



**FINAL**  
**FOUNDATION INVESTIGATION AND DESIGN REPORT**  
**RAINY RIVER TRIBUTARY CULVERT REPLACEMENT**  
**TOWNSHIP OF WORTHINGTON, DISTRICT OF RAINY RIVER**  
**AGREEMENT NO.: 2014-E-0059**  
**SITE NO.: 45-213/C**  
**GEOCRES NO. 52D-024**  
**GWP 6182-04-0**

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**FOUNDATION INVESTIGATION AND DESIGN REPORT  
RAINY RIVER TRIBUTARY CULVERT REPLACEMENT  
HIGHWAY 11  
TOWNSHIP OF WORTHINGTON, DISTRICT OF RAINY RIVER  
AGREEMENT NO.: 2014-E-0059  
SITE NO.: 45-213/C  
GEOCRES NO. 52D-024  
GWP 6182-04-00**

**PART 1: FACTUAL INFORMATION**

**1. INTRODUCTION**

DST Consulting Engineers Inc. (DST) has been retained by the prime consultant, Ainley Group, to conduct a foundation investigation and design report for the proposed Rainy River Tributary culvert replacement approximately 4.3 km West of Highway 621 and provided foundation investigation report to the Ministry of Transportation (MTO), Planning and Design, Central Region. This work was carried out under Agreement No.: 2014-E-0059. This report addresses the field investigation, laboratory test program, factual report on conditions (Part 1) and recommendations for design and construction for the proposed culvert replacement (Part 2).

**2. SITE DESCRIPTION**

The site is located on Highway 11, approximately 4.3 km West of Highway 621 (latitude 48.722221, longitude -94.486637), Township of Worthington, District of Rainy River, Northwestern Ontario.

Existing structure at this location is a 6.1 m wide X 1.85 m in height X 18.1 m in length Open Footing Box culvert with a thickness of soil cover of approximately 1.0 m. The culvert has wide cracks on both walls and soffit at centre, spall on West wall at bottom of crack with erosion occurring on the East wall. The walls of the culvert are slightly leaning outwards at the top with the base of the walls kicking in. Cracks were also identified at the inlet and outlet of the culvert with the top of the culvert deteriorating with exposed corroded rebars. The walls of the inlet and outlet were leaning 2.6° and 1.4° to the East and 3.1° and 1.4° to 3.8° to the West. The embankment at the culvert location is about 3 m high.

The surrounding area is moderately vegetated (Figures 2.1 and 2.2). Photographs were taken by others. Geological information is available from published *Ontario Geological Survey Map #52DNE* by the *Ontario Ministry of Natural Resources* for the Stratton area.

Glaciolacustrine clay and silt deposits, representative of deposition in Glacial Lake Agassiz II (Johnston 1915), occur throughout the Stratton area and are generally varved. In many places, thin beds and lenses of gravel and sand occur. Also, isolated boulders are scattered throughout the area. This terrain unit is till-like in many places and could be the calcareous till referred to by Johnston (1915) and Hills and Morwick (1944). Further discrimination is not possible at this scale of air photo interpretation. Deposits are thick in places, ranging from 10 to 20 m in the Southwest, and thin out over planar bedrock in the middle of the map-area. Near Lake of the Woods and along the Rainy River, the glaciolacustrine deposits appear to be more sandy. Commonly associated subordinate landforms include bedrock knobs and plains, organic terrain, and glaciolacustrine beaches. Eolian sand dunes also occur in minor pockets close to the Sable Islands in the northwestern part of the area.



Figure 2.1 Location of existing culvert on Highway 11 (looking South)



Figure 2.2 Location of existing culvert on Highway 11 (looking North)

### **3. INVESTIGATION PROCEDURES AND LABORATORY TESTING**

Field drilling was carried out during September 19<sup>th</sup> to September 21<sup>st</sup>, 2015 utilizing a CME 750 drill rig equipped for geotechnical drilling. A total of four (4) boreholes were advanced to depths ranging from 4.8 m to 16 m. The specified depth of 10 m below culvert invert level could not be achieved at BH 4 location due to site accessibility. Borehole 4 was hand augured to the depth of 4.8 m below the existing ground surface. The borehole locations and stratigraphic sections are shown on the Borehole Location Plan on Drawing 1 in Appendix C.

Borehole 1 was advanced 1.6 m East of the existing culvert, 6.2 m South of the outlet (Sta. 12+029) and advanced to a depth of 15.4 m below existing surface. Borehole 2 was advanced 3.2 m East of the existing culvert, 4.2 m North of the culvert inlet (Sta. 12+029) and advanced to a depth of 16m below the existing surface. Borehole 3 was advanced 8.8 m West of the existing culvert outlet, 1.5 m North of outlet (Sta. 12+015) and advanced to a depth of 14.5 m below the existing surface. Borehole 4 was advanced 1.0 m South of the existing culvert inlet (Sta. 12+024) and advanced to a depth of 4.8 m below the existing surface.



The ground surface elevations at the borehole locations were surveyed by DST personnel and referenced to an existing stake at the North-West corner of the existing culvert with an elevation of 334.92 m (Rainy River Tributary Creek Crossing at Tributary Creek and Hwy 11, Plan E-576-11-1). Table 3.1 summarizes the detail of borehole locations and depths.

All boreholes were abandoned using suitable abandonment barrier as described in Ontario Regulation 903 and its amendments. Boreholes were decommissioned by backfilling to the bottom of the road base with cuttings and bentonite chips. From the bottom of the road base, granular materials were replaced to the bottom of the asphalt and the asphalt was sealed with a cold patch.

Soil samples were obtained from the auger flights and from the split spoon sampler used for the standard penetration test (SPT). The SPT involves driving a 51 mm diameter thick-walled sampler into the soil under the energy of a 63.5 kg weight falling through 760 mm. The number of blows required to drive the sampler 305 mm is known as the standard penetration blow count (N) which provides an indication of the relative density or consistency of the soil. The soil samples collected during drilling were identified in the field, placed in labelled containers and transported to DST's laboratory in Thunder Bay for further analyses.

Classification and index tests were subsequently performed in the laboratory on samples collected from the boreholes to aid in the selection of engineering properties. Laboratory tests included moisture contents, Atterberg limits and particle size analyses. A total of fifty-four (54) moisture contents, two (2) particle size analyses, and twelve (12) Atterberg limits have been carried out for this assignment. Laboratory test results are presented in the Boreholes Logs and graphical plots attached in Appendix D (Enclosures).

Table 3-1 Detail of Borehole Location

Borehole ID	Station	Elevation (m)	Depth (m)	Offset (m)
BH1	12 + 029	336.8	15.4	1.7 Lt
BH2	12 + 029	336.6	16	6.0 Rt
BH3	12 + 015	335.2	14.5	10.9 Lt
BH4	12 + 024	334.5	4.8	10.2 Rt



#### 4. DESCRIPTION OF SUBSURFACE CONDITIONS

The subsurface conditions are presented based on the information obtained during power and hand auger drilling.

The generalized stratigraphy of the existing embankment and culvert inlet and outlet, based on the conditions encountered in the boreholes consists of sand fill at surface underlain by clay in Boreholes 1 and 2 which was again underlain by till in Borehole 1. Clay was encountered at surface in Borehole 3 and 4. Summary of soil stratigraphy is presented in Tables 4-1 and 4-2.

Table 4-1 Summary of soil strata at the culvert inlet and outlet locations (BH2, BH3 and BH4)

Layer	Depth (m)	Elevation (m)	Comments
Fill – Sand	0.0 to 2.3	335.7 to 333.4	BH2
Clay	2.3 to 16	333.4 to 319.7	BH2
	0.0 to 14.5	334.2 to 319.7	BH3
	0.0 to 4.8	333.6 to 328.8	BH4

Table 4-2 Summary of soil strata at the culvert location through the embankment (BH1)

Layer	Depth (m)	Elevation (m)	Comments
Fill – Sand	0.0 to 2.3	335.8 to 333.5	BH1
Clay	2.3 to 13.7	333.5 to 322.1	BH1
Till	13.7 to 15.4	322.1 to 320.4	BH1

##### 4.1 Fill – Sand

Sand fill with some gravel and fines was encountered in Borehole 1 and 2 at depths from 0.0 to 2.3 m (Elev. 336.8 to 334.5 m) and (Elev. 336.6 to 334.3 m) with a thicknesses of 2.3 m.

The SPT 'N' values vary from 6 to 9, indicating a loose condition. The moisture content of a sample tested was found to be 7 %. The sieve analysis laboratory test results are summarized in Table 4-3.

Table 4-3: Summary of Sieve Analysis - Fill - Sand

Laboratory Results – Sieve Analysis	
Gravel %	15
Sand %	74
Fines %	11

## 4.2 Clay

Clay was encountered at surface in Boreholes 3 and 4 and below the fill in Boreholes 1 and 2 at depths from 0.0 to 14.5m (Elev. 335.2 to 320.7 m), 0.0 to 4.8 m (Elev. 334.5 to 329.7 m), 2.3 to 13.7 m (Elev. 334.5 to 323.1 m), and 2.3 to 16 m (Elev. 334.3 to 320.6 m) with thicknesses of 14.5 m, 4.8 m, 11.4 m, and 13.7 m respectively.

Atterberg limits tests carried out on samples from Boreholes indicate that the clay has low to high plasticity. Field vane tests completed in Boreholes show shear strength between 30 to 100+ kPa indicating a firm to very stiff consistency. The moisture contents of samples tested was found to be between 18 to 28 %. The Atterberg limits laboratory test results are summarized in Table 4-4.

