



**FOUNDATION INVESTIGATION AND DESIGN REPORT**

**REHABILITATION OF HIGHWAY 21  
FROM BAYFIELD TO GODERICH, ONTARIO**

**CULVERT No. 56 AT STATION 25+232**

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

**MTO GEOCRES NO. 40P12-31**

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## TABLE OF CONTENTS

	<b>Page</b>
1.0 INTRODUCTION .....	1
2.0 SITE AND PROJECT DESCRIPTION .....	3
3.0 GEOLOGY .....	3
4.0 INVESTIGATION PROCEDURES .....	4
4.1 Field Investigation .....	4
4.2 Laboratory Tests .....	5
5.0 SUB-SURFACE CONDITIONS .....	5
5.1 Sand and Gravel Fill .....	6
5.2 Silty Sand Fill .....	6
5.3 Clayey Silt / Silty Clay .....	6
5.4 Groundwater Conditions .....	7
5.5 Limited Environmental Investigation .....	7
6.0 DISCUSSION AND RECOMMENDATIONS .....	8
6.1 Retaining walls .....	8
6.1.1 Comparison of Retaining Wall Options .....	8
6.1.2 Foundations .....	10
6.2 Retaining Wall Design .....	12
6.2.1 Slope Stability .....	12
6.2.2 Design Considerations .....	14
6.3 Excavation .....	14
6.4 Dewatering and Ditch Diversion .....	15
6.5 Backfilling .....	15
6.6 Temporary Shoring .....	16
6.7 Erosion Control .....	16
6.8 Soil Corrosivity .....	16
6.9 Earthquake Considerations .....	17
7.0 CLOSURE .....	18

## LIMITATIONS OF REPORT

## LIST OF CONSTRUCTION SPECIFICATIONS AND DRAWINGS

## **FIGURES**

Drawing No. 1	Culvert Location Plan
Drawing No. 2	Borehole Location Plan
Drawing No. 3	Stratigraphic Cross Sections

## **APPENDICES**

APPENDIX A:	Record of Borehole (BH G37)
APPENDIX B:	Laboratory Test Results
APPENDIX C:	Site Photographs (Photographs 1 and 2)
APPENDIX D:	Slope Stability Analysis Results

## 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, as shown in Drawing No. 1.

In May 2011, AMEC conducted a foundation investigation comprising 21 boreholes (BH G1 to BH G21) at the locations of eight existing culverts identified for rehabilitation / replacement. The design reports for these culverts have been submitted to MTO separately.

In March 2012, AMEC conducted additional foundation investigations at the locations of 11 additional existing culverts, as shown on Drawing No. 1. The number of boreholes and locations of the boreholes were based on the Highway 21 Culvert Recommendations Table (dated 18 January 2012). The details of the additional culverts investigated, and the boreholes advanced at each location, are summarized in Table 1.1.

**Table 1.1 - Culvert Details for Additional Foundation Investigations (March 2012)\***

Culvert No.	Station	Existing Culvert		Boreholes Drilled	Proposed Work	Foundation Investigation Requirement
		Type	Dimension			
2	10+267	Concrete Rigid Frame - Open Footing	0.9 x 0.9 x 38.5 m	BH G22 and BH G23	Extend culvert and clean out	Two boreholes for extension
8	11+691	Concrete Rigid Frame Box	3.75 x 2.30 x 68.4 m	BH G24 and BH G25	Rehabilitate and install RSS to stabilize steep roadway embankment	Foundations for RSS / slopes and protection system to stage the construction
10	12+138	Concrete Box	1.2 x 1.2 x 24.2 m	BH G26 and BH G27	Rehabilitate inlet, remove outlet precast block wing walls, place gabion wingwalls at east end. Construct CIP wingwalls at west outlet, including scour protection.	Two boreholes at outlet end for retaining wall foundations
17	13+835	Concrete Box	1.2 x 1.2 x 27.05 m	BH G28 and BH G29	Replace south west concrete retaining wall with CIP concrete retaining walls. Construct CIP concrete wingwall at	Two boreholes (southwest and northeast retaining walls)

Culvert No.	Station	Existing Culvert		Boreholes Drilled	Proposed Work	Foundation Investigation Requirement
		Type	Dimension			
					northeast.	
20	15+205	Concrete Arch - Open Footing	7.16 x 3.66 x 29.6 m	BH G30	Rehabilitate and install RSS to stabilize steep roadway embankment. Replace southwest wingwall	Foundations for RSS / slopes (both side of the roadway) and protection system to stage the construction. Protection will be installed approximately 2.5 m from centerline. One borehole for S/W wingwall.
31	18+380	Rigid Frame Box	3.66 x 1.52 x 21.4 m	BH G31, BH G32, BH G32A, BH G33 and BH G34	Rehabilitate concrete at both ends and soffit and add wingwalls or extend culvert	Boreholes required for a retaining wall between culverts 12-422, and 12-424 on Highway 21 and 12-423 on Cut Line Road , southeast of Intersection. Or lengthening of the culvert. (min. 4 BH for these 3 culverts total)
32	18+393		3.05 x 0.91 x 15.3 m		Rehabilitate and construct wing walls between this culvert and 12-422/C	
33	18+409		3.66 x 1.52 x 21.4 m		Rehabilitate and construct wing walls between this culvert and 12-423/C	
34	18+843	Concrete Frame - Open Footing	1.5 x 1.1 x 24.7 m	BH G35 and BH G36	Rehabilitate ends and replace wingwalls with CIP concrete. Repair culvert interior. Extend inlet end.	Two boreholes (one at each end)
56	25+232	Concrete Frame - Open Footing	2.9 x 0.9 x 20.8 m	BH G37	Replace sandbag wingwalls with gabions at west end and CIP concrete retaining wall at east end. Repair outlet concrete. Place scour protection.	One Foundation borehole (east end)
61	26+521	Concrete Frame - Open Footing	1.8 x 1.2 x 23.5 m	BH G38 and BH G39	Rehabilitate ends and replace sand bag retaining walls with CIP concrete retaining walls	Two Foundation boreholes (one at each end)

\* Based on Hwy 21 Culvert Summary Table dated (13 December 2011), and Hwy 21 Culvert Recommendations Table dated (18 January 2012).

The purpose of the additional foundation investigation was to obtain information on the subsurface conditions at the additional culvert sites (Table 1.1) by means of boreholes, in-situ tests and laboratory tests on selected soil samples. Based on AMEC's interpretation of the data obtained in the investigation, recommendations are provided on the geotechnical aspects of replacement / rehabilitation / extension of the culverts.

As per the Terms of Reference (TOR) in the Request for Proposal (Purchase Order Number: 3009-E-0022, dated March 2010), separate reports have been prepared - one for each culvert site, except at the intersection of Highway 21 and Cut Line Road, where one report has been prepared for the three culverts located at the intersection.

This report presents the results of foundation investigation together with design discussion and recommendations for the rehabilitation of Culvert No. 56 at Station 25+232.

The factual results of the soil conditions encountered in the boreholes and laboratory tests (without design discussion and recommendations) for the rehabilitation of Culvert No. 56 at Station 25+232 are presented in a separate report titled "Foundation Investigation Report".

## **2.0 SITE AND PROJECT DESCRIPTION**

The investigated culvert site (Station 25+232) is located about 2.75 km north of Union Road, between Bayfield and Goderich, Ontario (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 grades. The surrounding area is primarily rural in nature, with active agricultural operations and/or farm houses / vacant lands / wood lots. The embankment slopes were covered with vegetation at the time of the fieldwork. Site photographs showing the culvert are presented in Appendix C (Photographs 1 and 2).

As noted in Table 1.1 (Section 1.0), the existing culvert at this location is a 2.9 m wide, 0.9 m high and 20.8 m long concrete rigid frame structure with open footing. Preliminary Drawing No. S1 (Sheet S30), dated April 2012, indicated that the height of the existing embankment at the culvert location was about 2.7 m above the surrounding grade, and sandbag wingwalls were present at all four corners of the culvert. The existing sandbag wingwalls are proposed to be replaced by cast-in-place concrete retaining walls / gabions (or similar). Detail of the replacement culvert was not available at the time of preparation of this report.

## **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 Highway 21 Culvert Recommendation Table, one (1) borehole (BH G37) was advanced near the east end of the culvert. The borehole was drilled at mid shoulder area on the east side of Highway 21 and was extended to a depth of about 9.6 m below the existing granular surface (from elevation about 216.6 m to 207.0 m). The borehole was drilled at this location to determine the subsurface soil conditions for foundation recommendations. The as-drilled borehole location is presented on Drawing No. 2.

The fieldwork was performed on 13 March 2012, 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 (GBM 0011989U065, Sta. 19+755, El 206.086).

The drilling, sampling and in-situ testing operations were conducted by using solid-stem augers, using a track-mount drilling rig, owned and operated by Drilltech Drilling Inc. (Newmarket, Ontario) under the full-time supervision of experienced AMEC geotechnical personnel

Soil samples were generally taken at 0.76 m intervals for the initial 3 m depth 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 condition was observed in the borehole during sampling and upon completion of drilling. Groundwater depth, when encountered, is presented on the Record of Borehole.

Upon completion of drilling, the borehole was backfilled in accordance with the general requirements of Ministry of the Environment Regulation 903.

