



**FOUNDATION INVESTIGATION REPORT
REHABILITATION OF HIGHWAY 21
FROM BAYFIELD TO GODERICH, ONTARIO**

CULVERT REPLACEMENT AT STATION 12+810

**MINISTRY OF TRANSPORTATION ONTARIO - WEST REGION
PURCHASE ORDER NUMBER 3009-E-0022
GWP 834-93-00**

MTO GEOCRES NO. 40P12-28

Submitted to:

Ministry of Transportation Ontario - West Region

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TP110076

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1.0 INTRODUCTION

AMEC Environment & Infrastructure, a Division of AMEC Americas Limited (“AMEC”), was retained by the Ministry of Transportation Ontario - West Region (“MTO”) to provide Detail Design Services for the Rehabilitation of Highway 21, Ontario. The project highway is about 20 km long stretching northerly from about 1.85 km south of Bayfield River Bridge (Bayfield) to about 0.17 km north of Huckins Street (Goderich), Ontario. To provide the required geotechnical information for the Detail Design Services, AMEC conducted foundation investigation at the locations of eight (8) existing culverts identified for rehabilitation / replacement by AMEC Design Team. A site plan showing the culvert locations / stations is presented on Drawing No. 1.

The foundation investigation for the culverts comprised advancing a total of 21 boreholes (BH G1 to BH G21) as listed in Table 1.1. Culvert details, as provided by the Design Team, including the stations, type, dimensions and boreholes drilled are summarized in Table 1.1.

Table 1.1- Culvert Details*

Station	Existing Culvert		Boreholes Drilled	Proposed Work	Remarks
	Type	Dimension			
10+200 to 10+300	Concrete-open rigid frame	1.80 x 1.20 x 34.3 m	BH G1 to BH G6	Replacement or extension	Two culverts at Jowett's Grove Road Intersection with Hwy 21
	Concrete-open	0.91 x 0.91 x 40.0 m			
10+550	CSP	0.61 m diameter and 24.4 m length	BH G7 and BH G8	Replacement	
10+705	CSP	0.61 m diameter and 24.0 m length	BH G9 and BH G10	Replacement	
11+187	CSP	0.46 m diameter and 24.7 m length	BH G11 and BH G12	Replacement	
11+873	CSP	0.61 m diameter and 21.7 m length	BH G13 and BH G14	Replacement	
12+810	CSP	0.61 m diameter and 19.3 m length	BH G15 and BH G16	Replacement	
21+055	Concrete-open rigid frame	1.82 m x 5.49 m x 24.0 m	BH G17, BH G18 and BH G19	Replacement	
22+826	CSP	0.76 m diameter and 21.4 m length	BH G20 and BH G21	Replacement	

* from Culvert Summary Table provided by AMEC Design Team

The purpose of the foundation investigation was to obtain information on the subsurface conditions at the culvert sites by means of boreholes, in-situ tests and laboratory tests on selected samples. Based on AMEC's interpretation of the data obtained in the investigation, recommendations are provided on the geotechnical aspects of replacement of the culverts.

As per Terms of Reference (TOR) in the Request for Proposal (Purchase Order Number: 3009-E-0022, dated March 2010), separate reports have been prepared for each culvert site. This report presents the results of foundation investigation for the culvert at Station 12+810.

The design discussion and recommendations for Culvert at Station 12+810, including factual results of the soil conditions encountered in the boreholes and laboratory tests, are presented in a separate report titled "Foundation Investigation and Design Report".

2.0 SITE AND PROJECT DESCRIPTION

The investigated culvert site (at Station 12+810) is located about 610 m north of Bayfield Road north of Bayfield, Ontario (refer to Drawing No. 1).

At this location, Highway 21 is a two-lane, asphaltic concrete paved road with gravel shoulders on both sides, and runs on top of an embankment built up above the surrounding grade. The surrounding area is primarily rural in nature, with active agricultural operations and farm houses / vacant lands / wood lots.

The existing culvert at this location has been recommended by AMEC Design Team for replacement. Based on the Culvert Summary Table provided in Table 1.1, the existing culvert at this location is a CSP type, 0.61 m diameter and 19.3 m long. From the drawing provided by MTO (ETR Plate No. 171-21/13-0), the height of fill over the culvert is about 2.0 m \pm . The existing culvert has been recommended for replacement by the AMEC Design Team.

Site photographs showing the culvert are presented in Appendix C (Photographs 1 and 2).

3.0 GEOLOGY

Based on Map 2556 (Southern Sheet): 'Quaternary Geology of Ontario' prepared by Ministry of Northern Development and Mines of Ontario (1991), the site is located in an area of transition where the overburden comprises (i) St. Joseph Till (Huron - Georgian Bay lobe) consisting of silt to silty clay matrix, clay content increases southward, clast poor, and (ii) Glaciolacustrine deposits consisting of sand, gravelly sand and gravel; nearshore and beach deposits; and (iii) Glaciolacustrine deposits consisting of silt and clay, minor sand, basin and quiet water deposits.

4.0 INVESTIGATION PROCEDURES

4.1 Field Investigation

In accordance with the Terms of Reference for this investigation, two (2) boreholes were advanced - one on each side of the existing culvert. Borehole BH G15 was drilled near the culvert inlet, while Borehole BH G16 was advanced adjacent to the culvert outlet. The borehole locations are presented on Drawing No. 2.

The fieldwork was performed on 18 May 2011 after acquiring all necessary permits for road occupancy, and obtaining clearance for underground utilities. The ground surfaces at the borehole locations were surveyed with reference to the nearest geodetic benchmark (BM HCP # 102, Sta. 10+449.955, El 197.134).

The boreholes were advanced using solid-stem continuous-flight augers, with a track-mounted power-auger drilling rig under the full-time supervision of experienced geotechnical personnel from AMEC. Soil samples were generally taken at 0.76 m intervals for the initial 3 m of the borehole, and 1.5 m thereafter, while performing the Standard Penetration Test (SPT) in accordance with ASTM D1586. This consisted of freely dropping a 63.5 kg (140 lbs.) hammer for a vertical distance of 0.76 m (30 inches) to drive a 51 mm (2 inches) diameter O.D. split-barrel (split spoon) sampler into the ground. The number of blows of the hammer required to drive the sampler into the relatively undisturbed ground by a vertical distance of 0.30 m (12 inches) was recorded as SPT 'N' value of the soil, which indicated the consistency of cohesive soils or the compactness of non-cohesive soils.

The groundwater conditions were observed in the boreholes during sampling and upon completion of drilling. The groundwater depth measurements are presented on the Record of Boreholes. A single monitoring well was installed in Borehole BH G15 for long term monitoring of groundwater levels by the project hydrogeological team (the hydrogeological report is submitted separately). The groundwater levels were measured within the monitoring well on 14 June and 22 June 2011. The results of measurements are shown on the Record of Boreholes and summarized in Table 5.2 (Section 5.4).

Upon completion of drilling, Borehole BH G16 was backfilled with bentonite in accordance with the general requirements of Ministry of the Environment Regulation 903.

The soil samples were transported to AMEC's Advanced Soil Laboratory in Scarborough (Toronto) for further examination and laboratory soil testing. The program of laboratory testing included, where applicable, the following: grain size analysis, Liquid and Plastic Limit, in-situ water content determination, and soil corrosivity analysis.

The results of the in-situ and laboratory tests are presented in the corresponding Record of Boreholes (Appendix A) and Laboratory Test Results (Appendix B).

4.2 Laboratory Tests

In accordance with the Terms of Reference for this investigation, the following tests were conducted in the laboratory:

- In-situ water content determination (14);
- Grain size distribution analysis (4);
- Atterberg Limit tests (4); and
- Soil corrosivity (1).

The results of in-situ and laboratory tests are presented in the Record of Boreholes in Appendix A. The grain size distribution curves and plasticity chart are shown in Appendix B.

5.0 SUB-SURFACE CONDITIONS

Based on the investigation results, the soil profile consisted of topsoil underlain by native deposit (clayey silt) extending to the termination depths of the boreholes (elevation 189.6 m in BH G15 and 189.7 m in BH G16). In Borehole BH G16, clayey silt fill was encountered between the topsoil and the native clayey silt.

