FOUNDATION INVESTIGATION AND DESIGN REPORT

REHABILITATION OF HIGHWAY 21
FROM BAYFIELD TO GODERICH, ONTARIO

CULVERT NO. 34 AT STATION 18+843

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

MTO GEOCRES NO. 40P12-19

Submitted to:

Ministry of Transportation Ontario - West Region

3rd Floor, 659 Exeter Road
London, Ontario, N6E 1L3
Canada

Submitted by:

AMEC Environment & Infrastructure,
a Division of AMEC Americas Limited

104 Crockford Boulevard
Scarborough, Ontario, M1R 3C3
Canada

Tel: (416) 751-6565
Fax: (416) 751-7592

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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)*

Culvert No.	Station	Existing Culvert		Boreholes Drilled	Proposed Work	Foundation Investigation Requirement
		Type	Dimension			
2	10+267	Concrete Rigid Frame - Open Footing	0.9 x 0.9 x 38.5 m	BH G22 and BH G23	Extend culvert and clean out	Two boreholes for extension
8	11+691	Concrete Rigid Frame Box	3.75 x 2.30 x 68.4 m	BH G24 and BH G25	Rehabilitate and install RSS to stabilize steep roadway embankment	Foundations for RSS / slopes and protection system to stage the construction
10	12+138	Concrete Box	1.2 x 1.2 x 24.2 m	BH G26 and BH G27	Rehabilitate inlet, remove outlet precast block wing walls, place gabion wingwalls at east end. Construct CIP wingwalls at west outlet, including scour protection.	Two boreholes at outlet end for retaining wall foundations
17	13+835	Concrete Box	1.2 x 1.2 x 27.05 m	BH G28 & BH G28A and BH G29	Replace southwest concrete retaining wall with CIP concrete retaining walls. Construct CIP	Two boreholes (southwest and northeast retaining walls)

Culvert No.	Station	Existing Culvert		Boreholes Drilled	Proposed Work	Foundation Investigation Requirement
		Type	Dimension			
					concrete wingwall at northeast.	
20	15+205	Concrete Arch - Open Footing	7.16 x 3.66 x 29.6 m	BH G30	Rehabilitate and install RSS to stabilize steep roadway embankment. Replace southwest wingwall.	Foundations for RSS / slopes (both sides of the roadway) and protection system for construction. Protection will be installed. One borehole for southwest wingwall.
30	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)
31	18+393		3.05 x 0.91 x 15.3 m		Rehabilitate and construct wing walls between this culvert and 12-422/C	
32	18+409		3.66 x 1.52 x 21.4 m		Rehabilitate and construct wing walls between this culvert and 12-423/C	
34	18+843	Concrete Frame - Open Footing	1.5 x 1.1 x 24.7 m	BH G35 and BH G36	Rehabilitate ends and replace wingwalls with CIP concrete. Repair culvert interior. Extend inlet end.	Two boreholes (one at each end)
56	25+232	Concrete Frame - Open Footing	2.9 x 0. 9 x 20.8 m	BH G37	Replace sandbag wingwalls with gabions at west end and CIP concrete retaining wall at east end. Repair outlet concrete. Place scour protection.	One Foundation borehole (east end)
61	26+521	Concrete Frame - Open Footing	1.8 x 1.2 x 23.5 m	BH G38 and BH G39	Rehabilitate ends and replace sand bag retaining walls with CIP concrete retaining walls	Two Foundation boreholes (one at each end)

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

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

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

This report presents the results of foundation investigation together with design discussion and recommendations for the rehabilitation of Culvert No. 34 at Station 18+843.

The factual results of the soil conditions encountered in the boreholes and laboratory tests (without design discussion and recommendations) of Culvert No. 34 at Station 18+843 are presented in a separate report titled "Foundation Investigation Report".

2.0 SITE AND PROJECT DESCRIPTION

The investigated culvert site (at Station 18+843) is located about 7 m north of Cut Line Road, north of Bayfield, Ontario (Drawing No. 1).

At this location, Highway 21 is a two-lane asphaltic concrete paved road with gravel shoulders on both sides, and runs on top of an embankment built up above the surrounding 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. Site photographs showing the culvert are presented in Appendix C (Photographs 1 and 2).

As noted in Table 1.1 (Section 1.0), the existing culvert at this location is a 1.1 m high x 1.5 m wide x 24.7 m long, concrete rigid frame structure with open footing. Preliminary Drawing No. S1, dated April 2012 (Culvert No. 34, Sheet S20) indicates that the height of the existing embankment at the culvert location is about 2.0 m above the surrounding grade.

Currently, there are existing sand bag retaining walls at all four corners of the existing culvert, which are proposed to be removed and replaced with new header retaining walls at both culvert ends.

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 G35 and G36) were advanced with SPT sampling at the culvert on each side of Highway 21. Borehole BH G35 was drilled, east of Highway 21, near the culvert inlet to an approximate depth of 6.6 m below the existing grade (Elevation 196.8 m). Borehole BH G36 was advanced at mid-shoulder on the west side of Highway 21 to an approximate depth of 9.6 m below the existing grade (Elevation 196.0 m). A monitoring well was installed in BH G35 for hydrogeological study. One borehole (BH G35A) was advanced to about 3.0 m depth beside BH G35 by augering without sampling for installation of a second, shallow, monitoring well. The results of the hydrogeological study are presented in a separate report. The as-drilled borehole locations are presented on Drawing No. 2.

The fieldwork was performed on 7 March 2012 after acquiring all necessary permits for road occupancy, and obtaining clearance for underground utilities. The ground surfaces at the borehole locations were surveyed with reference to the nearest geodetic benchmark (GBM 0011989U064, Sta. 18+377.189, El 203.775).

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

Soil samples were generally taken at 0.76 m intervals for the initial 3 m of the borehole, and 1.5 m thereafter, while performing the Standard Penetration Test (SPT) in accordance with ASTM D1586. This consisted of freely dropping a 63.5 kg (140 lbs.) hammer for a vertical distance of 0.76 m (30 inches) to drive a 51 mm (2 inches) diameter O.D. split-barrel (split spoon) sampler into the ground. The number of blows of the hammer required to drive the sampler into the relatively undisturbed ground by a vertical distance of 0.30 m (12 inches) was recorded as SPT ‘N’ value of the soil which indicated the consistency of cohesive soils or the compactness of non-cohesive soils.

The groundwater conditions were observed in the boreholes during sampling and upon completion of drilling. The groundwater depth measurements are presented on the Record of Boreholes.

Upon completion of drilling, Borehole BH G36 was backfilled with bentonite in accordance with the general requirements of Ministry of the Environment Regulation 903.

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

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.

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

The results of the in-situ and laboratory tests are presented in the corresponding Record of 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 (15);
- Grain size distribution analysis (4);
- Atterberg Limit tests (4); and
- Soil corrosivity (1).

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

5.0 SUB-SURFACE CONDITIONS

Based on the investigation results, the soil profile at the borehole locations consisted predominantly of ground surface cover (topsoil / sand and gravel fill) underlain by fill soils (silty sand) overlying native deposit comprising clayey silt / silty clay, which extended to the termination depths of the boreholes at elevations of about 196.8 m in BH G35, and about 196.0 m in BH G36.

The stratigraphic units and groundwater conditions at the borehole locations are discussed in the following sections. Detailed information is provided in the Record of Boreholes (Appendix

A). Interpolated stratigraphical cross sections through the existing culvert are provided in Drawing No. 3.

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

5.1 Ground Surface Cover

Topsoil

Borehole BH G35 advanced near the toe of the existing culvert inlet encountered topsoil at the existing grade. The measured thickness of the topsoil was about 450 mm. The topsoil consisted primarily of organic matter with some rootlets and soils.

The thickness of topsoil could vary between and beyond the borehole locations. A single moisture content measured in the topsoil was 37 %.