Upon recovery, all soil samples were screened using a hand-held hydrocarbon surveyor (RKL Eagle), the results of which are presented on the Record of Borehole.

One selected sample was tested for soil corrosivity potential with respect to concrete and steel, the results of which are discussed in Section 6.8.

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 grain size analysis, Liquid and Plastic Limits, in-situ water content determination, and soil corrosivity analysis, which was subcontracted to Maxxam Analytics, an accredited CAEL laboratory located in Mississauga, Ontario.

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

AMEC will retain the soil samples for a period of one year after completion of the project, unless otherwise advised in writing by MTO.

## **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 (10);
- Grain size distribution analysis (2);
- Atterberg Limit tests (2); and
- Soil corrosivity (1).

The results of in-situ and laboratory tests are presented in the Record of Borehole 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 at the borehole location consisted predominantly of surficial sand and gravel fill underlain by fill soil (silty sand) overlying native clayey silt / silty clay deposit extending to the termination depth of the borehole (Elevation 207.0 m).

The stratigraphic units and groundwater conditions at the borehole location is discussed in the following sections. Detailed information is provided in the Record of Borehole in Appendix A. Interpolated stratigraphical cross sections through the existing culvert are provided in Drawing No. 3.

It should be noted that the soil and groundwater conditions may vary beyond the borehole location.



## **5.1 Sand and Gravel Fill**

Sand and gravel fill was encountered at the existing grade in the borehole drilled through the existing shoulder. The measured thickness of the sand and gravel fill was about 400 mm.

The sand and gravel fill was brown in color, and contained trace to some silt and trace organic matter.

A single SPT N-value measured in the sand and gravel fill was 15 blows per 0.3 m. The measured moisture content in the sand and gravel fill was 29 %. The high moisture content was due inclusion of organic matter.

## **5.2 Silty Sand Fill**

Silty sand fill was encountered below the sand and gravel fill. The silty sand fill extended to about 2.9 m below the existing grade (Elevation 213.7 m). The silty sand fill was brown in color, and contained trace gravel and organic matter.

The SPT 'N' values of the silty sand fill ranged from 2 to 11 blows per 0.3 m. The measured moisture contents in the silty sand fill ranged from 6 % to 25 %. The high moisture contents noted in two samples (SS3 and SS4) were due to inclusion of organic matter and/or perched water.

## **5.3 Clayey Silt / Silty Clay**

Native clayey silt / silty clay was encountered below the silty sand fill. The clayey silt / silty clay extended to the termination depth of the borehole at elevation of about 207.0 m.

The clayey silt / silty clay was grey in color, and contained some sand, and trace gravel and cobbles / boulders. The SPT 'N' values of the clayey silt / silty clay ranged widely from 18 to 35 blows per 0.3 m, indicating a very stiff to hard consistency. The measured moisture contents in the clayey silt / silty clay ranged from 12 % to 14 %.

Grain size analyses and Atterberg Limit tests were completed on 2 samples of the clayey silt / silty clay, and the results are presented in Table 5.1.

**Table 5.1 - Grain Size Distribution Analyses and Atterberg Limit Test Results**  
**(Clayey Silt / Silty Clay)**

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 G37	SS 5	3.1 - 3.5 (213.5 - 213.1)	5	16	49	30	24	13	11	CL
BH G37	SS 7	6.1 - 6.6 (210.5 - 210.0)	2	19	47	32	25	13	12	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 condition in the open borehole was observed during and on completion of drilling. Groundwater was measured at a depth of about 4.1 m below the existing grade (Elevation 212.5 m  $\pm$ ).

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 and water level in the creek.

#### 5.5 Limited Environmental Investigation

In accordance with the Terms of Reference and AMEC proposal, soil samples obtained during the geotechnical field drilling program were field screened for evidence of environmental impact. The field screening activities included measuring the combustible organic vapours (COV) in the headspace of samples with a portable hydrocarbon surveyor instrument (RKI Eagle).

No visual or olfactory evidence of environmental impact was observed in the fill and native soil samples recovered from the borehole. The measured COV concentrations in soil samples were relatively low, generally ranging from non-detect to 5 ppm, with two samples recording slightly elevated measurement of 54 ppm and 195 ppm as shown in the Record of Borehole. The samples recording slightly elevated values did not display any visual evidence of environmental impact. The COV results are semi-quantitative at best and are generally used only for relative sample comparison purposes when selecting samples for laboratory analysis. Based on the field screening results, evidence of environmental impact is not suspected.

## **6.0 DISCUSSION AND RECOMMENDATIONS**

In preparation of this report, the following information was considered:

- I. Highway 21 Culvert Recommendations Table, dated 18 January 2012.
- II. Highway 21 Culvert Summary Table, dated 13 December 2011.
- III. AMEC Preliminary Drawing No. S1 (Sheet No. S30), dated April 2012, for Culvert No. 56 at Station 25+232.
- IV. Contract Drawings (CS Submission), Contract No. 2012-3028

Based on the cross-section drawing, sand bag wingwalls are currently present at all four corners of the culvert. The project comprises the following components:

- Replacement of the existing sand bag wingwalls at all four corners with new retaining walls;
- Installation of a head wall over the top of the east end of the culvert.

The following sections discuss the geotechnical aspects of the new retaining walls. The recommendations should be reviewed when the detail design is available.

### **6.1 Retaining walls**

Based on the cross-section drawing, the length and height of each of the four new retaining walls, one on each end of the culvert, will be about 2.0 m to 2.5 m and 1.5 m to 2.0 m, respectively. Cast-in-place concrete or gravity-type retaining walls or Retained Soil System (RSS) walls are feasible, from the geotechnical viewpoint.

#### **6.1.1 Comparison of Retaining Wall Options**

A comparison of the feasible retaining wall structures is provided in Table 6.1.

**Table 6.1 - Comparison of Retaining Wall Structure Options**

Option	Description	Advantages	Disadvantages	Risks / Consequences	Cost Comparison
Cast-in-place concrete retaining wall	Typically, cantilever, reinforced-concrete, retaining wall.	Durable and low maintenance.  Not susceptible to erosion by water flow and ice forces.  No specialized contractor is needed.  Can be constructed as integral part of culvert header.	Rigid structure which may show minor cracks.  Labour intensive for placing reinforcing bars and formwork.  Possible need more time for construction to allow for curing concrete.	Temporary slope excavated into the existing road embankment may have to stand up longer before backfilling.	Medium to high
Gravity Type Retaining Wall - Gabion	Gabions are rectangular steel baskets filled with stone and stacked on one another.	Construction is relatively simple.  Flexible type of structure  Drain freely.	Gabions are labour-intensive in order to properly place stones inside the gabion baskets.  Steel cages may not be stable in long term.  Gabion may be subject to erosion by creek water flow and ice forces.	Maintenance or replacement may be frequent.	Medium to low
Gravity Type Retaining Wall - Armourstone	Armourstones are large sized stones, typically up to 1 m wide by 1 m high by 1.5 m long.	Construction is relatively simple.  Flexible type of structure.  Drain freely.  Good resistance to water flow and ice forces.  Possibly less installation time.	Source and transportation to site may be high	May require some maintenance	Medium to low
Retained Soil System (RSS)	Stone/concrete facade in front of soil mass	Flexible type of structure	RSS requires specialised contractor	May require some maintenance	Medium

Option	Description	Advantages	Disadvantages	Risks / Consequences	Cost Comparison
	reinforced with metal strips or geogrids.		<p>according to MTO's DSM.</p> <p>Facade material has to be properly selected to prevent erosion by water flow and ice forces.</p> <p>Labour intensive for construction.</p> <p>Reinforcing strips may not be durable.</p>		

Considering that the length and height of the new retaining walls at this site, gravity type retaining wall (gabion, armourestone) would be preferred, from the geotechnical viewpoint. However, at the inlet (east) end, a cast-in-place concrete retaining wall may be preferable to prevent scouring.

### 6.1.2 Foundations

Based on the cross-section drawing, the top of footing of the existing culvert lies at an elevation of about 214.3 m and the underside of footing is below 213.4 m. The base of the new retaining walls should be at or below the undersides of the existing footings for the culvert, in order to avoid imposing additional loads onto the existing footings. Based on the investigation results for Borehole BH G37, the competent soil at the founding grade (elevation about 213.6 m and below) would comprise native very stiff to hard clayey silt / silty clay.

The geotechnical Ultimate Limit State (ULS)/Serviceability Limit State (SLS) values provided in Table 6.2 should be used for the design of the new retaining walls.

**Table 6.2 - SLS and ULS Values for Retaining Wall Design**

Structure	Relevant Borehole No.	Founding Stratum	Depth below Existing Grade (m)	Approximate Elevation (m)	Geotechnical Reaction at SLS (kPa)	Factored Geotechnical Resistance at ULS <sup>(1)</sup> , (kPa)
Retaining walls at inlet / outlet end	BH G37	Very stiff to hard clayey silt / silty clay	3.1 m (±) & below	213.4 m (±) and below	175	270

Note: <sup>(1)</sup> A resistance factor of  $\Phi = 0.5$  has been applied to the values provided.

The soil parameters in Table 6.3 may be used for design.