The stratigraphic units and groundwater conditions at the borehole locations are discussed in the following sections. Detailed information is provided in the Record of Boreholes (Appendix A). Interpolated stratigraphical cross sections showing the existing culvert are provided in Drawing No. 3.

Soil and groundwater conditions may vary between and beyond the borehole locations.

5.1 Topsoil

Topsoil was encountered at the existing grade in both boreholes. The measured thickness of topsoil was about 400 mm in Borehole BH G15, and 600 mm in Borehole BH G16. The topsoil consisted primarily of organic matter with some rootlets and soils.

The thickness of topsoil could vary between and beyond the borehole locations. The measured moisture contents in topsoil samples were 22 % and 25 %.

5.2 Clayey Silt Fill

Borehole BH G16 drilled adjacent to the culvert outlet encountered clayey silt fill underneath the topsoil. The clayey silt fill was likely native soil that had been disturbed or reworked possibly as a result of construction. The clayey silt fill extended to about 1.4 m below the existing grade.

The clayey silt fill was dark brown in color and contained some sand, trace rootlets and organic matter.

A single measured SPT 'N' value of the clayey silt fill was 6 blows per 0.3 m. The measured moisture content in the clayey silt fill was 26 %.

5.3 Clayey Silt

Native clayey silt was encountered below the topsoil in Borehole BH G15; and underneath the clayey silt fill in Borehole BH G16. The clayey silt extended to the termination depths of both boreholes (elevation 189.6 m \pm).

The clayey silt was brown in color, and contained trace sand, gravel and cobbles / boulders. The SPT 'N' values of the clayey silt ranged widely from 13 to 72 blows per 0.3 m, indicating a stiff to hard consistency. However, a SPT 'N' value of 3 blows per 0.3 m (soft consistency) was measure in Sample SS1 in Borehole BH G15. The measured moisture contents in the clayey silt ranged from 16 % to 22 %.

Grain size analyses and Atterberg Limit tests were completed on 4 samples of the clayey silt, and the results are presented in Table 5.1.

Table 5.1 - Grain Size Distribution Analysis and Atterberg Limit Test Results

Borehole No.	Sample No.	Depth (Elevation) (m)	Grain Size Distribution				Atterberg Limit			USCS Modified Group Symbol
			Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Liquid Limit	Plastic Limit	Plasticity Index	
BH G15	SS 2	0.8 - 1.2 (195.4 - 195.0)	0	3	85	12	25	17	8	CL
BH G15	SS 4	2.3 - 2.8 (193.9 - 193.4)	0	1	68	31	29	16	13	CL
BH G16	SS 4	2.3 - 2.8 (194.0 - 193.5)	0	3	84	13	20	16	4	CL- ML / ML
BH G16	SS 7	6.1 - 6.5 (190.1 - 189.7)	4	14	53	29	28	13	15	CL

The grain size distribution curves are presented in Figure No. B 1 and the plasticity chart is presented in Figure No. B 2, in Appendix B.

5.4 Groundwater Conditions

Groundwater conditions in the open boreholes were observed during and on completion of drilling. Groundwater was measured in open boreholes upon completion of drilling at a depth of about 3.2 m below the existing grade (elevation 193.0 m \pm) in Borehole BH G15, and about 4.7 m (elevation 191.5 m \pm) in Borehole BH G16.

The groundwater levels were also measured in the monitoring well installed in Borehole BH G15. The groundwater measurements are shown on the Record of Boreholes and summarized in Table 5.2.

Table 5.2 - Results of Groundwater Measurements

Borehole	Measured Groundwater Level			Remarks
	Date	Depth (m)	Elevation (m)	
BH G15	18 May 2011	3.2 m \pm	193.0 m \pm	Completion of drilling
	14 June 2011	0.6 m \pm	195.6 m \pm	In monitoring well
	22 June 2011	0.8 m \pm	195.4 m \pm	
	23 June 2011	0.3 m \pm	195.9 m \pm	
	16 Aug 2011	0.9 m \pm	195.3 m \pm	
	17 May 2012	0.8 m \pm	195.4 m \pm	
BH G16	18 May 2011	4.7 m \pm	191.5 m \pm	Completion of drilling

It should be pointed out that the groundwater at the site would fluctuate seasonally and can be expected to be somewhat higher during the spring months and in response to major weather events.

5.5 Soil Corrosivity

One soil sample (BH G15 - SS 2) was analysed by Maxxam Analytics Laboratory in Mississauga to determine the soil corrosivity potential with respect to concrete and steel. The Certificate of Analysis is included in Appendix B. A summary of the test results is presented in Table 5.3.

Table 5.3 - Results of Corrosivity Test

Soil Sample No.	pH	Electrical Conductivity $\mu\text{mho/cm}$	Resistivity (ohms-cm)	Chloride ($\mu\text{g/g}$)	Sulphate ($\mu\text{g/g}$)
BH G15 - SS 2	7.6	166	6000	<20	<20

The test results have shown that the sulphate content of the soil is <20 ppm ($\mu\text{g/g}$). As per Table 3 "Additional Requirements for concrete subjected to sulphate attack", Clause 4.1.1.6 of CSA Standards Specification A23.1-09, any soil which has sulphate content below 0.1% (i.e., 1,000 ppm or $\mu\text{g/g}$) is not considered aggressive with respect to concrete. As such, in accordance with Table 6 of CSA A23.1-09, Type GU (general use) cement can be used for concrete.

6.0 CLOSURE

The sub-soil information contained in this report should be used solely for the purpose of foundation assessment of the culvert site at Station 12+810 on Highway 21, north of Bayfield, Ontario.

The Limitations of Report is an integral part of this report.

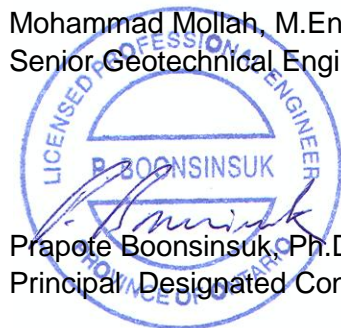
This report was prepared by Mohammad Mollah, M.Eng., P.Eng., and was reviewed by Dr. Prapote Boonsinsuk, Ph.D., P.Eng.

Sincerely,

**AMEC Environment & Infrastructure,
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LIMITATIONS OF REPORT

The information contained herein in no way reflects on the environmental aspects of the project, unless otherwise stated. Subsurface and groundwater conditions between and beyond the testholes may differ from those encountered at the testhole locations, and conditions may become apparent during construction, which could not be detected or anticipated at the time of the site investigation.

The number of testholes may not be sufficient to determine all the factors that may affect construction methods and costs. 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 conclusions as to how the subsurface conditions may affect their work. This work has been undertaken in accordance with normally accepted geotechnical engineering practices.

This report was prepared specifically for the culvert at Station 12+810 in Highway 21 north of Bayfield, Ontario, as described in the report. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. AMEC Environment & Infrastructure, a Division of AMEC Americas Limited, accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

DRAWINGS

DRAWING NO. 1	CULVERT LOCATION PLAN
DRAWING NO. 2	BOREHOLE LOCATION PLAN
DRAWING NO. 3	STRATIGRAPHIC CROSS SECTIONS



SCALE

1500m 0 1500 3000 4500 6000m

LEGEND

 CULVERT LOCATION

**AMEC Environment & Infrastructure,
a Division of AMEC Americas Limited**



**MINISTRY OF
TRANSPORTATION ONTARIO
WEST REGION**

TITLE
CULVERT LOCATION PLAN

PROJECT
REHABILITATION OF HIGHWAY 21 - FROM BAYFIELD TO GODERICH, ONTARIO
PURCHASE ORDER NUMBER: 3009-E-0022, WP 834-93-00, GEOCREs No.: 40P12-28

