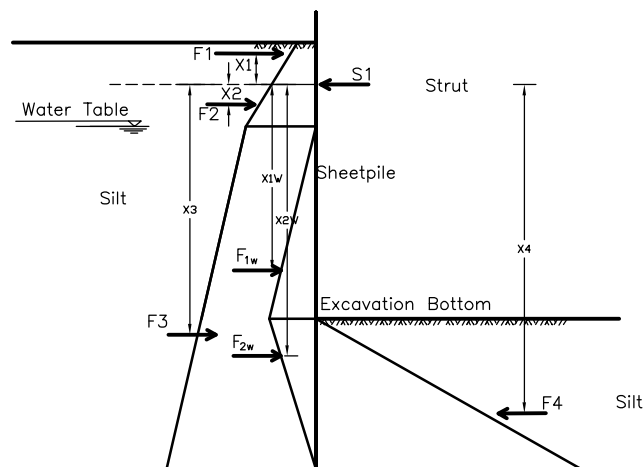
### **Stability Analyses**



(a) Geometry



(b) Stress distribution



(c) Forces and moment arms

—NOTES—

1. Cofferdam dimensions as shown are from Sheet SH3, Terraprobe's shoring details for construction of the West Abutment dated 15/Sept./2008.
2. Surcharge load ( $q=12\text{kPa}$ ) is taken from Sheet SH1, Terraprobe's shoring drawing for construction dated 15/Sept./2008.
3. Pressure diagrams, earth forces, and corresponding moment arms are only for conceptual illustration.
4. This figure should be read with subject report.