**Table 6.3 - Summary of Geotechnical Parameters**

Soil Stratum	Bulk Unit Weight of Soil, $\gamma$ (kN/m <sup>3</sup> )	Angle of Internal Friction (degree)	Earth Pressure Coefficient <sup>(1)</sup>		
			At-rest, $K_o$	Active, $K_a$	Passive, $K_p$
Silty Sand fill	18	28	0.53	0.35	2.0
Existing granular fill	21	32	0.47	0.30	2.0
Clayey silt / silty clay	20	28	0.53	0.35	2.0
Granular B	21	32	0.47	0.30	2.0
Granular A	22	35	0.43	0.27	2.0

<sup>(1)</sup> Values based on semi-empirical relations. The  $K_p$  (passive condition) values are reduced in order to limit the lateral soil movement that is required to mobilize the passive resistance.

A frost penetration depth of 1.2 m should be used at this site according to OPSD 3090.101.

The recommended SLS bearing value in Table 6.2 is based on a total settlement of up to 25 mm. Detailed foundation analysis will be necessary if accurate values of settlement are required.

The geotechnical horizontal resistance (against sliding) for spread footings should be designed using a coefficient of friction between concrete and subgrade of 0.35, which includes a resistance factor of 0.8.

The culvert footings will have to be protected against scour and erosion by providing rip-rap, vegetative cover, or equivalent as per OPSS 511 (*Construction Specification for rip-rap, rock protection, and granular sheeting*) and OPSS 1004 (*Material Specifications for Aggregates* –

*Miscellaneous*) and OPSS 810.010 (*Backfill, backfill transition and cover for the concrete culvert*). Scour protection should be designed by an experienced engineer.

For construction of foundations, OPSS 902 (*Construction Specifications for Excavating and Backfilling of Structures*) should be followed.

Any organic soils and other deleterious materials encountered must be excavated from beneath the foundation limits. The excavation should be inspected by qualified geotechnical personnel. Lean concrete mud mat (or approved material) should be placed at the exposed subgrade for foundation construction.

Materials for gabion wall, if used, must comply with OPSS 1430 (*Material Specification for Gabion Baskets and Mats*).

***Excavations for the new retaining walls should be carried out carefully to ensure that the existing foundation of the adjacent culvert is not compromised.***

The excavation, backfill and groundwater control are discussed in the following sections.

## **6.2 Retaining Wall Design**

Based on Contract Drawings (Sheet 195, dated April 2012), the existing sandbags are to be replaced with gabion walls at the west side of the culvert and with cast-in-place (CIP) reinforced concrete retaining walls at the east side of the culvert. The details of the walls are shown in Sheets 195 and 196. The gabion walls at the west end are about 1.5 m high, with the top of the wall at the same elevation as the top of culvert. The CIP retaining walls at the east end would be about 2.4 m high, with the top of the wall about 0.3 m higher than the top of culvert, with a head wall constructed over the culvert. It should be noted that the base of the wall foundation should be a minimum of 1.2 m below finished grade in order to prevent frost heaving.

### **6.2.1 Slope Stability**

A global slope stability analysis was carried out for the section with the CIP retaining wall at the east side of the culvert at Station 25+232 using GeoStudio 2007 Slope/W software (Version 7.17) employing the Morgenstern-Price method. Potential slip surfaces using a grid-based search were considered to determine the critical slip surface (with the lowest factor of safety against slope instability). Both short-term (undrained / end of construction) and long-term loading (drained) conditions were considered.

As per Sheet 195 (General Arrangement) of the Contract Drawing prepared in April 2012, the top of the proposed retaining wall at the location is about 0.3 m above the top of the existing culvert. The width and depth (thickness) of the wall base (foundation) are 2.1 m and 0.6 m respectively. The total wall height, including a 0.6 m deep wall base (foundation), is about

2.4 m. The dimensions of the wall and foundation shown in the contract drawing have been used for the analysis. Road/embankment widening is not planned.

Table 6.4 summarizes the soil parameters used for the global stability analysis. These soil parameters were assumed based on the soil conditions encountered in Borehole BH G37. The highest groundwater was encountered at an elevation of about 212.5 m. For the slope stability analyses, the groundwater was assumed to be at near the invert level, which would be at an elevation of about 214.4 m, to account for potentially highest groundwater level. Granular fill has been assumed behind the wall, as shown in Sheet Contract Drawings. For the analysis, it has been assumed that there is no accumulation of water behind the wall. Proper drainage system should be constructed to avoid accumulation of water behind the wall.

For live loads (traffic loads), a surcharge of 16 kPa was applied on the pavement areas.

**Table 6.4 - Summary of Soil Parameters**

Soil Type	Unit Weight (kN/m <sup>3</sup> )	Total Stress		Effective Stress	
		c (kPa)	Φ (deg)	c' (kPa)	Φ' (deg)
Existing fill	18	0	28	0	28
Very stiff to hard clayey silt/ silty clay	20	100	0	0	28
Granular Fill	21	0	32	0	32
Retaining Wall	23	200	36	200	36

\* The parameters for retaining wall were assumed only for slope stability modelling to disregard slip surface through the wall.

The results of the slope stability analysis are presented in Appendix D. Table 6.5 summarizes the results of slope stability analysis.

**Table 6.5: Results of Slope Stability Analysis**

Analyzed Section (Station)	Calculated Minimum Factor of Safety	
	Total Stress Analysis (Short Term)	Effective Stress Analysis (Long Term)
25+232	6.7	1.8

Generally, a minimum factor of safety of 1.3 is sufficient for a stable slope. Based on the results, the calculated minimum factor of safety is equal to or greater than 1.8. Therefore, the proposed should be stable.



### 6.2.2 Design Considerations

The following aspects should be considered for the design of the retaining wall:

- Recommendations provided in Section 6.1 should be followed for design of the retaining wall. The geotechnical ULS/SLS values provided in Table 6.2 and soil parameters provided in Table 6.3 may be used for the design of wall.
- For global slope stability, the minimum width of the foundation (CIP wall), which is the distance from the front face of the wall to the heel edge of the wall base (foundation), should be 1.4 m.
- If any change is made in foundation design, especially the width (as described above), height of wall and/or elevation of footing, the stability should be re-analyzed.
- Adequate and proper drainage system should be provided behind the retaining wall to prevent accumulation of water behind wall, especially for the CIP wall. Otherwise, the width of the footing may have to be increased.
- The founding level for the wall base (CIP wall) should be located a minimum of 1.2 m below the finished grade to prevent frost heave. Otherwise, equivalent thermal protection may be required.
- Other aspects of the retaining wall stability (i.e., sliding, overturning, etc.) should be assessed by the retaining wall designers.

### 6.3 Excavation

All excavations should be carried out in accordance with the Occupational Health and Safety Act and Regulations for Construction Projects. The soils to be excavated can be classified as follows:

Silty sand fill	Type 3
Very stiff to hard clayey silt / silty clay	Type 2

Accordingly, a bank slope of 1H:1V is required for excavations in Type 2 and Type 3 soils in accordance with the Occupational Health and Safety Act and Regulations for Construction Projects. For Type 2 soil, a 1.2 m high vertical cut at the bottom of excavation may generally be constructed. A flatter slope may be required depending on the site and groundwater conditions. The excavation work should comply with OPSS 902 (*Construction Specification for Excavating and backfilling of Structures*). If open cut excavation cannot be carried out due to space restriction, temporary shoring will be required. The temporary shoring is discussed in Section 6.6.

Excavated materials should be stock piled at least 3 m from the edge of the excavation to avoid the slope instability.

Cobbles and boulders should be expected within the soils. **The construction contract should include a Nonstandard Special Provision (NSSP) to warn the contractor of the possible presence of cobbles / boulders.**

There may be underground utilities (gas, water, sewer and telephone) within the road embankment which may be exposed during the excavation. All utilities, if present, should be adequately supported or relocated prior to excavation work. Approval should be sought from relevant authorities and utilities companies regarding excavation works around such services.

#### **6.4 Dewatering and Ditch Diversion**

Based on the groundwater conditions encountered in Borehole BH G37 (Section 5.4), the groundwater would likely be encountered at an elevation of 212.5 m ( $\pm$ ), which is below to the invert elevation of the existing culvert. Excavation to replace the existing sand bag wingwalls may encounter perched groundwater in the silty sand fill and/or groundwater. Groundwater seepage, if encountered during excavation could be dewatered using a system of filtered sumps and pumps. High rates of seepage may occur from surface water and dewatering effort could require an increased number of filtered sumps and pumps.

A cofferdam (earth dyke) or similar may be required to prevent water flow from entering the work area and/or reduce the water inflow into the excavation.

Dewatering plans must consider any flows from the highway side drains / ditches that enter into the drain / ditch at the culvert location.

Dewatering and ditch diversion activities should proceed ahead of the excavation operation.

#### **6.5 Backfilling**

The backfilling for retaining wall should comply with OPSS 902 (*Construction Specification for Excavating and backfilling of Structures*). Backfill should be placed according to OPSS 206 (*Construction Specification for Grading*), and compacted according to OPSS 501 (*Construction Specification for Compacting*). Backfill for the retaining wall should conform to OPSD 3121.150 (*Minimum Granular Backfill Requirement - Walls Retaining*).

The new retaining walls should be backfilled with granular soil (OPSS Granular 'A' or Granular 'B' complying OPSS 1010).