Sand and Gravel Fill

Sand and gravel fill was encountered at the existing grade in Borehole BH G36, which was drilled through the shoulder. The measured thickness of the sand and gravel fill was 300 mm. A single SPT ‘N’ value measured in the sand and gravel fill was 9 blows per 0.3 m. The measured moisture content in the sand and gravel was 10 %.

5.2 Silty Sand Fill

Silty sand fill was encountered below the topsoil in Borehole BH G35, and below the sand and gravel fill in BH G36. The silty sand fill extended to about 0.7 m depth (Elevation 202.7 m) in Borehole BH G35, and 3.5 m depth (Elevation 202.2 m) in Borehole BH G36 below the existing grade.

The silty sand fill was dark brown in color and contained trace to some clay, and trace organic matter. The SPT ‘N’ values within the silty sand fill ranged from 4 to 25 blows per 0.3 m. The measured moisture contents in the silty sand fill ranged from 10 % to 18 %.

5.3 Clayey Silt / Silty Clay

Native clayey silt / silty clay was encountered below the silty sand fill in both boreholes. The clayey silt / silty clay extended to the termination depth of about 6.6 m below the existing grade at Elevation 196.8 m in Borehole BH G35, and termination depth of about 9.6 m below the existing grade at Elevation 196.0 m in Borehole BH G36.

The clayey silt / silty clay was brown to grey in color, and contained trace to some sand to ‘sandy’ and trace gravel. The SPT ‘N’ values of the clayey silt / silty clay ranged from 27 to 41 blows per 0.3 m, indicating a very stiff to hard consistency. The measured moisture contents in the clayey silt / silty clay ranged from 13 % to 15 %.

Grain size analyses and Atterberg Limit tests were completed on 4 samples of the clayey silt / silty clay, the results of which 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 G35	SS 2	0.8 - 1.2 (202.6 - 202.2)	2	21	48	29	26	13	13	CL
BH G35	SS 6	4.6 - 5.0 (198.8 - 198.3)	3	12	47	38	27	13	14	CL
BH G36	SS 6	4.6 - 5.0 (201.0 - 200.6)	2	15	49	34	26	13	13	CL
BH G36	SS 9	9.2 - 9.6 (196.5 - 196.1)	5	13	47	35	26	13	13	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.

Two monitoring wells were installed in Boreholes BH G35 and BH G35A for hydrogeological study. The hydrogeological report is presented separately.

The groundwater measurements are shown on the Record of Boreholes and summarized in Table 5.2.

Table 5.2 - Results of Groundwater Measurements

Borehole	Measured Groundwater Level			Remarks
	Date	Depth (m)	Elevation (m)	
BH G35	7 March 2011	Dry	-	Completion of drilling
	17 May 2012	0.89 m ±	202.51 m ±	In monitoring well
BH G35A	7 March 2011	Dry	-	Completion of drilling
	17 May 2012	0.72 m ±	202.68 m ±	In monitoring well
BH G36	7 March 2011	Dry	-	Completion of drilling

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

5.5 Limited Environmental Investigation

In accordance with the Terms of Reference, soil samples obtained during the geotechnical field drilling program from Borehole BH G35 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 15 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, environmental impact is not anticipated.

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. S0), dated April 2012, for Culvert No. 34 at Station 18+843.
IV. Contract Drawings (CS Submission), Contract No. 2012-3028

The project comprises the following components:

- Replacement of existing sand bag retaining walls at all four corners with new retaining walls;
- Installation of head walls over both ends of the culvert.

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

6.1 Retaining Walls

Based on the cross-section drawing, the length and height of each of the four new retaining walls, one on each end of the culvert, will be about 2.8 m and 2.5 m respectively. Cast-in-place concrete or gravity-type retaining walls or Retained Soil System (RSS) walls are feasible, from the geotechnical viewpoint.

The following sections discuss the geotechnical aspects of feasible new retaining wall types.

6.1.1 Comparison of Retaining Wall Options

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

Table 6.1 - Comparison of Retaining Wall Structure Options

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

Option	Description	Advantages	Disadvantages	Risks / Consequences	Cost Comparison
			Labour intensive for construction. Reinforcing strips may not be durable.		

Considering that the length and height of the new retaining walls at this site, cast-in-place concrete retaining wall may be preferred, from the geotechnical viewpoint, because it can be an integral part of the culvert header and its resistance to scouring is high.

6.1.2 Foundations

Based on the cross-section drawing, the top of the footing of the existing culvert lies at elevations of about 202.3 m and 202.28 m at the inlet and outlet, respectively. The base of the new retaining walls should be at or below the undersides of the existing footings for the culvert, in order to avoid imposing additional loads onto the existing footings. The investigation results for both boreholes BH G35 (inlet) and BH G36 (outlet) indicated that the soil at and below Elevations 202.7 m and 202.2 m would comprise native, very stiff to hard, clayey silt / silty clay. If fill soils are encountered at the founding level, the fill soil should be sub-excavated down to competent native soil. The grade can be restored to the proposed founding elevation by backfilling, with lean concrete, which will prevent water from entering and flowing through the backfill.

For the culvert, cut-off walls, if not already present, should be installed to prevent flow below the culvert that could erode base materials.

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

Table 6.2 - SLS and ULS Values for Design

Borehole No.	Founding Stratum	Depth Below Existing Grade (m)	Approximate Elevation (m)	Geotechnical Reaction at SLS (kPa) (2)	Factored Geotechnical Resistance at ULS(1) (2) (kPa)
BH G35	Very stiff to hard clayey silt / silty clay	0.8 m (±) and below	202.6 m (±) and below	250	375
BH G36	Very stiff to hard clayey silt / silty clay	3.5 m (±) and below	202.2 m (±) and below	250	375

Note: (1) A resistance factor of Φ = 0.5 has been applied to the values provided.
Higher values could be provided, if required, subject to detailed foundation analysis.

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

Table 6.3 - Summary of Geotechnical Parameters

Soil Stratum	Bulk Unit Weight of Soil, γ (kN/m^3)	Angle of Internal Friction (degree)	Earth Pressure Coefficient(1)		
			At-rest, K_o	Active, K_a	Passive, K_p
Existing fill (loose)	17	28	0.53	0.35	2.0
Existing fill (compact)	18	30	0.50	0.33	2.0
Existing granular fill	21	32	0.47	0.30	2.0
Clayey silt / silty clay	20	28	0.53	0.35	2.0
Granular B	21	32	0.47	0.30	2.0
Granular A	22	35	0.43	0.27	2.0

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

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

The culvert footings will have to be protected against scour and erosion by providing rip-rap, vegetative cover, or equivalent as per OPSS 511 and OPSS 1004 and OPSD 810.010. Scour protection should be designed by an experienced engineer.

For construction of foundations, OPSS 902 (Nov/10) (*Construction Specifications for Excavating and Backfilling* - Structures) should be followed. Backfill, backfill transition and cover for the concrete culvert should conform to OPSD 803.010, and those of retaining walls / wingwalls should conform to OPSD 3121.150.

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

The excavation and groundwater control are discussed in Section 6.3 and Section 6.4, respectively.

6.2 Retaining Wall Design

Based on Contract Drawings, the existing sandbags are to be replaced with cast-in-place (CIP) reinforced concrete retaining walls at all corners of the culvert. The details of the walls are shown in Sheets 184 and 185. The walls are about 1.5 m above the top of the existing culvert footing. Typically, as per the Contract Drawings, the bases of the wall foundations are 1.2 m below the top of the existing culvert footing in order to prevent frost heaving. It should be noted that base of the wall foundation should also be a minimum of 1.2 m below finished grade in order to prevent frost heaving.

6.2.1 Slope Stability

A global slope stability analysis was carried out for one typical section at the proposed retaining wall at the west side of the culvert at approximate Station 18+843 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 184 (General Arrangement) of the Contract Drawing prepared in April 2012, the top of the proposed retaining wall at the location is about 1.5 m above the top of the existing culvert footing. The base of the wall foundation is about 1.2 m below the top of existing culvert footing (Elevation 202.3 m). The width and depth of the wall base (foundation) are 2.1 m and 0.6 m respectively. The total wall height, including a 0.6 m deep wall base (foundation), is about 2.7 m. The dimensions of the wall and foundation shown in the contract drawing have been used for the analysis. Road/embankment widening is not planned.

