



FINAL

**FOUNDATION INVESTIGATION AND DESIGN REPORT
SOUTH BERENS CREEK CULVERT REPLACEMENT
NUNGESSER ROAD
DISTRICT OF KENORA
AGREEMENT NO.: 2014-E-0059
SITE NO.: 41N-080/C
GEOCRES NO. 52N-011
GWP 6374-14-00**

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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

DST Consulting Engineers Inc. has been retained by the prime consultant, Ainley Group to conduct a foundation investigation and design report for the proposed culvert replacement at South Berens Creek, 92 km north of Highway 125 on Nungesser Rd. This work was carried out under Agreement No.: 2014-E-0059, Geotechnical Retainer. 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 Nungesser Road, approximately 92 km North of Highway 125 (latitude 51.672284, longitude -93.735245), unsurveyed territory in the District of Kenora, Ontario.

Existing structure at this location is a 3.3 m in diameter X 22.56 m in length Corrugated Steel Plate (CSP) culvert with a depth of soil cover of approximately 0.94 m. The existing culvert structure (Figures 2.1 to 2.2) built in 1973 and inspection by others was identified to be torn/damaged at the top 3.0 m of the inlet, moderate to severe corrosion and section loss on bottom half of the culvert, corrosion spots on the soffits and exterior of culvert, and localized flaked galvanized coating on top of the culvert.

Based on our review of Ontario Structure Inspection Manual, the embankment at the culvert location is about 4 m high and side slope of the embankment is approximately 1.5H:1V. The surrounding area is moderately vegetated and wooded (Figure 2.1 and 2.2). Photographs were taken by others.



Figure 2.1 Location of existing culvert on Nungesser Road (looking East upstream)



Figure 2.2 Location of existing culvert on Nungesser Road (looking West downstream)

3. INVESTIGATION PROCEDURES AND LABORATORY TESTING

Field drilling was carried out on August 14 to August 16, 2015 utilizing a CME 750 drill rig equipped for geotechnical drilling. A total of five (5) boreholes were advanced to depths ranging from 9.6 m to 14.3 m. The specified depth of 10 m below culvert invert level could not be achieved at BH 2 location due to blow up of sand into auger. Two additional boreholes were advanced to confirm the sand blow up conditions and it was found out that sand blow up in augers occurred in all five boreholes. However stratigraphy is based on original three boreholes. The locations of the boreholes are shown in the attached drawing.

The borehole locations and stratigraphic sections are shown on the Borehole Location Plan and Drawings 1 and 2 in Appendix C. Borehole 1 was advanced at (Sta. 10+064), 3.6 m left of centreline and advanced to a depth of 14.3 m below existing surface. Borehole 2 was advanced at (Sta. 10+063), 0.4 m right of centreline and advanced to a depth of 9.6 m below the existing surface. Borehole 3 was advanced at (Sta. 10+057), 4.1 m right of centreline and advanced to a depth of 14.3 m below the existing surface. Borehole 4 was advanced at (Sta. 10+066), 5.9 m left of centreline and advanced to a depth of 9.8 m. Borehole 5 was advanced at (Sta. 10+049), 6.1 m right of centreline to a depth of 9.8 m.

The ground surface elevations at the borehole locations were surveyed by DST personnel and referenced to benchmark elevation of 335.781 m HCP 100 (N=5726568.640 , E=253821.680) as indicated on drawings supplied to DST by MTO. 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 condition 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 except Boreholes 4 and 5 to aid in the selection of engineering properties. Laboratory tests included moisture contents, Atterberg limits, particle size analyses and chemical tests. A total of seventeen (17) moisture contents and eight (8) sieve analyses and one (1) Atterberg limit, a set of chemical test 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 from centreline (m)
BH1	10+064	337.1	14.3	3.7 Lt
BH2	10+063	337.2	9.6	0.4 Rt
BH3	10+057	336.8	14.3	4.1 Rt
BH4	10+066	336.6	9.8	5.9 Lt
BH5	10+049	337.2	9.8	6.1 Rt

4. DESCRIPTION OF SUBSURFACE CONDITIONS

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

The generalized stratigraphy of the existing embankment, based on the conditions encountered in the boreholes consists of sand and gravel fill underlain by silty sand which further overlies sand to the termination of the boreholes. The stratigraphy encountered in Borehole 3 consist of sand and gravel fill underlain sand and silt which further overlies sand to the termination of the borehole. Organics with wood was also encountered within the sand and gravel fill and silty sand layer. The summary of the soil strata are summarized in Table 4-1 below.

Table 4-1 Summary of soil strata at the Embankment (BH1, BH2, BH3, BH4 and BH5)

Layer	Depth (m)	Elevation (m)	Comments
Fill – Sand and Gravel	0.0 to 3.3	337.1 to 333.8	BH1
	2.1 to 4.4	335.1 to 332.8	BH2
	0.0 to 3.8	336.8 to 333.0	BH3
	0.0 to 2.9	336.6 to 333.7	BH4
	0.0 to 2.9	337.2 to 334.3	BH5
Fill - Sand	0.0 to 2.1	337.2 to 335.1	BH2
	3.8 to 4.7	333.0 to 332.1	BH3
	2.9 to 3.4	334.3 to 333.8	BH5
Silty Sand	3.3 to 6.6	333.8 to 330.5	BH1
	4.4 to 6.6	332.8 to 330.6	BH2
	2.9 to 6.3	333.7 to 330.3	BH4
	3.4 to 6.6	333.8 to 330.6	BH5
Sand and Silt	4.7 to 5.2	332.1 to 331.6	BH3
Sand	6.6 to 14.3	330.5 to 322.8	BH1
	6.6 to 9.6	330.6 to 327.6	BH2
	5.2 to 14.3	331.6 to 322.5	BH3
	6.3 to 9.8	330.3 to 326.9	BH4
	6.6 to 9.8	330.6 to 327.5	BH5

4.1 Fill – Sand and Gravel

Fill – Sand and Gravel with trace fines was encountered in all boreholes at depths from 0.0 to 3.3 m (Elev. 337.1 to 333.8 m), 2.1 to 4.4 m (Elev. 335.1 to 332.8 m), 0.0 to 3.8 m (Elev. 336.8 to 333.0 m), 0.0 to 2.9 m (Elev. 336.6 to 333.7 m), and 0.0 to 2.9 m (Elev. 337.2 to 334.3 m) with thicknesses of 3.3 m, 2.3 m, 3.8 m, 2.9 m and 2.9 m in boreholes 1, 2, 3, 4, and 5 respectively. Numerous cobbles were also encountered within the fill in Borehole 1.

The SPT 'N' values vary from 5 to 31, indicating a loose to dense condition. High SPT N values are indicative of cobbles encountered within the fill. The moisture contents of samples tested range found to be 2 to 6 %. The sieve analysis laboratory test results are summarized in Table 4-2.

Table 4-2: Summary of Sieve Analysis - Fill - Sand and Gravel

Laboratory Results – Sieve Analysis	
Gravel %	40 to 54
Sand %	43 to 58
Fines %	2 to 6

4.2 Fill – Sand

Fill - Sand with some gravel to gravelly and trace fines was encountered in Borehole 2, 3 and 5 at depths from 0.0 to 2.1 m (Elev. 337.2 to 335.1 m), 3.8 to 4.7 m (Elev. 333.0 to 332.1 m), and 2.9 to 3.4 m (Elev. 334.3 to 333.8 m) with thicknesses of 2.1 m, 0.9 m and 0.5 m respectively. Organics with to some wood was encountered in the sand fill in Borehole 3 at depths from 4.1 m to 4.7 m (Elev. 332.7 to 332.1 m)

The SPT 'N' values vary from 5 to 31, indicating a loose to dense condition. The moisture contents of samples tested range found to be 3 to 58 %. The sieve analysis laboratory test results are summarized in Table 4-4.