DWN BY:
KW

CHK'D BY:
PB

PROJECTION:
-

DATUM:
-

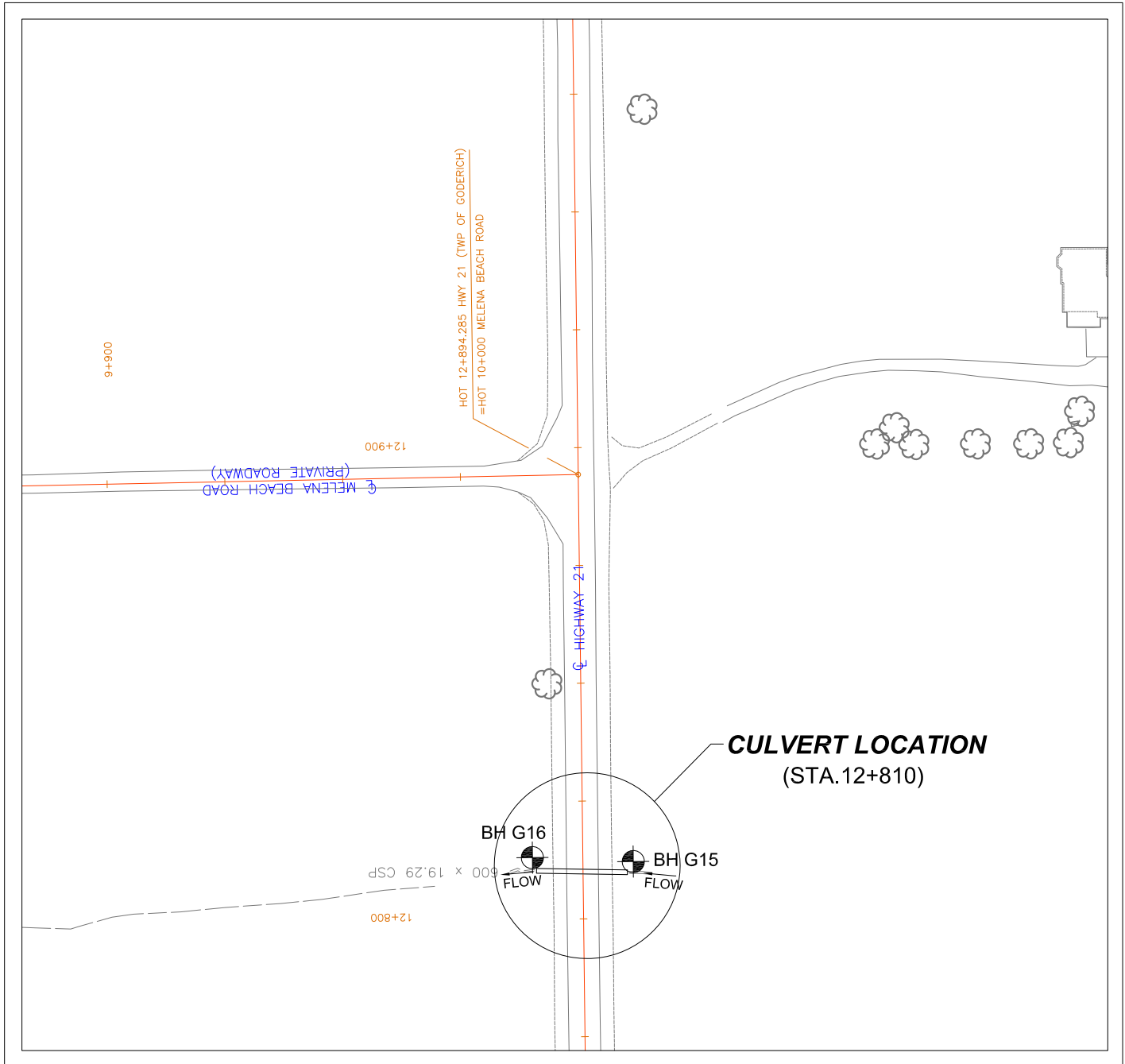
REV. NO.:
A

SCALE:
AS SHOWN

DATE:
JANUARY 2013



PROJECT NO.:
TP110076

DRAWING No.
1



SCALE



AMEC Environment & Infrastructure, a Division of AMEC Americas Limited			CLIENT LOGO 	CLIENT MINISTRY OF TRANSPORTATION ONTARIO WEST REGION	
TITLE BOREHOLE LOCATION PLAN			DWN BY: KW	DATUM: -	DATE: JANUARY 2013
PROJECT REHABILITATION OF HIGHWAY 21 - FROM BAYFIELD TO GODERICH, ONTARIO			CHK'D BY: PB	REV. NO.: A	PROJECT NO: TP110076
PURCHASE ORDER NUMBER: 3009-E-0022, WP 834-93-00, GEOCREs No.: 40P12-28			PROJECTION: -	SCALE: AS SHOWN	DRAWING No. 2

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

PURCHASE ORDER NUMBER:
3009-E-0022

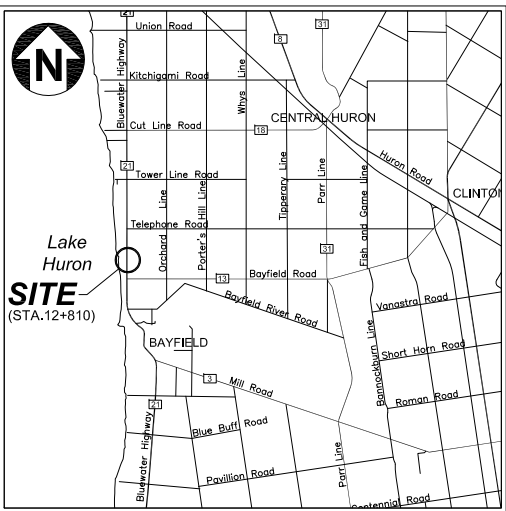
G.W.P. No.
834-93-00

REHABILITATION OF HWY 21 FROM BAYFIELD TO GODERICH
GEOCRES No.40P12-28
CULVERT AT STA 12+810
STRATIGRAPHIC CROSS SECTION

SHEET
1 OF 1



AMEC Environment & Infrastructure,
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KEY PLAN