Table 6.4 summarizes the soil parameters used for the global stability analysis. These soil parameters were assumed based on the soil conditions encountered in Boreholes BH G35 and BH G36. The highest groundwater was encountered in a monitoring well installed in Borehole BH G35A, which was installed beside BH G35, at an elevation of about 202.7 m. For the slope stability analyses, groundwater level was assumed at the same elevation as the highest measured groundwater. Granular fill has been assumed behind the wall. For the analysis, it has been assumed that there is no water accumulation behind the wall. Proper drainage system should be constructed to avoid accumulation of water behind the wall.

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

Table 6.4 - Summary of Soil Parameters

Soil Type	Unit Weight (kN/m^3)	Total Stress		Effective Stress	
		c (kPa)	Φ (deg)	c' (kPa)	Φ' (deg)
Existing fill	18	0	28	0	28
Very stiff to hard clayey silt/ silty clay	20	100	0	0	28
Granular Fill	21	0	32	0	32
Retaining Wall	23	200	26	200	36

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

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

Table 6.5: Results of Slope Stability Analysis

Analyzed Section (Station)	Calculated Minimum Factor of Safety	
	Total Stress Analysis (Short Term)	Effective Stress Analysis (Long Term)
18+843	3.4	1. 4

Generally, a minimum factor of safety of 1.3 is required for a stable slope. Based on the results, the calculated minimum factor of safety is greater than 1.3. Therefore, the embankment slope should be stable.

6.2.2 Design Considerations

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

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

6.3 Excavation

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

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

Accordingly, a bank slope of 1H:1V is required for excavations in Type 2 and Type 3 soils in accordance with the Occupational Health and Safety Act and Regulations for Construction Projects. For Type 2 soil, a 1.2 m high vertical cut at the bottom of excavation may generally be constructed. A flatter slope may be required depending on the site and groundwater conditions. The excavation work should comply with OPSS 902 (*Construction Specification for Excavating and backfilling - Structures*). Temporary shoring may be required, if a 1H:1V slope cannot be established during the construction of retaining walls, and should be in accordance with OPSS 539 (Construction Specification for Temporary Protection Systems). The temporary shoring is discussed in Section 6.6.

Excavated materials should be stockpiled at least 3.0 m from the edge of the excavation to avoid slope instability.

Cobbles and boulders should be expected within the soils.

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

6.4 Dewatering and Drain / Ditch Diversion

No major groundwater problem is anticipated during excavation for the proposed culvert extension, although some perched groundwater and/or surface runoff may be encountered. 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. The base of the excavation should be graded towards a sump in order to drain any surface water inflow into the excavation and avoid excessive softening of the founding subgrade.

For the construction of retaining walls, provision must be made to divert water flows from one side of the road to the other during construction, if necessary.

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

A small cofferdam (earth dyke) may be required to keep water flow from entering the work area. Dewatering and drain / ditch diversion activities should proceed ahead of the excavation operation.

6.5 Backfilling

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

The retaining wall 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 µm (according to OPSS 1860) be installed between the free draining granular backfill and earth fill / native soils, or immediately behind and underneath the wall, to prevent migration of fines.

6.6 Temporary Shoring

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

The design of temporary shoring should be carried out in accordance with Section 6.9 of Canadian Highway Bridge Design Code CAN/CSA-S6-06. The soil parameters are provided in Table 6.3 (Section 6.1).

6.7 Erosion Control

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

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

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

6.8 Soil Corrosivity

One soil sample (BH G35 - SS 1B) was analysed by Maxxam Analytics Laboratory in Mississauga to determine the soil corrosivity potential with respect to concrete and steel. The Certificate of Analysis is included in Appendix B. A summary of the test results are presented in Table 6.6.

Table 6.6 - Results of Corrosivity Test

Soil Sample No.	pH	Electrical Conductivity µmho/cm	Resistivity (ohm-cm)	Chloride (µg/g)	Sulphate (µg/g)
BH G35 - SS1B	7.7	290	3400	90	20

The test results have shown that the sulphate content of the soil is 20 ppm (µg/g). As per Table 3 entitled “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 µg/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 (3400 ohm-cm), the degree of corrosivity should be considered as “moderate” for exposed metallic structures. This is based on a comparison of the test results to literature reference (J.D. Palmer, Soil Resistivity Measurement and Analysis, Materials Performance, Volume 13, 1974).

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

6.9 Earthquake Considerations

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

7.0 CLOSURE

The sub-soil information contained in this report should be used solely for the purpose of foundation assessment of the culvert site at Culvert No. 34 at Station 18+843 on Highway 21, Ontario.

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

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

Sincerely,

AMEC Environment & Infrastructure,
a Division of AMEC Americas Limited

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

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

LICENSED PROFESSIONAL ENGINEER
S. MALLA
100025829
PROVINCE OF ONTARIO

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

LICENSED PROFESSIONAL ENGINEER
P. BOONSINSUK
PROVINCE OF ONTARIO

AMEC Environment & Infrastructure,
a Division of AMEC Americas Limited

LIMITATIONS OF REPORT

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

The design recommendations given in this report are applicable only to the project described in the text, and then only if constructed substantially in accordance with the details stated in this report.

The comments made in this report relating to potential construction problems and possible methods of construction are intended only for the guidance of the designer. The number of testholes may not be sufficient to determine all the factors that may affect construction methods and costs. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusions as to how the subsurface conditions may affect their work. This work has been undertaken in accordance with normally accepted geotechnical engineering practices.

This report was prepared specifically for the culvert at Station 18+843 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
Specifications	
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 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
Drawings	
OPSD 208.010	Benching of Earth Slopes
OPSD 803.010	Backfill, backfill transition and cover for the concrete culvert
OPSD 810.010	Rip-rap treatment for sewer and culvert outlets
OPSD 3121.150	Minimum granular backfill requirements - walls retaining