Table 4-4: Summary of Atterberg Limits- Clay

Laboratory Results – Atterberg Limits	
Liquid Limit %	26 to 55
Plastic Limit %	13 to 25
Plastic Index %	9 to 36

## 4.3 Till

Till was encountered below the clay in Borehole 1 at the depth of 13.7 to 15.4 m (Elev. 323.1 to 321.4) with a thickness of 1.7 m. No recovery of sample was obtained, SPT 'N' values range from 57 to 62, indicating a very dense condition.

## 4.4 Groundwater

At the time of the field investigation, groundwater was only observed in Borehole 3. No groundwater was encountered in Boreholes 1, 2 or 4. However, the groundwater levels can be expected to vary with the season and precipitation events.

Table 4-5: Groundwater depth

Borehole	Groundwater Depth (m)	Groundwater Elev. (m)
Borehole 3	1.30	332.9

#### 4.5 Chemical Tests

Selected soil samples were submitted to ALS Laboratories Thunder Bay for chemical analyses (pH, sulphate, conductivity, resistivity and Chloride) to assess the potential for corrosion and sulphate attack on buried structures.

The results are presented below in Table 4-6 and a copy of the Laboratory Certificate of Analysis is provided in Appendix D.

Table 4-6: Chemical Test Results

Sample ID	Moisture (%)	Sulphate (mg/kg)	Chloride (mg/kg)	pH	Conductivity (ohms/cm)	Resistivity (ohm - cm)
BH1 @ 2.4 m depth	3.42	29	224	8.02	480	2080

The analytical results of the soil samples were compared with applicable Canadian Standards Association (CSA) standards as shown in Table 4-7 below

The chemical sulphate content analyses for representative soil sample tested indicate a sulphate concentration of 29 mg/kg or 0.0029 % in soil. The results were compared with Canadian Standards Association (CSA) Standards A23.1 for sulphate attack potential on concrete structures and possess a “negligible” risk for sulphate attack on concrete material and accordingly, conventional GU or MS Portland cement may be used in the construction of the proposed concrete elements.

The pH value for the soil samples was reported to be 8.02, indicating a durable condition against corrosion. These results were evaluated using Table 2 of Building Research Establishment (BRE) Digest 363 (July 1991). The pH is greater than 5.5 indicating the concrete will not be exposed to attack from acids. The chloride content of the selected soil sample was also compared with the threshold level and present negligible concrete corrosion potential. Soil resistivity and conductivity was found to be 2080 ohm-cm and 480 ohms / cm respectively for the sample analysed from BH1.

Table 4-7: Additional requirements for concrete subjected to Sulphate Attack

Class of Exposer	Degree of Exposer	Water soluble Sulphate in soil sample (%)	Cementing Material to be used
S-1	Very Severe	> 2.0	HS or HSb
S-2	Severe	0.20 – 2.0	HS or HSb
S-3	Moderate	0.10 – 0.20	MS, MSb, LH, HS, or HSb

\* Information from Table 3 of CSA Standards A23.1-04

## 5. MISCELLANEOUS

Site work was carried out during September 19<sup>th</sup> to September 21<sup>st</sup>, 2015 utilizing a CME 750 all-terrain drill supervised by DST. Soil samples collected during drilling were identified in the field, placed in labelled containers and transported to DST's laboratory in Thunder Bay for further analysis. Interpretation of the data and preparation of the report was completed by Selorm Danku, P.Eng and reviewed by Dr Masud Karim, P.Eng who is the designated principal contact for MTO projects.

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**PART 2: ENGINEERING DISCUSSIONS AND RECOMMENDATIONS**

**6. PROJECT DESCRIPTION**

DST Consulting Engineers Inc. (DST) has been retained by the prime consultant, Ainley Group, to conduct a foundation investigation and design report for the proposed culvert replacement at Rainy River Tributary, 4.3 km West of Highway 621 on the Highway 11 and provided foundation investigation report to Ministry of Transportation (MTO), Central Region. This work was carried out under Agreement No.: 2014-E-0059, Geotechnical Retainer.

Existing structure at this location is a 6.1 m wide X 1.85 m in height X 18.1 m in length Open Footing Box culvert with a thickness of soil cover of approximately 1.0 m. The culvert has wide cracks on both walls and soffit at centre, spall on West wall at bottom of crack with erosion occurring on the East wall. The walls of the culvert are slightly leaning outwards at the top with the base of the walls kicking in. Cracks were also identified at the inlet and outlet of the culvert with the top of the culvert deteriorating with exposed corroded rebars. The walls of the inlet and outlet were leaning 2.6° and 1.4° to the East and 3.1° and 1.4° to 3.8° to the West. The embankment at the culvert location is about 3 m high. The surrounding area is moderately vegetated.

Generalized stratigraphy of the existing embankment, based on the conditions encountered in boreholes, consists of sand fill underlain by clay. Till (gravelly soil) was encountered in Borehole 1 below clay layer.

This section presents interpretation of the geotechnical data presented in the factual report and provides geotechnical design recommendations and construction concerns for the proposed culvert replacement.

## **6.1 Replacement Structure**

Three options (Box culvert, Twin Corrugated Steel Pipe Culvert, and Open Footing Box Culvert or Conspan Precast Concrete Arch Culvert) have been discussed as replacement structure. It is understood that open cut excavation will be used to replace the structure. The design of the replacement structure must be in accordance with the Canadian Highway Bridge Design Code CAN/CSA-S6-06 (CHBDC, 2006) and all relevant Ministry of Transportation specifications and guidelines.

## **6.2 Foundation Design**

The culverts will be located at approximately the same vertical and horizontal alignment of the existing culvert structure. As the proposed culverts are not expected to be heavily loaded, a shallow foundation is considered suitable for this site.

If sub-excavation for frost effects is carried out in the dry (with adequate dewatering controls), the material can be replaced with Granular A material meeting OPSS.PROV 1010 specifications and compacted to a minimum of 95 % of standard Proctor maximum dry density in accordance with OPSS.PROV 501 "Construction Specification for Compacting". If sub-excavation for frost effects is carried out in the wet (water is maintained at or above adjacent groundwater table), all foundation preparation should be completed in accordance with OPSS 421 "Construction Specification for Pipe Culvert Installation in Open Cut", any specifications provided in the contract documents and as indicated in Section 6.7, Bedding.

### **6.2.1 Foundation Design (Box culvert)**

It is assumed that the culvert will be located approximately at the same elevation and location as the existing concrete box culvert. As the proposed culvert is not expected to be heavily loaded, a shallow foundation is considered suitable for this site. The geotechnical resistance was estimated for the ultimate limit state (ULS) and serviceability limit state (SLS) for a maximum settlement of 25 mm. The resistance at ULS was calculated by applying load resistance factor of 0.5 in accordance with the Bridge Design Code (CHBDC) CAN/CSA-S6-06 section 6.6, and is shown in Table 6-1

While ULS is not relevant at final condition due to significant soil cover, SLS is not relevant for temporary condition. Therefore SLS reported here are for final condition. The recommended bearing resistance of at SLS is in reference to an allowable net increase over the existing site condition.

The geotechnical resistance was estimated assuming a strip footing consisting of a width equal to the width of the box culvert (6.1 m) and placed at a depth of 4 m from the ground surface where clay soil can be encountered. The culvert can be installed on bedding material placed on undisturbed native clay soils.

Table 6-1 Geotechnical resistances

Footing Size	Ultimate bearing capacity (kPa)	Resistance at ULS (kPa)	Resistance at SLS (kPa)
B = 6.1 m	320	160	45

To achieve SLS resistance of more than 60 kPa for the box culvert, with limiting 25 mm maximum settlement, clay soil of up to 3.5 m depth (328.3 m elevation) from the proposed culvert base (331.8 m elevation) shall be replaced with compacted granular bedding soil. However, DST anticipates that the total settlement will be occurred by reloading of removed embankment during culvert construction. DST assumes most of the settlement will be completed during the construction period and no major settlement issue is expected if the load after culvert replacement is less or equal to the existing embankment load.

Where unsuitable or unstable soils are encountered, such as soil mixed with organic, the foundation soils must be removed to a firm or hard soils and replaced to the foundation grade with Granular "A" material meeting OPSS.PROV 1010 specifications and compacted to a minimum of 95% of standard Proctor maximum dry density.

### 6.2.2 Foundation Design (Open Footing)

It is assumed that the culvert will be located at approximately the same vertical and horizontal alignment as the existing structure. As the proposed culvert is not expected to be heavily loaded, a shallow foundation is considered suitable for this site.

The geotechnical resistance was estimated for the ultimate limit state (ULS) and serviceability limit state (SLS) for a maximum settlement of 25 mm. The resistance at ULS was calculated by applying load resistance factor of 0.5 according to the Bridge Design Code (CHBDC) CAN/CSA-S6-06 section 6.6, and is shown in Table 6-2. The geotechnical resistance was estimated assuming a strip footing of various widths with a length equal to 18.1 m situated at depth between 3.3 m and 5.3 m (333.5 and 331.5 m elevations) below the existing road elevation where clay soil will be encountered.