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

Laboratory Results – Sieve Analysis	
Gravel %	33
Sand %	62
Fines %	5

4.3 Silty Sand

Silty sand with organics was encountered below the fill in Boreholes 1, 2, 4, and 5 at depths 3.3 m to 6.6 m (Elev. 333.8 to 330.5 m), 4.4 m to 6.6 m (Elev. 332.8 to 330.6 m), 2.9 to 6.3 m (Elev. 333.7 to 330.3 m), and 3.4 to 6.6 m (Elev. 333.8 to 330.6 m) with thickness of 3.3 m 2.2 m, 3.4 m and 3.2 m respectively.

The SPT 'N' values vary from 5 to 8, indicating a loose condition. The moisture contents of samples tested range found to be 23 to 68 %. Organic content test carried out on selected samples indicate the silty sand material consist of 7 % organic matter. The sieve analysis laboratory test results are summarized in Table 4-5.

Table 4-4: Summary of Sieve Analysis - Silty Sand

Laboratory Results – Sieve Analysis	
Gravel %	0 to 3
Sand %	58 to 64
Fines %	36 to 39

4.4 Sand and Silt

Sand and silt with organics was encountered below the sand fill in Borehole 3 at the depth of 4.7 m to 5.2 m (Elev. 332.1 to 331.6 m) with a thickness of 0.5 m.

SPT 'N' value was 3, indicating a very loose condition. However blow counts may not represent accurate relative density conditions due to the blow up in the sand. The moisture contents of the Sand and silt layer was 18 %. Organic content test carried out on selected samples indicate the sand and silt material consist of 11 % organic matter .The laboratory test results are summarized in Table 4-6.

Table 4-5: Summary of Sieve Analysis – Sand and Silt

Laboratory Results – Sieve Analysis	
Gravel %	3
Sand %	49
Fines %	48

4.5 Sand

Sand with to trace gravel and silt was encountered beneath the silty sand in Boreholes 1,2, 4, and 5 and beneath the sand and silt in Borehole 3 at depths from 6.6 m to 14.3 m (Elev. 330.5 to 322.8 m) in Borehole 1, 6.6 m to 9.6 m (Elev. 330.6 to 327.6 m) in Borehole 2, 5.2 m to 14.3 m (Elev. 331.6 to 322.5 m) in Borehole 3, 6.3 to 9.8 m (Elev. 330.3 to 326.9 m) in Borehole 4, and 6.6 to 9.8 m (Elev. 330.6 to 327.5 m) in Borehole 5 with thicknesses of 7.7 m, 3.0 m, 7.7 m, 3.5 m and 3.2 m respectively.

SPT 'N' values vary from 2 to 54, indicating a very loose to very dense condition. However very low SPT 'N' numbers could be the result of sand blow up in augers. The moisture contents of the sand layer vary from 18 to 19 %. The laboratory test results are summarized in Table 4-7.

Table 4-6: Summary of Sieve Analysis – Sand

Laboratory Results – Sieve Analysis	
Gravel %	3
Sand %	95
Fines %	2

4.6 Groundwater

Groundwater levels in the boreholes where seepage was noted were measured upon completion of borehole drilling and prior to backfilling of the borehole. This information is included on the Borehole Logs in Appendix D.

At the time of the field investigation groundwater was observed in Borehole 1, 2, and 3. However, the groundwater levels can be expected to vary with the season and precipitation events. Groundwater levels were not taken in Boreholes 4 and 5 at the time of investigation.

Table 4-7: Groundwater depth

Borehole	Groundwater Depth (m)	Groundwater Elev. (m)
Borehole 1	3.05	334.0
Borehole 2	3.18	334.0
Borehole 3	3.27	333.5

4.7 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 4-8 and a copy of the Laboratory Certificate of Analysis is provided in **Appendix D**.

Table 4-8: Chemical Test Results

Sample ID	Moisture (%)	Sulphate (mg/kg)	Chloride (mg/kg)	pH	Conductivity (umhos/cm)	Resistivity (ohm - cm)
BH1 @ 3.3 m depth	12.7	26	<20	5.11	19.3	51800

The analytical results of the soil samples were compared with applicable Canadian Standards Association (CSA) standards as shown in Table 4-9 below

The chemical sulphate content analyses for representative soil sample tested indicate a sulphate concentration of 26 mg/kg or 0.0026 % 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 5.11, indicating a condition subject to corrosion. These results were evaluated using Table 2 of Building Research Establishment (BRE) Digest 363 (July 1991). The pH is less than 5.5 indicating the concrete will 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 19.3 ohm-cm and 51800 umhos / cm respectively for the sample analysed from BH1.

Table 4-9: 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 the week of August 14th to August 16th, 2015 utilizing a CME 750 all-terrain drill supervised by DST personnel. 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. has been retained by the prime consultant, Ainley Group to conduct a foundation investigation and design report for the proposed culvert replacement at South Berens Creek, 92 km north of Highway 125 on Nungesser Rd. This work was carried out under Agreement No.: 2014-E-0059, Geotechnical Retainer.

Existing culvert structure at this location is 3.3 m in diameter X 22.56 m in length, Corrugated Steel Plate (CSP) twin culvert with a depth of soil cover of approximately 0.94 m. The existing culvert structure was built in 1973 and was identified as torn/damaged at the top 3.0 m of the inlet, moderate to severe corroded and section loss on bottom half of the culvert, corrosion spots on the soffits and exterior of culvert, and localized flaked galvanized coating on top of the culvert.

The embankment at the culvert location is approximately 4 m high and side slope of the embankment is approximately 1.5H:1V. The surrounding area is moderately vegetated and wooded.

Generalized stratigraphy of the existing embankment, based on the conditions encountered in boreholes, consists of sand and gravel fill underlain by silty sand which underlain again by sand. Silt and sand with organics material was found in Borehole 3.

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, Single Pipe Corrugated Steel Plate Culvert (3990 mm dia), and 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. As the cross sectional area of the replacement structure is larger than the existing culvert, the overall effect on the culvert foundation soils by the embankment load will be a decrease in stress at the base of the culvert.

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 and Single Pipe Corrugated Steel Plate Culvert (SPCSP))

It is anticipated that the culvert will be placed at the same location and elevation as the existing CSP culverts. As the proposed culvert is not expected to be heavily loaded, a shallow foundation is considered suitable for this site. For single pipe corrugated steel plate circular culvert (3990 mm diameter) replacement option, there is no foundation issue. Therefore bearing resistance is not further discussed for CSP replacement option.

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 an allowable net resistance at foundation elevations based on the condition at the site.

The geotechnical resistance was estimated assuming a strip footing consisting of a width equal to the width of the box culvert (3.6 m) and a depth of the culvert base equal to 0 m, which is a temporary condition prior to backfill that will be encountered during construction. Depth of box culvert footing is at 5.2 m from the existing ground surface (331.93 m elevation) where silty sand can be encountered. Settlement of the structure can be considered negligible due to the marginal expected change in net loading. The culvert can be installed below the top of pavement and bedding material placed on undisturbed native soils.