DRAWINGS

SCALE

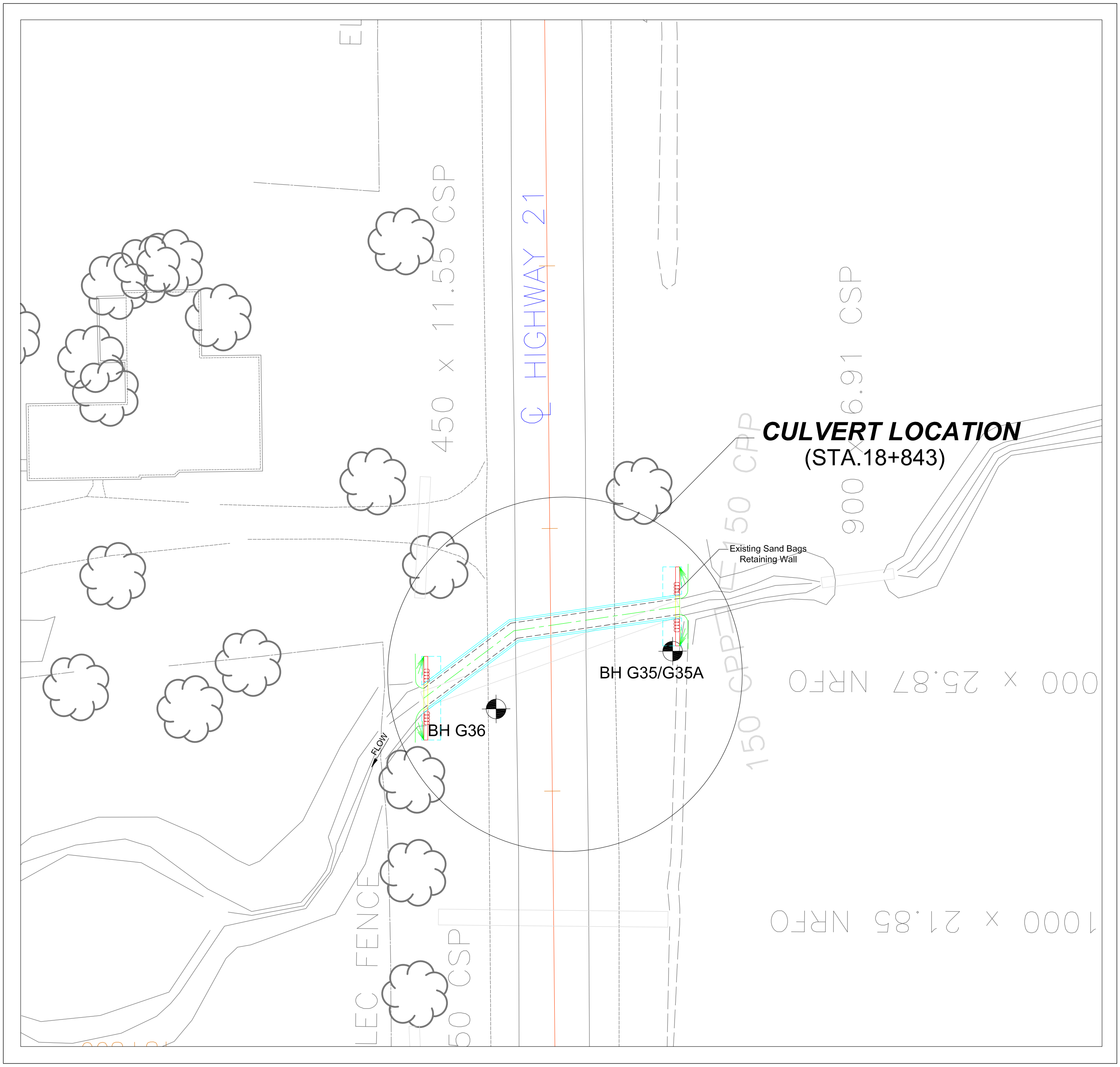
1500m 0 1500 3000 4500 6000m

LEGEND

● CULVERT LOCATION

AMEC Environment & Infrastructure, a Division of AMEC Americas Limited	amec	CLIENT LOGO: Ontario	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, GEOCRES No.: 40P12-19	CHK'D BY: PB	REV. NO.: A	PROJECT NO: TP110076
	PROJECTION: -	SCALE: AS SHOWN	DRAWING No. 1



SCALE

5m 0 5 10 15 20m

AMEC Environment & Infrastructure, a Division of AMEC Americas Limited	amec	CLIENT LOGO Ontario	CLIENT MINISTRY OF TRANSPORTATION ONTARIO WEST REGION

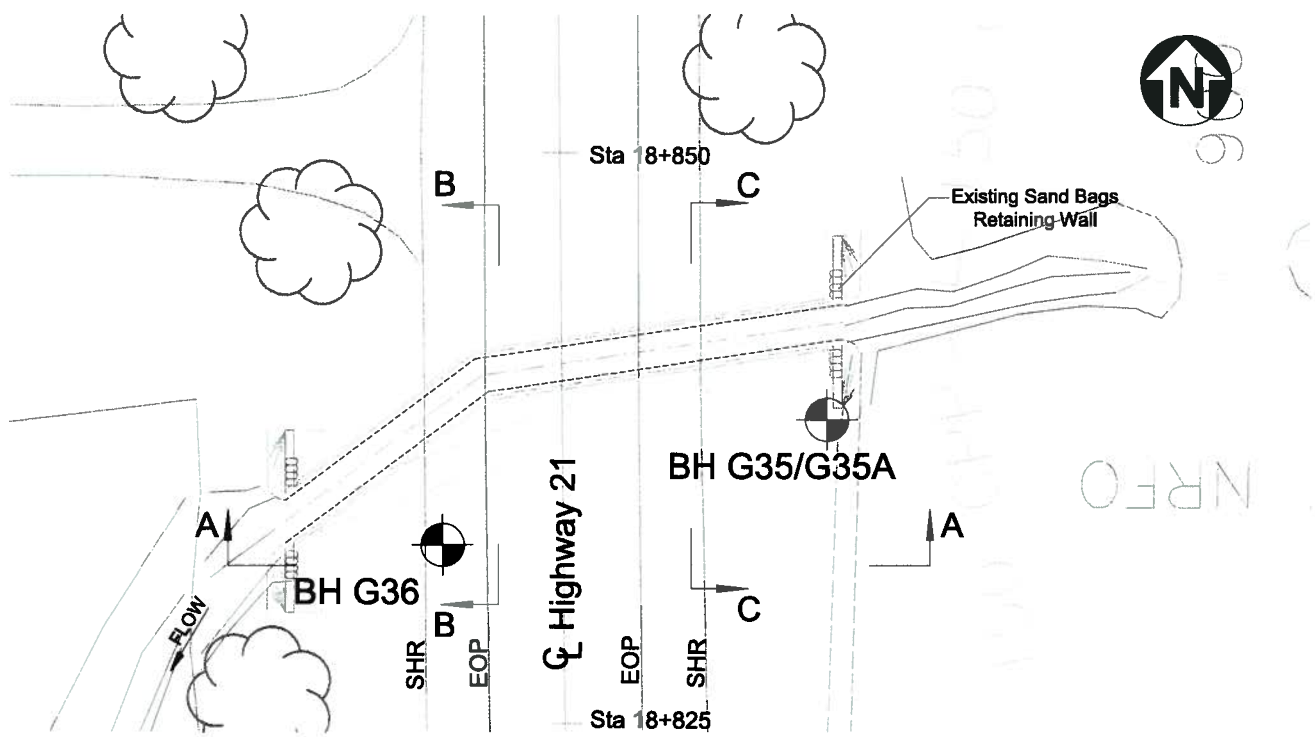
TITLE BOREHOLE LOCATION PLAN	DWN BY: KW	DATUM: -	DATE: JANUARY 2013
PROJECT REHABILITATION OF HIGHWAY 21 - FROM BAYFIELD TO GODERICH PURCHASE ORDER NUMBER: 3009-E-0022, WP 834-93-00, GEOCRES No.: 40P12-19	CHK'D BY: PB	REV. NO.: A	PROJECT NO: TP110076
	PROJECTION: -	SCALE: AS SHOWN	DRAWING No. 2

METRIC

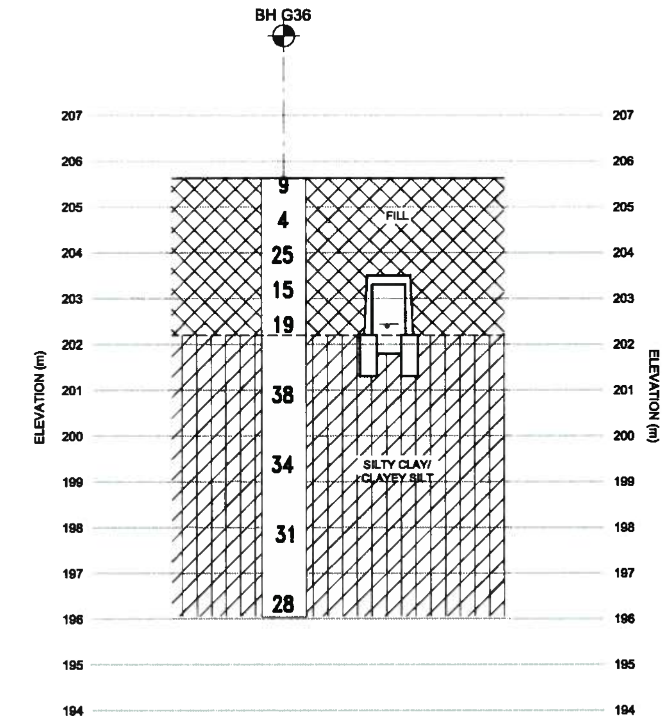
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

