



**FOUNDATION INVESTIGATION AND DESIGN REPORT**

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

**CULVERT NO. 61 AT STATION 26+521**

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

**MTO GEOCRES NO. 40P12-32**

*Submitted to:*

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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, 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)\***

| Station | Existing Culvert                    |                      | Boreholes Drilled | Proposed Work   | Foundation Investigation Requirement   |
|---------|-------------------------------------|----------------------|-------------------|---|--|
|         | Type                                | Dimension            |                   |   |  |
| 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  |
| 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 |
| 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                   |
| 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 northeast.   | Two boreholes (southwest and northeast retaining walls)                      |

| Station | Existing Culvert              |                      | Boreholes Drilled                          | Proposed Work   | Foundation Investigation Requirement   |
|---------|-------------------------------|----------------------|--|---|--|
|         | Type                          | Dimension            |  |   |  |
| 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.                |
| 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) |
| 18+393  |                               | 3.05 x 0.91 x 15.3 m |  | Rehabilitate and construct wing walls between this culvert and 12-422/C   |  |
| 18+409  |                               | 3.66 x 1.52 x 21.4 m |  | Rehabilitate and construct wing walls between this culvert and 12-423/C   |  |
| 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)  |
| 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)   |
| 26+521  | Concrete Frame - Open Footing | 1.8 x 1.2 x 23.5 m   | BH G38 and BH G39                          | Rehabilitate ends and replace sandbag 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 rehabilitation of the existing culvert (No. 61) at Station 26+521.

The factual results of the soil conditions encountered in the boreholes and laboratory tests (without design discussion and recommendations) for the rehabilitation of the existing culvert (No. 61) at Station 26+521 are presented in a separate report titled "Foundation Investigation Report".

## **2.0 SITE AND PROJECT DESCRIPTION**

The investigated culvert site (at Station 26+521) is located about 4 km north of Union Road, south of Goderich, Ontario (Drawing No. 1).

At this location, Highway 21 is a two-lane, asphaltic concrete paved road with gravel shoulders on both sides with fence, 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 embankment slopes were covered with vegetation at the time of the fieldwork.

As noted in Table 1.1 (Section 1.0), the existing culvert at this location is a 1.8 m wide x 1.2 m high x 23.5 m concrete, rigid frame structure with open footing. Preliminary Drawing No. S1 dated April 2012 (Sheet S35) indicates that the height of the existing embankment at the culvert location is about 1.3 m above the surrounding grade. Currently, sandbag wingwalls are in place at each end of the culvert. The existing sandbag wingwalls at both sides of both ends of the culvert are recommended to be replaced with cast-in-place concrete retaining walls (or similar). Details of the replacement culvert were not available at the time of preparing this report.

At the time of field work, the investigated areas at the ends of the existing culvert were covered with vegetation. 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 Culvert Recommendations, two (2) boreholes (BH G38 and G39) were advanced, one on each side of Highway 21. Borehole BH G38 was advanced at mid-shoulder of Highway 21 near the culvert inlet to an approximate depth of 9.6 m below the existing grade (Elevation 208.1 m), while, Borehole BH G39 was drilled near the culvert outlet to an approximate depth of 6.6 m below the existing grade (Elevation 209.9 m). The as-drilled borehole locations are presented on Drawing No. 2.

The fieldwork was performed on 14 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 (BM HCP # 102, Sta. 10+449.955, El 197.134).

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

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, wherever encountered, are presented on the Record of Boreholes.

Upon completion of drilling, the boreholes were 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 (RKI Eagle), the results of which are presented on the Record of Boreholes.

One selected sample was tested for soil corrosivity potential with respect to concrete and steel, the results of which are discussed in Section 6.7.

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. Testing to determine the corrosivity potential of the soils was performed by 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 Boreholes (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 (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, and the results of soil corrosivity test are shown in Appendix B.

## **5.0 SUB-SURFACE CONDITIONS**

Based on the investigation results, the soil profile consisted predominantly of ground surface cover (topsoil / sand and gravel fill) underlain by fill soils (silty sand / silty clay) overlying native clayey silt / silty clay deposit extending to the termination depths of the boreholes at elevations of about 208.1 m in Borehole BH G38, and about 209.9 m in BH G39.

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 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 between and beyond the borehole locations.

## **5.1 Ground Surface Cover**

Sand and gravel fill was encountered at the existing surface in Borehole BH G38 advanced through the Highway 21 shoulder. The measured thickness of sand and gravel fill was about 500 mm.

A single SPT N-value measured in the sand and gravel fill was 15 blows per 0.3 m. The corresponding moisture content measured in the sand and gravel fill was 6 %.

Topsoil was encountered at the existing grade in BH G39. The measured thickness of the topsoil was about 500 mm.

Thickness of topsoil may differ at locations beyond the borehole.

## **5.2 Silty Sand / Silty Clay Fill**

Silty sand and silty clay fill was encountered below the sand and gravel fill in Borehole BH G38, while silty sand fill was encountered in Borehole BH G39. The silty sand / silty clay fill extended to a depth of about 2.8 m (Elevation 214.9 m) in Borehole BH G38, and the silty sand fill extended to a depth of about 0.8 m (Elevation 215.7 m) in Borehole BH G39.

The silty sand was dark brown in color, while the silty clay was brown / grey in color. SPT 'N' values measured within the silty sand / silty clay fill varied from 2 to 6 blows per 0.3 m. The water contents determined within the silty sand / silty clay fill were 13 % and 20 %.

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

Native clayey silt / silty clay was encountered below the silty sand / silty clay fill in both boreholes. The clayey silt / silty clay extended to the termination depths of the boreholes at elevations of about 208.1 m in BH G38 and about 209.9 m in BH G39.

The clayey silt / silty clay was brown in color, and contained some sand to 'sandy' and trace gravel. The SPT 'N' values of the clayey silt / silty clay ranged widely from 9 to 43 blows per 0.3 m. Typically, the SPT 'N'-values were greater than 17 blows per 0.3 m indicating a very stiff to hard consistency. An exceptionally low N-value of 9 blows per 0.3 m was measured within Sample SS 2 in Borehole BH G39. The measured moisture contents in the clayey silt / silty clay ranged from 11 % to 14 %.

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

**Table 5.1 - Grain Size Distribution Analysis 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 G38       | SS 5       | 3.1 - 3.5<br>(214.6 - 214.2) | 2                       | 26       | 47       | 25       | 20              | 11            | 9                | CL                         |
| BH G38       | SS 9       | 9.1 - 9.6<br>(208.6 - 208.0) | 1                       | 12       | 52       | 35       | 24              | 13            | 11               | CL                         |
| BH G39       | SS 2       | 0.8 - 1.2<br>(215.7 - 215.3) | 2                       | 21       | 52       | 25       | 25              | 14            | 11               | CL                         |
| BH G39       | SS 5       | 3.1 - 3.5<br>(213.4 - 213.0) | 7                       | 25       | 45       | 23       | 19              | 11            | 8                | 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. Both boreholes were dry on completion of drilling.

The results of groundwater measurements are shown on the Record of Boreholes.

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 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 boreholes. The measured COV concentrations in all soil samples were relatively low, ranging from non-detect to 20 ppm as shown in the Record of Boreholes. 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. S35), dated April 2012, for Culvert No. 61 at Station 26+521.
- IV. Contract Drawings (CS Submission), Contract No. 2012-3028

Based on the cross-section drawing, sandbag wingwalls are currently in place at both sides of each end of the culvert, and are about 1 m long and 2 m high. The invert elevations at the inlet and outlet of the culvert are 215.18 m and 215.25 m respectively.