Table 6-2 Geotechnical resistances for open footing culverts

Footing Width L=18.1 m	Depth of Soil Cover	Depth of Founding Level from Road Surface, m	Ultimate bearing capacity (kPa)	Factored Resistance at ULS (kPa)	Resistance at SLS (kPa)
B = 1.0 m	0	3.3	300	150	150
	1.0	4.3	360	180	160
	1.5	4.8	390	195	160
	2.0	5.3	420	210	160
B = 1.2 m	0	3.3	300	150	130
	1.0	4.3	350	175	135
	1.5	4.8	380	190	140
	2.0	5.3	405	200	140
B = 1.5 m	0	3.3	300	150	110
	1.0	4.3	345	170	110
	1.5	4.8	365	180	115
	2.0	5.3	385	190	115
B = 2.5 m	0	3.3	300	150	75
	1.0	4.3	330	165	75
	1.5	4.8	340	160	80
	2.0	5.3	350	175	80

### 6.3 Lateral and Sliding Resistances

The analysis of horizontal and vertical effects of earth loads on the culvert can be performed considering soil parameters given in Table 6-3 and as described in Section 7.6.3.1 in Canadian Highway Bridge Design Code. Temporary bracing and shoring may be designed using the typical soil parameters given in Table 6-3, however the designer/contractor should verify the appropriate soil parameters for the designs of specific bracing and shoring system.

It is recommended that all excavations be either adequately sloped or securely shored and braced to prevent earth caving and to provide a safe and stable work area. The design should incorporate the effects of hydrostatic pressure, traffic surcharge and retained sloping earth conditions in the bracing design.

Table 6-3 Typical Soil Parameters for Earth Loads

Soil type	Unit weight (kN/m <sup>3</sup> )	Internal drained friction angle (Deg)	Interface friction angle* $\delta$ (Deg)	Adhesion $\alpha$
Fill Sand	21	30	19	-
Clay	18	24	-	19

\*between soil and concrete

Table 6-4 Lateral Earth Pressure Coefficients

Soil type	Active Earth Pressure ( $K_a$ )	Passive Earth Pressure, ( $K_p$ )	Earth Pressure at Rest, ( $K_0$ )
Equation *	$\left(\frac{1 - \sin\phi}{1 + \sin\phi}\right)$	$\left(\frac{1 + \sin\phi}{1 - \sin\phi}\right)$	$(1 - \sin\phi)$
Fill Sand & Gravel	0.33	3.00	0.50
Clay	0.42	2.37	0.59

\*  $\phi$  is an angle of internal friction

\*\*The earth pressure coefficients provided here are for the normally consolidated soils condition considering fully mobilized condition

For over consolidated (OC) soils, the earth pressure coefficient at rest condition should be corrected using a following relationship

$$K_{0(OC)} = K_{0(NC)} * (OCR)^{0.5}$$

Where

$K_{0(OC)}$ = Earth pressure coefficient over consolidated soils

$K_{0(NC)}$ = Earth pressure coefficient normally consolidated soils

OCR= Over Consolidation Ratio

The sliding resistance can be calculated using the following formulae.

$$F_r = W (\tan\delta)$$

Where,

$\delta$  = Interface friction angle

W= Total weight of the soil element retained per unit length of the retaining wall

#### **6.4     Staged Construction**

It is understood that two staged construction method is being considered to complete the culvert replacement, with vertical shoring and minor road widening with sideslopes at the excavation. The staged construction includes two (2) stages. Stage 1 is making a temporary lane at one side of the road, diverting lane to temporary lane and excavating other side of the road for the culvert replacement work. Stage 2 is making temporary lane on the completed culvert side, diverting lane to that temporary lane and excavating remaining side for the culvert replacement work.

Road widening with side slope of 1.5H:1.0V method or vertical shoring method using a wall can be used. Use of temporary concrete or sheet pile wall will be required if the vertical shoring method is selected. Excavation depth of approximately 4.5 m may be required for the staged construction. The soil profile of the site consists of pavement layers underlying clay before encountering granular (till) layer. The final embankment foreslopes should be reinstated as presented in Section 6.12 Embankment Foreslopes.

Slope stability analyses using Slope W software indicate that factor of safety for excavation depth of 4.5 m from the road surface with 1.5H:1V without present of surface water is 1.1 (Drained), 1.8 (undrained). The embankment slopes at the inlet and outlet should be 1.5H: 1V. Embankment with sideslopes 1.5H: 1V at the excavation for culvert replacement is feasible with a factor of safety of 1.1 for short term duration without presence of surface water at the site.

#### **6.5     Earth Excavation**

Earth excavation will be required adjacent to the existing and replacement structure and may require temporary surface water ditch diversion and temporary support for traffic. As a minimum, the procedures should be in accordance with OPSS 902 "Construction Specifications for Excavating and Backfilling-Structures". Where temporary protection systems are required they shall be constructed in accordance with OPSS.PROV 539 "Construction Specification for Temporary Protection Systems" and Section 6.6 "Roadway Protection".

According to O.Reg. 213/91, s.226, the soils in the area of interest classify as Type 3. Type 3 soils generally are stiff to firm and compact to loose or are previously excavated soil, exhibit signs of surface cracking, exhibit signs of seepage, if it is dry, may run easily into a conical pile and have a low degree of internal strength. In accordance with O. Reg. 213/91, s.227 (3), if an excavation contains more than one type of soil, the soil shall be classified with the highest number as described

in section 226. These should be assessed and confirmed in the field as construction progresses.

If organic materials are encountered during excavation, the excavations to remove these organics and wood should be completed in accordance with OPSS.PROV 209 "Construction Specification for Embankments Over Swamps and Compressible Soils".

Open excavation without shoring could be completed provided that the soils are sloped back sufficiently to maintain sidewall stability and protect workers. For excavations above the groundwater table, it is recommended that a side slopes no steeper than 1.5H: 1V are maintained. Dewatering is therefore recommended in that case. The stability of the excavation side slopes will be highly dependent on the contractor's methodology and ability to effectively dewater the excavation. Bottom width of excavation should be 4 to 6 m wider than maximum width of proposed replacement culvert.

## **6.6     Roadway Protection**

Roadway protection for this project should be constructed in accordance with the requirements of the Occupational Health and Safety Act of Ontario (OHSA), O.Reg. 213/91.

Since temporary roadway protection is required during the structure replacement, installation of a sheet pile or soldier pile wall may be considered to ensure the stability of the bank and is a feasible option. The design of roadway protection may be performed using the typical soil parameters given in Table 6-3 and Table 6-4, however the designer/contractor should verify the appropriate soil parameters for the designs. As the potential of encountering concrete, rock fill, cobbles and boulders exists, the contractor should be prepared to handle this with the selection of adequate driving or vibratory equipment as well as steel thickness. The construction methodology must be in accordance with all applicable standards and regulations related to the method proposed. The contractor's method and equipment must be suitable for the site conditions and materials used.

## **6.7     Bedding**

The foundation soils, silts in particular, will be very susceptible to disturbance and weakening as a result of traffic, standing water and frost. Any foundation soils that could be disturbed shall be protected. The bottom of the excavation on which the culvert or granular pad is to rest shall not be disturbed. The bedding placement should commence immediately after the final removal of material to the foundation level has been completed.

The bedding for the structure should be designed in accordance with Section 7.8 of the CHBDC. The bedding shall be a minimum of 0.5 m thick and extend to a minimum width (half of the width of culvert) beyond all sides of the culvert. The bedding material should consist of “Granular A” as per Soil Group I in accordance with Table 7.4 of the Canadian Highway Bridge Design Code. The “Granular A” shall be in accordance to OPSS.PROV 1010. The “Granular A” should be placed in layers not exceeding 200 mm in thickness, loose measurement, and each layer compacted to a minimum of 95 % of standard Proctor maximum dry density. The middle one-third of the culvert width of the top bedding layer, having minimum thickness of 75 mm, shall be loosely placed and uncompacted.

If construction is performed without dewatering, bedding material should consist of 19 mm Type I or II clear stone as defined in OPSS.PROV 1004.05.02. If fine materials are present beneath the clear stone a non-woven geotextile (OPSS 1860.07.05.01 Class II) with the filtration opening size (FOS) less than 135 µm may be required for separation. No compaction is required of the clear stone.

## **6.8     Sidefill and Overfill**

The material used for culvert sidefill should not contain debris, organic matter, frozen materials, or large stones of a diameter greater than one-half the thickness of the compacted layers being placed or 100 mm, whichever is smaller. Soils shall be deposited uniformly on each side of the structure in order to prevent lateral displacement. The minimum width of the sidefill should be at least half of the culvert width on each side. The sidefill should consist of Granular A” and compacted to 95% of standard Proctor maximum dry density.

Overfill should consist of “Granular A” and should be compacted to not greater than the compaction or equivalent stiffness of soils in the sidefill zone and bedding. The backfill materials should be separated from the adjacent soil with a non-woven Class II geotextile, with a filtration opening size of between 50 and 100 µm, specified in OPSS 1860 “Material Specifications for Geotextiles”.

## **6.9     Channel Diversion and Dewatering**

The culvert shall be replaced by diverting the creek channel temporarily adjacent to the existing culvert. It is important to ensure that a flood in the channel does not cause damage to the partly constructed permanent works, to the temporary works or to plant. Floods have a habit of occurring

overnight or at weekends and inadequate temporary works can fail with expensive consequences.

If the creek has comparatively a small amount of flow that may depend on the season, it may be feasible for the creek flow to be directed by staging construction. In order to prevent back up of water from upstream and downstream, a dyke made of sand bags has sometimes been used as a hydraulic barrier. However, a sheet pile vertical cut-off wall will provide better control of both surface and groundwater. A suitable sump and pump system, possibly supported by an efficient well-point system, will be required to dewater and stabilize the excavation. A well designed well-point system with a suitable diameter of well point at an appropriate spacing will perform better for working under dry condition and to prevent disturbance of the excavation base through sand boiling and hydraulic heave. It should be noted that depending on the season, depth of excavation and amount of water flow through the creek may vary. The contractor should be prepared to tackle this situation. The contractor should be alerted of the high water table and surface water, for example through a non-standard special provision (NSSP).