The retaining walls should be provided with a positive drainage system to prevent the built up of hydrostatic pressure. It is recommended that a non-woven Class II geotextile with an FOS of 75-150  $\mu$ m (according to OPSS 1860) be installed between the free draining granular backfill and earth fill / native soils, or immediately behind and underneath the wall, to prevent migration of fines.

## 6.6 Temporary Shoring

Proper shoring in order to support the sides of excavation may be needed for the construction of the retaining walls, if open excavation cannot be used due to site restriction. The temporary shoring of the excavation should conform to OPSS 539: "Construction Specification for Temporary Protection Systems".

The temporary shoring system should be designed to resist the lateral earth, surcharge and hydrostatic pressure which could occur during construction. The design of temporary shoring should be carried out in accordance with the latest edition of Canadian Highway Bridge Design Code CAN/CSA-S6-06. Soil parameters summarized in Table 6.3 may be used for design considerations.

## 6.7 Erosion Control

The protective measures noted in OPSD 800 series to deal with erosion (outlet treatment) should be considered for design.

Inlet and outlet protection in accordance with OPSS 511, OPSS1004 and OPSD 810.010 are recommended to prevent erosion adjacent to the culvert as well as scour that could undermine the culvert foundation. A non-woven Class II geotextile with an FOS of 75-150  $\mu\text{m}$  should be placed below the rip-rap, according to OPSS 1860, to minimize the potential for erosion of fine particles from below the inlet / outlet treatment.

The embankment slope surface should be covered with topsoil and seeded / sodded with OPSS 802, OPSS 803 and OPSS 804, as soon as possible.

## 6.8 Soil Corrosivity

One soil sample (BH G37 - 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 are presented in Table 6.6.

**Table 6.6 - 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 G37 - SS 2	8.05	785	1300	350	<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.

Based on the results of soil resistivity of analyzed soil sample, the degree of corrosivity should be considered as "very severe" for exposed metallic structures. This is based on a comparison of the test results to literature reference (J.D. Palmer, Soil Resistivity Measurement and Analysis, Materials Performance, Volume 13, 1974).

A corrosion specialist should be retained, if necessary, to review the test results and provide recommendation for the most effective protection solutions.

## **6.9 Earthquake Considerations**

In conformance with the criteria in Clause 4.4.6.2 in Section 4: Seismic Design of the Canadian Highway Bridge Design Code CAN/CSA-S6-06, the site soil profile is Type I.

## 7.0 CLOSURE

The sub-soil information contained in this report should be used solely for the purpose of foundation assessment of the Culvert No. 56 at Station 25+232 on Highway 21, between Bayfield and Goderich, Ontario.

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

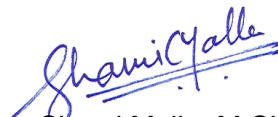
This report was prepared by Mohammad Mollah, M.Eng., P.Eng., and Shami Malla, M.Civ.Eng., P. Eng., and was reviewed by Prapote Boonsinsuk, Ph.D., P.Eng.

Sincerely,

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



Mohammad Mollah, M.Eng., P.Eng.  
Senior Geotechnical Engineer



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Project Manager



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Principal Designated Contact





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

**LIMITATIONS OF REPORT**

The conclusions and recommendations given in this report are based on information determined at the testhole locations. 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 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 the details stated in this report.

The comments made in this report relating to potential construction problems and possible methods of construction 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. 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 25+232 in Highway 21, 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.

### List of Construction Specifications and Drawings

Specification / Drawing	Title
<b>Specifications</b>	
OPSS 180 (Nov/11)	General Specification for the Management and Disposal of Excess Materials
OPSS 206 (Nov/09)	Construction Specification for Grading (Re-issued 2010-11)
OPSS 501 (Nov/10)	Construction Specification for Compacting
OPSS 511 (Apr/11)	Construction Specification for rip-rap, rock protection, and granular sheeting
OPSS 539 (Nov/09)	Construction Specification for temporary protection systems
OPSS 572 (Nov/03)	Construction Specification for Seed and Cover
OPSS 802 (Nov/10)	Construction Specification for Topsoil
OPSS 803 (Nov/10)	Construction Specification for Sodding
OPSS 804 (Nov/10)	Construction Specification for Seed and Cover
OPSS 902 (Nov/10)	Construction Specifications for excavating and Backfilling of structures
OPSS 1004 (Nov/06)	Material Specifications for Aggregates - Miscellaneous
OPSS 1010(Apr/04)	Material Specifications for Aggregates – Base, subbase, select subgrade, and backfill material
OPSS 1430 (Nov/07)	Material Specification for Gabion Baskets and Mats
OPSS 1860 (Apr/12)	Material Specification for Geotextiles
SSP 599S23 (Mar/06)	Special Provision for Materials, Quality Control and Quality Assurance Testing and Acceptance Criteria for Precast Concrete Facing Elements including Panels
<b>Drawings</b>	
OPSD 208.010	Benching of Earth Slopes
OPSD 803.010	Backfill, backfill transition and cover for the concrete culvert
OPSD 810.010	Rip-rap treatment for sewer and culvert outlets
OPSD 3121.150	Minimum granular backfill requirements - walls retaining

## **DRAWINGS**

<b>DRAWING NO. 1</b>	<b>CULVERT LOCATION PLAN</b>
<b>DRAWING NO. 2</b>	<b>BOREHOLE LOCATION PLAN</b>
<b>DRAWING NO. 3</b>	<b>STRATIGRAPHIC CROSS SECTIONS</b>





#### SCALE

1500m 0 1500 3000 4500 6000m

#### LEGEND



CULVERT LOCATION

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



**CLIENT**  
**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.: 40P12-31

**DWN BY:**  
KW

**CHK'D BY:**  
PB

**PROJECTION:**  
-

**DATUM:**  
-

**REV. NO.:**  
A

**SCALE:**  
AS SHOWN

**DATE:**  
JANUARY 2013

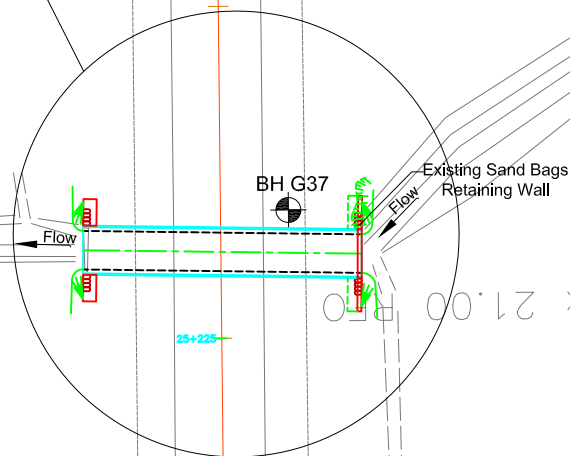
**PROJECT NO:**  
TP110076

**DRAWING No.**  
**1**



002+302

**CULVERT LOCATION**  
(STA.25+232)



SCALE



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



**CLIENT**  
**MINISTRY OF**  
**TRANSPORTATION ONTARIO**  
**WEST REGION**

**TITLE**  
**BOREHOLE LOCATION PLAN**

**PROJECT**  
**REHABILITATION OF HIGHWAY 21 - FROM BAYFIELD TO GODERICH**  
PURCHASE ORDER NUMBER: 3009-E-0022, WP 834-93-00, GEOCREs No.: 40P12-31