2000m 0 2000 4000 6000 8000m

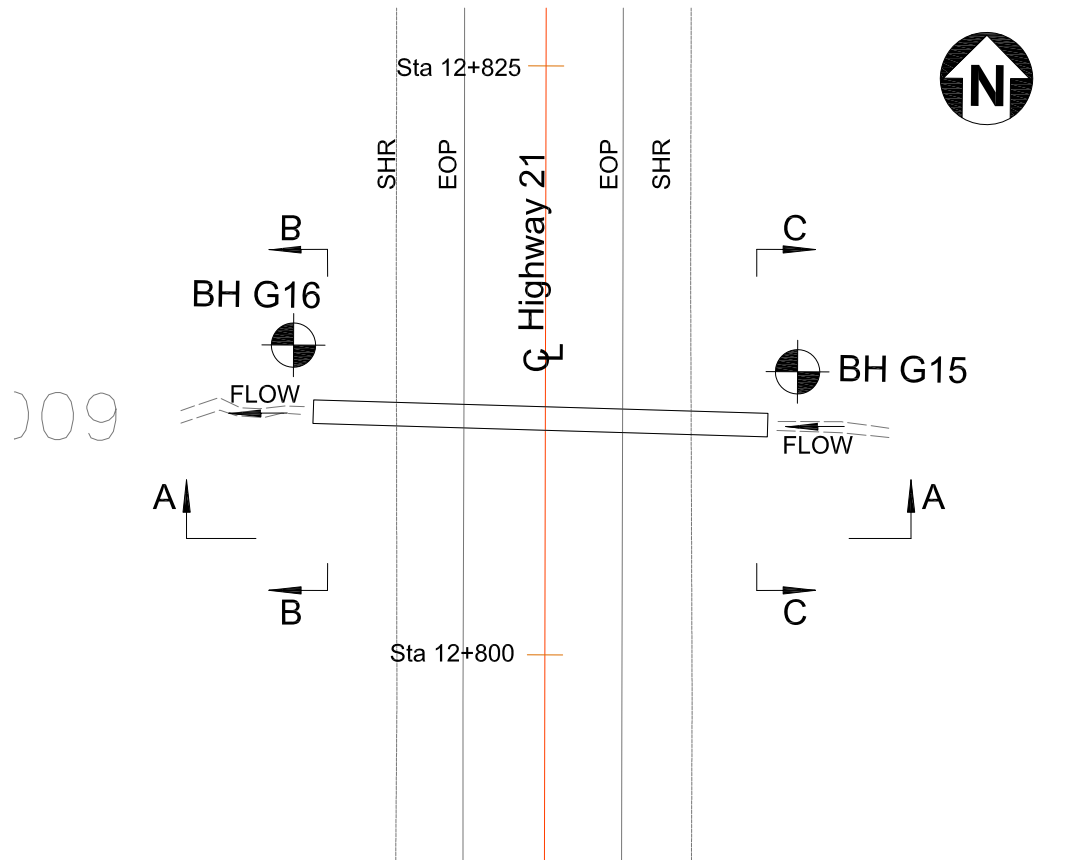
Approximate Scale

LEGEND

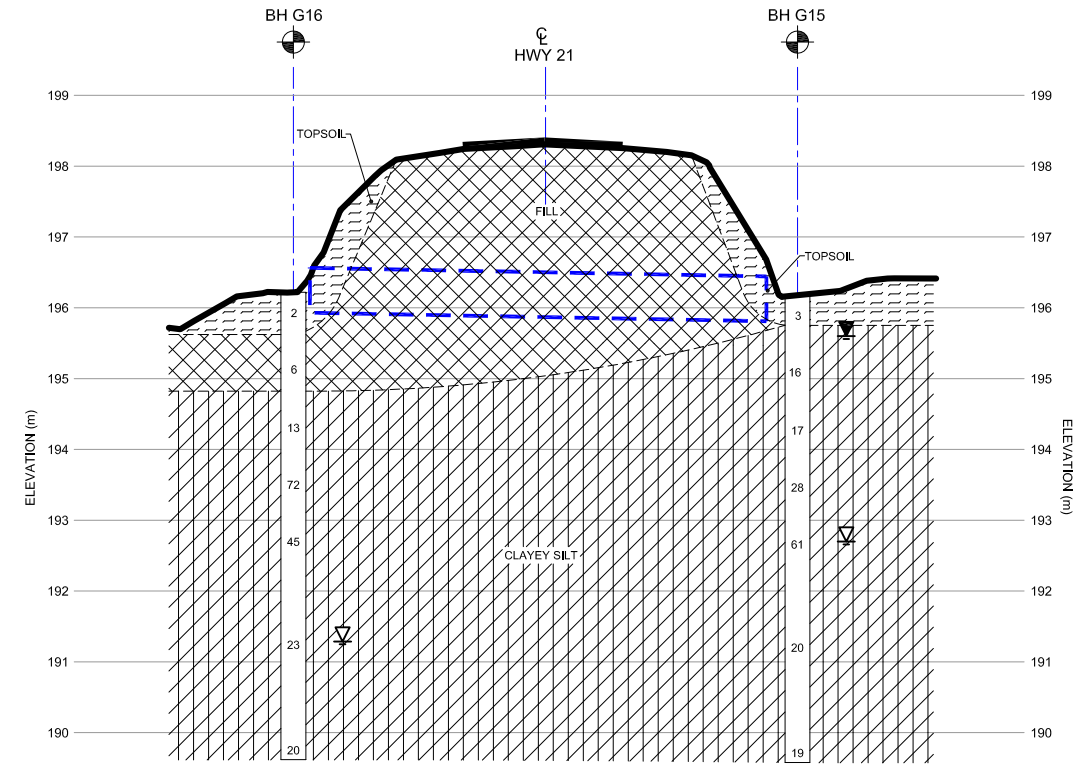
- BOREHOLE LOCATION
- GROUNDWATER LEVEL AT TIME OF INVESTIGATION
- GROUNDWATER LEVEL IN MONITORING WELL
- EOP EDGE OF PAVEMENT
- SHR SHOULDER ROUND

DESCRIPTION	UTM COORDINATES		ELEVATION (m)
	NORTHING	EASTING	
BH G15	4826850	443051	196.18
BH G16	4826850	443029	196.22

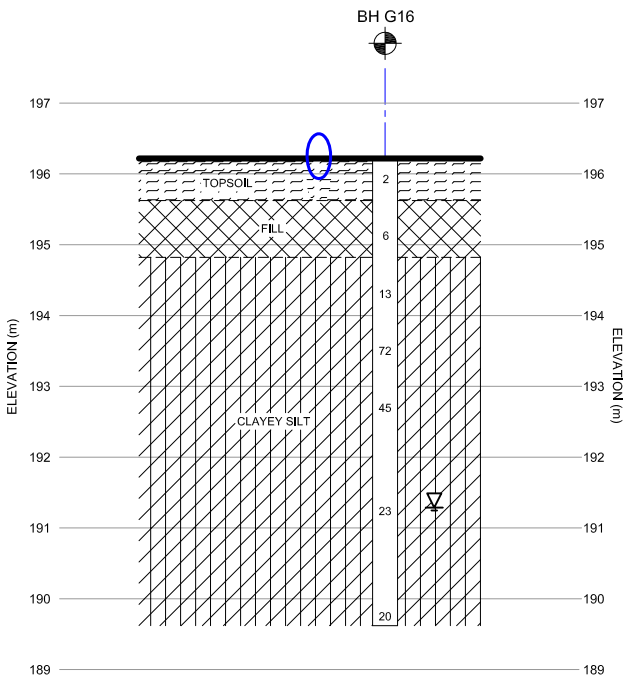
- NOTES:
- The boundaries between soil strata have been established only at borehole locations. Between boreholes, the boundaries are assumed from geological evidence and may be subject to considerable error.
 - This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
 - Borehole without was dry.



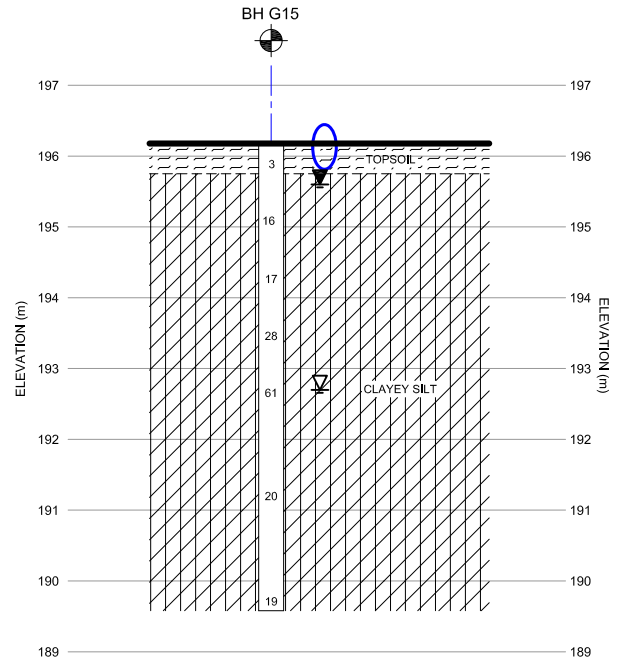
PLAN



SECTION A-A



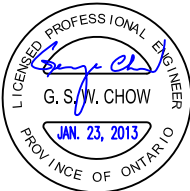
SECTION B-B



SECTION C-C

SOIL STRATIGRAPHY

- TOPSOIL
- FILL
- CLAYEY SILT



0 4 8 12m HOR
0 1 2 3m VER
SCALE

REVISIONS				
DESIGN PB	CHK PB	CODE CHBDC-06	CL 625-ONT	DATE JAN. 2013
DRAWN KW	CHK HS	SITE 12+810		DWG 3

APPENDIX A
RECORD OF BOREHOLES

EXPLANATION OF BOREHOLE LOG

This form describes some of the information provided on the borehole logs, which is based primarily on examination of the recovered samples, and the results of the field and laboratory tests. Additional description of the soil/rock encountered is given in the accompanying geotechnical report.