The project comprises replacement of the existing sandbag wingwalls possibly with a cast-in-place (CIP) retaining wall. Other retaining wall types considered feasible are gravity-type retaining walls (e.g. gabion, armourstone, Retained Soil System). Each of the new retaining walls would be up to 3 m long and 2 m high.

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 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. | <p>Durable and low maintenance.</p> <p>Not susceptible to erosion by water flow and ice forces.</p> <p>No specialized contractor is needed.</p> | <p>Rigid structure which may show minor cracks.</p> <p>Labour intensive for placing reinforcing bars and formwork.</p> <p>Possible need more time for construction to allow for curing concrete.</p> | Temporary slope excavated into the existing road embankment may have to stand up longer before backfilling. | Medium to high  |

| Option                                    | Description  | Advantages  | Disadvantages   | Risks / Consequences                        | Cost Comparison |
|---|--|---|---|---|-----------------|
| Gravity Type Retaining Wall - Gabion,     | Gabions are rectangular steel baskets filled with stone and stacked on one another.      | Construction is relatively simple.<br><br>Flexible type of structure,<br><br>Drain freely.  | Gabions are labour-intensive in order to properly place stones inside the gabion baskets.<br><br>Steel cages may not be stable in long term.<br><br>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.<br><br>Flexible type of structure,<br><br>Drain freely.<br><br>Good resistance to water flow and ice forces.<br><br>Possibly less installation time. | Source and transportation to site may be high.  |   | Medium to low   |
| Retained Soil System (RSS)                | Stone/concrete facade in front of soil mass reinforced with metal strips or geogrids.    | Flexible type of structure  | RSS requires specialised contractor according to MTO's DSM.<br><br>Facade material has to be properly selected to prevent erosion by water flow and ice forces.<br><br>Labour intensive for construction.<br><br>Reinforcing strips may not be durable. | May require some maintenance.               | Medium          |

Considering that the length and height of the new retaining walls at this site, Gravity Type Retaining Wall (e.g. Gabion Wall, Armourstone,) would be the better option, from the geotechnical viewpoint, because of relatively simple construction and flexible structure.

## 6.2 Foundations

Based on the cross-section drawing, the underside of footing of the existing culvert lies below an elevation of about 214.6 m. The underside of footing of the new retaining walls / wingwalls is anticipated to be at about the same grade. Based on the investigation results for Boreholes BH G38 and BH G39, the competent soil at the founding grade (elevation about 214.6 m and below) would comprise native very stiff clayey silt / silty clay.

The geotechnical Ultimate Limit State (ULS)/Serviceability Limit State (SLS) values provided in Table 6.1 should be used for the design of the new retaining walls / wingwalls.

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

| Structure                 | 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  | BH G38       | Very stiff to hard clayey silt / silty clay | 2.8 m (±) & below              | 214.9 m (±) and below     | 175                                | 270  |
| Retaining walls at outlet | BH G39       | Very stiff to hard clayey silt / silty clay | 1.5 m (±) & below              | 215.0 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 6.2 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, $K_p$ |
| Existing fill soils      | 18  | 28                                  | 0.53                                      | 0.35          | 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 values in Table 6.1 are based on a total settlement of up to 25 mm. Detailed foundation analysis will be necessary if accurate values of settlement are required.

For sliding resistance, an unfactored coefficient of friction of 0.35 should be considered at the base, which includes a resistance factor of 0.8.

For preparation of the subgrade for the new retaining walls, OPSS 902 (*Construction Specifications for Excavating and Backfilling - Structures*) should be followed. Minimum granular backfill requirement for retaining walls should comply with OPSS 3121.150 (*Minimum Granular Backfill Requirements - Walls Retaining*)

Any topsoil, organic soils and other deleterious materials encountered must be removed from the footprint of the foundations. Excavation to replace soft / loose soils should be carried out carefully to ensure that the foundation of existing culvert is not compromised. The exposed subgrade should be verified by proof-rolling (or other acceptable method), and any loose, soft or unstable areas sub-excavated and replaced with competent material.

The new retaining walls should be backfilled with granular soil (OPSS Granular 'A' or Granular 'B' complying OPSS 1010), and compacted as per OPSS 501 (*Construction Specification for Compacting*). Materials for gabion wall, if used, must comply with OPSS 1430 (*Material Specification for Gabion Baskets and Mats*).

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

**Excavations for constructing the new retaining walls should be carried out carefully to ensure that the existing foundation of the adjacent culvert and the existing road embankment are not compromised.**

The excavation and groundwater control are further discussed in Section 6.4 and Section 6.5.

### **6.3 Retaining Wall Design**

Based on Contract Drawings, the existing sandbags are to be replaced with gabion walls at all corners of the culvert. The details of the walls are shown in Sheet 201. The walls are about 2.0 m high, with the top of the wall at the same level at the top of the existing culvert. Typically, as per the Contract Drawings, the bases of the gabion wall are matched with the base of the existing culvert footing.

### 6.3.1 Slope Stability

A global slope stability analysis was carried out for one typical section at the proposed retaining wall near the west end of the culvert at approximate Station 26+521 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 201 (General Arrangement) of the Contract Drawing prepared in April 2012, the height of the proposed gabion wall at the location is about 2.0 m. The base of the wall is approximately at the same elevation at the base of the existing culvert footing. The width of the gabion wall is about 2.0 m (as per Sheet 206). 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 Boreholes BH G38 and BH G39. Groundwater was not encountered in the boreholes during the field investigation. For the slope stability analyses, the groundwater was assumed to be the invert level, which would be at an elevation of about 215.2 m, to account for potentially highest groundwater level. Granular fill has been assumed behind the wall. For the analysis, it has been assumed that the water accumulation behind the wall would be only up to the invert level (Elevation 216.4m). Proper drainage system should be constructed to avoid additional 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                               | 25           | 0       | 0                | 28       |
| Stiff to hard clayey silt/silty clay | 20                               | 75           | 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<br>(Short Term) | Effective Stress Analysis<br>(Long Term) |
| 26+521                     | 5.8                                   | 1.6                                      |

Generally, a 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 1.7. Therefore, the gabion walls with the embankment slope should be stable. It should be noted that the analysis has been carried out assuming the plausible condition of a very high groundwater level (up to the top of the culvert).

### 6.3.2 Design Considerations

Following aspects should be considered for the design of the retaining wall:

- Recommendations provided in Section 6.2 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 retaining wall (gabion) should be 2.0 m.
- If any change is made in foundation design, especially the width, height of wall and/or elevation of footing, the stability should be re-analyzed.
- Geotextile should be provided over the existing soil prior to placing the granular fill behind the gabion walls to prevent migration of the fines.

### 6.4 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 clay / 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.

## **6.5 Dewatering and Ditch Diversion**

No groundwater was encountered on completion of the drilling work. Excavation for new retaining walls may encounter groundwater due to seepage from creek water and/or groundwater. Groundwater seepage is expected to be slow through the clayey silt / silty clay soils, and could be dewatered using a system of sumps and pumps. High rates of seepage may occur from surface water, and dewatering effort could require an increased number of sumps and pumps.

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

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

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

## **6.6 Temporary Shoring**

The temporary shoring of the excavation, if required, 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 (May 2010). Soil parameters summarized in Table 6.3 may be used for design considerations.

## 6.7 Soil Corrosivity

To determine the soil corrosivity potential with respect to concrete and steel, one soil sample (BH G38 - SS 2) was submitted to Maxxam Analytics Laboratory in Mississauga, and tested for pH, soluble chloride, sulphate, electrical conductivity and resistivity. The test results are presented in Table 6.4. The Certificate of Analysis is included in Appendix B.