**DWN BY:**  
KW

**CHK'D BY:**  
PB

**PROJECTION:**  
-

**DATUM:**  
-

**REV. NO.:**  
A

**SCALE:**  
AS SHOWN

**DATE:**  
JANUARY 2013

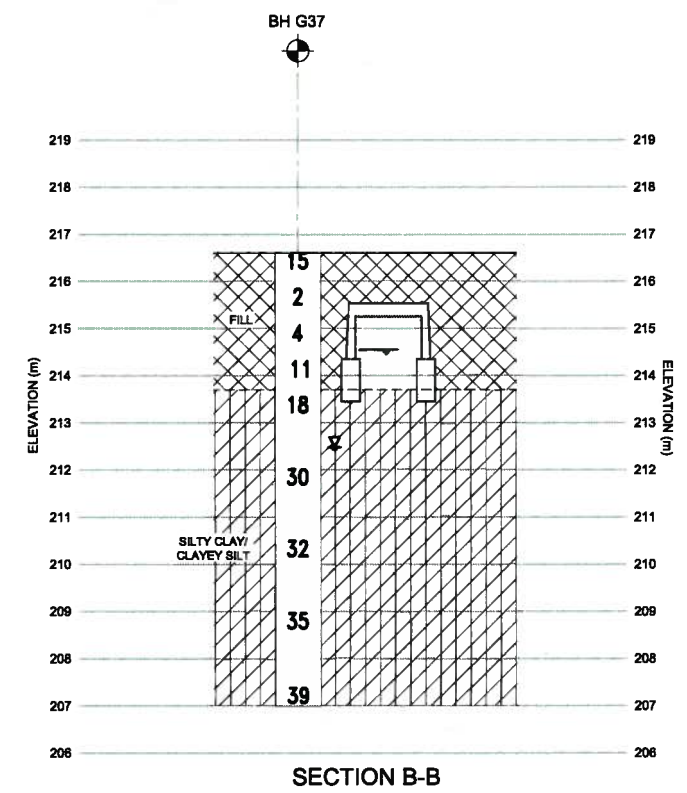
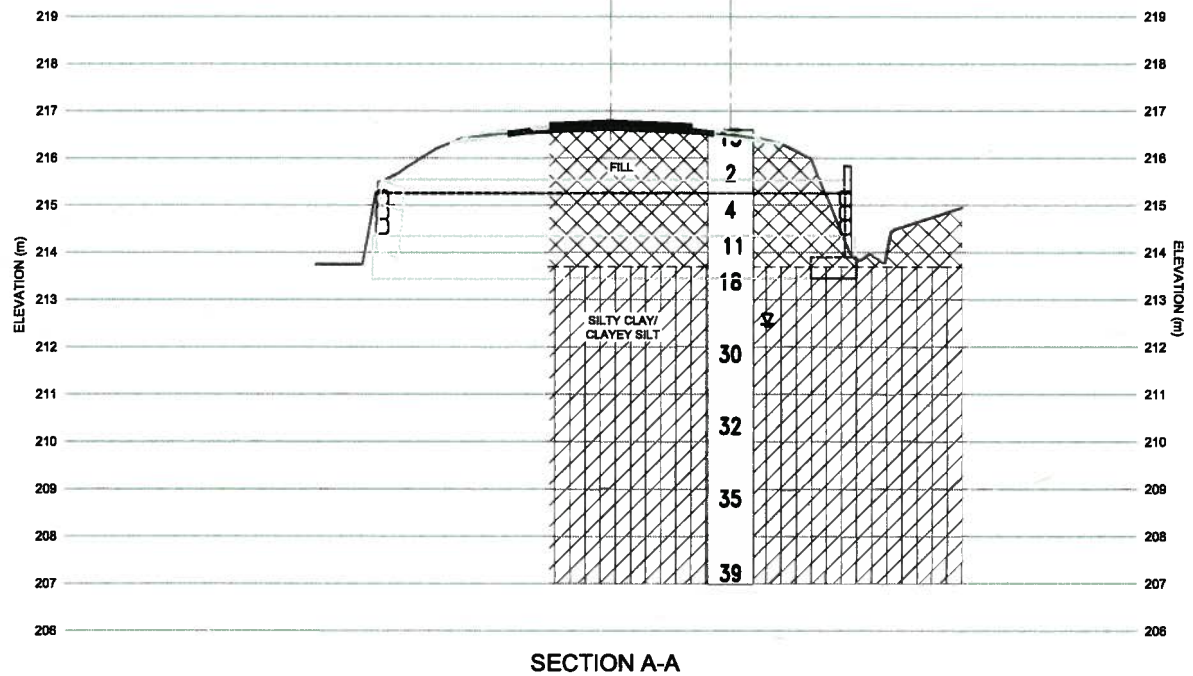
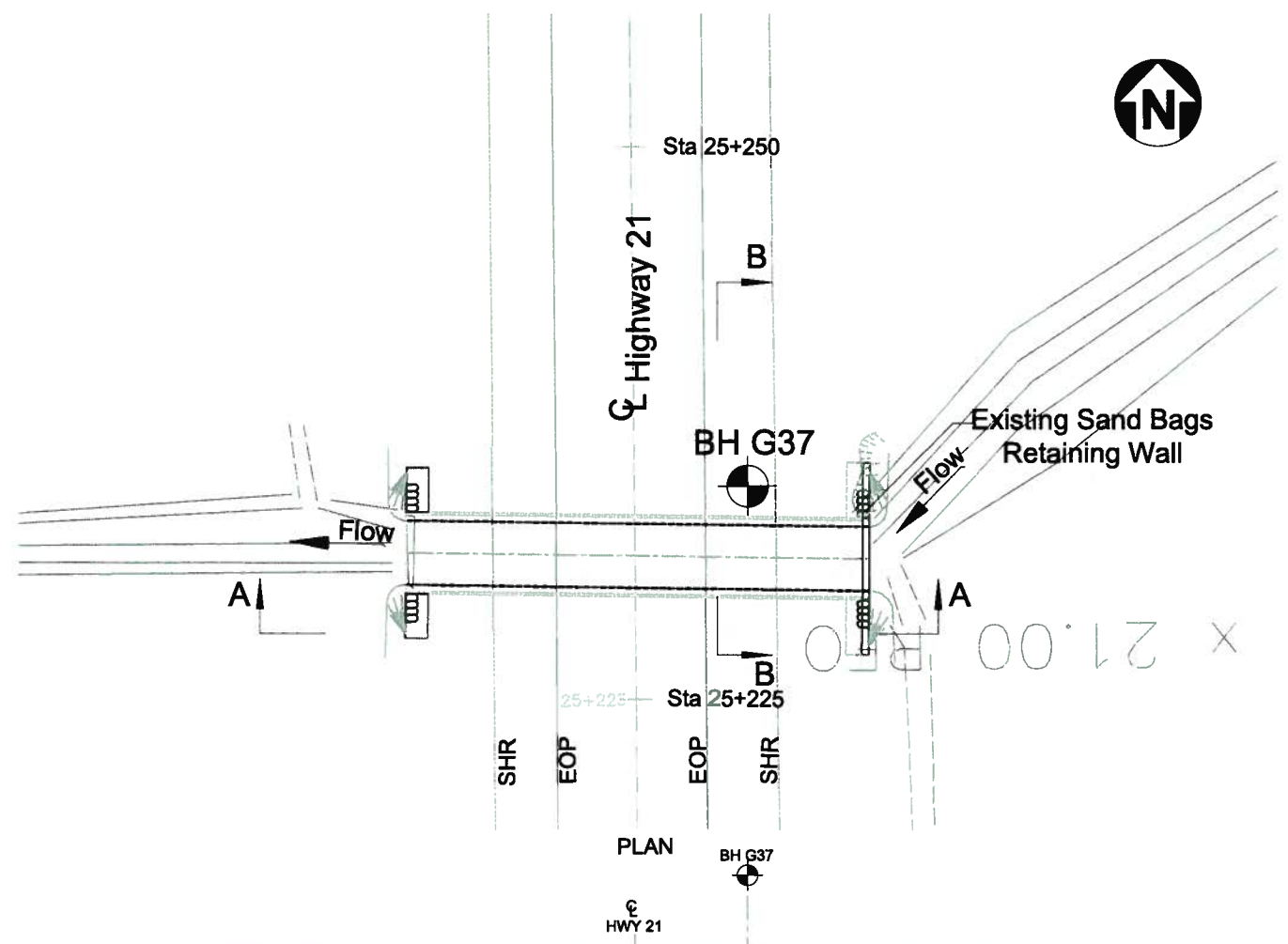
**PROJECT NO:**  
TP110076

**DRAWING No.**  
2

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

PURCHASE ORDER NUMBER: <b>3009-E-0022</b>	
G.W.P. No. <b>834-93-00</b>	
REHABILITATION OF HWY 21 FROM BAYFIELD TO GODERICH GEOCRES No.40P12-31 <b>CULVERT AT STA 25+232</b> STRATIGRAPHIC CROSS SECTION	
<b>amec</b> AMEC Environment & Infrastructure, a Division of AMEC Americas Limited	

**SHEET**  
**1 OF 1**



LEGEND			
	BOREHOLE LOCATION		
	GROUND WATER LEVEL AT TIME OF INVESTIGATION		
EOP	EDGE OF PAVEMENT		
SHR	SHOULDER ROUND		
DESCRIPTION	UTM COORDINATES		ELEVATION (m)
	NORTHING	EASTING	
BH G37	4839289	443150	216.6

- 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.

**SOIL STRATIGRAPHY**



LICENSED PROFESSIONAL ENGINEER  
*S. MALLA*  
100025829  
11 Mar '13  
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER  
*P. BOONSINSUK*  
11 Mar '13  
PROVINCE OF ONTARIO



AMEC Reference: TP110076

REVISIONS				
DESIGN	CHK	CODE	CL	DATE
PB	PB	CHBDC-06	625-ONT	JAN. 2013
DRAWN	KW	CHK	HS	SITE
				25+232
				DWG
				3

P:\GEOProjects\2011\TP110076-HWY 21005-Foundations\Drawings...ITB112041 - Washburn Drain.DWG

**APPENDIX A**  
**RECORD OF BOREHOLE**

## 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

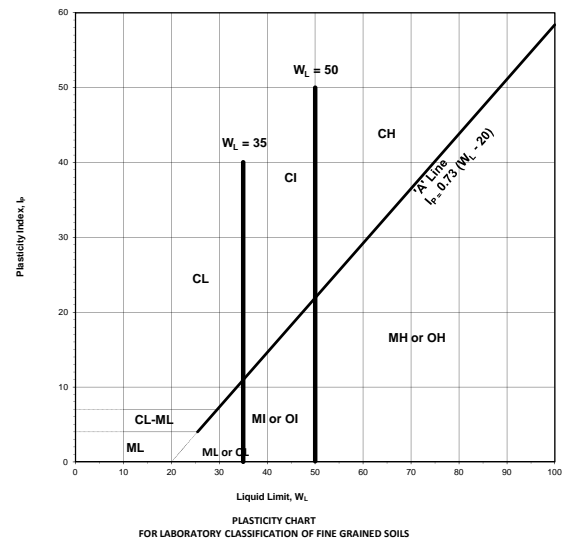
## Based on MTC Soil Classification Manual