Table 6-1 Geotechnical resistances

Footing Size	Ultimate bearing capacity (kPa)	Resistance at ULS (kPa)	Resistance at SLS (kPa)
B = 3.6 m	260	130	55

Bearing resistance for SLS was found to be significantly lower than the resistance for ULS. However, the soil encountered is sandy in nature and immediate settlement only is expected. Therefore, culvert could be designed with ULS resistance provided that significant culvert settlement will be occurred during the construction time.

Where unsuitable or unstable soils are encountered, such as soil mixed with organic, as it was found up to 6.6 m depth in the BH1, 5.2 m depth in BH2 and 3, 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 (Corrugated Steel Plate Arch Culvert on 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. As the cross sectional area of the existing CIP culvert will remove the existing soil materials, the overall effect on the culvert foundation soils will be a small decrease in stress at the base of the culvert.

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 6.6.3.6, and is shown in Table 6-2. The geotechnical resistances were estimated assuming a strip footing of various widths with a length equal to 24.0 m situated at depths between 5.5 and 7.0 m below the existing road elevation (331.7 m and 330.2 m elevation) where silty sand and coarse/medium sand can be encountered.

Table 6-2 Geotechnical resistances for open footing culverts

Footing Width L=24 m	Depth of Soil Cover, m	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	1.0	5.5	255	125	120
	1.2	5.7	290	145	125
	1.5	6.0	340	170	130
	2.5	7.0	520	260	175
B = 1.2 m	1.0	5.5	270	135	105
	1.2	5.7	305	150	110
	1.5	6.0	360	180	115
	2.5	7.0	535	265	155
B = 1.5 m	1.0	5.5	290	145	90
	1.2	5.7	330	165	95
	1.5	6.0	380	190	100
	2.5	7.0	565	280	130
B = 2.2 m	1.0	5.5	345	170	70
	1.2	5.7	380	190	75
	1.5	6.0	435	215	75
	2.5	7.0	620	310	100
B = 3.0 m	1.0	5.5	405	200	60
	1.2	5.7	440	220	60
	1.5	6.0	500	250	65
	2.5	7.0	685	340	85

Where unsuitable or unstable soils are encountered, such as soil mixed with organic, as it was found up to 6.6 m depth in the BH1, 5.2 m depth in BH2 and 3, 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.

6.3 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 and Table 6-4, 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 ³)	Internal drained friction angle (Deg)	Interface friction angle* δ (Deg)
Fill Sand & Gravel	22	32	21
Fill Sand	19	30	20
Silty Sand	19	30	18
Sand	19	30	19
Sand and Silt	19	28	18

*Interface friction angle 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	0.30	3.25	0.47
Fill Sand	0.33	3.00	0.50
Silty Sand	0.36	2.76	0.53
Sand	0.34	2.88	0.51
Sand and Silt	0.36	2.76	0.53

* ϕ is an angle of internal friction

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

6.4 Staged Construction

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.

The method of road widening with sideslopes 2.0H : 1V at the excavation for culvert replacement is a staged construction and road widening to provide a single lane of traffic without a detour. If sideslopes to be 1.5H:1V, the surface water must be away from the sideslopes. The staged construction includes two (2) stages, Stage 1 and Stage 2 is a temporary lane diversion which involves temporary detour of traffic to the single lane.

Slope stability analyses indicate that factor of safety for excavation depth of 6.6 m from the road surface with 1.5H:1.0V without present of surface water is 1.1 (Drained). Dewatering operation is required for using 1.5H:1.0V slope (See NSSP 2). The embankment slopes at the inlet and outlet should be 2H: 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.

The vertical shoring method for culvert replacement is staged construction to provide a single lane of traffic without a detour, Stage 1 and Stage 2 is a temporary lane diversion which involves temporary detour of traffic to the single lane and as well as the installation of level II roadway protection. Use of temporary concrete barriers or steel sheet piles will be required. The

final embankment foreslopes should be reinstated as presented in Section 6.12 Embankment Foreslopes. The soil profile of the site consists of granular material.

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. This method can more readily accommodate excavation of large boulders, if encountered during excavation. 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 and Type 4. 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. Type 4 soils generally are soft to very soft and very loose in consistency, very sensitive and upon disturbance are significantly reduced in natural strength, run easily or flow unless it is completely supported before excavation procedure, have almost no internal strength, are wet or muddy and exerts substantial fluid pressure on its supporting system. 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.

Organic material were encountered in the boreholes (depths up to 6.6 m in BH 1, 5.2 m in

BH2 and 3). Organic material shall be removed and replaced with compacted bedding material. Excavation may be required between 5.2 m and 6.6 m depth for the organic material removal.

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. This soil investigation does show evidence rock fill, cobbles and boulders along the soil profile, this may create a construction constrain to install any driven retaining wall (See NSSP 1).

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 for silty soil is about 2.5 m. The frost susceptible soils shall not be used adjacent to the culvert wall within the depth of frost penetration from the road 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 2.5 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 300 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.

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. Cobbles encountered in the borehole may obstruct pile driving work.

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

Table 7-1 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"> • Relatively non permeable. • Increase erosion control capacity. • Ease installation when working below ground water table. • Can design with suitable factor of safety. 	<ul style="list-style-type: none"> • Difficult driving through cobbles, concrete • High installation cost. • Special construction equipment and design required.
Sideslope 1.5H:1V	<ul style="list-style-type: none"> • Does not require specialized equipment. • Relatively short construction time. • Low construction cost. • Can achieve suitable factor of safety 	<ul style="list-style-type: none"> • Permeable. • Increased erosion due to exposed material. • Low factor of safety with increasing excavation depth.

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

Foundation Option	Feasibility	Advantages	Disadvantages	Relative Costs	Risks/Consequences
Option 1- Concrete Box	Feasible, preferred option.	No bearing capacity concerns. Negligible culvert settlement. 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)
Option 2-Open Footing	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).
Option 3- Corrugated Steel Plate Culvert	Feasible	No bearing capacity concerns. Minimal culvert settlement. Use of this option could shorten construction time.	Requires roadway protection system. Higher 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:



Selorm Danku, P.Eng.
Geotechnical Engineer

Reviewed by:



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

MINISTRY OF TRANSPORTATION, ONTARIO PR-D-707 89-05

N 5726600

6550 N 5726550

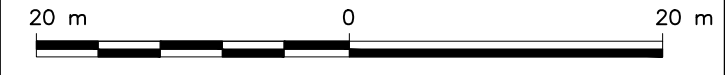
N 5726500

E 253850

E 253900

E 253950

E 254000



METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETERS + METERS

AGNo2014-E-0059

GWPNo6374-14-00

SITENo41N-080/C

GEOCRESN52-N-011

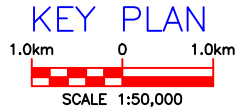
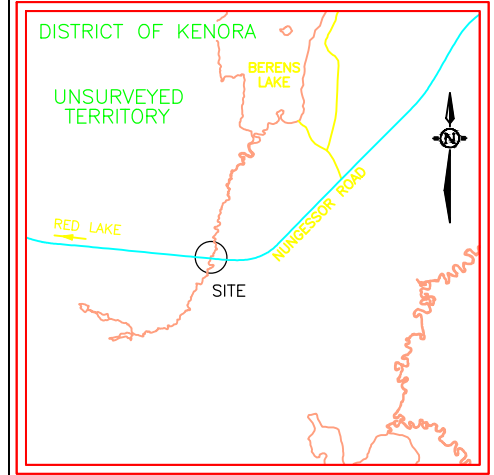
SHEET

CULVERT REPLACEMENT

SOUTH BERENS CREEK CULVERT

Survey13-06

Revised



LEGEND

● Borehole

No.	Elevation	Zone	Northing	Easting	Station	Offset
BH1	337.066	16	5726566 m N	253948 m E	10+064	3.6 m LT
BH2	337.191	16	5726562 m N	253946 m E	10+063	0.4 m RT
BH3	336.821	16	5726559 m N	253940 m E	10+057	4.1 m RT
BH4	336.600	16	5726568 m N	253950 m E	10+066	5.9 m LT
BH5	337.200	16	5726558 m N	253933 m E	10+049	6.1 m RT

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

DST

consulting engineers

DST Consulting Engineers Inc.