**Table 6.4 - 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 G38 - SS2    | 7.35 | 949  | 1100                  | 450                          | <20                          |

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 (1100 ohm-cm), the degree of corrosivity should be considered as “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.

## 6.8 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 (May 2010), the site soil profile is Type I.

## 7.0 CLOSURE

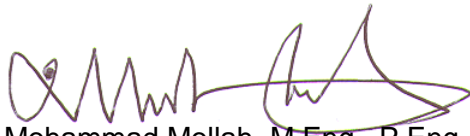
The sub-soil information contained in this report should be used solely for the purpose of foundation assessment of the culvert site at Station 26+521 on Highway 21, south of Goderich, Ontario.

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

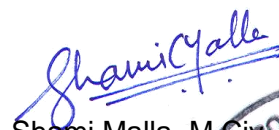
This report was prepared by Mohammad Mollah, M.Eng., P.Eng. and Shami Malla, M. Civ. Eng., P. Eng., and was reviewed by Prapote Boonsinsuk, Ph.D., P.Eng.

Sincerely,

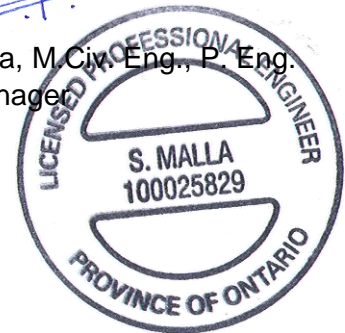
**AMEC Environment & Infrastructure,  
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Senior Geotechnical Engineer



Shami Malla, M. Civ. Eng., P. Eng.  
Project Manager



Prapote Boonsinsuk, Ph.D., P.Eng.  
Principal Designated Contact



**AMEC Environment & Infrastructure,  
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**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 26+521 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 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,  
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CLIENT LOGO



CLIENT

**MINISTRY OF  
TRANSPORTATION ONTARIO  
WEST REGION**

TITLE  
**CULVERT LOCATION PLAN**

DWN BY:  
KW

DATUM:  
-

DATE:  
JANUARY 2013

PROJECT  
**REHABILITATION OF HIGHWAY 21 - FROM BAYFIELD TO GODERICH, ONTARIO**  
PURCHASE ORDER NUMBER: 3009-E-0022, WP 834-93-00, GEOCRETS No.: 40P12-32

CHK'D BY:  
PB

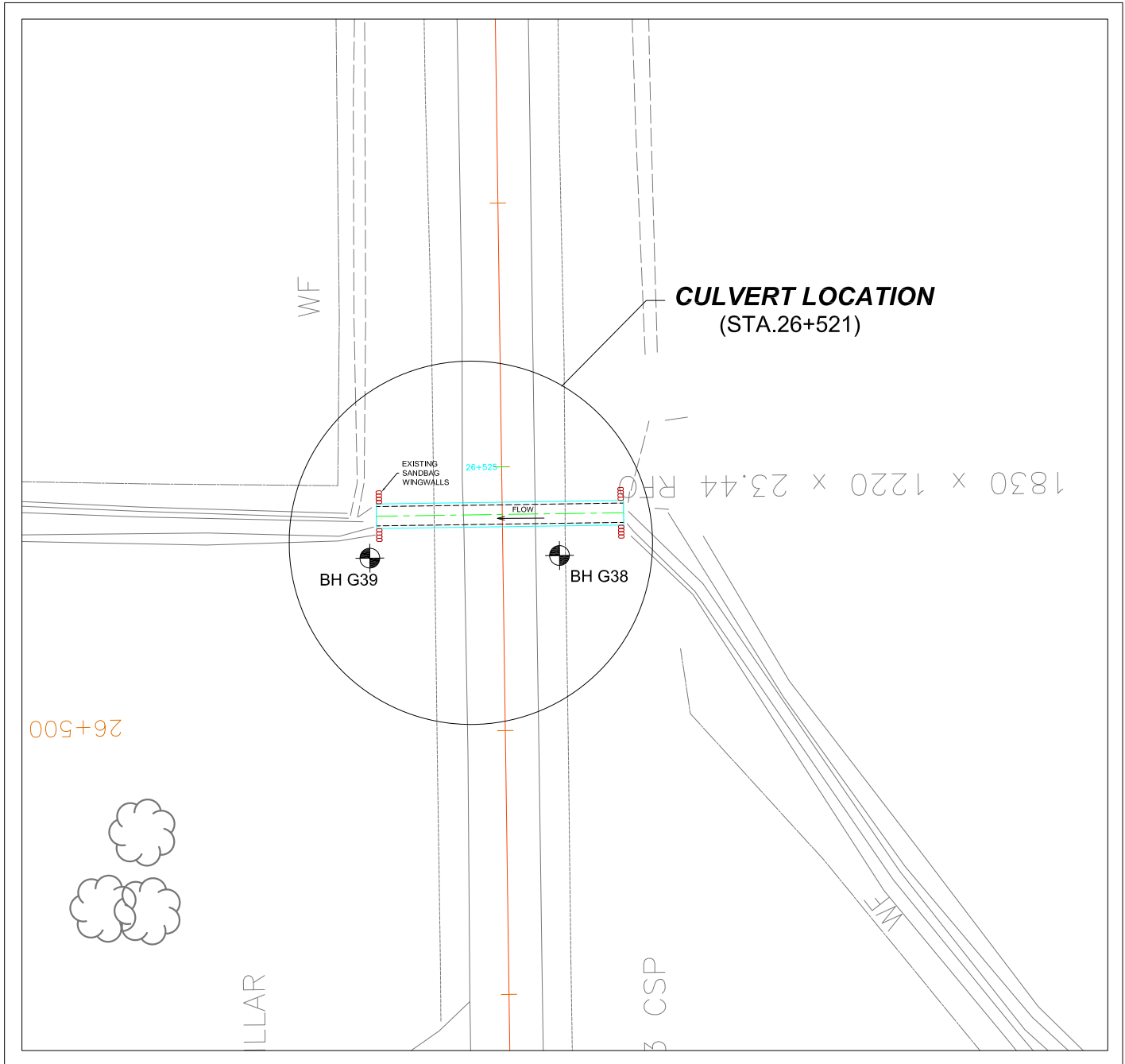
REV. NO.:  
A

PROJECT NO:  
TP110076

PROJECTION:  
-

SCALE:  
AS SHOWN

DRAWING No.  
**1**



SCALE



AMEC Environment & Infrastructure,  
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CLIENT LOGO