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, & HARDNESSOF 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)				FOR UNDISTURBED SOILS AND INFORMATION ON STRUCTURE, STRATIFICATION, CONSISTENCY IN UNDISTURBED AND REMOLDED STATES, MOISTURE & DRAINAGE CONDITION.	NOT MEETING ALL GRADATION FOR SW
		NONE	QUICK	NONE	ML				
		MEDIUM TO HIGH	NONE TO VERY SLOW	MEDIUM	CL		SILTY CLAYS (INORGANIC), GRAVELLY CLAYS, SANDY CLAYS, LEAN CLAYS		
		LIQUID LIMIT BETWEEN 35 AND 50	SLIGHT TO MEDIUM	SLOW	SLIGHT		OL	ORGANIC SILT OF LOW PLASTICITY, ORGANIC SANDY SILTS	
	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		
	HIGH ORGANIC SOILS							ATTERBERG LIMITS BELOW A- LINE OR $I_p$ LESS THAN 4	ABOVE A-LINE WITH $I_p$ BETWEEN 4 AND 7 ARE BORDERLINE CASES REQUIRING USE OF DUAL SYMBOLS
								ATTERBERG LIMITS ABOVE A- LINE WITH $I_p$ GREATER THAN 7	

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 FOR EXAMPLE GW-GC WELL GRADED GRAVEL-SAND MIXTURE WITH CLAY BINDER



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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 G37

1 OF 1

G.W.P. 834-93-00 LOCATION Sta.25+232, 5.8m E of CL of Rd, 2.0m N of Culvert C/L, E443150 N4839269 ORIGINATED BY JF  
DIST Goderich HWY 21 BOREHOLE TYPE 150 mm diameter borehole (Solid Stem) COMPILED BY SC  
DATUM Geodetic DATE March 13, 2012 - March 13, 2012 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 W <sub>p</sub> NATURAL MOISTURE CONTENT W   LIQUID LIMIT W <sub>L</sub>			SOIL VAPOUR READING PPM	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL			
									○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE															
216.6 0.0	brown <b>Sand and Gravel FILL</b> trace to some silt trace organic matter moist brown <b>Silty Sand FILL</b> trace gravel moist ----- trace organic matter wet		1	SS	15									29 <sub>○</sub>			0		5	16	49	30		
216.2 0.4			2	SS	2										15 <sub>○</sub>								5	
			3	SS	4										6 <sub>○</sub>								195	
			4	SS	11										25 <sub>○</sub>								54	
213.7 2.9	grey <b>CLAYEY SILT / SILTY CLAY</b> some sand trace gravel very stiff to hard  trace cobbles / boulders in SS6  trace cobbles / boulders in SS 7		5	SS	18									23 <sub>○</sub>			0		2	19	47	32		
			6	SS	30										18 <sub>○</sub>								0	
			7	SS	32										12 <sub>○</sub>								0	

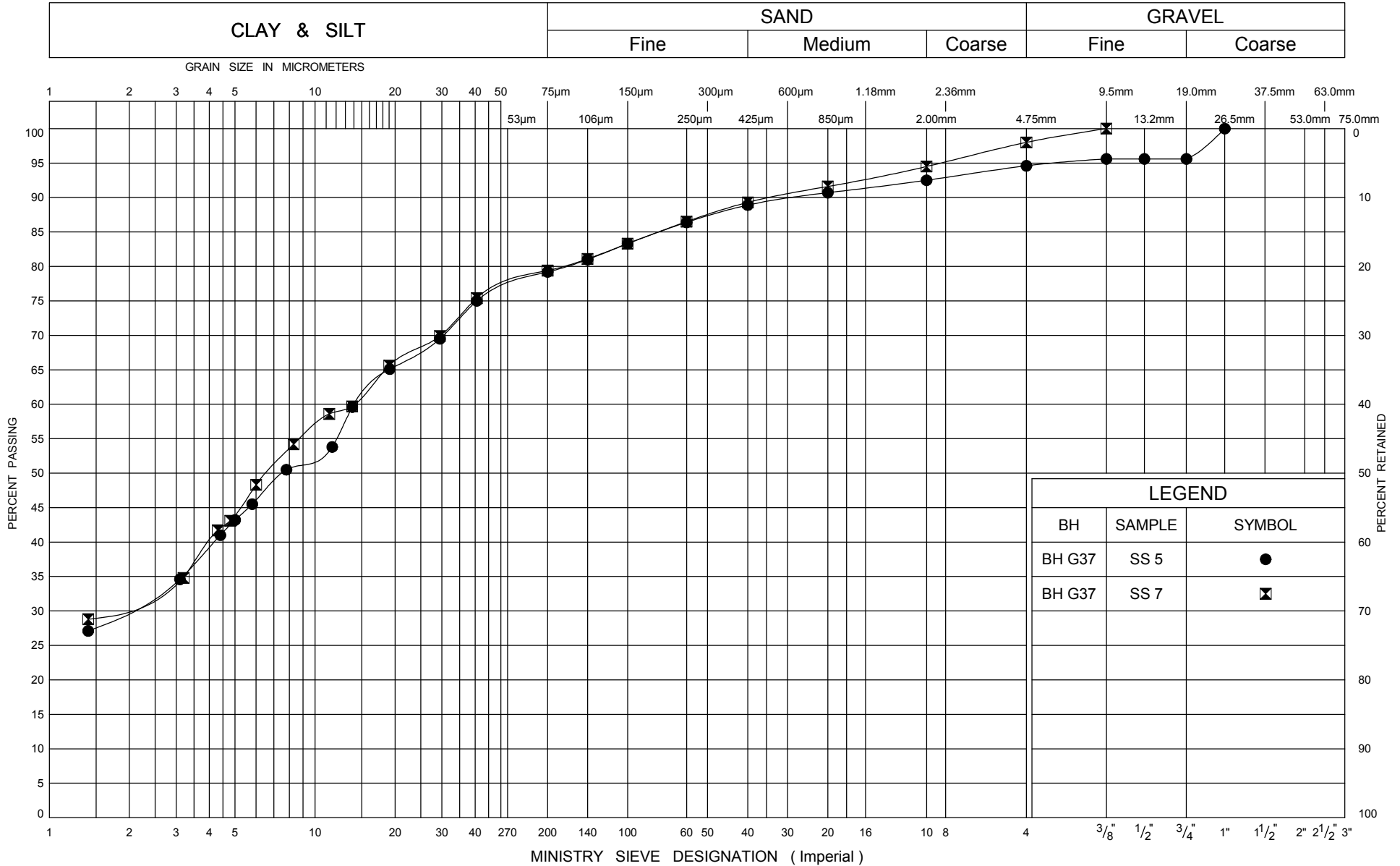
+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