605 Hewitson Street

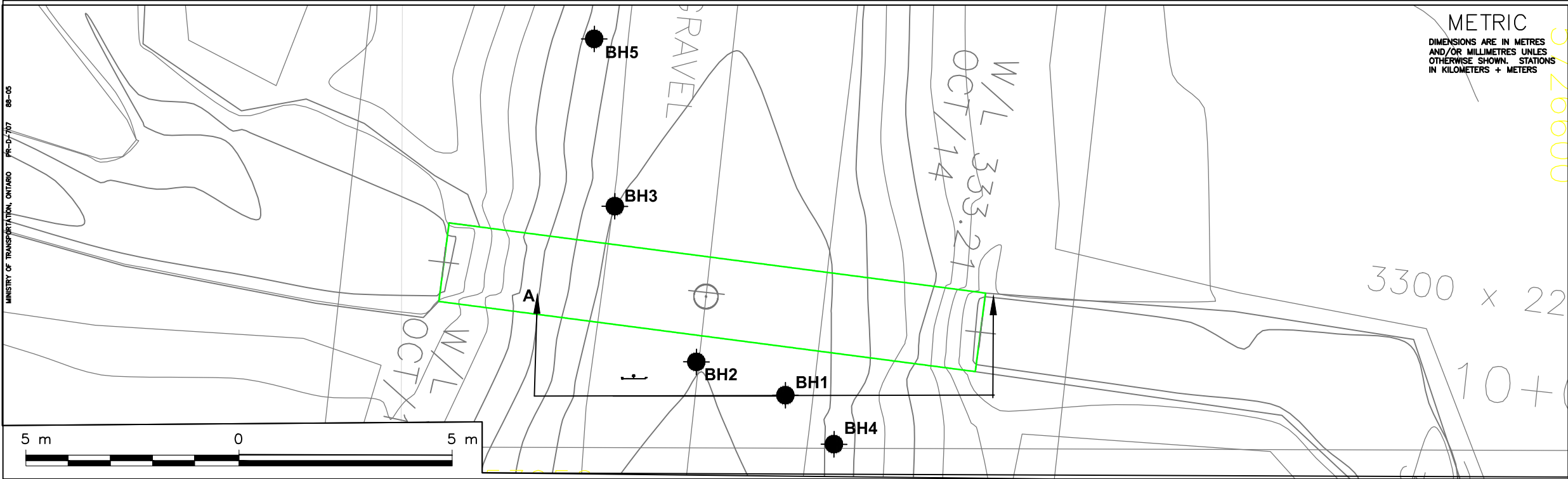
Thunder Bay, ON P7B 5V5

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DRAWING 1

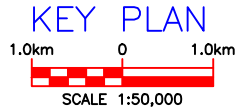
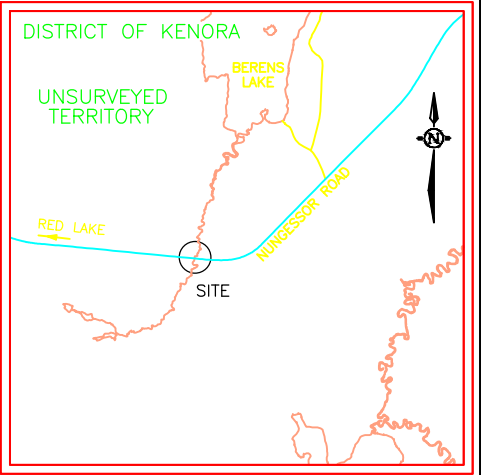