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.: 40P12-32

DWN BY:  
KW

CHK'D BY:  
PB

PROJECTION:  
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DATUM:  
-

REV. NO.:  
A

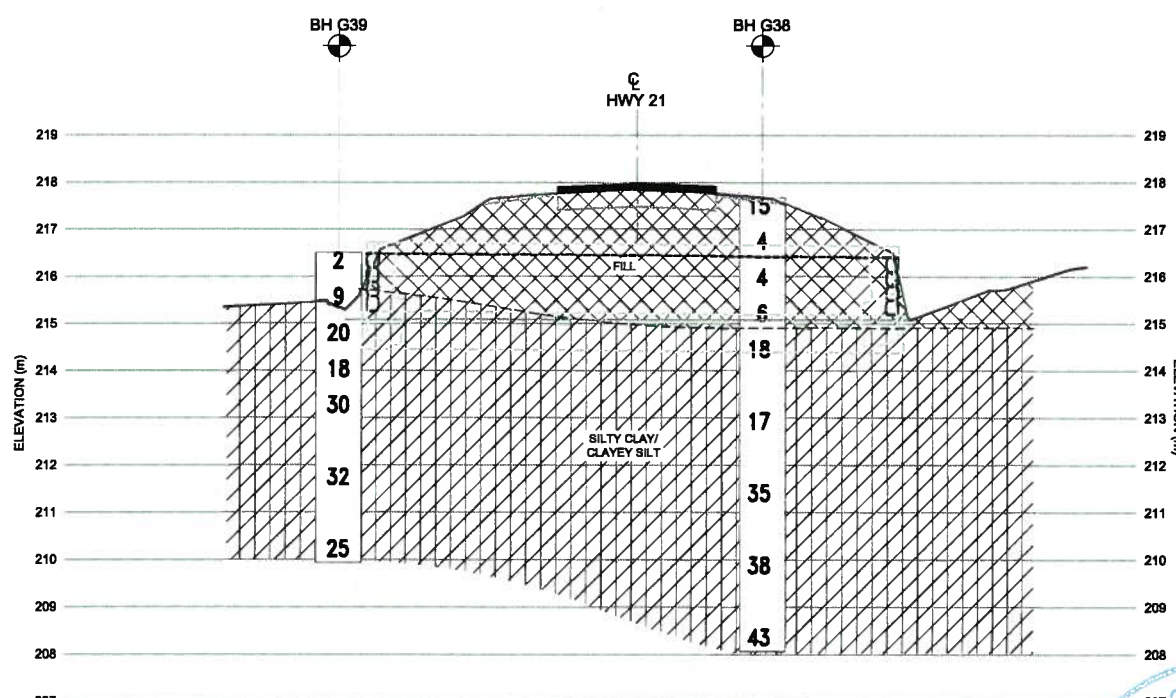
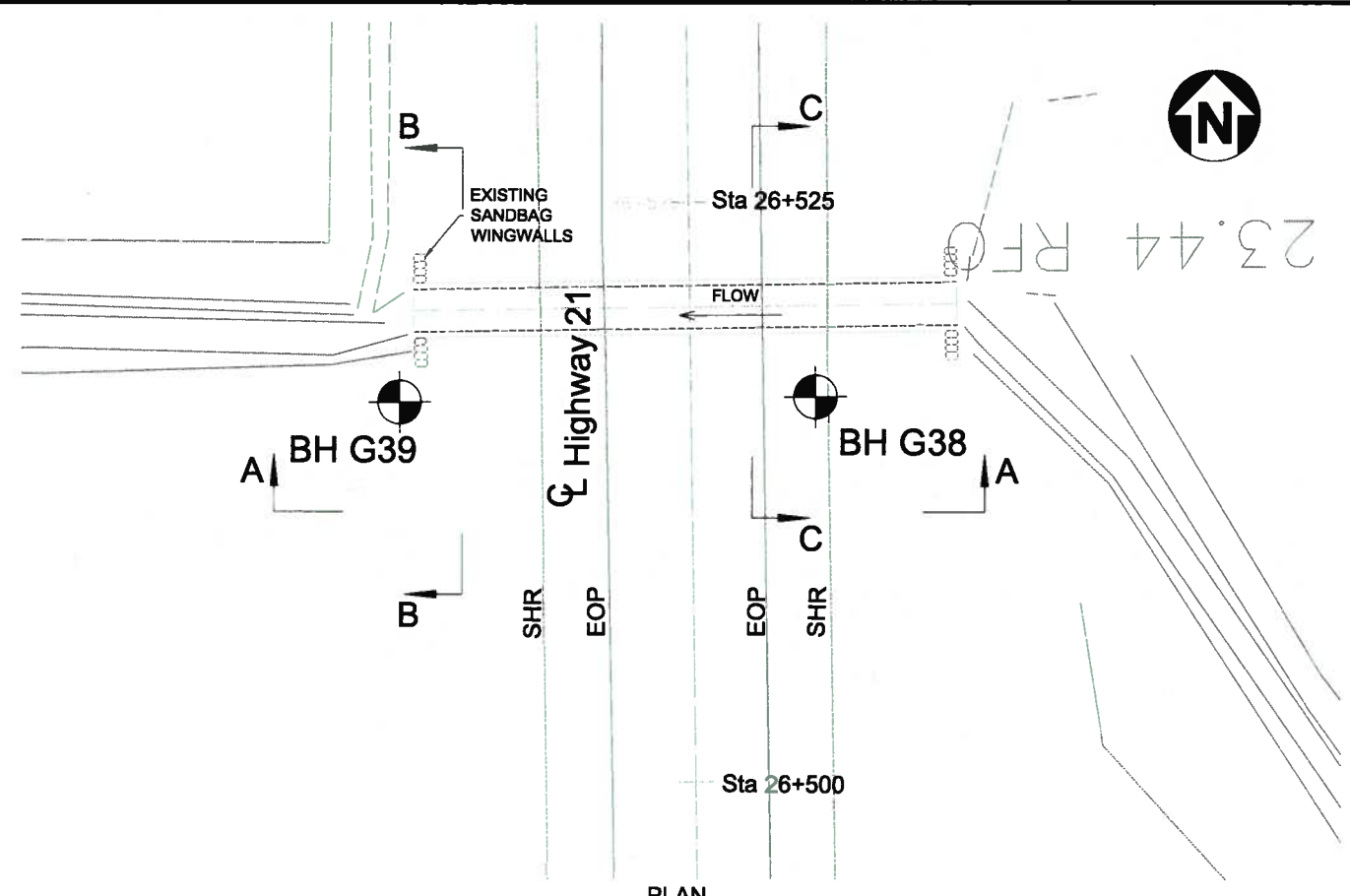
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AS SHOWN