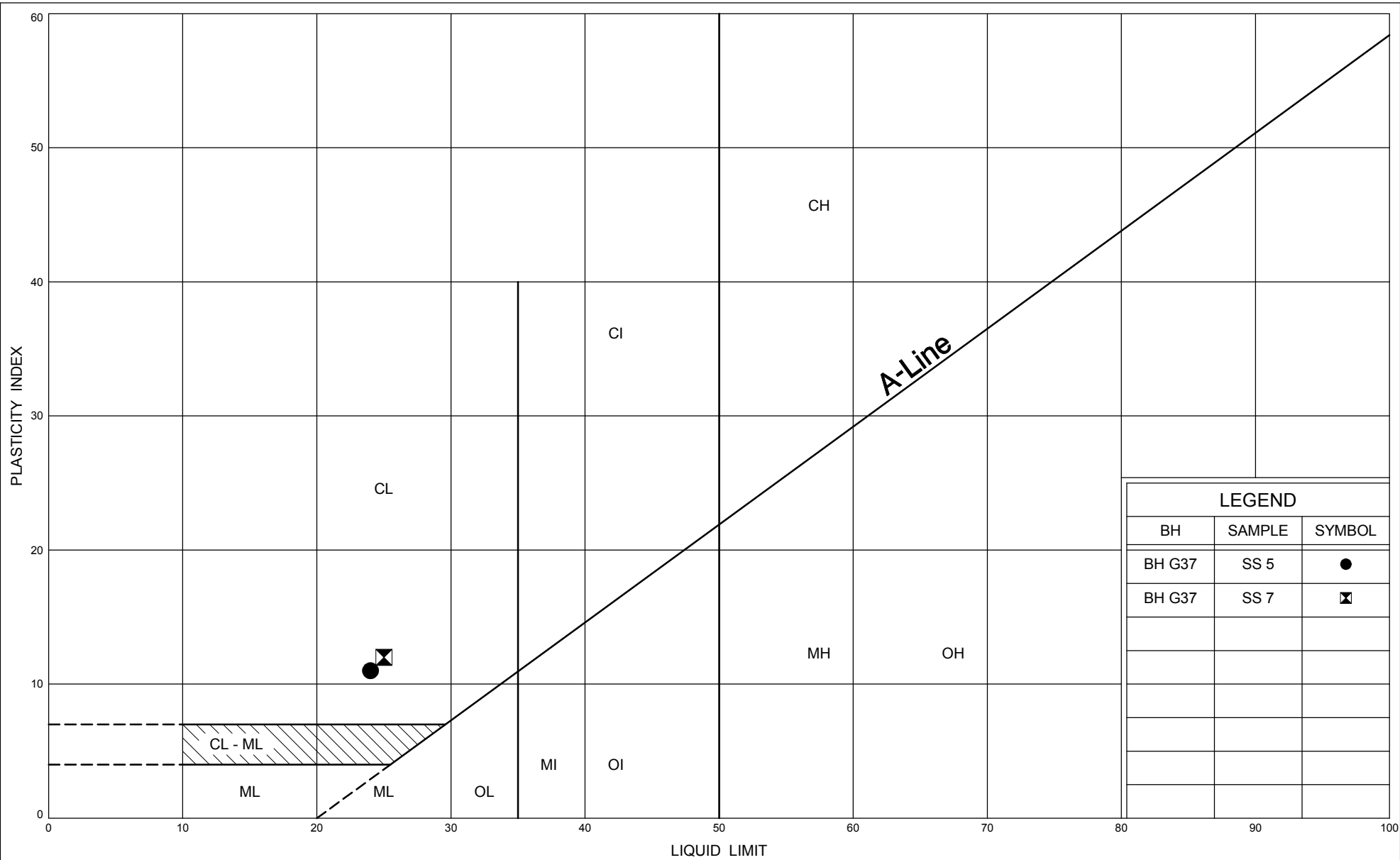


## **APPENDIX B**

### **LABORATORY TEST RESULTS**

# UNIFIED SOIL CLASSIFICATION SYSTEM





Your Project #: TP110076.05  
Your C.O.C. #: 27188503, 271885-03-01

**Attention: Shami Mala**  
AMEC Environment & Infrastructure  
Scarborough  
104 Crockford Blvd  
Scarborough, ON  
CANADA M1R3C3

**Report Date: 2012/03/23**

## CERTIFICATE OF ANALYSIS

**MAXXAM JOB #: B238403**  
**Received: 2012/03/19, 12:10**

Sample Matrix: Soil  
# Samples Received: 9

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Method Reference
Chloride (20:1 extract)	9	N/A	2012/03/23	CAM SOP-00463	EPA 325.2
Conductivity	9	N/A	2012/03/23	CAM SOP-00414	APHA 2510
pH CaCl <sub>2</sub> EXTRACT	8	2012/03/22	2012/03/22	CAM SOP-00413	SM 4500H+ B
pH CaCl <sub>2</sub> EXTRACT	1	2012/03/22	2012/03/23	CAM SOP-00413	SM 4500H+ B
Resistivity of Soil	9	2012/03/19	2012/03/23	CAM SOP-00414	APHA 2510
Sulphate (20:1 Extract)	9	N/A	2012/03/23	CAM SOP-00464	EPA 375.4

### Remarks:

Maxxam Analytics has performed all analytical testing herein in accordance with ISO 17025 and the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act. All methodologies comply with this document and are validated for use in the laboratory. The methods and techniques employed in this analysis conform to the performance criteria (detection limits, accuracy and precision) as outlined in the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act. Reporting results to two significant figures at the RDL is to permit statistical evaluation and is not intended to be an indication of analytical precision.

The CWS PHC methods employed by Maxxam conform to all prescribed elements of the reference method and performance based elements have been validated. All modifications have been validated and proven equivalent following the 'Alberta Environment Draft Addenda to the CWS-PHC, Appendix 6, Validation of Alternate Methods'. Documentation is available upon request. Maxxam has made the following improvements to the CWS-PHC reference benchmark method: (i) Headspace for F1; and, (ii) Mechanical extraction for F2-F4. Note: F4G cannot be added to the C6 to C50 hydrocarbons. The extraction date for samples field preserved with methanol for F1 and Volatile Organic Compounds is considered to be the date sampled.

Maxxam Analytics is accredited by SCC (Lab ID 97) for all specific parameters as required by Ontario Regulation 153/04. Maxxam Analytics is limited in liability to the actual cost of analysis unless otherwise agreed in writing. There is no other warranty expressed or implied. Samples will be retained at Maxxam Analytics for three weeks from receipt of data or as per contract.

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

../2

Maxxam Job #: B238403  
Report Date: 2012/03/23

AMEC Environment & Infrastructure  
Client Project #: TP110076.05

-2-

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: 2

Maxxam Job #: B238403  
Report Date: 2012/03/23

AMEC Environment & Infrastructure  
Client Project #: TP110076.05

### RESULTS OF ANALYSES OF SOIL

Maxxam ID		MV6494	MV6495	MV6496	MV6497	MV6498		
Sampling Date		2012/03/13 10:00	2012/03/13 10:00	2012/03/13 10:10	2012/03/13 10:10	2012/03/13 09:50		
	<b>Units</b>	<b>G22-SS6</b>	<b>G26-SS4</b>	<b>G28-SS2</b>	<b>G31-SS2</b>	<b>G35-SS1B</b>	<b>RDL</b>	<b>QC Batch</b>
<b>Calculated Parameters</b>								
Resistivity	ohm-cm	3400	1400	970	1700	3400		2793995
<b>Inorganics</b>								
Soluble (20:1) Chloride (Cl)	ug/g	90	350	550	290	90	20	2799578
Conductivity	umho/cm	292	734	1030	598	290	2	2799683
Available (CaCl2) pH	pH	7.64	7.41	7.71	7.72	7.71		2798076
Soluble (20:1) Sulphate (SO4)	ug/g	25	54	<20	<20	20	20	2799579

Maxxam ID		MV6499	MV6500		MV6501		MV6502		
Sampling Date		2012/03/16 14:30	2012/03/16 14:40		2012/03/16 15:50		2012/03/16 14:50		
	<b>Units</b>	<b>G24-SS4</b>	<b>G30-SS2</b>	<b>QC Batch</b>	<b>G37-SS2</b>	<b>QC Batch</b>	<b>G38-SS2</b>	<b>RDL</b>	<b>QC Batch</b>
<b>Calculated Parameters</b>									
Resistivity	ohm-cm	1300	800	2793995	1300	2793995	1100		2793995
<b>Inorganics</b>									
Soluble (20:1) Chloride (Cl)	ug/g	380	640	2799578	350	2799578	450	20	2799578
Conductivity	umho/cm	771	1250	2799683	785	2799683	949	2	2799683
Available (CaCl2) pH	pH	7.47	7.82	2798076	8.05	2799276	7.35		2798048
Soluble (20:1) Sulphate (SO4)	ug/g	<20	<20	2799579	<20	2799579	<20	20	2799579

RDL = Reportable Detection Limit  
QC Batch = Quality Control Batch

Maxxam Job #: B238403  
Report Date: 2012/03/23

AMEC Environment & Infrastructure  
Client Project #: TP110076.05

### Test Summary

**Maxxam ID** MV6494  
**Sample ID** G22-SS6  
**Matrix** Soil

**Collected** 2012/03/13  
**Shipped**  
**Received** 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

**Maxxam ID** MV6495  
**Sample ID** G26-SS4  
**Matrix** Soil

**Collected** 2012/03/13  
**Shipped**  
**Received** 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

**Maxxam ID** MV6496  
**Sample ID** G28-SS2  
**Matrix** Soil

**Collected** 2012/03/13  
**Shipped**  
**Received** 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

Maxxam Job #: B238403  
Report Date: 2012/03/23

AMEC Environment & Infrastructure  
Client Project #: TP110076.05

### Test Summary

**Maxxam ID** MV6497  
**Sample ID** G31-SS2  
**Matrix** Soil

**Collected** 2012/03/13  
**Shipped**  
**Received** 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

**Maxxam ID** MV6498  
**Sample ID** G35-SS1B  
**Matrix** Soil

**Collected** 2012/03/13  
**Shipped**  
**Received** 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

**Maxxam ID** MV6499  
**Sample ID** G24-SS4  
**Matrix** Soil

**Collected** 2012/03/16  
**Shipped**  
**Received** 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE



Maxxam Job #: B238403  
Report Date: 2012/03/23

AMEC Environment & Infrastructure  
Client Project #: TP110076.05

### Test Summary

**Maxxam ID** MV6500  
**Sample ID** G30-SS2  
**Matrix** Soil

**Collected** 2012/03/16  
**Shipped**  
**Received** 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

**Maxxam ID** MV6501  
**Sample ID** G37-SS2  
**Matrix** Soil

**Collected** 2012/03/16  
**Shipped**  
**Received** 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2799276	2012/03/22	2012/03/23	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

**Maxxam ID** MV6502  
**Sample ID** G38-SS2  
**Matrix** Soil

**Collected** 2012/03/16  
**Shipped**  
**Received** 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798048	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

Maxxam Job #: B238403  
Report Date: 2012/03/23

AMEC Environment & Infrastructure  
Client Project #: TP110076.05

### Test Summary

**Maxxam ID** MV6502 Dup  
**Sample ID** G38-SS2  
**Matrix** Soil

**Collected** 2012/03/16  
**Shipped**  
**Received** 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

Maxxam Job #: B238403  
Report Date: 2012/03/23

AMEC Environment & Infrastructure  
Client Project #: TP110076.05

Package 1	10.7°C
-----------	--------

Each temperature is the average of up to three cooler temperatures taken at receipt

**GENERAL COMMENTS**

Maxxam Job #: B238403  
Report Date: 2012/03/23

AMEC Environment & Infrastructure  
Client Project #: TP110076.05

### 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
2799578	Soluble (20:1) Chloride (Cl)	2012/03/23	107	75 - 125	106	75 - 125	<20	ug/g	NC	35		
2799579	Soluble (20:1) Sulphate (SO <sub>4</sub> )	2012/03/23	114 <sup>(1)</sup>	75 - 125	104	85 - 115	<20	ug/g	NC <sup>(2)</sup>	35		
2799683	Conductivity	2012/03/23					<2	umho/cm	0.1	35	99	75 - 125

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.