A continuous dewatering operation must be provided to keep the excavation stable and free of water. The excavation must be monitored daily throughout the duration of excavation until the completion of backfilling to confirm this. The dewatering system must be maintained and the surrounding area monitored for impacts to items such as, but not limited to, settlement and groundwater usage. The control of water from the dewatering operation should be accordance with OPSS 518 "Construction Specification for Control of Water from Dewatering Operations".

#### **6.10 Erosion Control**

Erosion control is essential at inlet and outlet for the successful performance of a culvert. Generally, rip-rap is used to avoid the erosion at inlet and outlet of the culvert. The rip-rap slows down the flow close to the channel bed and prevents culvert failure by the undermining.

To prevent erosion of the surrounding soils at the inlet, rip-rap Treatment shall be applied in accordance with OPSD 810.020 "Rip-Rap Treatment for Ditch Inlets" and OPSS 511 "Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting".

The outlet shall be rip-rapped to prevent erosion of the surrounding soils in accordance with OPSD 810.010 "Rip-Rap treatment for Sewer and Culvert Outlets" and OPSS 511 "Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting".

To prevent undermining of the bedding (if culvert option is used), cutoff walls shall be installed along the entrance and exit end bottom sides of culvert. Cutoff walls should be designed based on velocity of the water flow and the type of soil underneath.

The temporary erosion and sedimentation measures during the construction of culvert shall be controlled as described in OPSS 805 "Construction Specification for Temporary Erosion and Sedimentation Control Measures".

### **6.11 Frost Protection**

In accordance with OPSD 3090.100 "Foundation Frost Depths for Northern Ontario", the frost penetration at this location is about 2.0 m. The frost susceptible soils shall not be used within the frost penetration length from the culvert wall, culvert sides and pavement surface. The soils under the culvert are highly frost susceptible (capable of forming thick ice lenses with the associated pressures and heave).

During winter season, ice may form inside the culvert and a low flow rate may assist the ice formation. It is expected that ice may extend to the culvert invert and frost could therefore extend into the soils below the culverts, possibly as deep as 2.0 m. The frost heave may generate additional stresses on the culvert foundation and walls.

Three design approaches are commonly applied; designing the culvert with enough strength and rigidity to tolerate these pressures (recognizing that the maximum differential pressures and movements as a result of frost lensing cannot be accurately quantified); removing the frost susceptible soils within the frost zone; or providing adequate insulation to reduce frost penetration. As the frost penetration is extended below the invert level of the culvert, the frost protection should be in accordance with OPSD 803.030 and 803.031 "Frost Treatment - Pipe Culverts, Frost Penetration Line below Bedding Grade" and "Frost Treatment - Pipe Culverts, Frost Penetration Line between Top of the Pipe and Bedding Grade".

If sub-excavation for frost effects is carried out in the dry (with adequate dewatering controls), the material can be replaced with Granular B Type 1 material compacted to 95% of standard proctor maximum dry density. If the excavation is in the wet (water is maintained at or above adjacent groundwater table) then the material should be rockfill or clear stone surrounded by geotextile, without the need for compaction. Depending on the structural design of the culvert, partial sub-excavation (less than 2.0 m) may also be considered to reduce differential stresses associated



with frost; however the exact pressures and movements cannot be accurately quantified.

Acceptable insulation to prevent frost penetration would be 127 mm Dow Styrofoam Highload 40 Insulation or an equivalent material with a compressive strength of approximately 275 kPa or greater. For a region that has a freezing index greater than 1500 Celsius Degree-Days it is recommended that the insulation be placed beneath the structure and extend 2.44 m from the face of the buried structure. Insulation layer shall be covered with minimum 300 mm of soil to prevent buoyancy and movement of the insulation material.

#### **6.12 Embankment Foreslopes**

Existing culvert foreslopes are approximately 1.5H: 1V on both the west and east embankments. The foreslopes should be reinstated with a slope not steeper than 2H: 1V if being constructed with granular materials. The foreslopes should be reinstated with a slope not steeper than 1.5H: 1V if being constructed with rock fill. The minimum thickness of rock fill must be greater than 2 m to achieve an adequate FOS for the reinstated rock fill embankment.

#### **6.13 Construction Concerns**

The main construction issues those need to be addressed for this site are removal of cover/embankment materials, staged removal of the existing culvert, provisions required for temporary roadway protection, diversion of the channel, excavation below the water table and reinstatement of the embankment fill. These items are important for the successful installation of the new culvert.

A quality verification Engineer shall be required to inspect the condition of the foundation and surrounding soils before installation of bedding and other backfills and ensure the width of trench and trench wall slopes are suitable, and ensure compliance with material placements and compaction methods.

## 7. CLOSURE

Summarizes the advantages and disadvantages of the use of concrete or steel sheet piles wall and 1.5H: 1V sideslopes for roadway protection. Since it is a temporary roadway protection and factor of safety of 1.1 can be achieved, 1.5H: 1V sideslopes without surface water presence is considered to be a recommended option however design of roadway protection is the responsibility of the contractor as per the contract drawings.

Table 7-1 Advantages and Disadvantages of Roadway Protection Methods

Roadway Protection Option	Advantages	Disadvantages
Concrete or steel sheet pile wall	<ul style="list-style-type: none"> <li>• Relatively non permeable.</li> <li>• Increase erosion control capacity.</li> <li>• Ease installation when working below ground water table.</li> <li>• Can design with suitable factor of safety.</li> </ul>	<ul style="list-style-type: none"> <li>• Difficult driving through cobbles, concrete.</li> <li>• High installation cost.</li> <li>• Special construction equipment and design required.</li> </ul>
Sideslope 1.5H:1V	<ul style="list-style-type: none"> <li>• Does not require specialized equipment.</li> <li>• Relatively short construction time.</li> <li>• Low construction cost.</li> <li>• Can achieve suitable factor of safety</li> </ul>	<ul style="list-style-type: none"> <li>• Permeable.</li> <li>• Increased erosion due to exposed material.</li> <li>• Low factor of safety with increasing excavation depth.</li> </ul>

Table 7-2 Advantages and Disadvantages of the Proposed Culvert Options

Foundation Option	Feasibility	Advantages	Disadvantages	Relative Costs	Risks/Consequences
<b>Option 1- Concrete Box Culvert</b>	Feasible	Use of pre-cast members could reduce construction time.  Low maintenance cost.	Requires roadway protection system.	Low to Moderate cost.	In general terms low risk option. (except for shoring)
<b>Option 2-Open Footing</b>	Feasible	Use of pre-cast members could reduce construction time.  Low maintenance cost	Use of this option could increase construction time.  Requires foundation excavation and preparation.  Requires roadway protection system.	Moderate cost.	In general terms low risk option (except for shoring).
<b>Option 3- Corrugated Steel Plate Culvert</b>	Feasible	No bearing capacity concerns.  Minimal culvert settlement.	Requires roadway protection system.  High maintenance cost.	Low to Moderate cost.	Low risk option. (except for shoring)

## 8. REFERENCES

- Canadian Foundation Engineering Manual. 2006. Fourth Edition, Canadian Geotechnical Society.
- Canadian Highway Bridge Design Code. 2006, CAN/CSA-S6-06, A National Standard of Canada, Canadian standards Association.
- Municipal and Provincial Common, Volume 1 - General & Construction Specifications, "*Ontario Provincial Standard for Roads & Public Works*" Spec No. OPSS 511, 517, 518, 805, 902.
- Municipal and Provincial Common, Volume 2 - Material Specifications, "*Ontario Provincial Standard for Roads & Public Works*" Spec No. OPSS 1860.
- Municipal and Provincial Common, Volume 3 - Drawings for Roads, Barriers, Drainage, Sanitary Sewers, Watermains and Structures, "*Ontario Provincial Standard for Roads & Public Works*" Spec No. OPSD 203.040, 803.010, 803.030, 803.031, 810.010, 810.020, 3090.100.
- Occupational Health and Safety Act and Regulation, June 2002, Revised Statutes of Ontario, 1990, Chapter O.1, O.Reg. 213/91.
- Provincial-Orientated, Volume 5 - MTO General Conditions of Contract and General & Construction Specifications, "*Ontario Provincial Standard for Roads & Public Works*" Spec No. OPSS.PROV 209, 501, 510, 539.
- Provincial-Orientated, Volume 6 - Material Specifications, "*Ontario Provincial Standard for Roads & Public Works*" Spec No. OPSS.PROV 1004, 1010.
- The Surveys and Design Office, Highway Engineering Division, Ministry of Transportation, 1990, Pavement Design and Rehabilitation Manual.

## **9. LIMITATIONS OF REPORT**

A description of limitations which are inherent in carrying out site investigation studies is given in Appendix 'A', and this forms an integral part of this report.

For DST CONSULTING ENGINEERS INC.

Prepared by:

Reviewed by:



Selorm Danku, P.Eng.  
Geotechnical Engineer



Dr. ASM Masud Karim, P.Eng.  
Regional Manager – Infrastructure

**Appendix A**

**LIMITATIONS OF REPORT**

# **LIMITATIONS OF REPORT**

## **GEOTECHNICAL STUDIES**

The data, conclusions and recommendations which are presented in this report, and the quality thereof, are based on a scope of work authorized by the Client. Note that no scope of work, no matter how exhaustive, can identify all conditions below ground. Subsurface and groundwater conditions between and beyond the testholes may differ from those encountered at the specific locations tested, and conditions may become apparent during construction which were not detected and could not be anticipated at the time of the site investigation. Conditions can also change with time. It is recommended practice that DST Consulting Engineers be retained during construction to confirm that the subsurface conditions throughout the site do not deviate materially from those encountered in the testholes. The benchmark and elevations used in this report are primarily to establish relative elevation differences between the testhole locations and should not be used for other purposes, such as grading, excavation, planning, development, etc.