GENERAL INFORMATION

Project details, borehole number, location coordinates and type of drilling equipment used are given at the top of the borehole log.

SOIL LITHOLOGY

Elevation and Depth

This column gives the elevation and depth of inferred geologic layers. The elevation is referred to the datum shown in the Description column.

Lithology Plot

This column presents a graphic depiction of the soil and rock stratigraphy encountered within the borehole.

Description

This column gives a description of the soil strata, based on visual and tactile examination of the samples augmented with field and laboratory test results. Each stratum is described according to the *MTC Soil Classification Manual*.

The compactness condition of cohesionless soils (SPT) and the consistency of cohesive soils (undrained shear strength) are defined as follows (*Ref. MTC Soil Classification Manual*):

Compactness of	
<u>Cohesionless Soils</u>	<u>SPT N-Value*</u>
Very loose	0 to 5
Loose	5 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	> 50

Consistency of	
<u>Cohesive Soils</u>	<u>Undrained Shear Strength</u>
	<u>kPa</u>
Very soft	0 to 12
Soft	12 to 25
Firm	25 to 50
Stiff	50 to 100
Very stiff	100 to 200
Hard	Over 200

* For penetration of less than 0.3 m, N-values are indicated as the number of blows for the penetration achieved (e.g. 50/25: 50 blows for 25 centimeter penetration).

Soil Sampling

Sample types are abbreviated as follows:

SS	Split Spoon	TW	Thin Wall Open (Pushed)	RC	Rock Core	GS	Grab Sample
AS	Auger Sample	TP	Thin Wall Piston (Pushed)	WS	Washed Sample	AR	Air Return Sample

Additional information provided in this section includes sample numbering, sample recovery and numerical testing results.

Field and Laboratory Testing

Results of field testing (e.g., SPT, pocket penetrometer, and vane testing) and laboratory testing (e.g., natural moisture content, and limits) executed on the recovered samples are plotted in this section.

Instrumentation Installation

Instrumentation installations (monitoring wells, piezometers, inclinometers, etc.) are plotted in this section. Water levels, if measured during fieldwork, are also plotted. These water levels may or may not be representative of the static groundwater level depending on the nature of soil stratum where the piezometer tips are located, the time elapsed from installation to reading and other applicable factors.

Comments

This column is used to describe non-standard situations or notes of interest.

MTC SOIL CLASSIFICATION

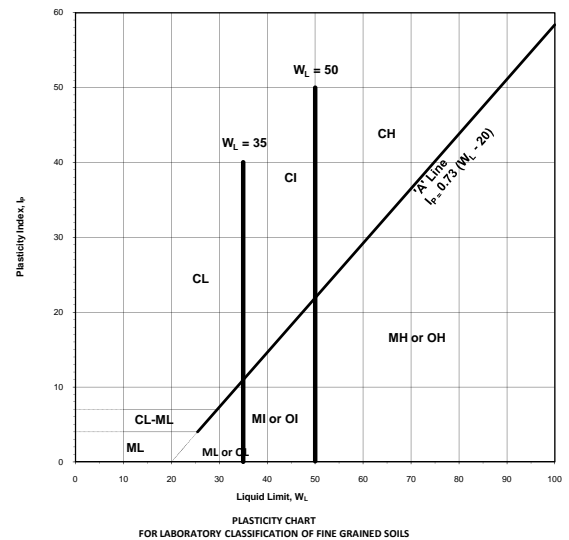
Based on MTC Soil Classification Manual



MAJOR DIVISION					GROUP SYMBOL	TYPICAL DESCRIPTION	INFORMATION REQUIRED FOR DESCRIBING SOILS	LABORATORY CLASSIFICATION CRITERIA		
COARSE GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 75µm)	GRAVELS MORE THAN HALF THE COARSE FRACTION LARGER THAN 4.75mm	CLEAN GRAVELS (LITTLE OR NO FINES)	WIDE RANGE IN GRAIN SIZE & SUBSTANTIAL AMOUNTS OF ALL INTERMEDIATE PARTICULAR SIZE		GW	WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	GIVE TYPE, NAME, IF NECESSARY, INDICATE APPROX % OF SAND & GRAVEL ; MAX SIZE; ANGULARITY, SURFACE CONDITION, & HARDNESS OF THE COARSE GRAINS, LOCAL OR GEOLOGICAL NAME & OTHER PERTINENT DESCRIPTIVE INFORMATION, & SYMBOL IN PARENTHESIS.	$C_u = \frac{D_{60}}{D_{10}}$ GREATER THAN 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ BETWEEN 1 AND 3		
			PREDOMINANTLY ONE SIZE OF A RANGE OF SIZES WITH STONE INTERMEDIATE SIZES MISSING		GP	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES				
		GRAVEL WITH FINES (APPLICABLE AMOUNT OF FINES)	NON PLASTIC FINES (FOR IDENTIFICATION PROCEDURES SEE ML BELOW)		GM	SILTY GRAVELS, POORLY GRADED GRAVEL-SAND- SILT MIXTURES				
			PLASTIC FINES (FOR IDENTIFICATION PROCEDURES SEE CL BELOW)		GC	CLAYEY GRAVELS, POORLY GRADED GRAVEL-SAND-CLAY MIXTURES				
	SANDS MORE THAN HALF THE COARSE FRACTION SMALLER THAN 4.75mm	CLEAN SANDS (LITTLE OR NO FINES)	WIDE RANGE IN GRAIN SIZE & SUBSTANTIAL AMOUNT OF ALL INTERMEDIATE PARTICLE SIZES		SW	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	FOR UNDISTURBED SOILS ADD INFORMATION ON STRATIFICATION, DEGREE OF COMPACTNESS, CEMENTATION, MOISTURE CONDITION & DRAINAGE CHARACTERISTICS	NOT MEETING ALL GRADATION REQUIREMENTS FOR GW		
			PREDOMINANTLY ONE SIZE OR A RANGE OF SIZES WITH SOME INTERMEDIATE SIZE MISSING		SP	POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES				
		SANDS WITH FINES (APPLICABLE AMOUNT OF FINES)	NON PLASTIC FINES (FOR IDENTIFICATION PROCEDURES SEE ML BELOW)		SM	SILTY SANDS, POORLY GRADED SAND-SILT MIXTURES				
			PLASTIC FINES (FOR IDENTIFICATION PROCEDURES SEE CL BELOW)		SC	CLAYEY SANDS, POORLY GRADED SAND-CLAY MIXTURES				
	FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT SMALLER THAN 75µm)	IDENTIFICATION PROCEDURE ON FRACTION SMALLER THAN 425µm						USE GRAIN SIZE CURVE IN IDENTIFYING THE FACTORS AS GIVEN UNDER FIELD IDENTIFICATION DETERMINE PERCENTAGE OF GRAVEL & SAND FROM GRAIN SIZE CURVE, DEPENDING ON PERCENTAGE OF FINES (FRACTION SMALLER THAN 75 µm) COARSE GRAINED SOILS ARE CLASSIFIED AS FOLLOWS: LESS THAN 5% GW, GP, SW, SP MORE THAN 12% GM, GC, SM, SC 5% TO 12% BORDER LINE CASES REQUIRE USE OF DUAL SYMBOL	$C_u = \frac{D_{60}}{D_{10}}$ GREATER THAN 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ BETWEEN 1 AND 3	
		LIQUID LIMIT LESS THAN 35	DRY STRENGTH (CRUSHING CHARACTERISTICS)	DILATANCY (REACTION TO SHAKING)	TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT)					
NONE			QUICK	NONE	ML	INORGANIC SILTS & SANDY SILTS OR SLIGHTLY PLASTICITY, ROCK FLOUR				
MEDIUM TO HIGH			NONE TO VERY SLOW	MEDIUM	CL	SILTY CLAYS (INORGANIC), GRAVELLY CLAYS, SANDY CLAYS, LEAN CLAYS				
SLIGHT TO MEDIUM			SLOW	SLIGHT	OL	ORGANIC SILT OF LOW PLASTICITY, ORGANIC SANDY SILTS				
LIQUID LIMIT BETWEEN 35 AND 50		NONE TO SLIGHT	SLOW TO QUICK	SLIGHT	MI	INORGANIC COMPRESSIBLE FINE SANDY SILT WITH CLAY OF MEDIUM PLASTICITY, CLAYEY SILTS				
		HIGH	NONE	MEDIUM TO HIGH	CI	SILTY CLAYS (INORGANIC) OF MEDIUM PLASTICITY				
		SLIGHT TO MEDIUM	VERY SLOW	SLIGHT	OI	ORGANIC SILTY CLAYS OF MEDIUM PLASTICITY				
		LIQUID LIMIT GREATER THAN 50	SLIGHT TO MEDIUM	SLOW TO NONE	MEDIUM	MH	INORGANIC SILTS, HIGHLY COMPRESSIBLE MICACEOUS OR DIATOMEACACOUS FINE SANDY SILTS, ELASTIC SILTS			
HIGH TO VERY HIGH			NONE	HIGH	CH	CLAYS (INORGANIC) OF HIGH PLASTICITY, FAT CLAYS				
MEDIUM TO HIGH			NONE TO VERY SLOW	SLIGHT TO MEDIUM	OH	ORGANIC CLAYS OF HIGH PLASTICITY				
READILY IDENTIFIED BY COLOUR, ODOUR, SPONGY FEEL & FREQUENTLY BY FIBROUS TEXTURE			Pt	PEAT AND OTHER HIGHLY ORGANIC SOILS						