DATE:  
JANUARY 2013

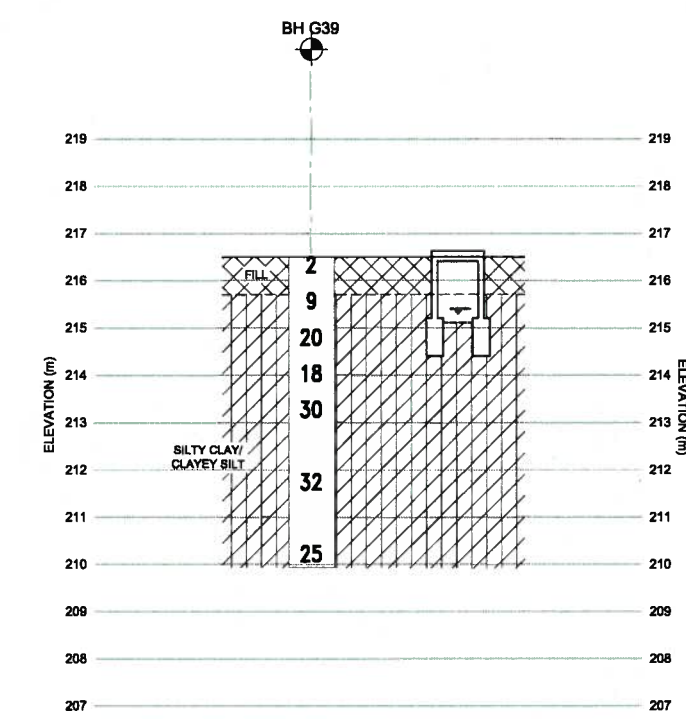
PROJECT NO:  
TP110076

DRAWING No.  
2

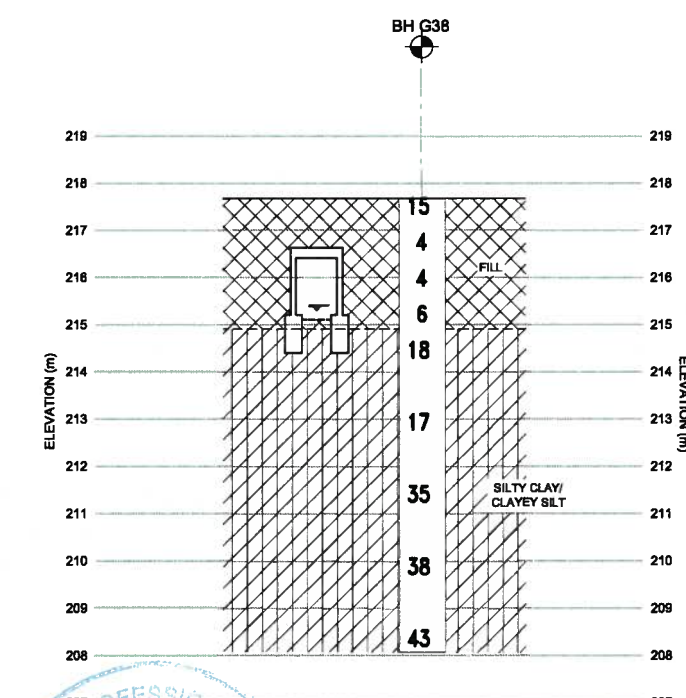




SECTION A-A



SECTION B-B



SECTION C-C





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

|  |  |
|--|--|
| PURCHASE ORDER NUMBER:<br><b>3009-E-0022</b>   |  |
| G.W.P. No.<br><b>834-93-00</b>   |  |
| REHABILITATION OF HWY 21 FROM BAYFIELD TO GODERICH<br><b>GEOCRES No.40P12-32</b><br><b>CULVERT AT STA 26+521</b><br><b>STRATIGRAPHIC CROSS SECTION</b> |  |
| <b>amec</b><br>AMEC Environment & Infrastructure,<br>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<br>(m) |
|   | NORTHING                                    | EASTING |                  |
| BH G38  | 4840546                                     | 443157  | 217.7            |
| BH G39  | 4840545                                     | 443142  | 216.5            |

- 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.



AMEC Reference: TP110076

|           |        |               |            |                |
|-----------|--------|---------------|------------|----------------|
| DESIGN PB | CHK PB | CODE CHBDC-06 | CL 625-ONT | DATE JAN. 2013 |
| DRAWN KW  | CHK HS | SITE 26+521   | DWG 3      |                |

P:\GEOProjects\2011\TP-Burlington\TP110076-HWY 21\05-Foundations\Drawings\112041 - Washburn Drain.DWG

**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                |

| <u>Consistency of Cohesive Soils</u> | <u>Undrained Shear Strength</u><br><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

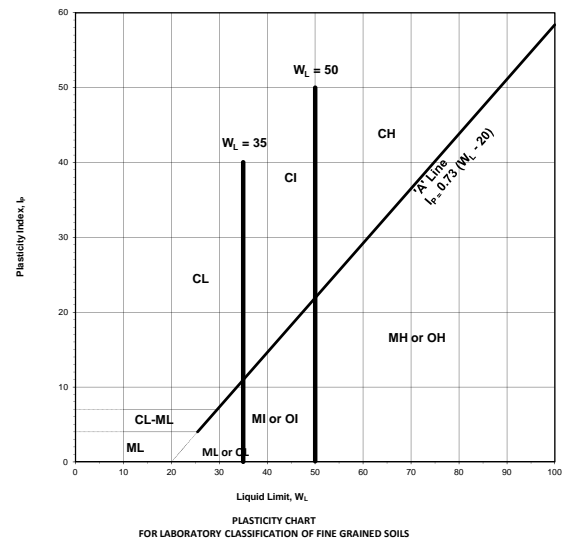
## Based on MTC Soil Classification Manual



| 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                          |   | FOR UNDISTURBED SOILS ADD INFORMATION ON STRATIFICATION, DEGREE OF COMPACTNESS, CEMENTATION, MOISTURE CONDITION & DRAINAGE CHARACTERISTICS | NOT MEETING ALL GRADATION REQUIREMENTS FOR GW   |  |  |  |  |  |  |
|  |   |   | PLASTIC FINES (FOR IDENTIFICATION PROCEDURES SEE CL BELOW)                         | GC   | CLAYEY GRAVELS, POORLY GRADED GRAVEL-SAND-CLAY MIXTURES                          |   |  |   |  |  |  |  |  |  |
| FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT SMALLER THAN 75µm)  | SILT AND CLAYS  | SANDS MORE THAN HALF THE COARSE FRACTION LARGER 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   |  |   | 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                       |  |  |  |  |
|  |   |   |  | PLASTIC FINES (FOR IDENTIFICATION PROCEDURES SEE CL BELOW)                       | SC   | CLAYEY SANDS, POORLY GRADED SAND-CLAY MIXTURES  |  |   |  |  |  |  |  |  |
|  |   | IDENTIFICATION PROCEDURE ON FRACTION SMALLER THAN 425µm     |  |  |  |   |  | ATTERBERG LIMITS ABOVE A- LINE WITH $I_p$ GREATER THAN 7  |  |  |  |  |  |  |
|  |   | LIQUID LIMIT LESS THAN 35                                   | DRY STRENGTH (CRUSHING CHARACTERISTICS)  | DILATANCY (REACTION TO SHAKING)  | TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT)                                       |   |  | GIVE TYPE, NAME, IF NECESSARY, INDICATE DEGREE AND CHARACTER OF PLASTICITY, AMOUNT AND MAXIMUM SIZE OF COURSE GRAINS, COLOUR IN WET CONDITION, ODOUR, IF ANY, LOCAL OR GEOLOGIC NAME & OTHER PERTINENT DESCRIPTIVE INFORMATION & SYMBOL IN PARENTHESIS. | LESS THAN 5% GW, GP, SW, SP<br>MORE THAN 12% GM, GC, SM, SC<br>5% TO 12% BORDER LINE CASES REQUIRE USE OF DUAL SYMBOL. | $C_u = \frac{D_{60}}{D_{10}}$ GREATER THAN 6;<br>$C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ BETWEEN 1 AND 3 |  |  |  |  |
|  |   |   | 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            | FOR UNDISTURBED SOILS AND INFORMATION ON STRUCTURE, STRATIFICATION, CONSISTENCY IN UNDISTURBED AND REMOLDED STATES, MOISTURE & DRAINAGE CONDITION. |  |  |
|  |   |   |  | 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 DIATOMEACOUS 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   |  |  |  |
|  |   |   | HIGH ORGANIC SOILS   |  | READILY IDENTIFIED BY COLOUR, ODOUR, SPONGY FEEL & FREQUENTLY BY FIBROUS TEXTURE |   |  |   |  |  | Pt   | PEAT AND OTHER HIGHLY ORGANIC SOILS  | 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<br>BOULDERS > 200 mm |                         |         |   | NOT ROUNDED:<br>ROCK FRAGMENTS > 75 mm<br>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 G38