The design recommendations given in this report are applicable only to the project described in the text and then only if constructed substantially in accordance with details stated in this report. Since all details of the design may not be known, we recommend that we be retained during the final stage to verify that the design is consistent with our recommendations, and that assumptions made in our analysis are valid.

Unless otherwise noted, the information contained herein in no way reflects on environmental aspects of either the site or the subsurface conditions.

The comments given in this report on potential construction problems and possible methods are intended only for the guidance of the designer. The number of testholes may not be sufficient to determine all the factors that may affect construction methods and costs, e.g. the thickness of surficial topsoil or fill layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusion as to how the subsurface conditions may affect their work.

Any results from an analytical laboratory or other subcontractor reported herein have been carried out by others, and DST Consulting Engineers Inc. cannot warranty their accuracy. Similarly, DST cannot warranty the accuracy of information supplied by the client.



**Appendix B**

**DESCRIPTION OF TERMS**

## EXPLANATION OF TERMS USED IN REPORT

**SPT 'N' VALUE:** THE STANDARD PENETRATION TEST (SPT) N VALUE OF THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51 mm O.D. SPLIT BARREL SAMPLES TO PENETRATE 0.3 m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5 kg, FALLING FREELY A DISTANCE OF 0.76 m. FOR PENETRATION OF LESS THAN 0.3 m 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 (DCPT):** CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51 mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3 m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

### ***SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS***

#### **TEXTURAL CLASSIFICATION OF SOILS**

BOULDERS	COBBLES	GRAVEL	SAND	SILT	CLAY
GREATER THAN 200 mm	75 TO 200 mm	4.75 TO 75 mm	0.075 TO 4.75 mm	0.002 TO 0.075 mm	LESS THAN 0.002 mm

#### **COARSE GRAIN SOIL DESCRIPTION (50% GREATER THAN 0.075 mm)**

TERMINOLOGY	TRACE OR OCCASIONAL	SOME	WITH	ADJECTIVE (e.g. SILTY OR SANDY)	AND (e.g. SAND AND SILT)
	LESS THAN 10%	10 TO 20%	20 TO 30%	30 TO 40%	40 TO 60%

#### **CONSISTENCY\*: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH ( $C_u$ ) AND SPT 'N' VALUES AS FOLLOWS**

$C_u$ (kPa)	0 – 12	12 – 25	25 – 50	50 - 100	100 - 200	> 200
N (BLOWS / 0.3 m)	<2	2 - 4	4 - 8	8 - 15	15 - 30	>30
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

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

N (BLOWS / 0.3 m)	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, 100 mm+ IN LENGTH EXPRESSED AS A PERCENTAGE OF THE LENGTH OF THE CORING RUN.

THE **ROCK QUALITY DESIGNATION (R.Q.D)** FOR MODIFIED RECOVERY IS:

R.Q.D (%)	0 – 25	25 – 50	50 – 75	75 – 90	90 – 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

#### **LEGEND OF RECORDS FOR BOREHOLES: SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE**

SS	SPLIT SPOON SAMPLE	WS	WASH SAMPLE
TW	THIN WALL SHELBY TUBE SAMPLE	AS	AUGER (GRAB) SAMPLE
PH	SAMPLER ADVANCED BY HYDRAULIC PRESSURE	TP	THIN WALL PISTON SAMPLE
WH	SAMPLER ADVANCED BY SELF STATIC WEIGHT	PM	SAMPLER ADVANCED BY MANUAL PRESSURE
SC	SOIL CORE	RC	ROCK CORE
	WATER LEVEL	$SENSITIVITY = \frac{UNDISTURBED\ SHEAR\ STRENGTH}{REMOLDED\ SHEAR\ STRENGTH}$	

\*HIERARCHY OF SOIL STRENGTH PREDICTION: **1)** LABORATORY TRIAXIAL TESTING. **2)** FIELD INSITU VANE TESTING. **3)** LABORATORY VANE TESTING. **4)** SPT VALUES. **5)** POCKET PENETROMETER.

# **Appendix C**

## **DRAWINGS**



UM  
TBAY TEL

12+000

11+990

N 5399273.508  
E 195427.011

RAINY RIVER  
TRIBUTARY CREEK

12+050

12+056.691



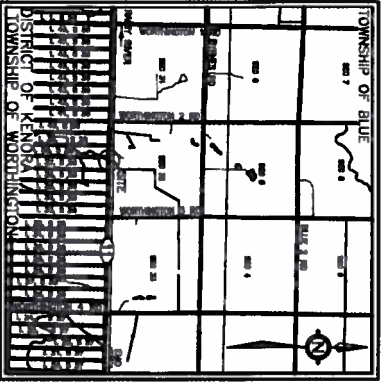
METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES UNLESS  
OTHERWISE SPECIFIED  
IN DIMENSIONS + METERS

AG No 2014-E-0059  
WP No 6182-04-01  
SITE No 45-213C  
GEOCRETS No 52D-024



SHEET

REPLACEMENT OF  
RAINY RIVER TRIBUTARY  
STA 11+990 TO STA 12+050  
Survey \_\_\_\_\_ Revised \_\_\_\_\_



KEY PLAN  
1.0 km 0 1.0 km

Legend

Borehole

No. Elevation Surveying Existing Existing Offset

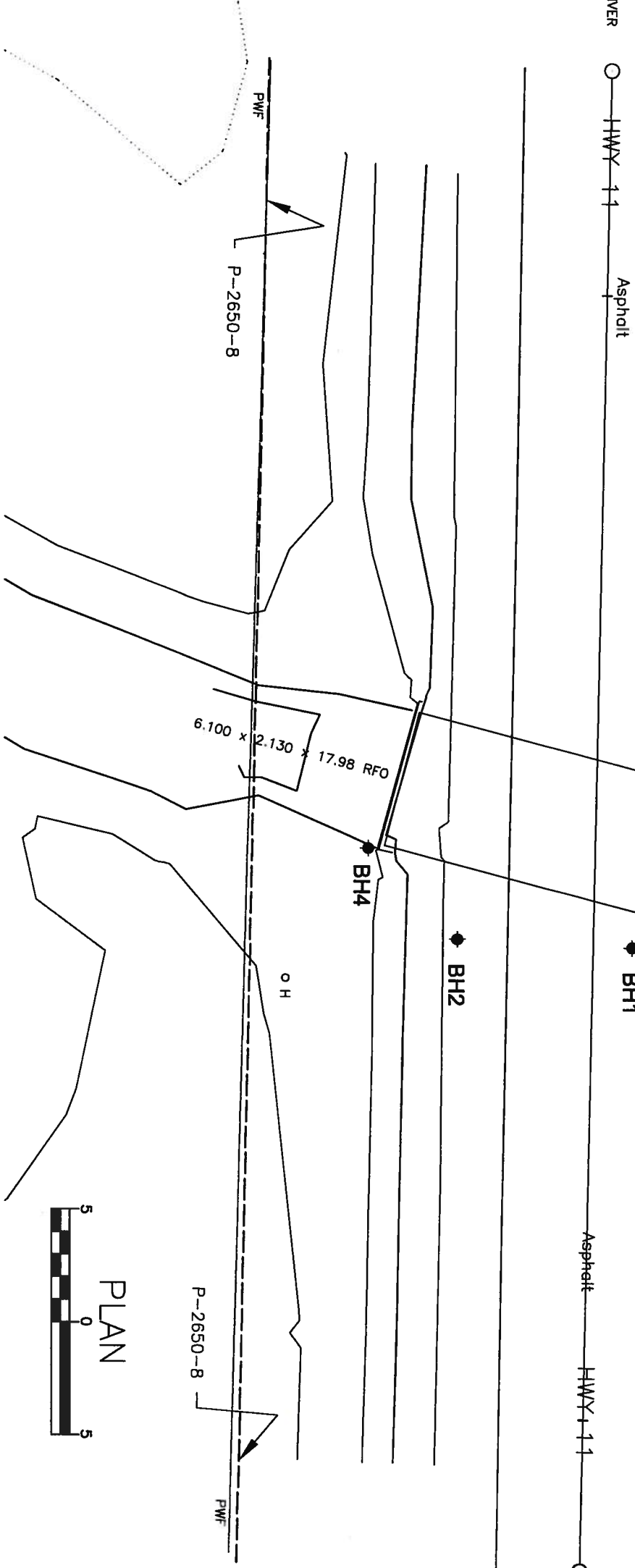
BH1	208.0	5200200 m N	100420 m S	12+020	1.7 m LT
BH2	208.0	5200200 m N	100420 m S	12+020	6.0 m RT
BH3	208.2	5200270 m N	100410 m S	12+015	10.0 m LT
BH4	204.5	5200270 m N	99420 m S	12+004	10.0 m RT


NOTE:  
The boundaries between and within have been established only at borehole  
locations. Distances between the boreholes are assumed by interpolation  
and may not represent actual conditions.