AG No 2014-E-0059
GWP No 6374-14-00
SITE No 41N-080/C
GEOCRES No 52-N-011

CULVERT REPLACEMENT
SOUTH BERENS CREEK CULVERT

Survey 13-06 Revised

SHEET



LEGEND

● Borehole
'N' Blows/0.3m (Std. Pen Test, 475 J/Blow)
Groundwater elevation

Fill
Organics
Topsoil
Till
Bedrock

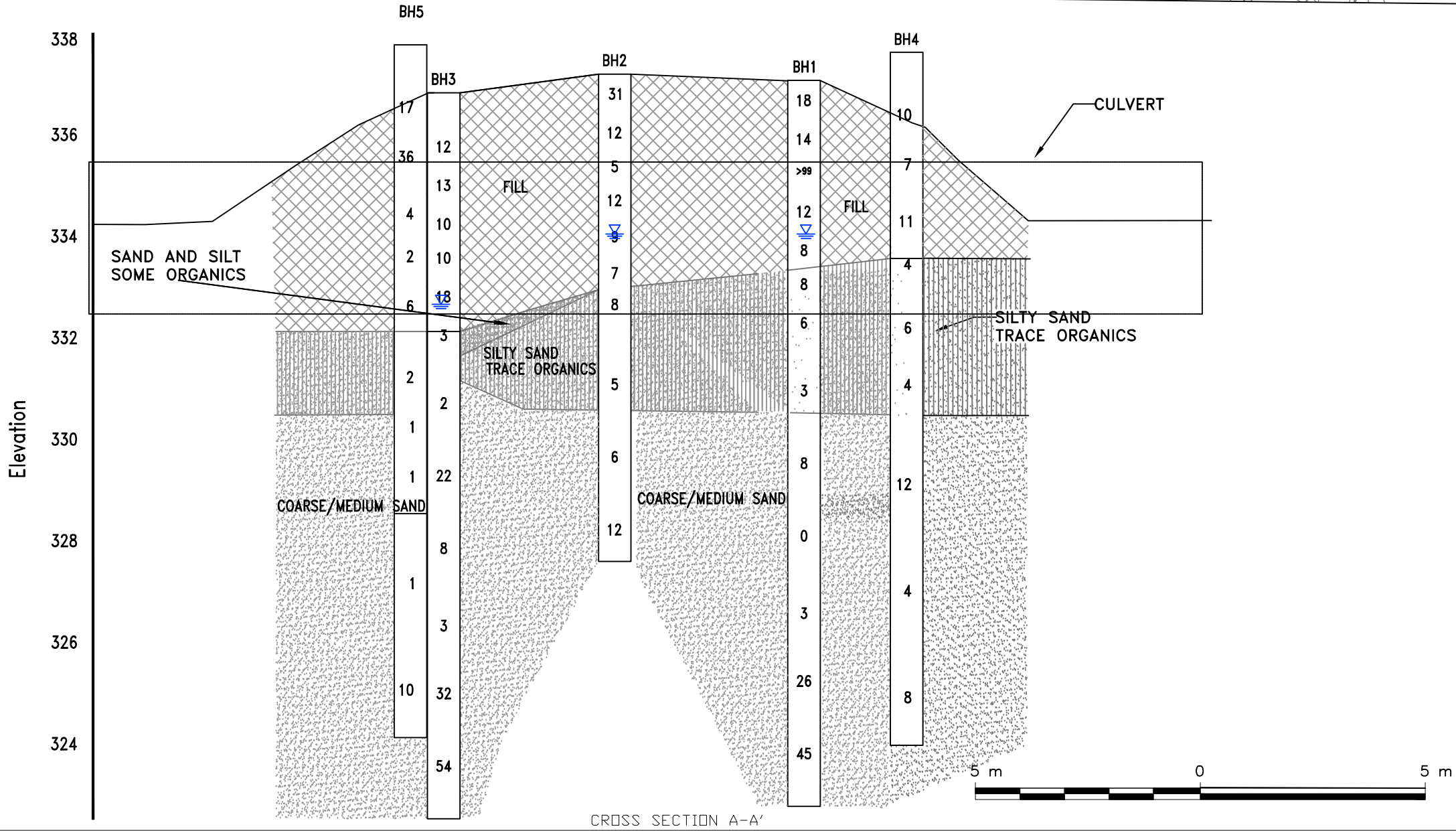
Sand
Silt
Clay
Sand & Gravel
Boulders

No.	Elevation	Zone	Northing	Easting	Station	Offset
BH1	337.066	16	5726566 m N	253948 m E	10+064	3.6 m LT
BH2	337.191	16	5726562 m N	253946 m E	10+063	0.4 m RT
BH3	336.821	16	5726559 m N	253940 m E	10+057	4.1 m RT
BH4	336.600	16	5726568 m N	253950 m E	10+066	5.9 m LT
BH5	337.200	16	5726558 m N	253933 m E	10+049	6.1 m RT

NOTE:
The boundaries between soil strata have been established only at borehole locations. Between boreholes 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. GWP 6374-14-00 LOCATION SOUTH BERENS CREEK ORIGINATED BY MM
 DIST HWY BOREHOLE TYPE HOLLOW STEM AUGER - 80 mm ID COMPILED BY MD
 DATUM Geodetic DATE 2015 08 14 CHECKED BY MK

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 (%)		
								20	40	60	80	100			W _p	W	W _L
337.1	GROUND SURFACE																
335.0	FILL - MEDIUM SAND AND GRAVEL, TRACE FINES AND COBBLES, BROWN, COMPACT TO VERY DENSE		SS1	SS	18		336								40 54 (6)		
			SS2	SS	14												
			SS3	SS	127											54 43 (3)	
2.1	FILL - MEDIUM TO COARSE SAND AND GRAVE, TRACE SILT, OCCASIONAL COBBLES, BROWN, COMPACT		SS4	SS	12			335									
SS4			SS	12													
334.2	FILL - COARSE SAND, SOME GRAVEL							334									
2.9																	
333.8	SILTY SAND WITH TRACE ORGANICS AND WOOD, BROWN TO GREY, VERY LOOSE TO LOOSE		SS5	SS	8				333								
3.3			SS6	SS	8												
			SS7	SS	6												
			SS8	SS	3												
330.5	COARSE SAND, SOME GRAVEL, TRACE SILT, BROWN, VERY LOOSE TO DENSE						330										
322.8			SS9	SS	8		329										
							328										
							327										
							326										
							325										
							324										
							323										
14.3	END OF BOREHOLE AT 14.3 m																

ONL MOT-HIGH VANES GS-TB-020823 BH LOGS - SOUTH BERENS CREEK.GPJ DST_MIN.GDT 16/2/16

+³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ENCLOSURE 1

RECORD OF BOREHOLE No BH2

1 OF 1

METRIC

W.P. GWP 6374-14-00 LOCATION SOUTH BERENS CREEK ORIGINATED BY MM
 DIST HWY BOREHOLE TYPE HOLLOW STEM AUGER - 80 mm ID COMPILED BY MD
 DATUM Geodetic DATE 2015 08 15 CHECKED BY MK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								20	40	60	80	100						○ UNCONFINED	+ FIELD VANE	□ QUICK TRIAXIAL
337.2	GROUND SURFACE																			
	FILL - SAND, GRAVELLY, TRACE FINES, DENSE TO LOOSE		SS1	SS	31															
			SS2	SS	12															
335.1			SS3	SS	5															
2.1	FILL - MEDIUM SAND AND GRAVEL, BROWN, COMPACT		SS4	SS	12															
334.3																				
2.9	FILL - COARSE SAND AND GRAVEL, BROWN, LOOSE		SS5	SS	9															
			SS6	SS	7															
332.8																				
4.4	FINE SILTY SAND, SOME ORGANICS AND WOOD, BROWN, LOOSE		SS7	SS	8															
332.0																				
5.2	SILTY SAND, GREY LOOSE																			
			SS8	SS	5															
330.6																				
6.6	MEDIUM SAND, SOME GRAVEL, TRACE SILT, BROWN, LOOSE TO COMPACT																			
			SS9	SS	6															

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

ENCLOSURE 2

ONL_MOT-HIGH VANES GS-TB-020823 BH LOGS - SOUTH BERENS CREEK.GPJ DST_MIN.GDT 16/2/16

RECORD OF BOREHOLE No BH4

1 OF 1

METRIC

W.P. GWP 6374-14-00 LOCATION SOUTH BERENS CREEK ORIGINATED BY MM
 DIST HWY BOREHOLE TYPE HOLLOW STEM AUGER - 80 mm ID COMPILED BY MD
 DATUM Geodetic DATE 2015 08 16 CHECKED BY MK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
336.6	GROUND SURFACE													
	FILL - MEDIUM TO COARSE SAND AND GRAVEL, BROWN		AS1	AS			336							
			SS1	SS	10									
			SS2	SS	7		335							
334.5														
2.1	FILL - COARSE SAND AND GRAVEL, BROWN													
333.7			SS3	SS	11		334							
2.9	SILTY SAND, TRACE ORGANICS, GREY, LOOSE		SS4	SS	4		333							
			SS5	SS	6									
			SS6	SS	4		332							
							331							
330.3			SS7	SS	12		330							
6.3	COARSE SAND, BROWN, LOOSE													
			SS8	SS	4		329							
							328							
			SS9	SS	8		327							
326.9	END OF BOREHOLE AT 9.8 m													
9.8														