1 OF 1

|  |   |                  |
|--|---|------------------|
| G.W.P. 834-93-00   | LOCATION Sta.26+521, 6.0m E of CL of Rd, 2.5m S of Culvert C/L, E43157 N4840546 | ORIGINATED BY JF |
| DIST Goderich HWY 21   | BOREHOLE TYPE 150 mm diameter borehole (Solid Stem)                             | COMPILED BY SC   |
| DATUM Geodetic   | DATE 14 March 2012 - 14 March 2012  | CHECKED BY SM    |
| PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario | JOB NO.   | TP110076         |

| SOIL PROFILE         |   |            | SAMPLES |      |            | GROUND WATER<br>CONDITIONS | DEPTH<br>m | ELEVATION SCALE<br>m | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |    |    |    |     | PLASTIC<br>LIMIT<br>W <sub>p</sub> | NATURAL<br>MOISTURE<br>CONTENT<br>W | LIQUID<br>LIMIT<br>W <sub>L</sub> | SOIL VAPOUR<br>READING<br>PPM | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%) |   |    |    |    |    |    |
|----------------------|---|------------|---------|------|------------|----------------------------|------------|----------------------|---|----|----|----|-----|------------------------------------|-------------------------------------|-----------------------------------|-------------------------------|---|---|----|----|----|----|----|
| ELEV<br>DEPTH<br>(m) | DESCRIPTION   | STRAT PLOT | NUMBER  | TYPE | "N" VALUES |                            |            |                      | SHEAR STRENGTH kPa                          |    |    |    |     |                                    |                                     |                                   |                               | WATER CONTENT (%)                                 |   |    | GR | SA | SI | CL |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
| 217.7                |   |            |         |      |            |                            |            |                      | 20  | 40 | 60 | 80 | 100 |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
| 0.0                  | brown<br><b>Sand and Gravel FILL</b><br>trace to some silt<br>moist   |            | 1       | SS   | 15         |                            |            |                      |   |    |    |    |     |                                    | 6 <sub>O</sub>                      |                                   |                               | 0   |   |    |    |    |    |    |
| 217.2                | 0.5   |            |         |      |            |                            |            | 217                  |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
| 216.8                | brown<br><b>Silty Sand FILL</b><br>trace cobbles / boulder  |            | 2       | SS   | 4          |                            | 1          |                      |   |    |    |    |     |                                    | 13 <sub>O</sub>                     |                                   |                               | 5   |   |    |    |    |    |    |
| 0.9                  | brown / grey<br><b>Silty Clay FILL</b><br>trace to some sand<br>trace gravel<br>trace organic matter in SS3 |            | 3       | SS   | 4          |                            |            | 216                  |   |    |    |    |     |                                    | 20 <sub>O</sub>                     |                                   |                               | 15  |   |    |    |    |    |    |
|                      |   |            | 4       | SS   | 6          |                            | 2          |                      |   |    |    |    |     |                                    |                                     |                                   |                               | 20  |   |    |    |    |    |    |
| 214.9                | 2.8   |            |         |      |            |                            |            | 215                  |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      | brown<br><b>CLAYEY SILT / SILTY CLAY</b><br>some sand to 'sandy', trace gravel<br>very stiff to hard        |            | 5       | SS   | 18         |                            | 3          |                      |   |    |    |    |     |                                    | 13 <sub>O</sub>                     |                                   |                               | 0   | 2 | 26 | 47 | 25 |    |    |
|                      |   |            |         |      |            |                            |            | 214                  |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            | 6       | SS   | 17         |                            | 4          |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            | 213                  |   |    |    |    |     |                                    | 13 <sub>O</sub>                     |                                   |                               | 0   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            | 212                  |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            | 7       | SS   | 35         |                            | 6          |                      |   |    |    |    |     |                                    | 13 <sub>O</sub>                     |                                   |                               | 0   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            | 211                  |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            | 210                  |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            | 8       | SS   | 38         |                            | 7          |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            | 209                  |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
| 208.1                | 9.6   |            | 9       | SS   | 43         |                            | 8          |                      |   |    |    |    |     |                                    | 14 <sub>O</sub>                     |                                   |                               | 0   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                               |   |   |    |    |    |    |    |

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

# RECORD OF BOREHOLE No BH G39

1 OF 1

|  |   |                  |
|--|---|------------------|
| G.W.P. 834-93-00   | LOCATION Sta.26+521, 13.0m W of CL, 3.5m S of Culvert C/L, E443142 N4840545 | ORIGINATED BY JF |
| DIST Goderich HWY 21   | BOREHOLE TYPE 150 mm diameter borehole (Solid Stem)                         | COMPILED BY SC   |
| DATUM Geodetic   | DATE 14 March 2012 - 14 March 2012  | CHECKED BY SM    |
| PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario | JOB NO.   | TP110076         |