CASE 1A



**Trow Associates Inc.**

56 QUEEN STREET EAST, SUIT 301  
BRAMPTON, ONTARIO, L6V 4M8  
(905) 796-3200

**PROJECT TITLE AND LOCATION:**

Kabinakagami River Bridge-  
Additional Boreholes  
Highway 11, New Liskeard

STABILITY ANALYSIS

CASE 1A

**PROJECT NO.** SD000391349A

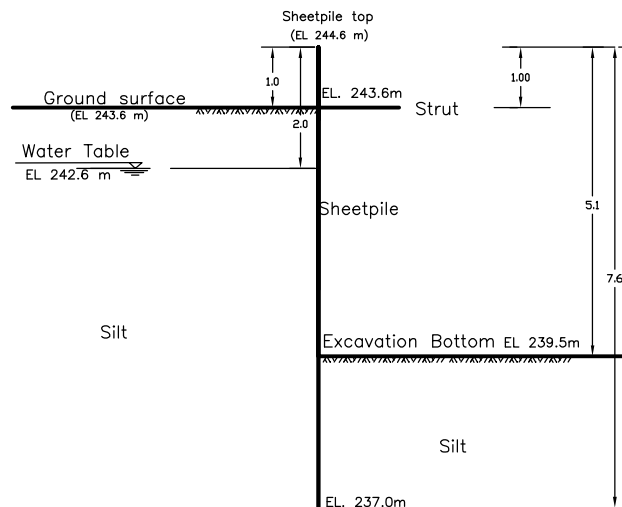
**DWN.:** GQ

**DATE:** AUGUST 2009

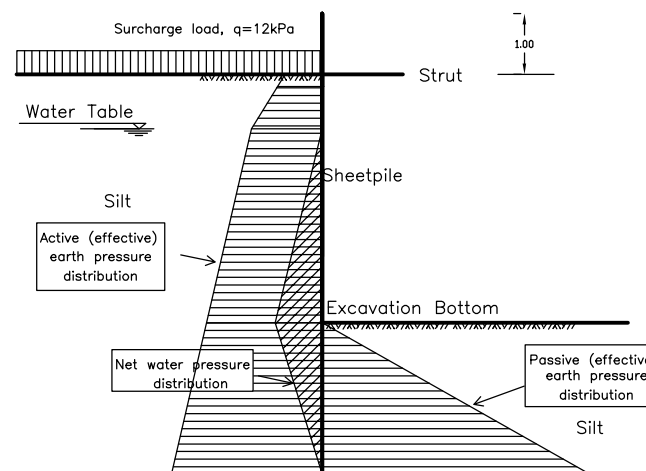
**CHKD.:** SM

**FIGURE** 1

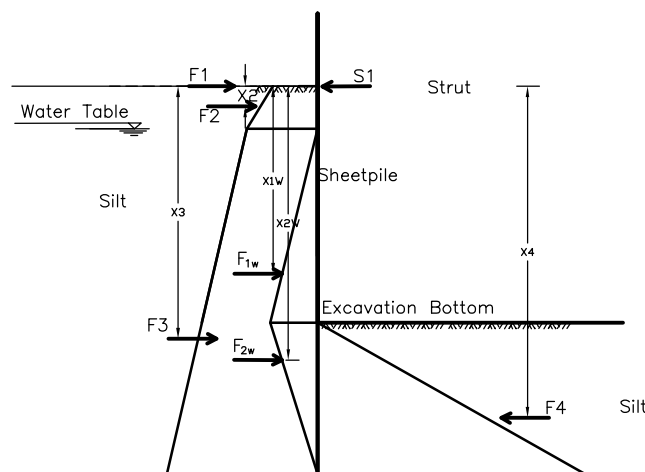
DIMENSIONS ARE IN METERS  
UNLESS OTHERWISE SHOWN



(a) Geometry



(b) Stress distribution

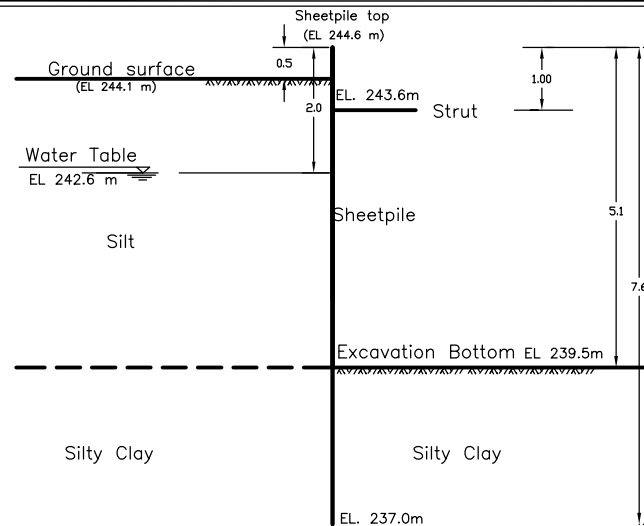


(c) Forces and moment arms

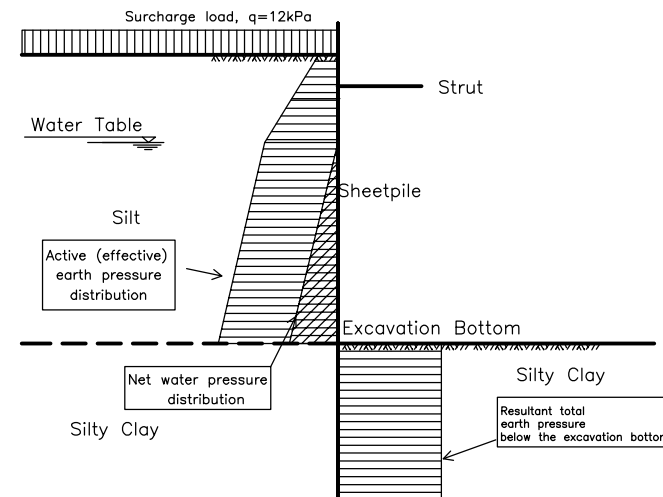
—NOTES—

1. Cofferdam dimensions as shown are from Sheet SH3, Terraprobe's shoring details for construction of the West Abutment dated 15/Sept./2008.
2. Surcharge load ( $q=12\text{kPa}$ ) is taken from Sheet SH1, Terraprobe's shoring drawing for construction dated 15/Sept./2008.
3. Pressure diagrams, earth forces, and corresponding moment arms are only for conceptual illustration.
4. This figure should be read with subject report.

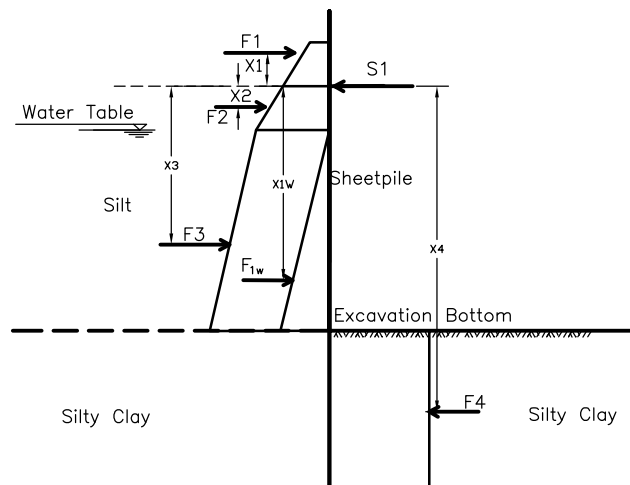
CASE 1B



(a) Geometry



(b) Stress distribution



(c) Forces and moment arms

—NOTES—

1. Cofferdam dimensions as shown are from Sheet SH3, Terraprobe's shoring details for construction of the West Abutment dated 15/Sept./2008.
2. Surcharge load ( $q=12\text{kPa}$ ) is taken from Sheet SH1, Terraprobe's shoring drawing for construction dated 15/Sept./2008.
3. Pressure diagrams, earth forces, and corresponding moment arms are only for conceptual illustration.
4. This figure should be read with subject report.

CASE 2



**Trow Associates Inc.**

56 QUEEN STREET EAST, SUIT 301  
BRAMPTON, ONTARIO, L6V 4M8  
(905) 796-3200

**PROJECT TITLE AND LOCATION:**

Kabinakagami River Bridge-  
Additional Boreholes  
Highway 11, New Liskeard

STABILITY ANALYSIS

CASE 2

**PROJECT NO.**

SD000391349A

**DWN.:**

GQ

**DATE:**

AUGUST 2009

**CHKD.:**

SM

**FIGURE**

3