ONL MOT-HIGH VANES GS-TB-020823 BH LOGS - SOUTH BERENS CREEK.GPJ DST_MIN.GDT 16/2/16

+³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ENCLOSURE 4

RECORD OF BOREHOLE No BH5

1 OF 1

METRIC

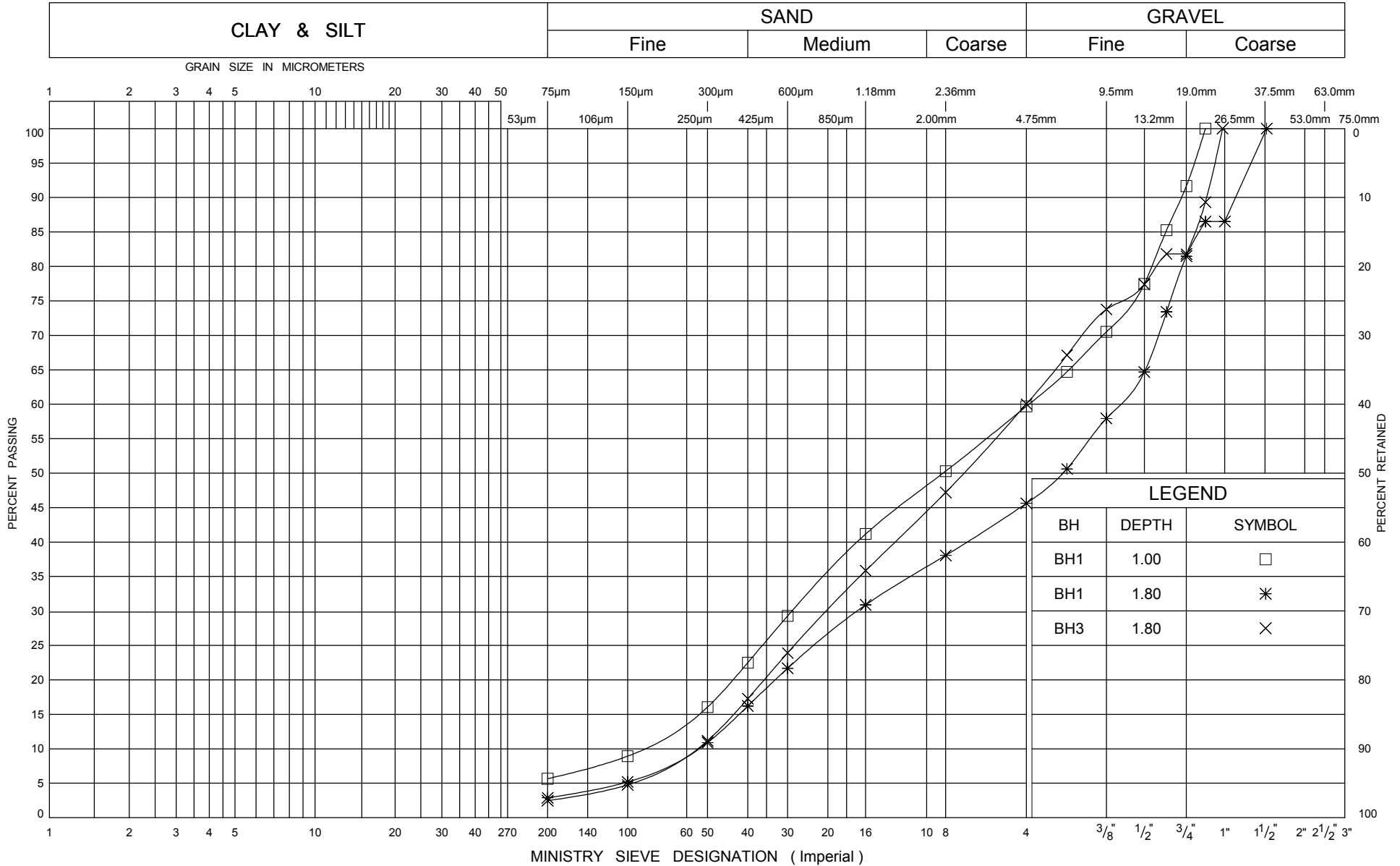
W.P. GWP 6374-14-00 LOCATION SOUTH BERENS CREEK ORIGINATED BY MM
DIST HWY BOREHOLE TYPE HOLLOW STEM AUGER - 80 mm ID COMPILED BY MD
DATUM Geodetic DATE 2015 08 16 CHECKED BY MK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
337.2	GROUND SURFACE													
	FILL - MEDIUM TO COARSE SAND AND GRAVEL, BROWN		AS1	AS			337							
			SS1	SS	17		336							
			SS2	SS	36									
335.1														
2.1	FILL - COARSE SAND AND GRAVEL, VERY LOOSE						335							
			SS3	SS	4									
334.3														
2.9	FILL - COARSE SAND, SOME GRAVEL, BROWN, VERY LOOSE		SS4	SS	2		334							
333.8														
3.4	SILTY SAND, TRACE ORGANICS, TRACE WOOD, GREY, LOOSE TO VERY LOOSE		SS5	SS	6		333							
			SS6	SS	2		332							
			SS7	SS	1									
			SS8	SS	1		331							
330.6														
6.6	COARSE SAND, BROWN, VERY LOOSE TO LOOSE						330							
			SS9	SS	1									
							329							
			SS10	SS	10		328							
327.5														
9.8	END OF BOREHOLE AT 9.8 m													