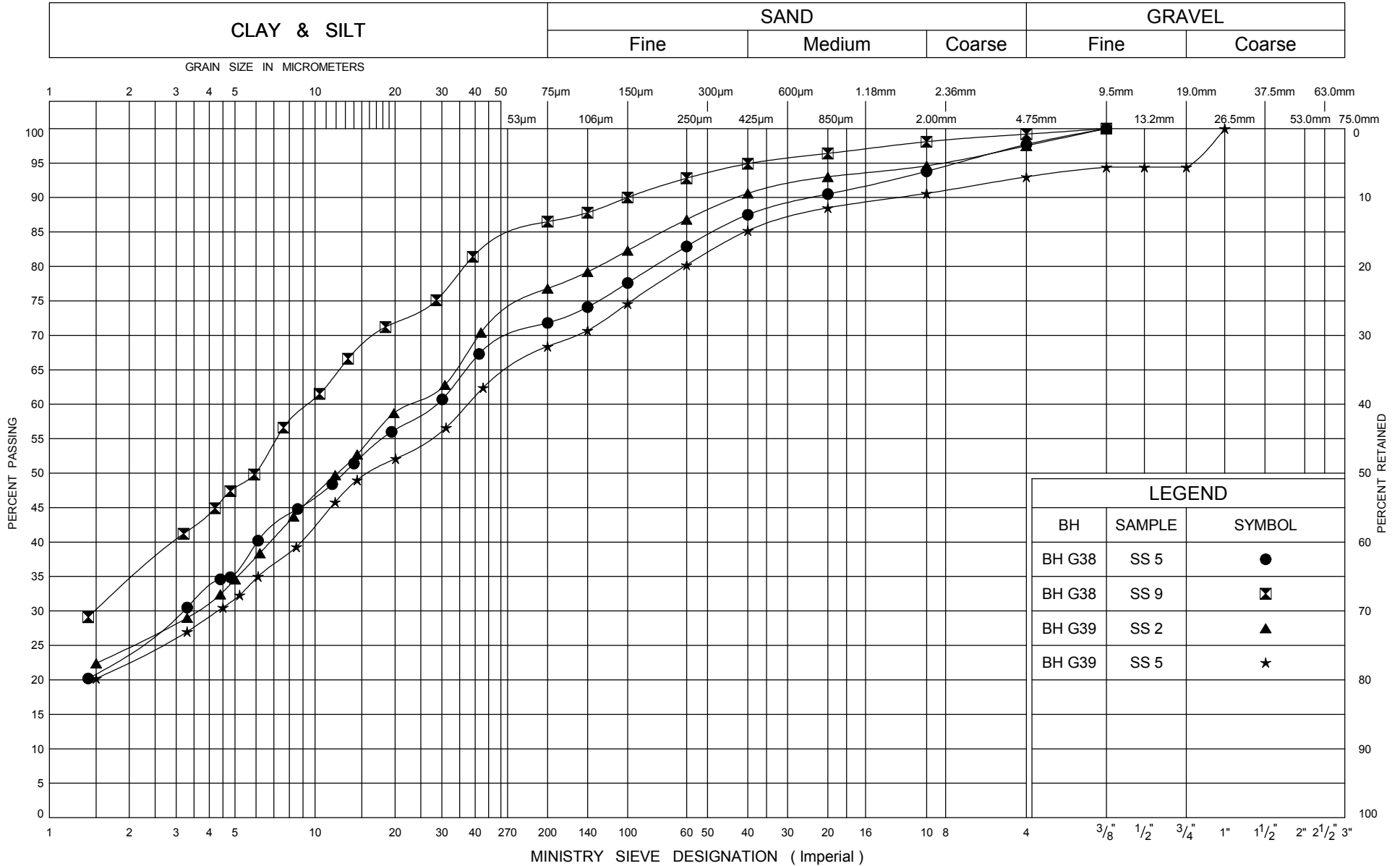
| SOIL PROFILE         |   |            | SAMPLES |      |            | GROUND WATER<br>CONDITIONS | DEPTH<br>m | ELEVATION SCALE<br>m | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |    |    |    |     | PLASTIC<br>LIMIT<br>W <sub>p</sub> | NATURAL<br>MOISTURE<br>CONTENT<br>W | LIQUID<br>LIMIT<br>W <sub>L</sub> | SOIL VAPOUR<br>READING | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%) |
|----------------------|---|------------|---------|------|------------|----------------------------|------------|----------------------|---|----|----|----|-----|------------------------------------|-------------------------------------|-----------------------------------|------------------------|---|
| ELEV<br>DEPTH<br>(m) | DESCRIPTION                             | STRAT PLOT | NUMBER  | TYPE | "N" VALUES |                            |            |                      | SHEAR STRENGTH kPa                          |    |    |    |     |                                    |                                     |                                   |                        |   |
| 216.5                |   |            |         |      |            |                            |            |                      | 20  | 40 | 60 | 80 | 100 |                                    |                                     |                                   |                        |   |
| 0.0                  | about 500 mm TOPSOIL                    |            | 1       | SS   | 2          |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   | 20                     |   |
| 216.0                |   |            |         |      |            |                            | 216        |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
| 0.5                  | dark brown                              |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
| 215.7                | Silty Sand FILL                         |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
| 0.8                  | with clay and organic matter            |            | 2       | SS   | 9          |                            | 1          |                      |   |    |    |    |     |                                    |                                     |                                   | 5                      | 2 21 52 25  |
|                      | brown                                   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
|                      | CLAYEY SILT / SILTY CLAY                |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
|                      | some sand to 'sandy'                    |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
|                      | trace gravel                            |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
|                      | stiff to hard                           |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
|                      |   |            | 3       | SS   | 20         |                            | 2          |                      |   |    |    |    |     |                                    |                                     |                                   | 5                      |   |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
|                      |   |            | 4       | SS   | 18         |                            | 214        |                      |   |    |    |    |     |                                    |                                     |                                   | 0                      |   |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
|                      |   |            |         |      |            |                            | 3          |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
|                      |   |            | 5       | SS   | 30         |                            | 213        |                      |   |    |    |    |     |                                    |                                     |                                   | 0                      | 7 25 45 23  |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
|                      |   |            |         |      |            |                            | 4          |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
|                      |   |            |         |      |            |                            | 212        |                      |   |    |    |    |     |                                    |                                     |                                   | 0                      |   |
|                      |   |            | 6       | SS   | 32         |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
|                      |   |            |         |      |            |                            | 5          |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
|                      |   |            |         |      |            |                            | 211        |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
|                      |   |            |         |      |            |                            | 6          |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
|                      | trace cobbles / boulders in SS7         |            | 7       | SS   | 25         |                            | 210        |                      |   |    |    |    |     |                                    |                                     |                                   | 0                      |   |
| 209.9                |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
| 6.6                  | End of Borehole                         |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
|                      | Groundwater Level on 14 March 2012: dry |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |
|                      |   |            |         |      |            |                            |            |                      |   |    |    |    |     |                                    |                                     |                                   |                        |   |

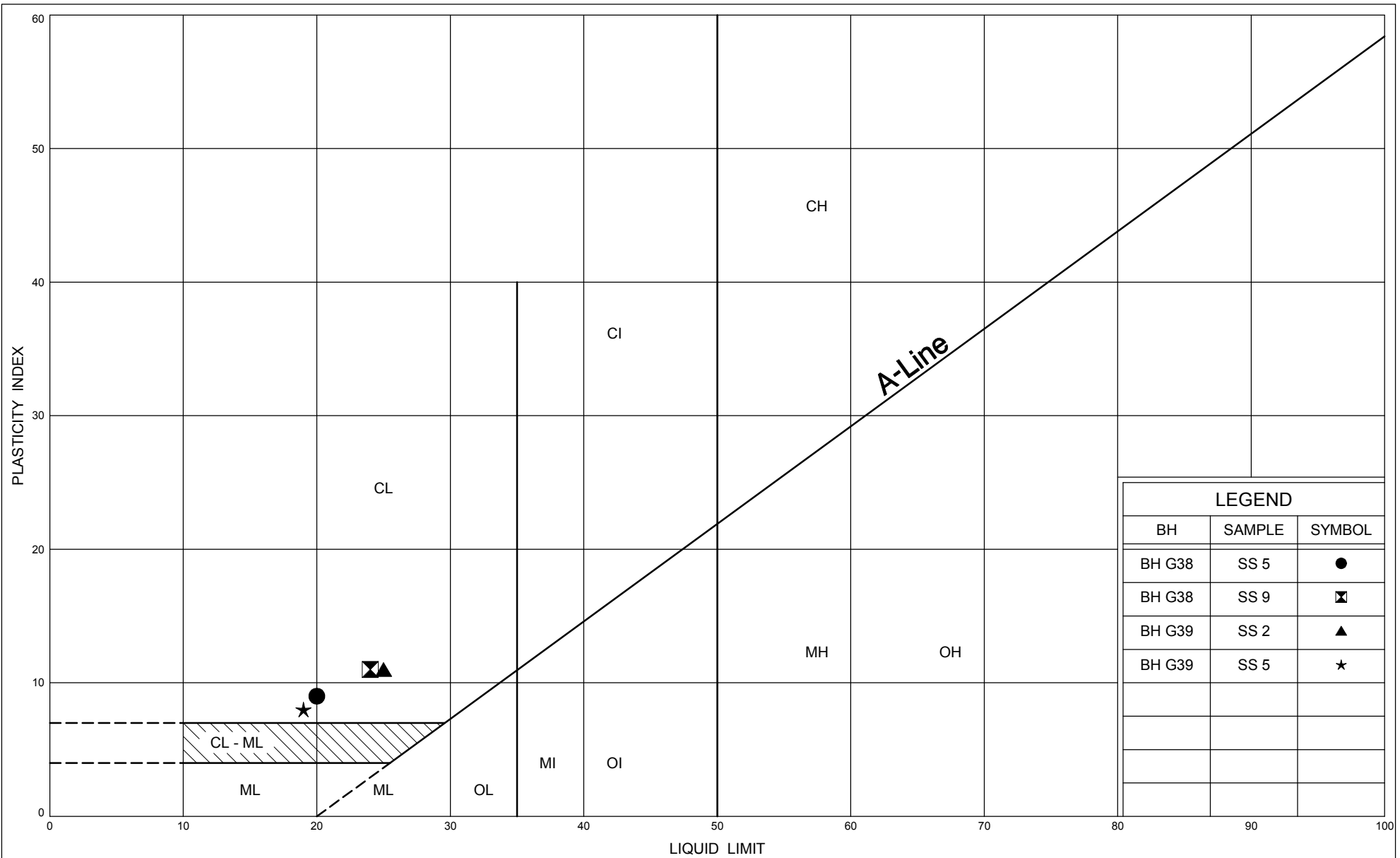
## **APPENDIX B**

### **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<br>Extracted | Date<br>Analyzed | Laboratory Method | Method<br>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<br>10:00 | 2012/03/13<br>10:00 | 2012/03/13<br>10:10 | 2012/03/13<br>10:10 | 2012/03/13<br>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<br>14:30 | 2012/03/16<br>14:40 |                 | 2012/03/16<br>15:50 |                 | 2012/03/16<br>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 (SO4) | 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**