USE GRAIN SIZE CURVE IN IDENTIFYING THE FACTORS AS GIVEN UNDER FIELD IDENTIFICATION

FRACTION	U.S STANDARD SIEVE SIZE		DEFINING RANGES OF PERCENTAGE BY WEIGHT OF MINOR COMPONENTS		
GRAVEL	COARSE	PASSING	RETAINED	PERCENT	DESCRIPTOR
		75 mm	26.5 mm		
SAND	FINE	26.5 mm	4.75 mm	40-50	AND
		COARSE	4.75 mm	2.00 mm	Y/EY
	MEDIUM	2.00 mm	425 µm	20-30	WITH
	FINE	425 µm	75 µm	10-20	SOME
FINES (SILT OR CLAY BASED ON PLASTICITY)		75 µm		1-10	TRACE
OVERSIZED MATERIAL					
ROUNDED OR SUBROUNDED: COBBLES 75 mm TO 200 mm BOULDERS > 200 mm				NOT ROUNDED: ROCK FRAGMENTS > 75 mm ROCKS > 0.76 CUBIC METRE IN VOLUME	



BOUNDARY CLASSIFICATION: BOUNDARY CLASSIFICATION: SOILS POSSESSING CHARACTERISTICS OF TWO GROUPS ARE DESIGNATED BY COMBINATIONS OF GROUP SYMBOLS FOF EXAMPLE GW-GC WELL GRADED GRAVEL-SAND MIXTURE WITH CLAY BINDER



AMEC Earth & Environmental,
a Division of AMEC American

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**MTC SOIL CLASSIFICATION MANUAL
ENGINEERING PROPERTIES OF SOIL**



TYPICAL NAMES OF SOIL GROUPS	GROUP SYMBOLS	PERMEABILITY WHEN COMPACTED	STRENGTH WHEN COMPACTED	COMPRESSIBILITY WHEN COMPACTED	WORKABILITY AS A CONSTRUCTION MATERIAL	SCOUR RESISTANCE	SUSCEPTIBILITY TO SURFICIAL EROSION	SUSCEPTIBILITY TO FROST ACTION	DRAINAGE CHARACTERISTICS
WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	GW	PERVIOUS	EXCELLENT	NEGLECTIBLE	EXCELLENT	MEDIUM	NEGLECTIBLE	NEGLECTIBLE	EXCELLENT
POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	GP	VERY PERVIOUS	GOOD	NEGLECTIBLE	GOOD	MEDIUM	NEGLECTIBLE	NEGLECTIBLE	EXCELLENT
SILTY GRAVELS, POORLY GRADED GRAVEL- SAND-SILT MIXTURES	GM	SEMI-PERVIOUS TO IMPERVIOUS	GOOD	NEGLECTIBLE	GOOD	LOW TO MEDIUM	SLIGHT	SLIGHT	FAIR TO SEMI IMPERVIOUS
CLAYEY GRAVELS, POORLY GRADED GRAVEL-SAND-CLAY MIXTURES	GC	IMPERVIOUS	GOOD TO FAIR	VERY LOW	GOOD	MEDIUM	SLIGHT	NEGLECTIBLE TO SLIGHT	PRACTICALLY IMPERVIOUS
WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	SW	PERVIOUS	EXCELLENT	NEGLECTIBLE	EXCELLENT	LOW TO MEDIUM	SLIGHT	NEGLECTIBLE	EXCELLENT
POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	SP	PERVIOUS	GOOD	VERY LOW	FAIR TO GOOD	LOW TO MEDIUM	MODERATE	NEGLECTIBLE TO SLIGHT	EXCELLENT
SILTY SANDS, POORLY GRADED SAND-SILT MIXTURES	SM	SEMI-PERVIOUS TO IMPERVIOUS	GOOD	LOW	FAIR	LOW	MODERATE	SLIGHT TO MODERATE	FAIR TO SEMI IMPERVIOUS IMPERVIOUS
CLAYEY SANDS, POORLY GRADED SAND WITH SOME CLAY MIXTURES	SC	IMPERVIOUS	GOOD TO FAIR	LOW	GOOD	VERY LOW TO LOW	MODERATE TO SLIGHT	NEGLECTIBLE	PRACTICALLY IMPERVIOUS
INORGANIC SILTS AND SANDY SILTS OF SLIGHT PLASTICITY, ROCK FLOUR	ML	SEMI-PERVIOUS TO IMPERVIOUS	FAIR	MEDIUM	FAIR	VERY LOW	SEVERE	SEVERE	FAIR TO POOR
INORGANIC CLAYEY SILTS OF LOW PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, LEAN CLAYS	CL	IMPERVIOUS	FAIR	MEDIUM	GOOD TO FAIR	LOW TO MEDIUM	SLIGHT TO MODERATE	MODERATE TO SEVERE	PRACTICALLY IMPERVIOUS
ORGANIC SILTS OF LOW PLASTICITY	OL	SEMI-PERVIOUS TO IMPERVIOUS	POOR	MEDIUM	FAIR TO POOR	VERY LOW TO LOW	SEVERE	SEVERE	POOR
INORGANIC COMPRESSIBLE SILTS OF MEDIUM PLASTICITY	MI	SEMI-PERVIOUS TO IMPERVIOUS	FAIR	MEDIUM TO HIGH	FAIR TO POOR	LOW	MODERATE	MODERATE TO SEVERE	FAIR TO POOR
INORGANIC SILTY CLAYS OF MEDIUM PLASTICITY	CI	IMPERVIOUS	FAIR TO POOR	HIGH	FAIR	LOW TO MEDIUM	SLIGHT	MODERATE TO SEVERE	SEMI IMPERVIOUS TO PRACTICALLY
ORGANIC SILTY CLAY OF MEDIUM PLASTICITY	OI	SEMI-PERVIOUS TO IMPERVIOUS	POOR	HIGH	POOR	VERY LOW TO LOW	SEVERE	MODERATE TO SEVERE	POOR TO PRACTICALLY IMPERVIOUS
INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS	MH	SEMI-PERVIOUS TO IMPERVIOUS	FAIR TO POOR	HIGH	POOR	VERY LOW	MEDIUM	SEVERE	POOR
INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS	CH	IMPERVIOUS	POOR	HIGH	FAIR TO POOR	LOW TO MEDIUM	SLIGHT TO NEGLECTIBLE	NEGLECTIBLE	PRACTICALLY IMPERVIOUS
ORGANIC CLAYS OF HIGH PLASTICITY	OH	IMPERVIOUS	POOR	HIGH	POOR	LOW	MODERATE	NEGLECTIBLE TO SLIGHT	PRACTICALLY IMPERVIOUS
PEAT AND OTHER HIGHLY ORGANIC SOILS	Pt	-	-	-	-	LOW	SEVERE	-	FAIR TO GOOD