PURCHASE ORDER NUMBER:	
3009-E-0022	
G.W.P. No. 834-93-00	
REHABILITATION OF HWY 21 FROM BAYFIELD TO GODERICH GEOCRES No.40P12-19 CULVERT AT STA 18+843 STRATIGRAPHIC CROSS SECTION	SHEET 1 OF 1

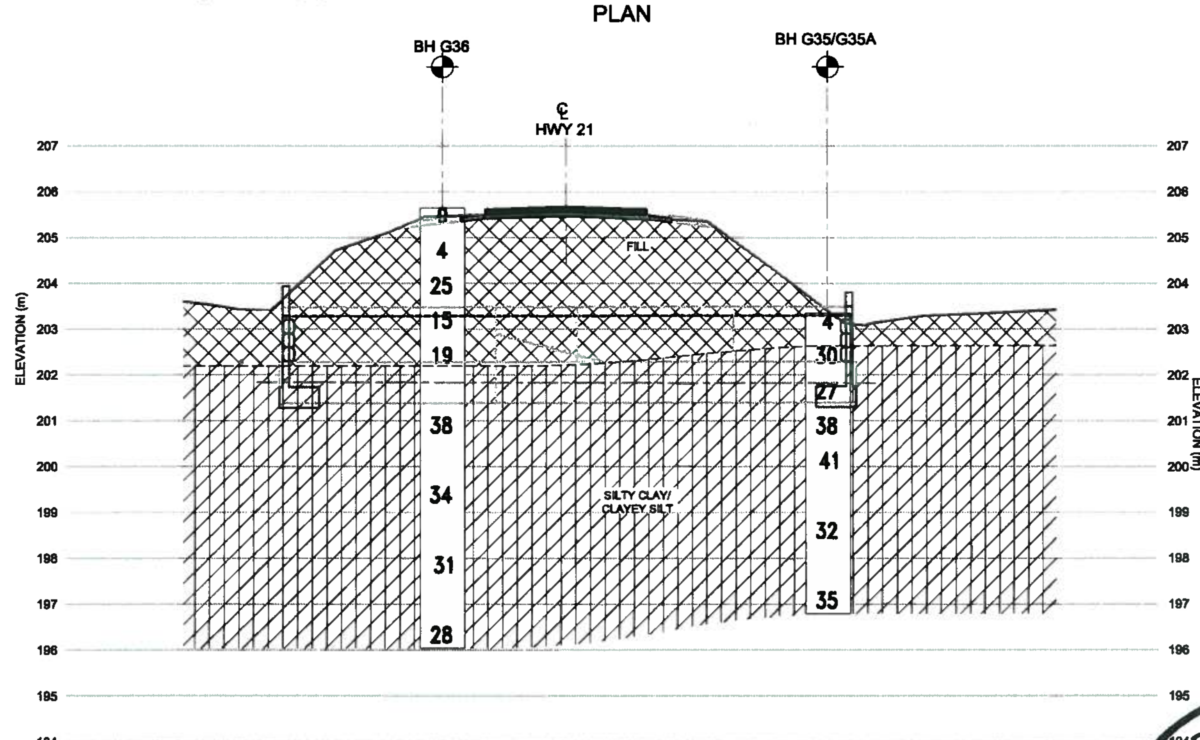
AMEC Environment & Infrastructure, a Division of AMEC Americas Limited



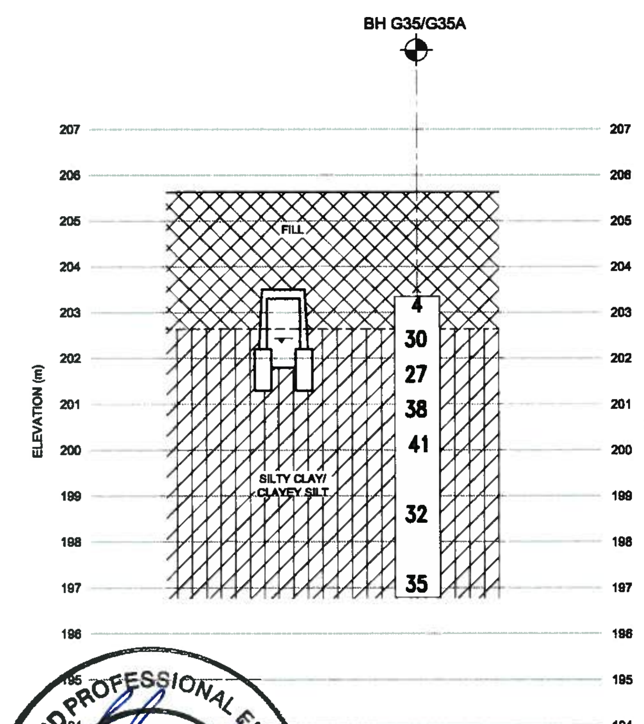
PLAN



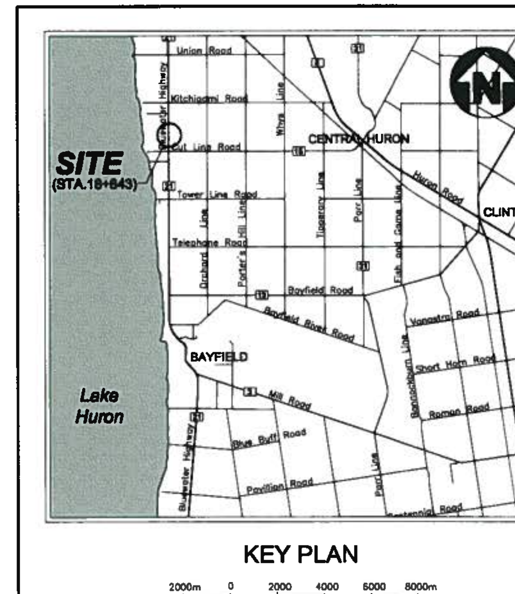
SECTION B-B



SECTION A-A



SECTION C-C



KEY PLAN

Approximate Scale

LEGEND

- BOREHOLE LOCATION
- GROUND WATER LEVEL AT TIME OF INVESTIGATION
- GROUND WATER LEVEL IN MONITORING WELL (HIGHEST)
- EOP EDGE OF PAVEMENT
- SHR SHOULDER ROUND

DESCRIPTION	UTM COORDINATES NORTHING	UTM COORDINATES EASTING	ELEVATION (m)
BH G35	4832867	443099	203.4
BH G36	4832858	443082	205.7

NOTES:

1. 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.
2. This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
3. Borehole without ▽ ▼ was dry.

SOIL STRATIGRAPHY

TOPSOIL   FILL   SILTY CLAY/ CLAYEY SILT

LICENSED PROFESSIONAL ENGINEER S. MALLA 100025829 26 Mar. 2013 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER P. BOONSINSUK 26 Mar '13 PROVINCE OF ONTARIO

SCALE 0 2 4 6m HOR; 0 1 2 3m VER

AMEC Reference: TP110076

DESIGN PB	CHK PB	CODE CHBDC-06	CL 625-ONT	DATE JAN. 2013
DRAWN KW	CHK HS	SITE 18+843		DWG 3

P:\GEO\Projects\2011\TP-Burlington\TP110076-HWY 21\05-Foundation\Drawings...\TB112041 - 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 stratums, 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 Cohesionless Soils	SPT N-Value*
Very loose	0 to 5
Loose	5 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	> 50