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DRAWING 1

PLAN  
5 0 5



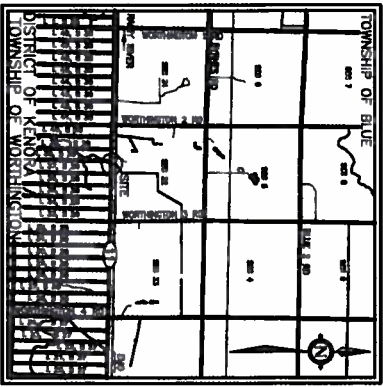
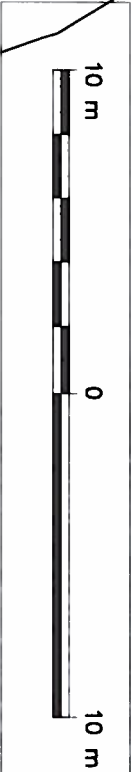
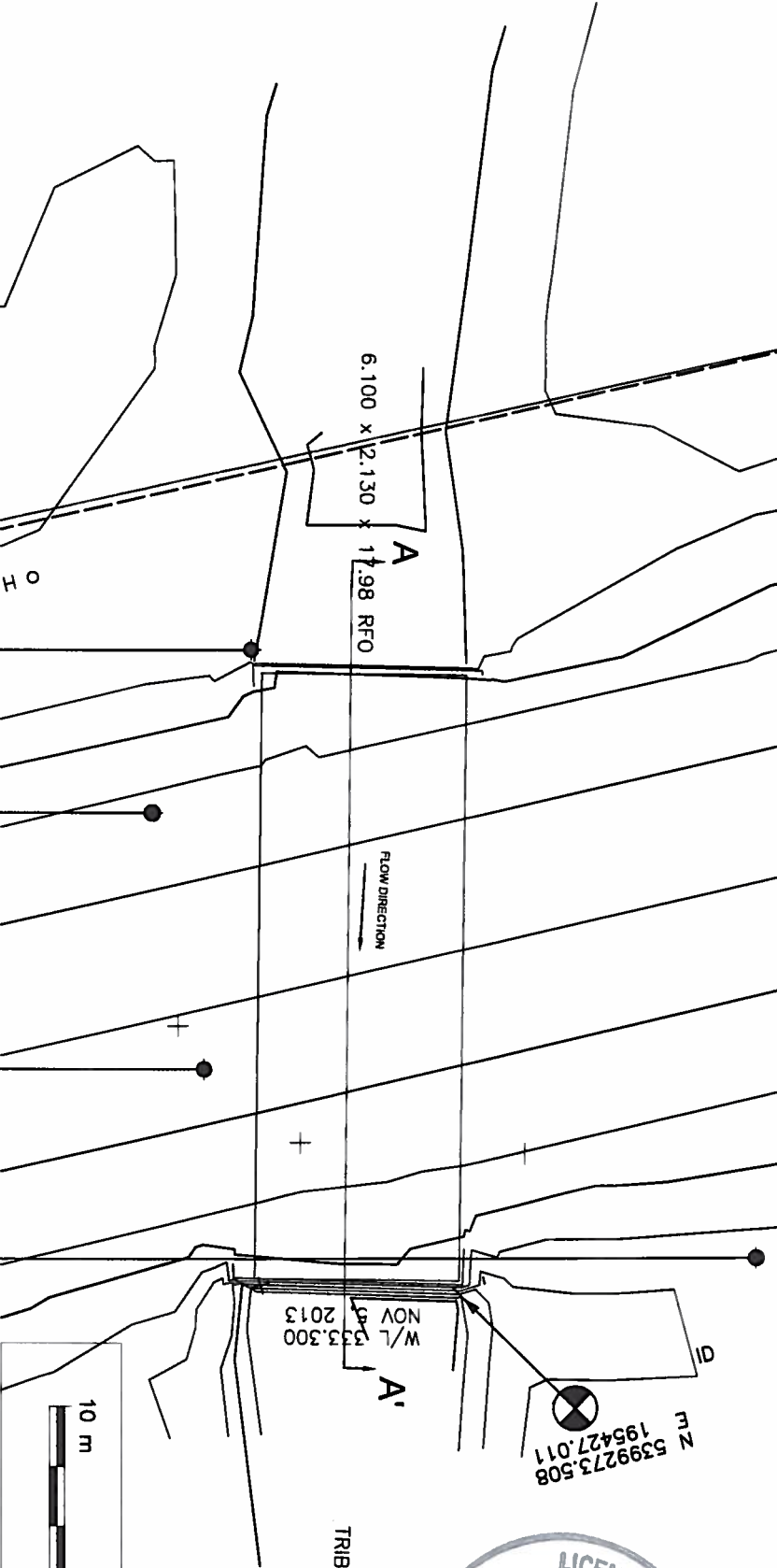
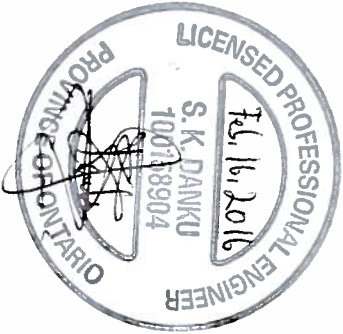
METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES UNLESS  
OTHERWISE SPECIFIED. DIMENSIONS  
IN PARENTHESES + METERS

AG No 2014-E-0059  
WP No 6182-04-01  
SITE No 45-213C  
GEOCRETS No 52D-024



REPLACEMENT OF  
RAINY RIVER TRIBUTARY  
STA 11+990 TO STA 12+050  
Survey \_\_\_\_\_ Revised \_\_\_\_\_

SHEET



KEY PLAN



LEGEND

- Borehole
- Blow/13m (Shl. Pen Test, 475 J/Blow)
- Groundwater Elevation
- Fill
- Organics
- Topsoil
- Clay
- Sand & Gravel
- Till
- Bedrock
- Sand
- Silt
- Clay
- Sand & Gravel
- Boulders

No.	Elevation	Matching	Existing	Station	Offset
-----	-----------	----------	----------	---------	--------

BH1	338.8	338.800 m N	150423 m E	124+03	1.7 m LT
BH2	338.6	338.600 m N	150423 m E	124+03	6.0 m RT
BH3	338.4	338.400 m N	150415 m E	124+03	14.0 m LT
BH4	338.4	338.400 m N	150423 m E	124+04	14.2 m RT


NOTE:  
The boundaries between and within have been established only at the location  
indicated. Between boundaries the boundaries are assumed by interpolation  
and may not represent actual conditions.

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DRAWING 2

**Appendix D**  
**ENCLOSURES**

# RECORD OF BOREHOLE No BH1

1 OF 1

METRIC

W.P. 6182-04-01 LOCATION RAINY RIVER TRIBUTARY ORIGINATED BY CH  
DIST Rainy River HWY 11 BOREHOLE TYPE HOLLOW STEM AUGER - 80 mm ID COMPILED BY SA  
DATUM GEODETIC DATE 2015 09 21 CHECKED BY BV

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT  W <sub>p</sub>	NATURAL MOISTURE CONTENT  W	LIQUID LIMIT  W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)
								○ UNCONFINED □ QUICK TRIAXIAL	+ FIELD VANE × LAB VANE							
335.8	GROUND SURFACE															
333.5 2.3	FILL - SAND, SOME GRAVEL, TRACE SILT, TRACE CLAY LOOSE		AS1	AS												
			SS1	SS	8											
			SS2	SS	6											
			SS3	SS	4											
			SS4	SS	6											
			SS5	SS	4											
			SS6	SS	9											
			SS7	SS	8											
			SS8	SS	8											
		ST1	TW													
			SS9	SS	13											
			SS10	SS	7											
			SS11	SS	19											
322.1																
13.7			SS12	SS	57										NO SAMPLE RECOVERY	
			SS13	SS	62										NO SAMPLE RECOVERY	
320.4																
15.4	END OF BOREHOLE AT 15.4 m														AUGER REFUSAL	

ONL MOT-HIGH VANES RAINY RIVER - GS-TB-020823.GPJ DATA TEMPLATE.GDT 2/2/16

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

ENCLOSURE 1

# RECORD OF BOREHOLE No BH2

1 OF 1

METRIC

W.P. 6182-04-01 LOCATION RAINY RIVER TRIBUTARY ORIGINATED BY CH  
DIST Rainy River HWY 11 BOREHOLE TYPE HOLLOW STEM AUGER - 80 mm ID COMPILED BY SA  
DATUM GEODETIC DATE 2015 09 19 CHECKED BY BV

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)			
								20	40							60	80	100
335.7	GROUND SURFACE																	
333.4 2.3	FILL - SAND, TRACE GRAVEL LOOSE BROWN          CLAY, TRACE SILT, TRACE GRAVEL FIRM TO VERY STIFF GREY		AS1	AS										17 69 (15)				
			SS1	SS	9													
			SS2	SS	8													
		SS3	SS	6														
		SS4	SS	6														
		SS5	SS	7														
		SS6	SS	6														
		SS7	SS	6														
		SS8	SS	5														
		SS9	SS	11														
		SS10	SS	12														
		SS11	SS	14														
		SS12	SS	17														
		SS13	SS	15														
SS14	SS	19																
319.7 16.0	END OF BOREHOLE AT 16.0 m																	

ONL MOT-HIGH VANES RAINY RIVER - GS-TB-020823.GPJ DATA TEMPLATE.GDT 2/2/16

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

ENCLOSURE 2



RECORD OF BOREHOLE No BH3

1 OF 1

METRIC

W.P. 6182-04-01 LOCATION RAINY RIVER TRIBUTARY ORIGINATED BY CH  
DIST Rainy River HWY 11 BOREHOLE TYPE HOLLOW STEM AUGER - 80 mm ID COMPILED BY SA  
DATUM GEODETIC DATE 2015 09 20 CHECKED BY BV

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)		
334.2	GROUND SURFACE							20	40	60	80	100					
	CLAY SOFT TO VERY STIFF GREY		AS1	AS		▽	334										
			SS1	SS	3		333										
			SS2	SS	8		332										
			SS3	SS	5		331										
			ST1	TW			330										
			SS4	SS	6		329										
			SS5	SS	8		328										
			SS6	SS	8		327										
			SS7	SS	12		326										
			SS8	SS	12		325										
			SS9	SS	14		324										
			SS10	SS	16		323										
			SS11	SS	18		322										
			SS12	SS	20		321										
319.7		END OF BOREHOLE AT 14.5 m							320								
14.5																	