RECORD OF BOREHOLE No. BH G15

G.W.P. 834-93-00		LOCATION Sta: 12+810, 2.3 m N of Culvert, 10.7 m Rt of CL of Rd, E 443051; N 4826850		1 OF 1	
DIST Goderich HWY 21		BOREHOLE TYPE 150 mm diameter borehole (Solid Stem)		ORIGINATED BY JF	
DATUM Geodetic		DATE May 18, 2011 - May 18, 2011		COMPILED BY SAL	
PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario				CHECKED BY SM	
				JOB NO. TP110076	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DEPTH m	ELEVATION m	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			SOIL VAPOUR READING	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				SHEAR STRENGTH kPa					WATER CONTENT (%)				
									20	40	60	80	100	W _p	W	W _L		
196.2	about 400 mm TOPSOIL		1	SS	3													
195.8	brown CLAYEY SILT trace sand soft to hard		2	SS	16													0 3 85 12
195.4			3	SS	17													
194.4			4	SS	28													0 1 68 31
193.4			5	SS	61													
192.4	grey		6	SS	20													
191.4	trace cobbles/boulders		7	SS	19													
189.6	End of Borehole Monitoring well details: - 50 mm diameter PVC pipe: - concrete: 0.0 - 0.3 m - bentonite plug: 0.3 - 1.2 m - sand pack 1.2 - 1.5 m - slotted pipe: 1.5 - 4.6 m - sand pack: 4.6 - 6.1 m - protective casing: 0.9 m above ground Groundwater level on 18-May-11 - 3.2 m (EL 193.0 m) 14-Jun-11 - 0.6 m (EL 195.6 m) 22-Jun-11 - 0.8 m (EL 195.4 m) 23-Jun-11 - 0.3 m (EL 195.9 m) 16-Aug-11 - 0.9 m (EL 195.3 m) 17-May-12 - 0.8 m (EL 195.4 m)																	

RECORD OF BOREHOLE No. BH G16

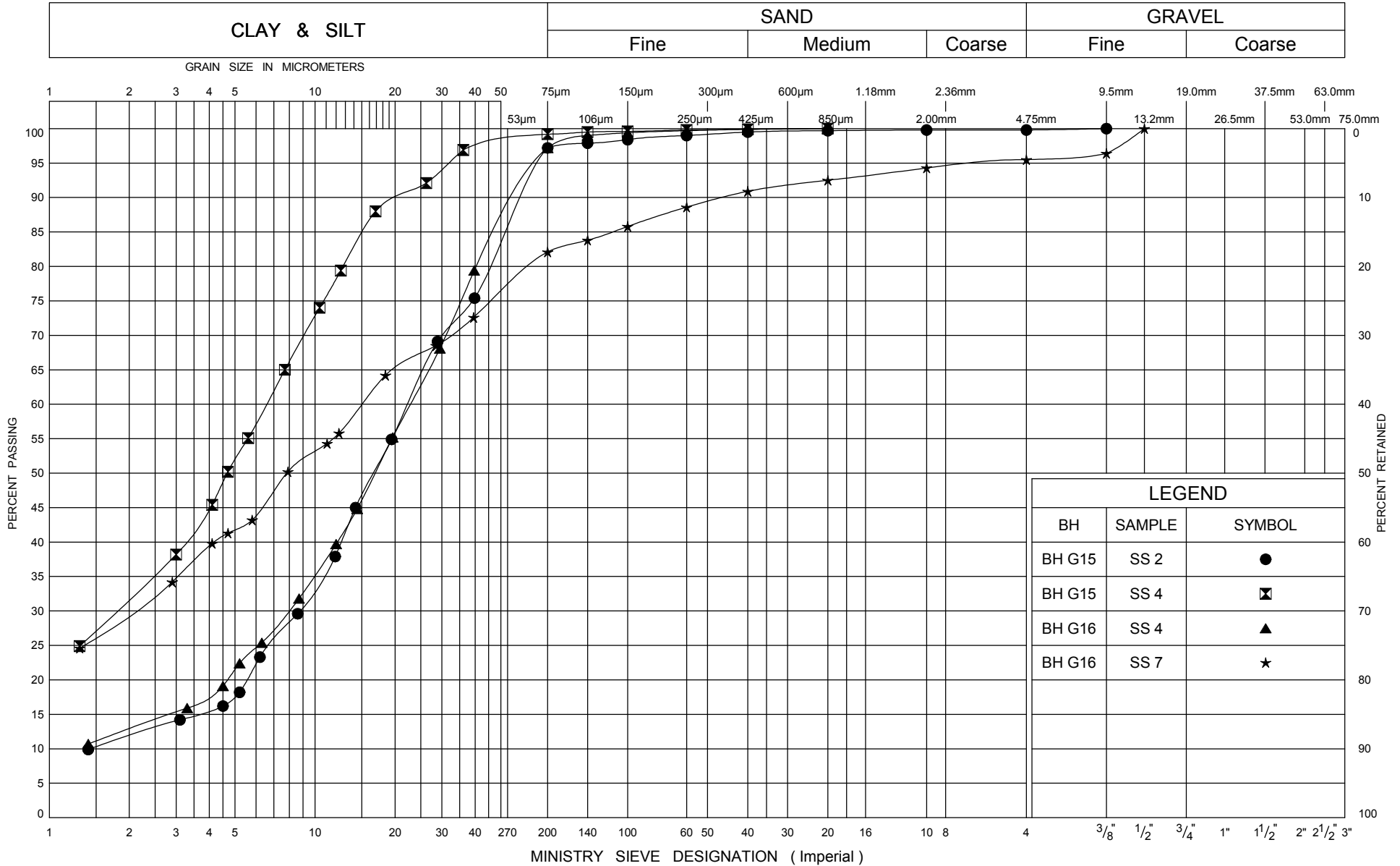
G.W.P. 834-93-00	LOCATION Sta: 12+810, 2.8 m N of Culvert, 10.7 m Lt of CL of Rd. E 443029; N 4826850	1 OF 1	ORIGINATED BY JF
DIST Goderich HWY 21	BOREHOLE TYPE 150 mm diameter borehole (Solid Stem)	COMPILED BY SAL	
DATUM Geodetic	DATE May 18, 2011 - May 18, 2011	CHECKED BY SM	
PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario		JOB NO. TP110076	