---

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

=====

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. 26 + 521)**



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 61 - Sta. 26+521 - West Side (Total Stress Analysis)  
C61-26+521 Retaining Wall (25 March 2013).gsz

Name: Granular Fill    Unit Weight: 21 kN/m<sup>3</sup>    Cohesion: 0 kPa    Phi: 32 °  
Name: Retaining Wall    Unit Weight: 23 kN/m<sup>3</sup>    Cohesion: 200 kPa    Phi: 36 °  
Name: Stiff to Hard Silty Clay/Clayey Silt (ST)    Unit Weight: 20 kN/m<sup>3</sup>    Cohesion: 75 kPa  
Name: Existing Fill (ST)    Unit Weight: 18 kN/m<sup>3</sup>    Cohesion: 25 kPa

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

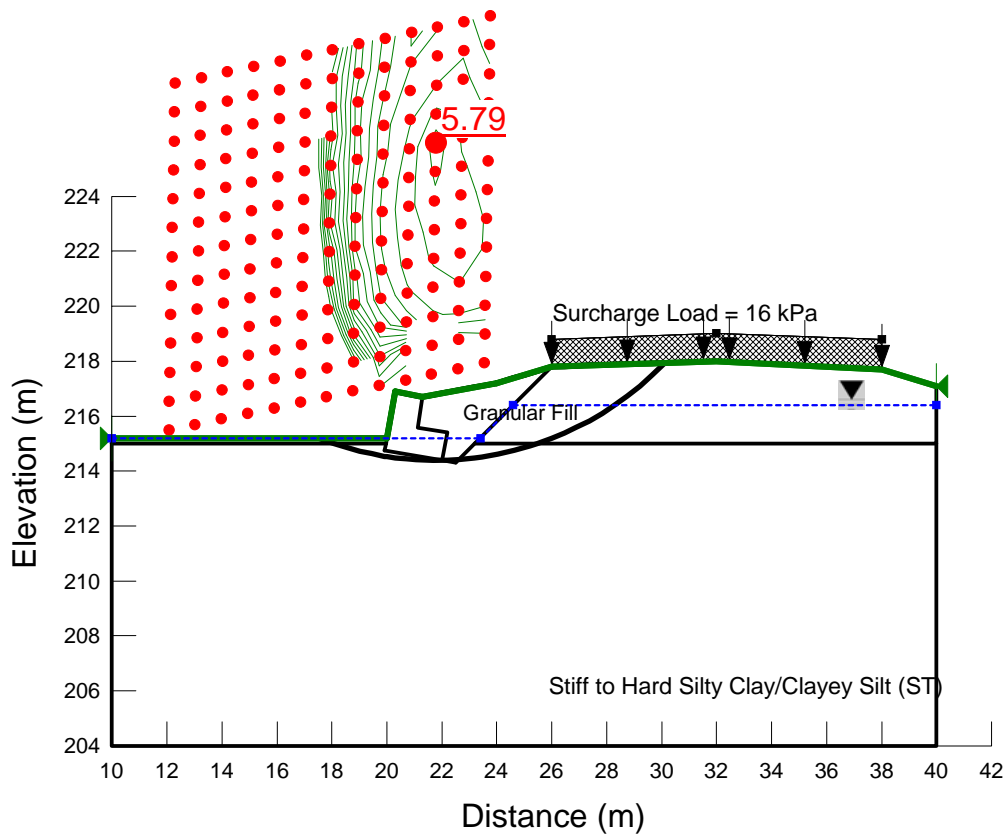


Figure D1 Slope Stability Analysis of Proposed Retaining Wall - Sta. 26+521  
(Total Stress Analysis)



TP110076 - Rehabilitation of HWY 21 from Bayfield to Goderich, ON  
Culvert 61 - Sta. 26+521 - West Side (Effective Stress Analysis)  
C61-26+521 Retaining Wall (25 March 2013).gsz

Name: Granular Fill    Unit Weight: 21 kN/m<sup>3</sup>    Cohesion: 0 kPa    Phi: 32 °  
Name: Stiff to Hard Silty Clay/Clayey Silt    Unit Weight: 20 kN/m<sup>3</sup>    Cohesion: 0 kPa    Phi: 28 °  
Name: Retaining Wall    Unit Weight: 23 kN/m<sup>3</sup>    Cohesion: 200 kPa    Phi: 36 °  
Name: Existing Fill    Unit Weight: 18 kN/m<sup>3</sup>    Cohesion: 0 kPa    Phi: 28 °

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

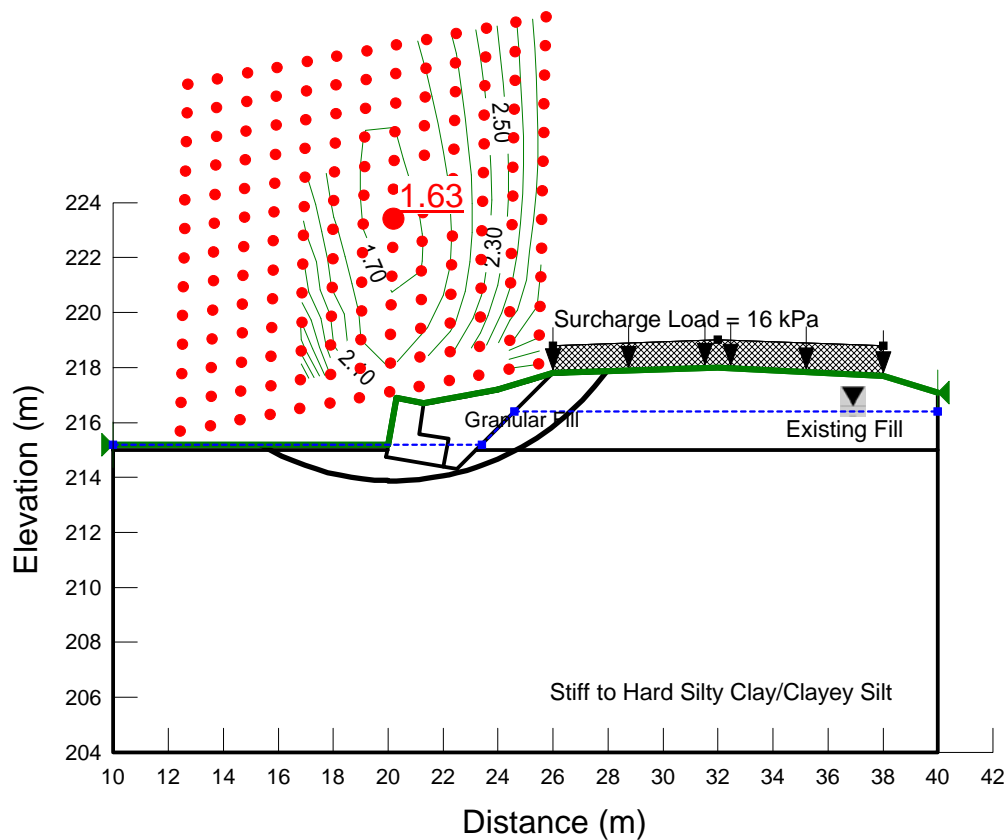


Figure D2 Slope Stability Analysis of Proposed Retaining Wall - Sta. 26+521  
(Effective Stress Analysis)