ONL MOT-HIGH VANES GS-TB-020823 BH LOGS - SOUTH BERENS CREEK.GPJ DST_MIN.GDT 16/2/16

+³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation
Ontario

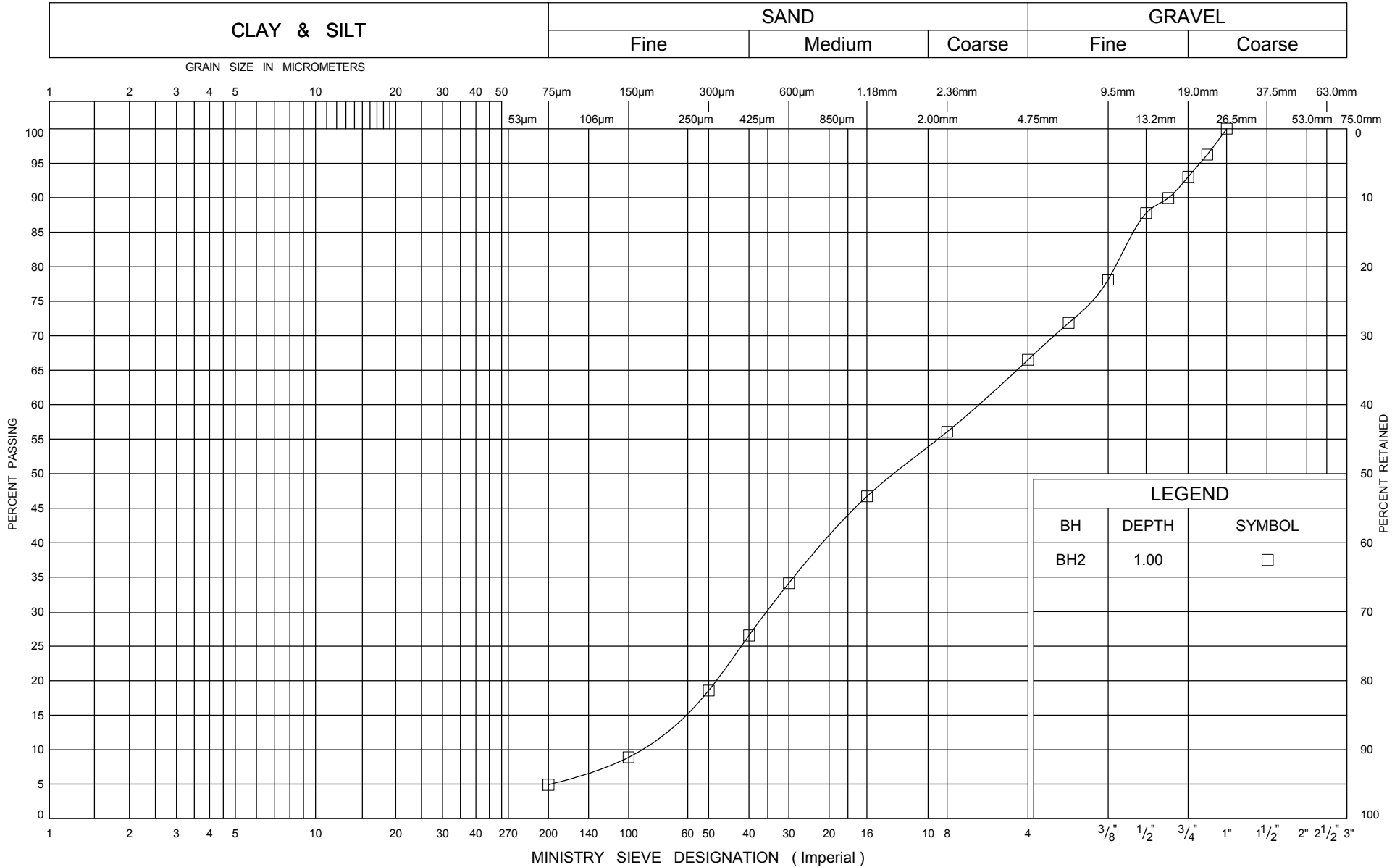
**GRAIN SIZE DISTRIBUTION
SOIL DESCRIPTION
FILL - SAND AND GRAVEL**

ENCLOSURE 6

DST REF. # GS-TB-020823

SOUTH BERENS CREEK CULVERT

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation
Ontario

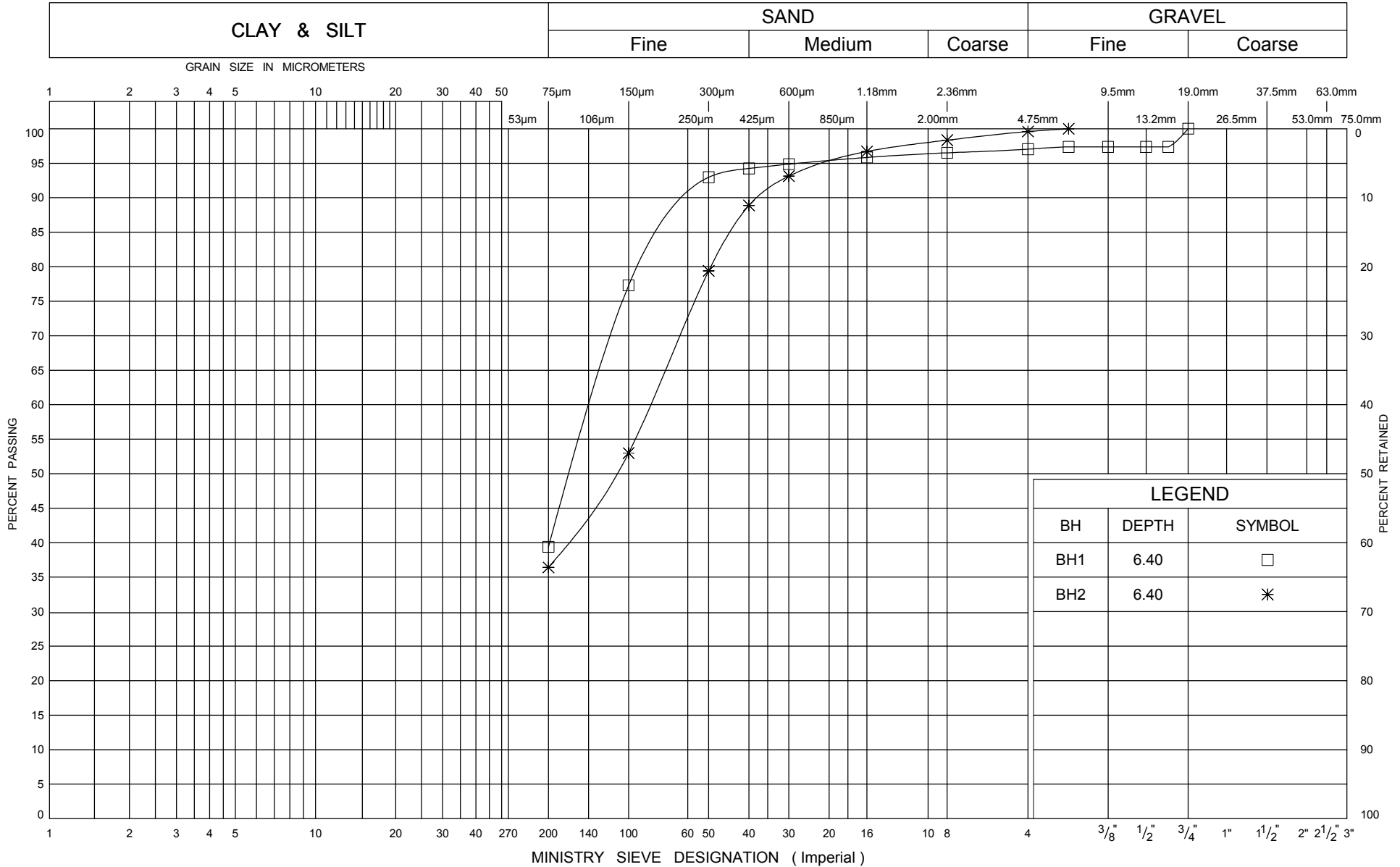
GRAIN SIZE DISTRIBUTION
SOIL DESCRIPTION
FILL - SAND

ENCLOSURE 7

DST REF. # GS-TB-020823

SOUTH BERENS CREEK CULVERT

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation
Ontario

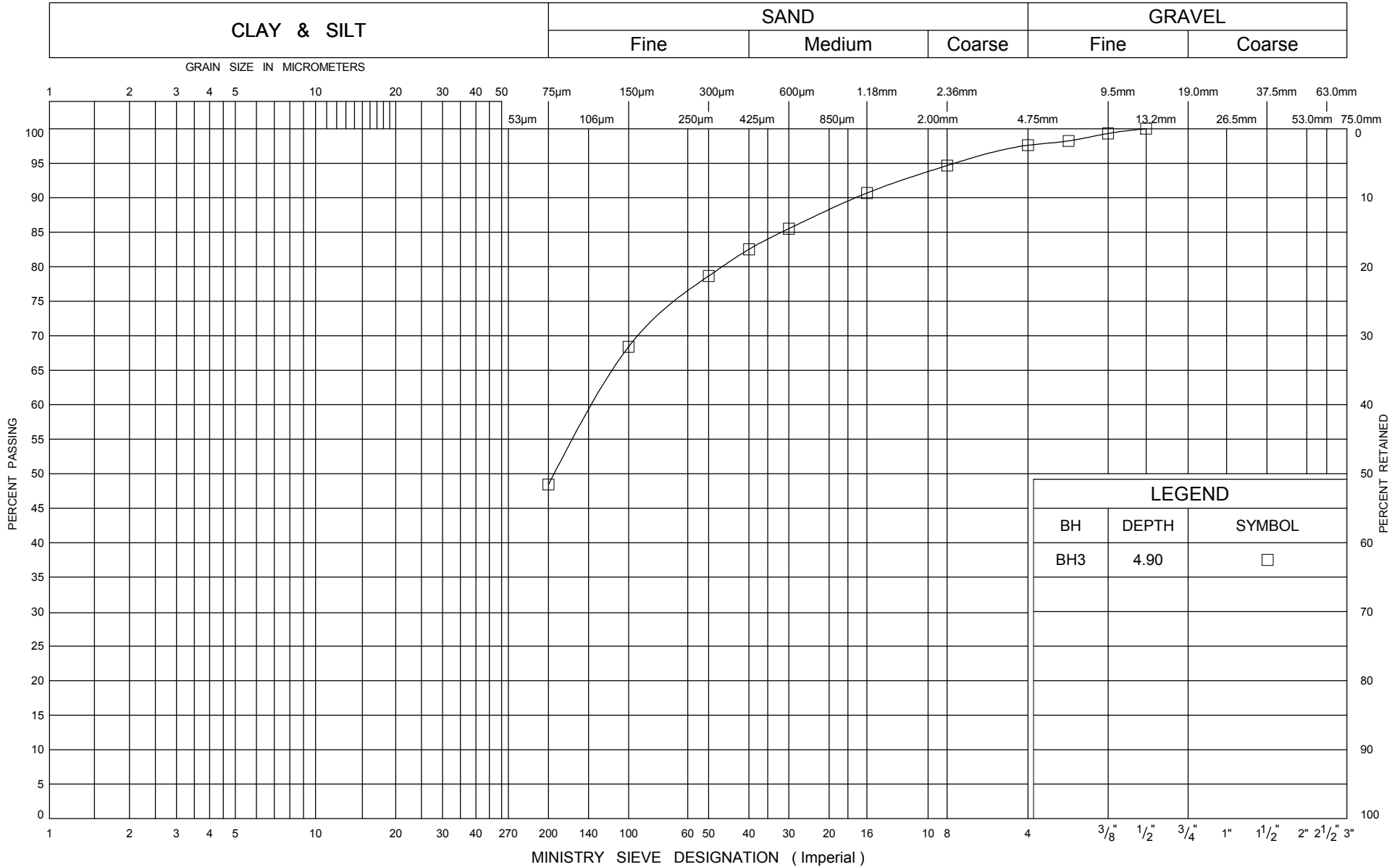
GRAIN SIZE DISTRIBUTION
SOIL DESCRIPTION
SILTY SAND

ENCLOSURE 8

DST REF. # GS-TB-020823

SOUTH BERENS CREEK CULVERT

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation
Ontario

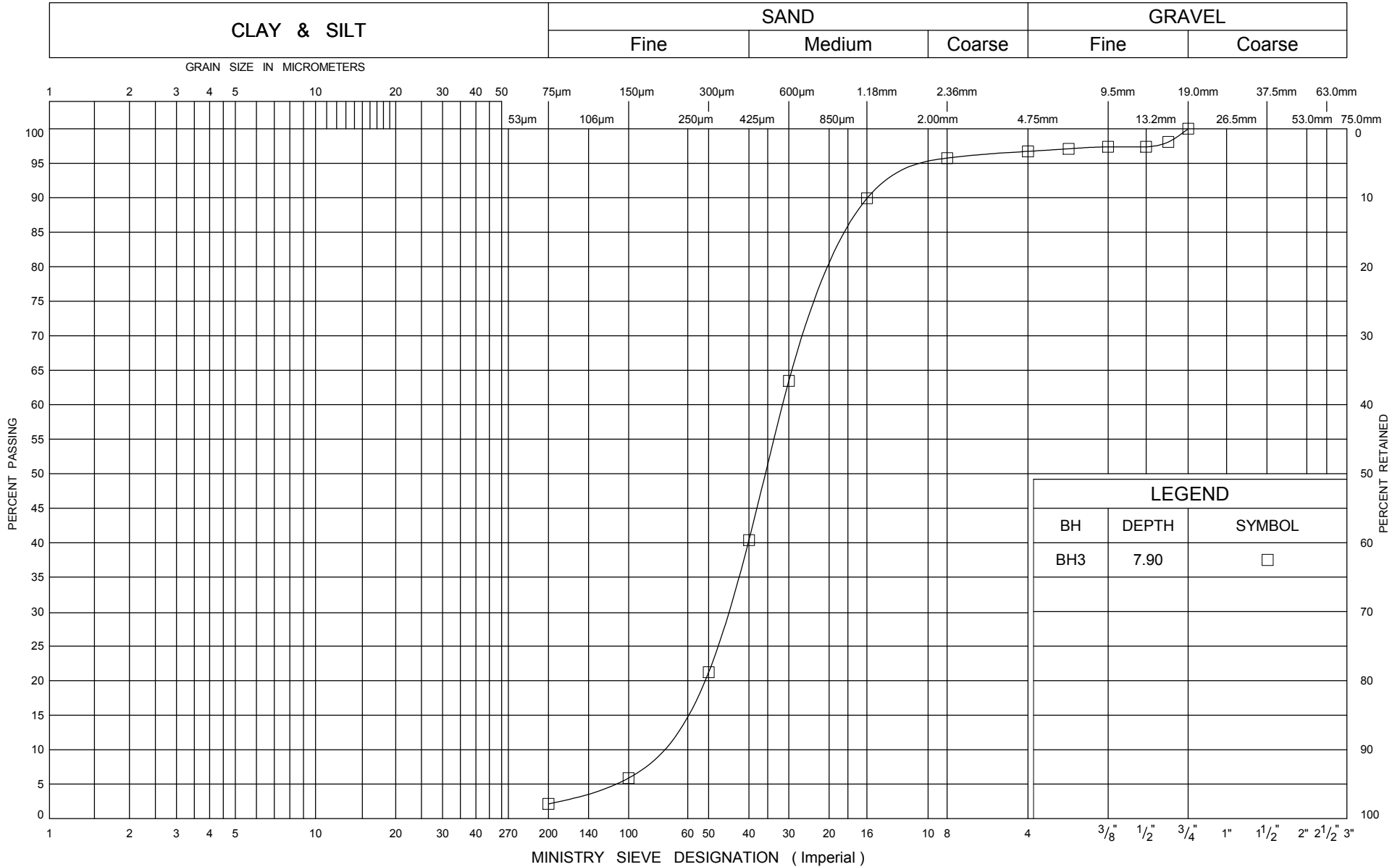
GRAIN SIZE DISTRIBUTION
SOIL DESCRIPTION
SAND AND SILT

ENCLOSURE 9

DST REF. # GS-TB-020823

SOUTH BERENS CREEK CULVERT

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation
Ontario

GRAIN SIZE DISTRIBUTION
SOIL DESCRIPTION
SAND

ENCLOSURE 10

DST REF. # GS-TB-020823

SOUTH BERENS CREEK CULVERT



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 07:59 (MT)
Version: FINAL

Client Phone: 807-345-3620

Certificate of Analysis

Lab Work Order #: L1709001
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
L1709001-1	SOUTH BEREMS CREEK							
Sampled By:	Client on 01-DEC-15 @ 00:01							
Matrix:	Soil							
Physical Tests								
Conductivity		19.3		4.0	umhos/cm	07-DEC-15	07-DEC-15	R3325981
% Moisture		12.7		0.10	%	04-DEC-15	05-DEC-15	R3325347
pH		5.11		0.10	pH units		07-DEC-15	R3326423