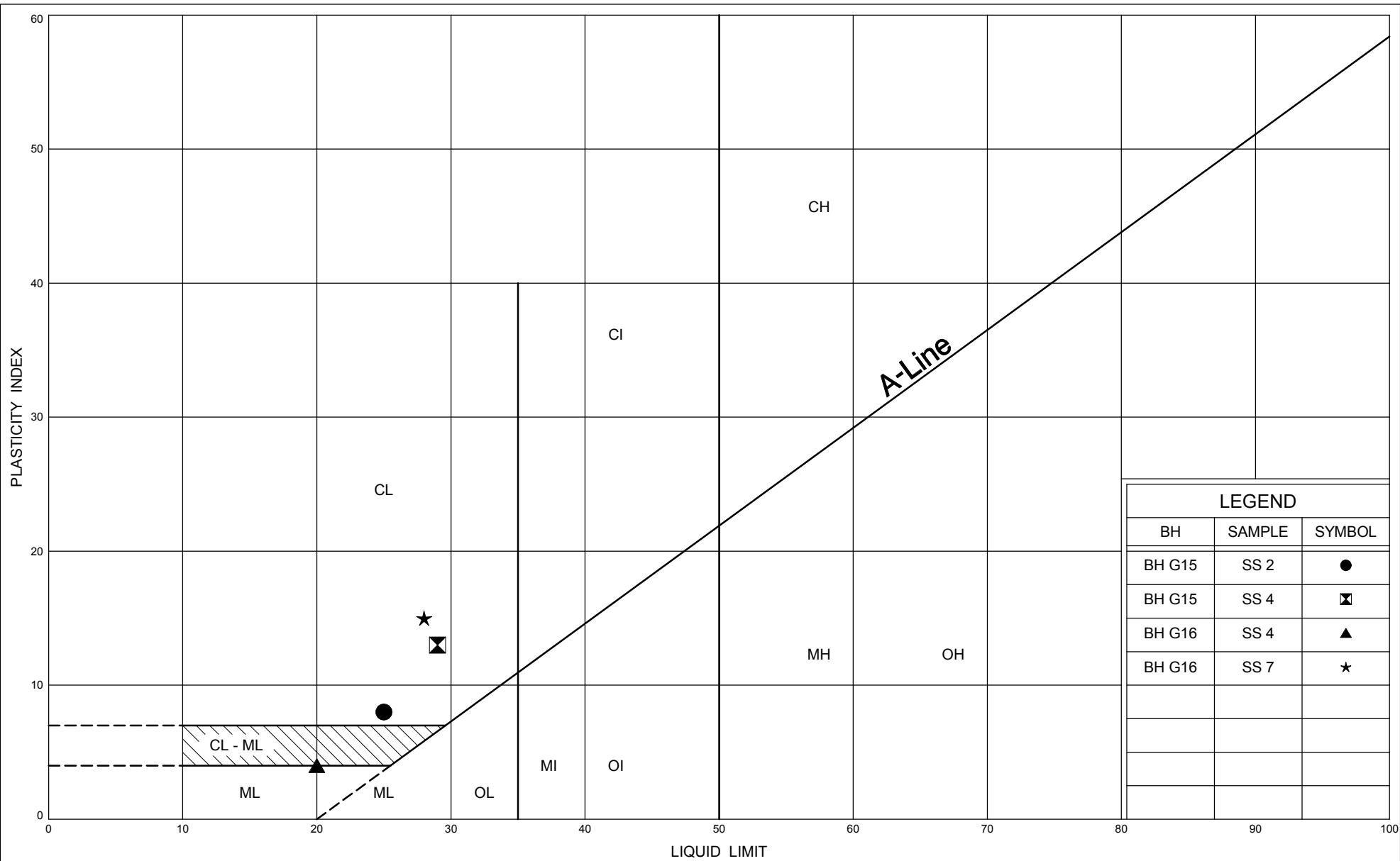
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DEPTH m	ELEVATION SCALE m	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			SOIL VAPOUR READING	REMARKS & GRAIN SIZE DISTRIBUTION (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				SHEAR STRENGTH kPa				WATER CONTENT (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
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APPENDIX B

LABORATORY TEST RESULTS

UNIFIED SOIL CLASSIFICATION SYSTEM





Ministry of
Transportation

Ontario

PLASTICITY CHART

Clayey Silt

Figure No. B2

G.W.P. 834-93-00

Culvert at Sta. 12+810, Hwy 21, Bayfield to Goderich

Your Project #: TP110076.5
 Site: HWY21 (7 CULVERTS)
 Your C.O.C. #: 32091

Attention: Shami Malla
 AMEC Earth & Environmental Ltd
 Scarborough
 104 Crockford Blvd
 Scarborough, ON
 CANADA M1R3C3

Report Date: 2011/06/06

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B175937
Received: 2011/05/27, 17:25

Sample Matrix: Soil
 # Samples Received: 7

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Method Reference
Chloride (20:1 extract)	4	N/A	2011/06/02	CAM SOP-00463	
Chloride (20:1 extract)	3	N/A	2011/06/04	CAM SOP-00463	
Conductivity	7	N/A	2011/06/02	CAM SOP-00414	APHA 2510
pH CaCl2 EXTRACT	6	2011/06/02	2011/06/02	CAM SOP-00413	SM 4500 H
pH CaCl2 EXTRACT	1	2011/06/03	2011/06/03	CAM SOP-00413	SM 4500 H
Resistivity of Soil	7	2011/05/30	2011/06/02	CAM SOP-00414	APHA 2510
Sulphate (20:1 Extract)	7	N/A	2011/06/04	CAM SOP-00464	EPA 375.4

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.
 * Results relate only to the items tested.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

GINA BAYBAYAN,
 Email: GBAYBAYAN@maxxam.ca
 Phone# (905) 817-5766

=====

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Total cover pages: 1

Maxxam Job #: B175937
Report Date: 2011/06/06

AMEC Earth & Environmental Ltd
Client Project #: TP110076.5
Project name: HWY21 (7 CULVERTS)

RESULTS OF ANALYSES OF SOIL

Maxxam ID		JQ4509	JQ4510	JQ4511		JQ4512		JQ4513		JQ4514		
Sampling Date		2011/05/16	2011/05/16	2011/05/16		2011/05/16		2011/05/18		2011/05/17		
	Units	BH G7 / SS2	BH G10 / SS4	BH G12 / SS4	QC Batch	BH G13 / SS2	QC Batch	BH G15 / SS2	QC Batch	BH G17 / SS3	RDL	QC Batch
Calculated Parameters												
Resistivity	ohm-cm	2600	530	1100	2502843	3200	2502843	6000	2502843	3200		2502843
Inorganics												
Soluble (20:1) Chloride (Cl)	ug/g	140	970	470	2508305	120	2506767	<20	2506767	49	20	2506767
Conductivity	umho/cm	389	1870	951	2506690	316	2506690	166	2506690	317	2	2506690
Available (CaCl2) pH	pH	7.61	7.50	7.60	2506893	7.81	2506893	7.61	2508147	7.93		2506893
Soluble (20:1) Sulphate (SO4)	ug/g	<20	<20	<20	2508307	<20	2506764	<20	2506764	120	20	2506764

Maxxam ID		JQ4515		
Sampling Date		2011/05/17		
	Units	BH G21 / SS2	RDL	QC Batch
Calculated Parameters				
Resistivity	ohm-cm	1900		2502843
Inorganics				
Soluble (20:1) Chloride (Cl)	ug/g	270	20	2506767
Conductivity	umho/cm	532	2	2506690
Available (CaCl2) pH	pH	7.74		2506893
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	2506764

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam Job #: B175937
Report Date: 2011/06/06

AMEC Earth & Environmental Ltd
Client Project #: TP110076.5
Project name: HWY21 (7 CULVERTS)

Package 1	20.3°C
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Each temperature is the average of up to three cooler temperatures taken at receipt

GENERAL COMMENTS

Maxxam Job #: B175937
Report Date: 2011/06/06

AMEC Earth & Environmental Ltd
Client Project #: TP110076.5
Project name: HWY21 (7 CULVERTS)

QUALITY ASSURANCE REPORT

QC Batch	Parameter	Date	Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	Units	Value (%)	QC Limits	% Recovery	QC Limits
2506690	Conductivity	2011/06/02					<2	umho/cm	2.4	35	103	75 - 125
2506764	Soluble (20:1) Sulphate (SO4)	2011/06/04	102	75 - 125	97	85 - 115	<20	ug/g	NC	35		
2506767	Soluble (20:1) Chloride (Cl)	2011/06/02	109	75 - 125	98	85 - 115	<20	ug/g	NC	35		
2508305	Soluble (20:1) Chloride (Cl)	2011/06/04	95	75 - 125	103	85 - 115	<20	ug/g	5.0	35		
2508307	Soluble (20:1) Sulphate (SO4)	2011/06/04	111	75 - 125	95	85 - 115	<20	ug/g	NC	35		

N/A = Not Applicable

RPD = Relative Percent Difference

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

QC Standard: A blank matrix to which a known amount of the analyte has been added. Used to evaluate analyte recovery.

Spiked Blank: A blank matrix to which a known amount of the analyte has been added. Used to evaluate analyte recovery.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (RPD): The RPD was not calculated. The level of analyte detected in the parent sample and its duplicate was not sufficiently significant to permit a reliable calculation.

Validation Signature Page

Maxxam Job #: B175937

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

A handwritten signature in black ink, appearing to read "Cristina Carriere", is written over a horizontal line.

CRISTINA CARRIERE, Scientific Services

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Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

APPENDIX C

SITE PHOTOGRAPHS



Photograph No. 1: View of inlet/outlet of culvert.



Photograph No. 2: View of road embankment near the culvert.