Consistency of Cohesive Soils	Undrained Shear Strength kPa
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 PARTICAL 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 DESCRICTIVE INFORMATION, & SYMBOL IN PARENTHESIS.	USE GRAIN SIZE CURVE IN IDENTIFYING THE FACTORS AS GIVEN UNDER FIELD IDENTIFICATION	$C_u = \frac{D_{60}}{D_{10}}$ GREATER THAN 4; $C_C = \frac{(D_{30})^2}{D_{10} X D_{60}}$ BETWEEN 1 AND 3	
		CLEAN GRAVELS (LITTLE OR NO FINES) – 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				
		GRAVEL WITH FINES (APPLICABLE AMOUNT OF FINES) – PLASTIC FINES (FOR IDENTIFICATION PROCEDURES SEE CL BELOW)	GC	CLAYEY GRAVELS, POORLY GRADED GRAVEL-SAND-CLAY MIXTURES				
	SANDS MORE THAN HALF THE COARSE FRACTION SMALLER THAN 4.75mm	CLEAN SANDS (LITTLE OR NO FINES) – WIDE RANGE IN GRAIN SIZE & SUBSTANTIAL AMOUNT OF ALL INTERMEDIATE PARTICLE SIZES	SW	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	FOR UNDISTURBED SOILS ADD INFORMATION ON STRATIFICATION, DEGREE OF COMPACTNESS, CEMENTATION, MOISTURE CONDITION & DRAINAGE CHARACTERISTICS		NOT MEETING ALL GRADATION REQUIREMENTS FOR GW	
		CLEAN SANDS (LITTLE OR NO FINES) – 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 Ip LESS THAN 4	ABOVE A-LINE WITH Ip BETWEEN 4 AND 7 ARE BORDERLINE CASES REQUIRING USE OF DUAL SYMBOLS
		SANDS WITH FINES (APPLICABLE AMOUNT OF FINES) – PLASTIC FINES (FOR IDENTIFICATION PROCEDURES SEE CL BELOW)	SC	CLAYEY SANDS, POORLY GRADED SAND-CLAY MIXTURES			ATTERBERG LIMITS ABOVE A- LINE WITH Ip GREATER THAN 7	

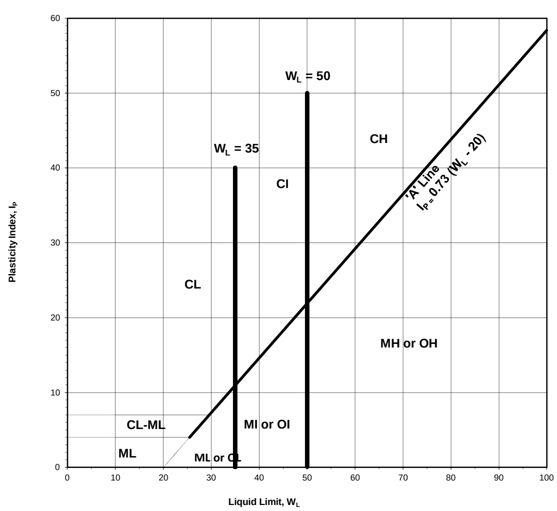
DETERMINE PERCENTAGE OF GRAVEL & SAND FROM GRAIN SIZE CURVE. DEPENDING ON PERCENTAGE OF FINES (FRACTION SMALLER THAN 75 µm) COARSE GRAINED SOILS ARE CLASSIFIED AS FOLLOWS:

LESS THAN 5% – GW, GP, SW, SP
MORE THAN 12% – GM, GC, SM, SC
5% TO 12% – BORDER LINE CASES REQUIRE USE OF DUAL SYMBOL.

FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT SMALLER THAN 75µm) – SILT AND CLAYS – IDENTIFICATION PROCEDURE ON FRACTION SMALLER THAN 425µm

LIQUID LIMIT	DRY STRENGTH (CRUSHING CHARACTERISTICS)	DILATANCY (REACTION TO SHAKING)	TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT)	GROUP SYMBOL	TYPICAL DESCRIPTION	INFORMATION REQUIRED FOR DESCRIBING SOILS	LABORATORY CLASSIFICATION CRITERIA	
LIQUID LIMIT LESS THAN 35	NONE	QUICK	NONE	ML	INORGANIC SILTS & SANDY SILTS OR SLIGHTLY PLASTICITY, ROCK FLOUR	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 DESCRICTIVE INFORMATION & SYMBOL IN PARENTHESIS.	$C_u = \frac{D_{60}}{D_{10}}$ GREATER THAN 6; $C_C = \frac{(D_{30})^2}{D_{10} X D_{60}}$ BETWEEN 1 AND 3	
	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 PLASTICIT, CLAYEY SILTS			
	HIGH	NONE	MEDIUM TO HIGH	CI	SILTY CLAYS (INORGANIC) OF MEDIUM PLASTICITY		NOT MEETING ALL GRADATION FOR SW	
	SLIGHT TO MEDIUM	VERY SLOW	SLIGHT	OI	ORGANIC SILTY CLAYS OF MEDIUM PLASTICITY	FOR UNDISTURBED SOILS AND INFORMATION ON STRUCTURE, STRATIFICATION, CONSISTANCY IN UNDISTURBED AND REMOLDED STATES, MOISTURE & DRAINAGE CONDITION.		
LIQUID LIMIT GREATER THAN 50	SLIGHT TO MEDIUM	SLOW TO NONE	MEDIUM	MH	INORGANIC SILTS, HIGHLY COMPRESSIBLE MICACEOUS OR DIATOMECACOUS FINE SANDY SILTS, ELASTIC SILTS		ATTERBERG LIMITS BELOW A- LINE OR Ip LESS THAN 4	ABOVE A-LINE WITH Ip BETWEEN 4 AND 7 ARE BORDERLINE CASES REQUIRING USE OF DUAL SYMBOLS
	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		ATTERBERG LIMITS ABOVE A- LINE WITH Ip GREATER THAN 7	
HIGH ORGANIC SOILS	READILY IDENTIFIED BY COLOUR, ODOUR, SPONGY FEEL & FREQUENTLY BY FIBROUS TEXTURE			Pt	PEAT AND OTHER HIGHLY ORGANIC SOILS			

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



PLASTICITY CHART
FOR LABORATORY CLASSIFICATION OF FINE GRAINED SOILS

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

AMEC Environment & Infrastructure,
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www.amec.com

MTC SOIL CLASSIFICATION MANUAL

ENGINEERING PROPERTIES OF SOIL

Ontario

TYPICAL NAMES OF SOIL GROUPS	GROUP SYMBOLS	PERMEABILITY WHEN COMPACTED	STRENGTH WHEN COMPACTED	COMPRESSIBILITY WHEN COMPACTED	WORKABILITY AS A CONSTRUCTION MATERIAL	SCOUR RESISTANCE	SUSCEPTIBI LIIY TO SURFICIAL EROSION	SUSCEPTIBILI TY TO FROST ACTION	DRAINAGE CHARACTERISTICS
WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	GW	PERVIOUS	EXCELLENT	NEGLIGIBLE	EXCELLENT	MEDIUM	NEGLIGIBLE	NEGLIGIBLE	EXCELLENT
POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	GP	VERY PERVI0US	GOOD	NEGLIGIBLE	GOOD	MEDIUM	NEGLIGIBLE	NEGLIGIBLE	EXCELLENT
SILTY GRAVELS, POORLY GRADED GRAVEL- SAND-SILT MIXTURES	GM	SEMI-PERVIOUS TO IMPERVIOUS	GOOD	NEGLIGIBLE	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	NEGLIGIBLE TO SLIGHT	PRACTICALLY IMPERVIOUS
WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	SW	PERVIOUS	EXCELLENT	NEGLIGIBLE	EXCELLENT	LOW TO MEDIUM	SLIGHT	NEGLIGIBLE	EXCELLENT
POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	SP	PERVIOUS	GOOD	VERY LOW	FAIR TO GOOD	LOW TO MEDIUM	MODERATE	NEGLIGIBLE 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	NEGLIGIBLE	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 PRACTICALL Y
ORGANIC SILTY CLAY OF MEDIUM PLASTICITY	OI	SEMI-PERVI0US 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 NEGLIGIBLE	NEGLIGIBLE	PRACT I.CALL Y IMPERVIOUS
ORGANIC CLAYS OF HIGH PLASTICITY	OH	IMPERVIOUS	POOR	HIGH	POOR	LOW	MODERATE	NEGLIGIBLE TO SLIGHT	PRACTICALLY IMPERVIOUS
PEAT AND OTHER HIGHLY ORGANIC SOILS	Pt	-	-	-	-	LOW	SEVERE	-	FAIR TO GOOD