ONL MOT-HIGH VANES RAINY RIVER - GS-TB-020823.GPJ DATA TEMPLATE.GDT 2/2/16

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

ENCLOSURE 3

# RECORD OF BOREHOLE No BH4

1 OF 1

METRIC

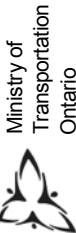
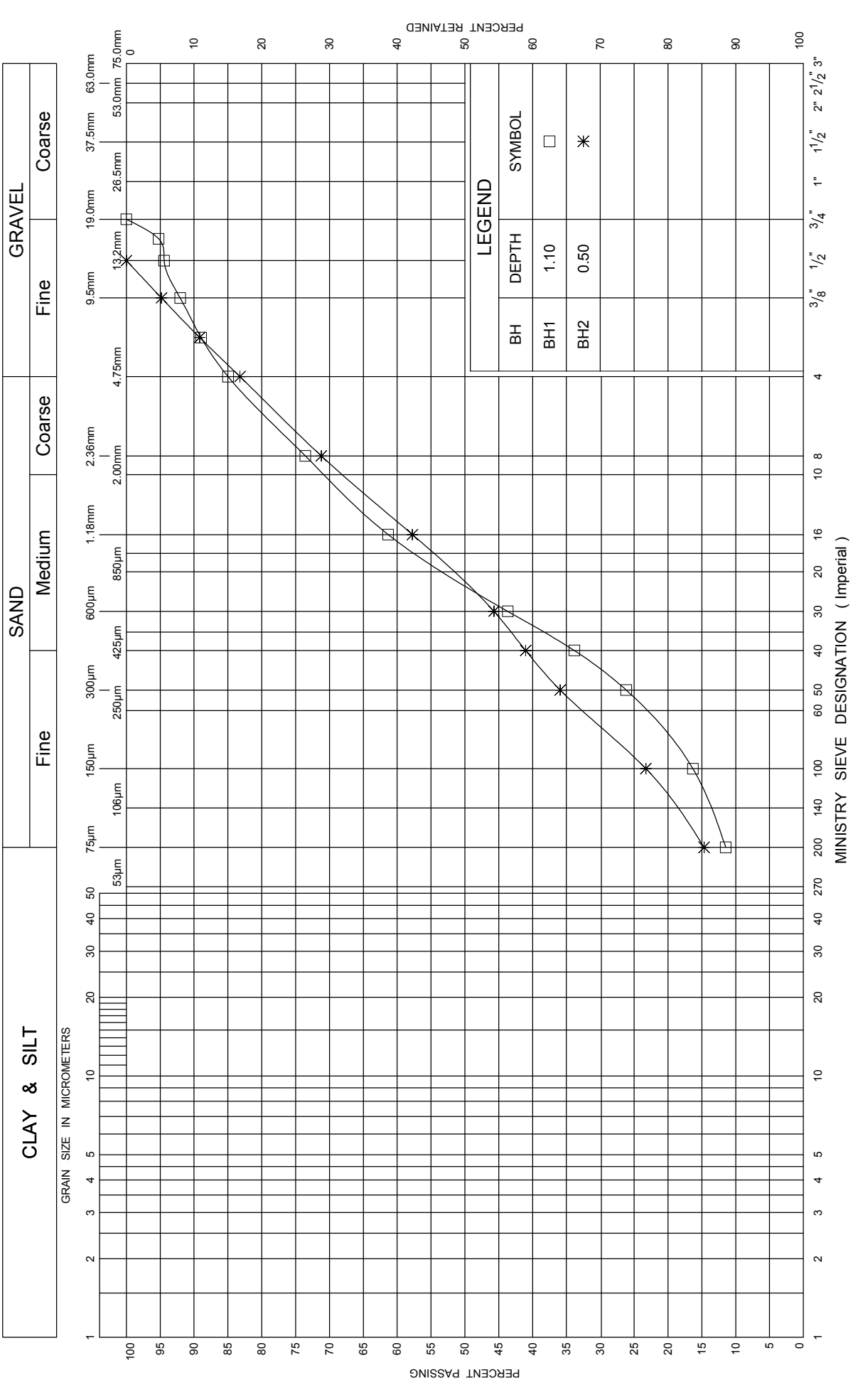
W.P. 6182-04-01 LOCATION RAINY RIVER TRIBUTARY ORIGINATED BY CH  
DIST Rainy River HWY 11 BOREHOLE TYPE HAND AUGER COMPILED BY SA  
DATUM GEODETIC DATE 2015 09 21 CHECKED BY BV

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT  w <sub>p</sub>	NATURAL MOISTURE CONTENT  w	LIQUID LIMIT  w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)	
								20 40 60 80 100	50 100 150 200 250							
333.6	GROUND SURFACE		AS1	AS												
	CLAY, TRACE SILT		AS2	AS												
			AS3	AS												
			AS4	AS												
			AS5	AS												
			AS6	AS												
			AS7	AS												
			AS8	AS												
			AS9	AS												
			AS10	AS												
			AS11	AS												
			AS12	AS												
328.8																
4.8	END OF BOREHOLE AT 4.8 m															