Resistivity		51800		100	ohm cm	07-DEC-15	07-DEC-15	R3325976
Leachable Anions & Nutrients								
Chloride		<20		20	mg/kg	04-DEC-15	08-DEC-15	R3327616
Anions and Nutrients								
Sulphate		26		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: L1709001

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

Quality Control Report

Workorder: L1709001

Report Date: 10-DEC-15

Page 2 of 2

Legend:

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.

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

COBBLES IN THE FILL STRATUM - Item No. 1

Non-Standard Special Provision

This special provision covers warning for the pile installation difficulty by cobbles and boulders presence in subsurface stratum.

The Contractor is advised of the following foundation conditions:

Occasional cobbles were identified within the fill stratum at the advanced borehole locations. The contractor shall be prepared for the potential for encountering cobbles or boulders at the site during excavation or installation of temporary roadway protection.

DEWATERING OPERATION REQUIREMENT - Item No. 2

Non-Standard Special Provision

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.

The contractor is also alerted that the site consists of cohesionless silty sand and sand soils submerged below the groundwater table. These soils are highly susceptible to slough, boil and cave under conditions of unbalanced hydrostatic pressure. The contractor is required to effect a dewatering scheme that will produce a drawdown of the water table 1 meter below the founding elevation, which permit the construction in the dry and that will prevent soil loss and soil disturbance at the founding elevation.