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RECORD OF BOREHOLE No BH G35

G.W.P. 834-93-00	LOCATION Sta 18+843, 11.5m E of Rd CL, 3.0m S of Culvert C/L, E443099 N4832867	ORIGINATED BY	JF
DIST Goderich HWY 21	BOREHOLE TYPE 150 mm diameter borehole (Solid Stem)	COMPILED BY	SC
DATUM Geodetic	DATE 7 March 2012 - 7 March 2012	CHECKED BY	SM
PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario		JOB NO.	TP110076

ELEV DEPTH (m)	DESCRIPTION	NUMBER	TYPE	"N" VALUES	DEPTH (m)	ELEVATION SCALE (m)	WATER CONTENT (%)	SOIL VAPOUR READING (PPM)	GR	SA	SI	CL
203.4 0.0	about 450 mm TOPSOIL	1	SS	4		203	37	15				
202.9 0.5	dark brown **Silty Sand FILL** some clay, trace organic matter moist											
202.7 0.7	brown **CLAYEY SILT / SILTY CLAY** some sand to 'sandy' trace gravel very stiff to hard trace cobbles / boulders in SS 3	2	SS	30	1	202	14	5	2	21	48	29
		3	SS	27	2		13	0				
	---- grey	4	SS	38		201	14	0				
		5	SS	41	3	200	15	0				
		6	SS	32	4, 5	199, 198	14	0	3	12	47	38
		7	SS	35	6	197	14	0				
196.8 6.6	**End of Borehole**											

Monitoring well details:

- 50 mm diameter PVC pipe:
- concrete: 0.0 - 0.3 m
- hole plug: 0.3 - 4.5 m
- sand pack 4.5 - 4.6 m
- slotted pipe: 4.6 - 6.1 m
- sand pack: 6.1 - 6.5 m
- protective casing: 0.9 m above ground.

Groundwater level on 7 March 2012: dry

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20, 40, 60; REMARKS & GRAIN SIZE DISTRIBUTION (%)

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

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RECORD OF BOREHOLE No BH G35A

G.W.P. 834-93-00	LOCATION Sta 18+843, 11.5m E of Rd CL, 3.0m S of Culvert C/L, E443099 N4832867	ORIGINATED BY	JF
DIST Goderich HWY 21	BOREHOLE TYPE 150 mm diameter borehole (Solid Stem)	COMPILED BY	SC
DATUM Geodetic	DATE 7 March 2012 - 7 March 2012	CHECKED BY	SM
PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario		JOB NO.	TP110076

SOIL PROFILE: ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	DEPTH m	ELEVATION SCALE m	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L; WATER CONTENT (%) (20 40 60)	SOIL VAPOUR READING PPM	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
203.4 0.0	**Augered down to 3.0 m to install monitoring well** refer to BH G35 for soil information						1 2	203 202 201				
200.4 3.0	**End of Borehole** **Monitoring well details:** - 50 mm diameter PVC pipe: - concrete: 0.0 - 0.3 m - hole plug: 0.3 - 1.5 m - slotted pipe: 1.5 - 3.0 m - protective casing: 0.9 m above ground. Groundwater level on 7 March 2012: dry						3					

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

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RECORD OF BOREHOLE No BH G36

G.W.P. 834-93-00 | LOCATION Sta 18+843, 5.3m W of Rd CL, 2.5m S of Culvert C/L, E443082 N4832858 | ORIGINATED BY JF

DIST Goderich HWY 21 | BOREHOLE TYPE 150 mm diameter borehole (Solid Stem) | COMPILED BY SC

DATUM Geodetic | DATE 7 March 2012 - 7 March 2012 | CHECKED BY SM

PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario | JOB NO. TP110076

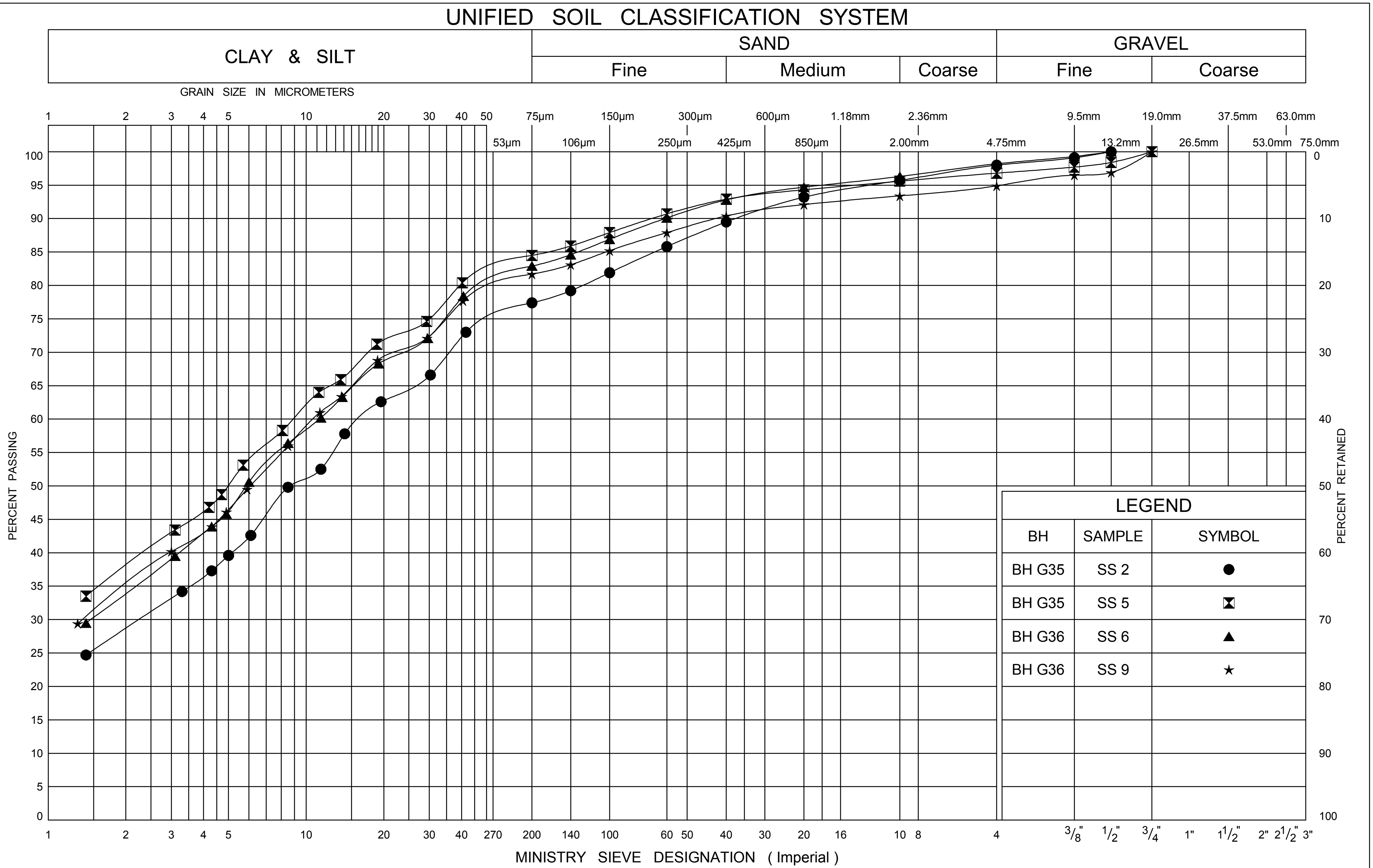
ELEV DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	NATURAL MOISTURE CONTENT (%)	GR	SA	SI	CL
205.7 / 0.0	brown **Sand and Gravel FILL** some silt moist	1	SS	9	10				
205.4 / 0.3	brown **Silty Sand FILL** trace gravel and clay moist	2	SS	4	15				
		3	SS	25	10				
		4	SS	15	18				
	some clay and trace organic matter in SS5	5	SS	19	16				
202.2 / 3.5	light brown / grey **CLAYEY SILT / SILTY CLAY** some sand, trace gravel very stiff to hard	6	SS	38	13	2	15	49	34
	--- grey	7	SS	34	14				
		8	SS	31	14				
		9	SS	28	15	5	13	47	35
196.0 / 9.6	**End of Borehole** Groundwater Level on 7 March 2012: dry								

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20, 40, 60; SOIL VAPOUR READING PPM; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL. Elevation scale 205–197 m; depth scale 1–9 m.