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

ENCLOSURE 4

UNIFIED SOIL CLASSIFICATION SYSTEM

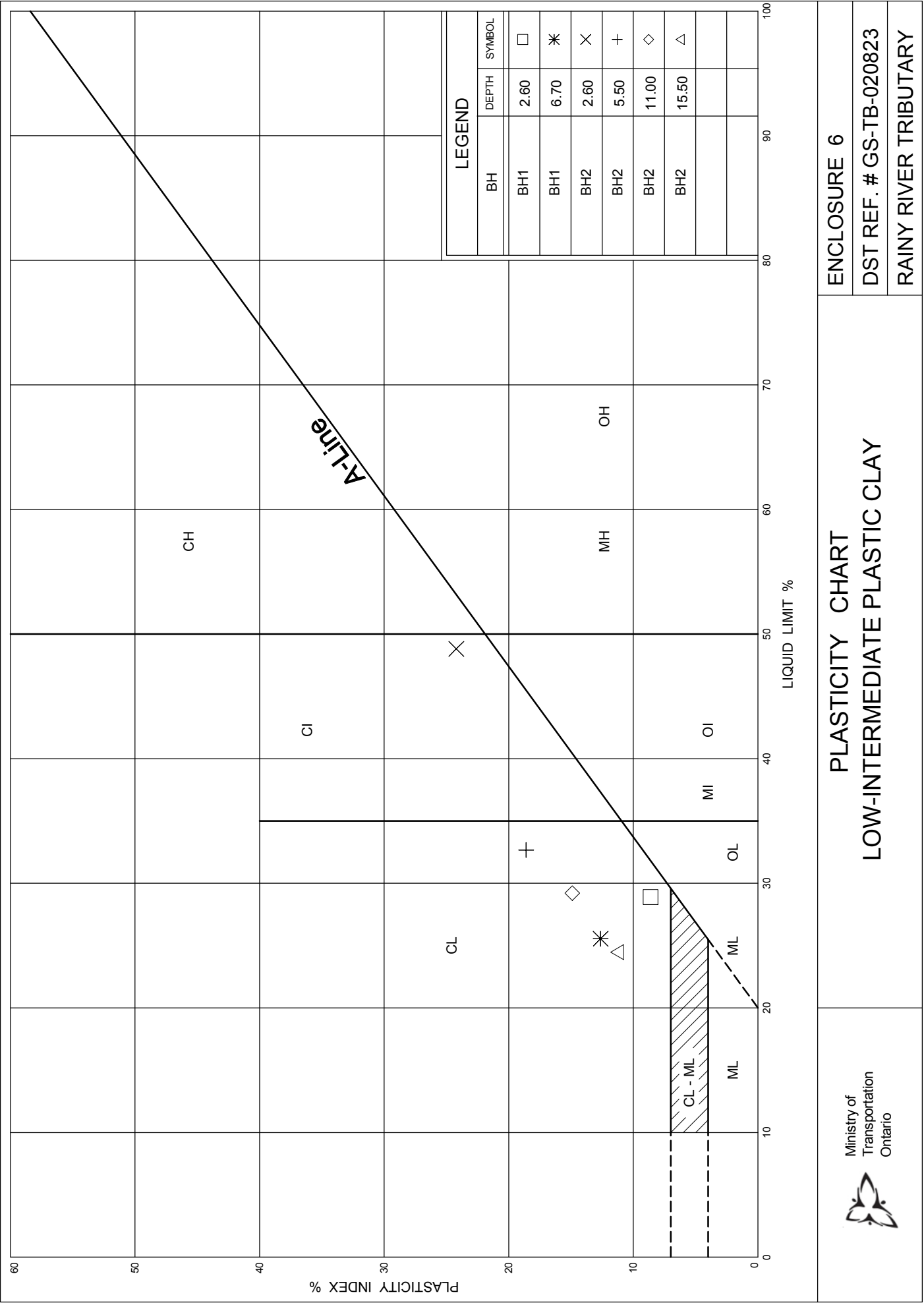


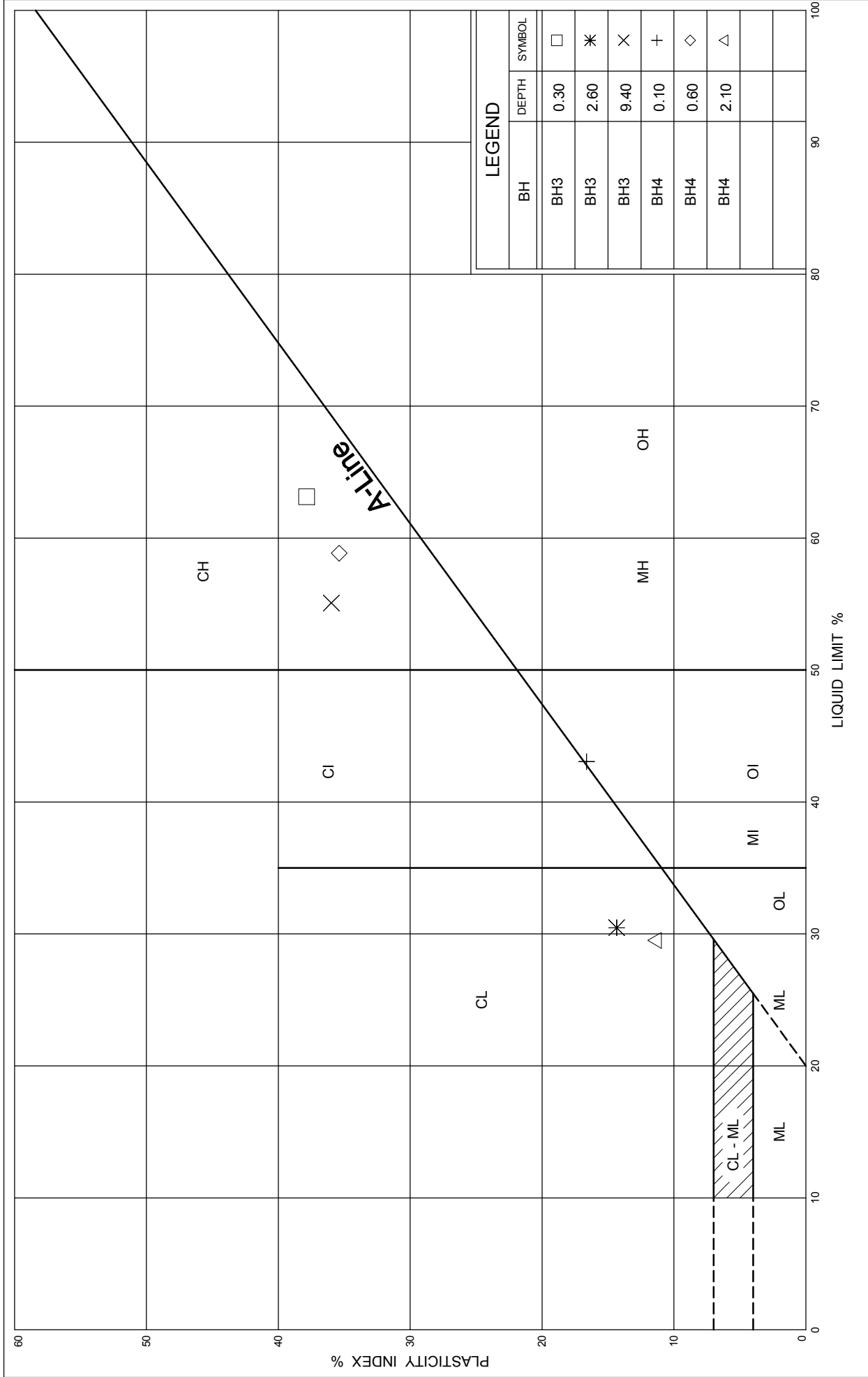
GRAIN SIZE DISTRIBUTION  
SOIL DESCRIPTION  
FILL - SAND

ENCLOSURE 5

DST REF. # GS-TB-020823

RAINY RIVER TRIBUTARY







DST Thunder Bay  
ATTN: Selorm Danku  
DST Consulting Engineers Inc.  
1120 Premier Way , Suite 200  
Thunder Bay ON P7B 0A3

Date Received: 01-DEC-15  
Report Date: 10-DEC-15 08:02 (MT)  
Version: FINAL

Client Phone: 807-345-3620

## Certificate of Analysis

Lab Work Order #: L1709005  
Project P.O. #: NOT SUBMITTED  
Job Reference:  
C of C Numbers:  
Legal Site Desc:

Rikki Thomson  
Account Manager

[This report shall not be reproduced except in full without the written authority of the Laboratory.]

ADDRESS: 1081 Barton Street, Thunder Bay, ON P7B 5N3 Canada | Phone: +1 807 623 6463 | Fax: +1 807 623 7598  
ALS CANADA LTD Part of the ALS Group A Campbell Brothers Limited Company

Sample Details/Parameters		Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L1709005-1	RAINY RIVER TRIB. CULVERT							
Sampled By:	Client on 01-DEC-15 @ 00:01							
Matrix:	Soil							
<b>Physical Tests</b>								
Conductivity		480		4.0	umhos/cm	07-DEC-15	07-DEC-15	R3325981
% Moisture		3.42		0.10	%	04-DEC-15	05-DEC-15	R3325347
pH		8.02		0.10	pH units		07-DEC-15	R3326423
Resistivity		2080		100	ohm cm	07-DEC-15	07-DEC-15	R3325976
<b>Leachable Anions &amp; Nutrients</b>								
Chloride		224		20	mg/kg	04-DEC-15	08-DEC-15	R3327616
<b>Anions and Nutrients</b>								
Sulphate		29		20	mg/kg	04-DEC-15	08-DEC-15	R3327616

\* Refer to Referenced Information for Qualifiers (if any) and Methodology.

## Reference Information

### Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
CL-WT	Soil	Chloride in Soil	EPA 300.0
EC-WT	Soil	Conductivity (EC)	EPA 9050A
A representative subsample is tumbled with de-ionized (DI) water. The ratio of water to soil is 2:1 v/w. After tumbling the sample is then analyzed by a conductivity meter.			
MOISTURE-WT	Soil	% Moisture	Gravimetric: Oven Dried
PH-WT	Soil	pH	MOEE E3137A
Soil samples are mixed in the deionized water and the supernatant is analyzed directly by the pH meter.			
RESISTIVITY-WT	Soil	Resistivity	MOECC E3138
Resistivity on a soil is a 2:1 extraction of DI water to soil. Sample is tumbled for 30 min. Conductivity of the extraction is taken and the inverse is calculated for resistivity.			
SO4-WT	Soil	Sulphate	EPA 300.0

\*\* ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
WT	ALS ENVIRONMENTAL - WATERLOO, ONTARIO, CANADA

### Chain of Custody Numbers:

#### GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.

mg/kg - milligrams per kilogram based on dry weight of sample

mg/kg wwwt - milligrams per kilogram based on wet weight of sample

mg/kg lwt - milligrams per kilogram based on lipid weight of sample

mg/L - unit of concentration based on volume, parts per million.

< - Less than.

D.L. - The reporting limit.

N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.

UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.

Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.



## Quality Control Report

Workorder: L1709005

Report Date: 10-DEC-15

Page 1 of 2

Client: DST Thunder Bay  
DST Consulting Engineers Inc. 1120 Premier Way , Suite 200  
Thunder Bay ON P7B 0A3

Contact: Selorm Danku

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
<b>CL-WT</b>								
<b>Soil</b>								
<b>Batch R3327616</b>								
<b>WG2226771-3</b>	<b>CRM</b>	<b>AN-CRM-WT</b>						
Chloride			102.9		%		70-130	08-DEC-15
<b>WG2226771-2</b>	<b>LCS</b>							
Chloride			95.9		%		70-130	08-DEC-15
<b>WG2226771-1</b>	<b>MB</b>							
Chloride			<20		mg/kg		20	08-DEC-15
<b>EC-WT</b>								
<b>Soil</b>								
<b>Batch R3325981</b>								
<b>WG2227671-1</b>	<b>MB</b>							
Conductivity			<4.0		umhos/cm		4	07-DEC-15
<b>MOISTURE-WT</b>								
<b>Soil</b>								
<b>Batch R3325347</b>								
<b>WG2226652-2</b>	<b>LCS</b>							
% Moisture			95.5		%		90-110	05-DEC-15
<b>WG2226652-1</b>	<b>MB</b>							
% Moisture			<0.10		%		0.1	05-DEC-15
<b>PH-WT</b>								
<b>Soil</b>								
<b>Batch R3326423</b>								
<b>WG2228014-1</b>	<b>LCS</b>							
pH			6.99		pH units		6.7-7.3	07-DEC-15
<b>SO4-WT</b>								
<b>Soil</b>								
<b>Batch R3327616</b>								
<b>WG2226771-3</b>	<b>CRM</b>	<b>AN-CRM-WT</b>						
Sulphate			110.5		%		60-140	08-DEC-15
<b>WG2226771-2</b>	<b>LCS</b>							
Sulphate			96.2		%		70-130	08-DEC-15
<b>WG2226771-1</b>	<b>MB</b>							
Sulphate			<20		mg/kg		20	08-DEC-15

# Quality Control Report

Workorder: L1709005

Report Date: 10-DEC-15

Page 2 of 2

## Legend:

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Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

## Hold Time Exceedances:

All test results reported with this submission were conducted within ALS recommended hold times.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

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The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

## **Appendix 'E'**

### **NSSP**

**DEWATERING OPERATION REQUIREMENT - Item No. 1**

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Non-Standard Special Provision

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This special provision covers the dewatering operation requirement.

Continuous dewatering operation is required for using 1.5H:1.0V unsupported slope during excavation for the culvert replacement work. There is stability issue for excavation using unsupported slope without dewatering operation.

It should be noted that depending on the season, depth of excavation and amount of water flow through the creek may vary. The contractor should be prepared to tackle this situation. The contractor should be noted of the high water table and surface water fluctuation for dewatering operation.