(1) - Matrix Spike Parent ID [MV6502-01]

(2) - Duplicate Parent ID [MV6502-01]

## Validation Signature Page

**Maxxam Job #: B238403**

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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, reading "Cristina Carriere", is written over a horizontal line.

CRISTINA CARRIERE, Scientific Services

=====

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**

**HIGHWAY 21, GODERICH, ONTARIO  
(CULVERT AT Sta. 25 + 532)**



PHOTOGRAPH NO. 1

Looking towards the existing  
culvert inlet area.



PHOTOGRAPH NO. 2

Looking towards the existing  
culvert outlet area.

**APPENDIX D**  
**SLOPE STABILITY ANALYSIS RESULTS**



TP110076 - Rehabilitation of HWY 21 from Bayfield to Goderich, ON  
Culvert 56 - Sta. 25+232 (Total Stress Analysis)  
C56-25+232 Retaining Wall (19 March 2013).gsz

Name: Granular Fill    Unit Weight: 21 kN/m<sup>3</sup>    Phi: 32 °  
Name: Existing Fill    Unit Weight: 18 kN/m<sup>3</sup>    Phi: 28 °  
Name: Retaining Wall    Unit Weight: 23 kN/m<sup>3</sup>    Phi: 36 °  
Name: Very Stiff to Hard Silty Clay/Clayey Silt (ST)    Unit Weight: 20 kN/m<sup>3</sup>

NOTE: For RSS, Cohesion = 200 kPa used only for slope stability modelling to disregard slip surface through RSS.

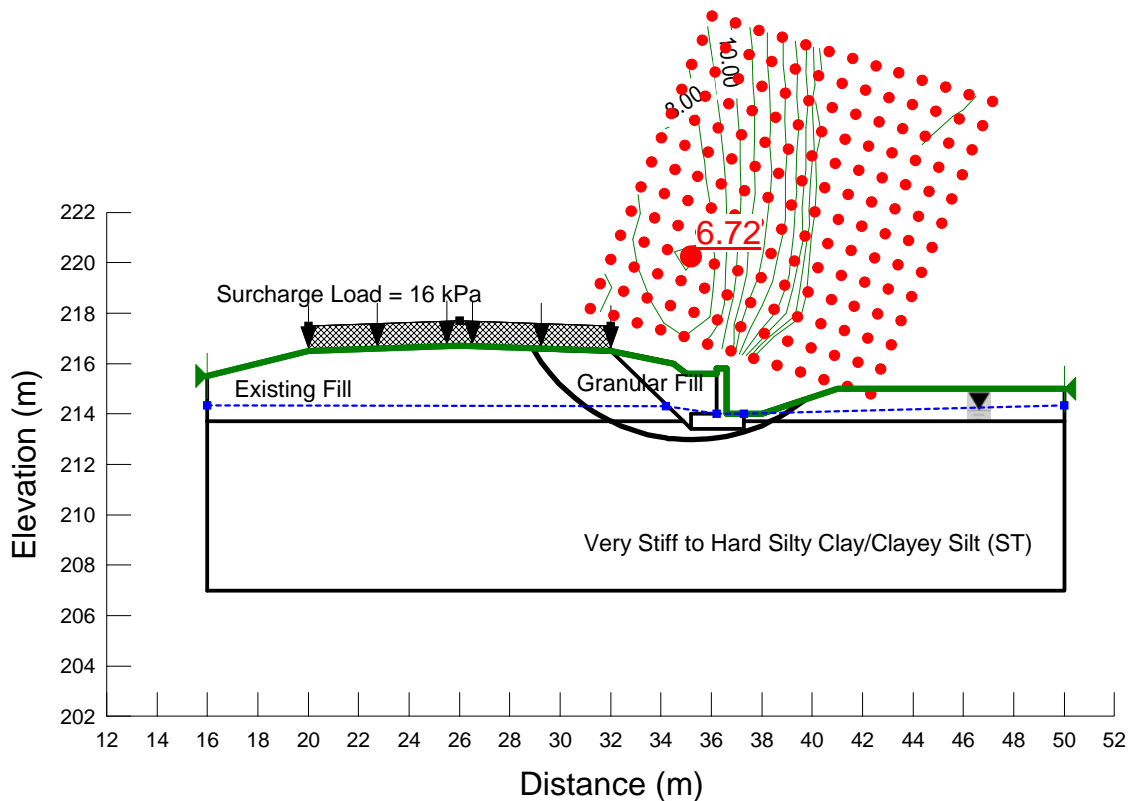


Figure D1 Slope Stability Analysis of Proposed Retaining Wall - Sta. 25+232  
(Total Stress Analysis)

TP110076 - Rehabilitation of HWY 21 from Bayfield to Goderich, ON  
 Culvert 56 - Sta. 25+232 (Effective Stress Analysis)  
 C56-25+232 Retaining Wall (19 March 2013).gsz

Name: Granular Fill    Unit Weight: 21 kN/m<sup>3</sup>    Phi: 32 °  
 Name: Existing Fill    Unit Weight: 18 kN/m<sup>3</sup>    Phi: 28 °  
 Name: Very Stiff to Hard Silty Clay/Clayey Silt    Unit Weight: 20 kN/m<sup>3</sup>    Phi: 28 °  
 Name: Retaining Wall    Unit Weight: 23 kN/m<sup>3</sup>    Phi: 36 °

NOTE: For wall, Cohesion = 200 kPa used only for slope stability modelling to disregard slip surface through the wall.

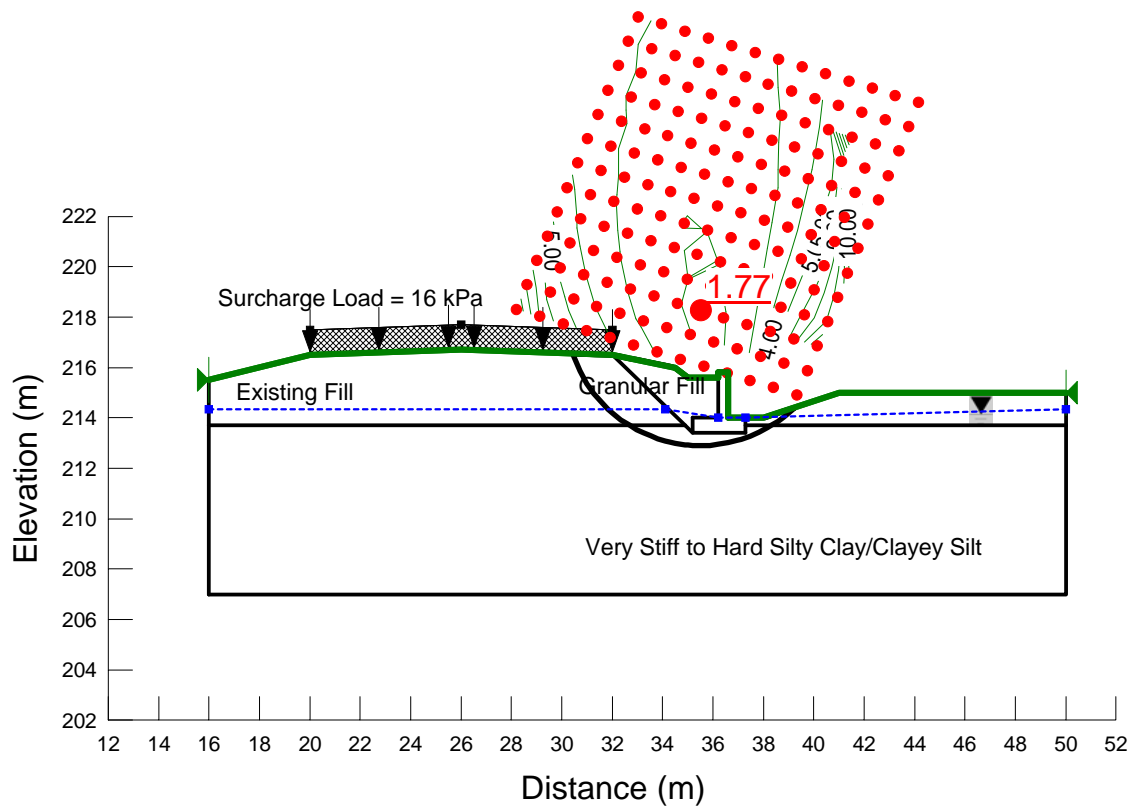


Figure D2 Slope Stability Analysis of Proposed Retaining Wall - Sta. 25+232  
 (Effective Stress Analysis)