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

APPENDIX B

LABORATORY TEST RESULTS



BH	SAMPLE	SYMBOL
BH G35	SS 2	●
BH G35	SS 5	⧗
BH G36	SS 6	▲
BH G36	SS 9	★

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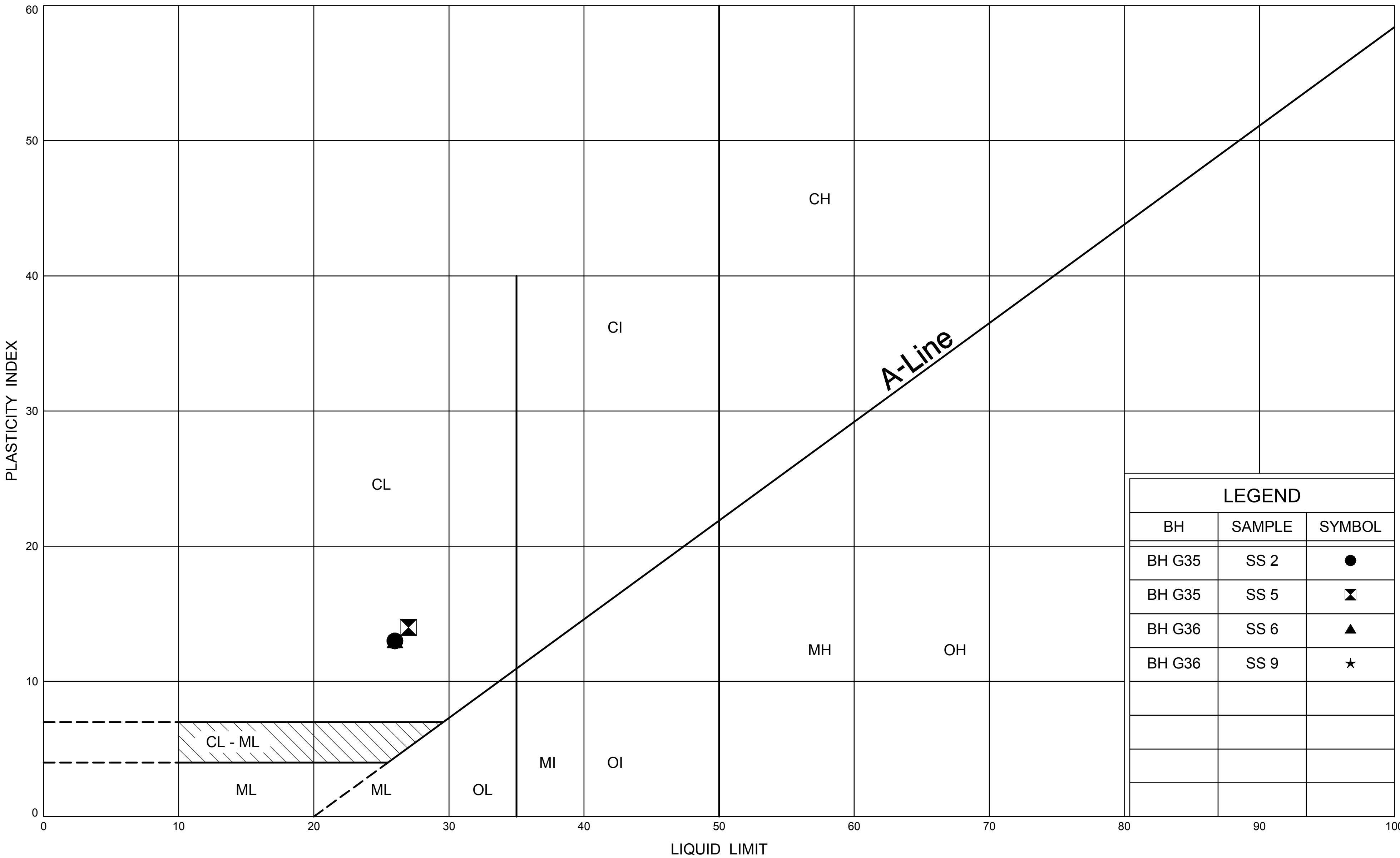
Ontario

GRAIN SIZE DISTRIBUTION
CLAYEY SILT / SILTY CLAY

Figure No. B 1

G.W.P. 834-93-00

Culvert at Sta. 18+843, Hwy 21, Bayfield to Goderich



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PLASTICITY CHART
CLAYEY SILT / SILTY CLAY

Figure No. B 2

G.W.P. 834-93-00

Culvert at Sta. 18+843, Hwy 21, Bayfield to Goderich

Maxxam

Success Through Science®

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

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

Report Date: 2012/03/23

CERTIFICATE OF ANALYSIS

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

Sample Matrix: Soil
Samples Received: 9

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Method Reference
Chloride (20:1 extract)	9	N/A	2012/03/23	CAM SOP-00463	EPA 325.2
Conductivity	9	N/A	2012/03/23	CAM SOP-00414	APHA 2510
pH CaCl2 EXTRACT	8	2012/03/22	2012/03/22	CAM SOP-00413	SM 4500H+ B
pH CaCl2 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

Encryption Key

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

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

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

Total cover pages: 2

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

AMEC Environment & Infrastructure
Client Project #: TP110076.05

RESULTS OF ANALYSES OF SOIL

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

Maxxam ID		MV6499	MV6500		MV6501		MV6502		
Sampling Date		2012/03/16 14:30	2012/03/16 14:40		2012/03/16 15:50		2012/03/16 14:50		
	Units	**G24-SS4**	**G30-SS2**	**QC Batch**	**G37-SS2**	**QC Batch**	**G38-SS2**	**RDL**	**QC Batch**
Calculated Parameters									
Resistivity	ohm-cm	1300	800	2793995	1300	2793995	1100		2793995
Inorganics									
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

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

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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

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

AMEC Environment & Infrastructure
Client Project #: TP110076.05

Test Summary

Maxxam ID MV6500 **Collected** 2012/03/16
Sample ID G30-SS2 **Shipped**
Matrix Soil **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 **Collected** 2012/03/16
Sample ID G37-SS2 **Shipped**
Matrix Soil **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 **Collected** 2012/03/16
Sample ID G38-SS2 **Shipped**
Matrix Soil **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

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Test Summary

Maxxam ID	MV6502 Dup	**Collected**	2012/03/16
Sample ID	G38-SS2	**Shipped**	
Matrix	Soil	**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

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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

			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% 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 (1)	75 - 125	104	85 - 115	<20	ug/g	NC (2)	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).

Cristina Carriere

CRISTINA CARRIERE, Scientific Services

===

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APPENDIX C

SITE PHOTOGRAPHS

HIGHWAY 21, GODERICH, ONTARIO
(CULVERT AT Sta. 18 + 843)

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 34 - Sta. 18+843 (Total Stress Analysis)
C34-18+843 Retaining Wall (19 March 2013).gsz

Name: Granular Fill Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 32 °
Name: Retaining Wall Unit Weight: 23 kN/m³ Cohesion: 500 kPa Phi: 36 °
Name: Existing Fill (ST) Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 30 °
Name: Very Stiff to Hard Silty Clay/Clayey Silt (ST) Unit Weight: 20 kN/m³ Cohesion: 100 kPa

NOTE: For retaining wall, Cohesion = 500 kPa used only for slope stability modelling to disregard slip surface through the wall.

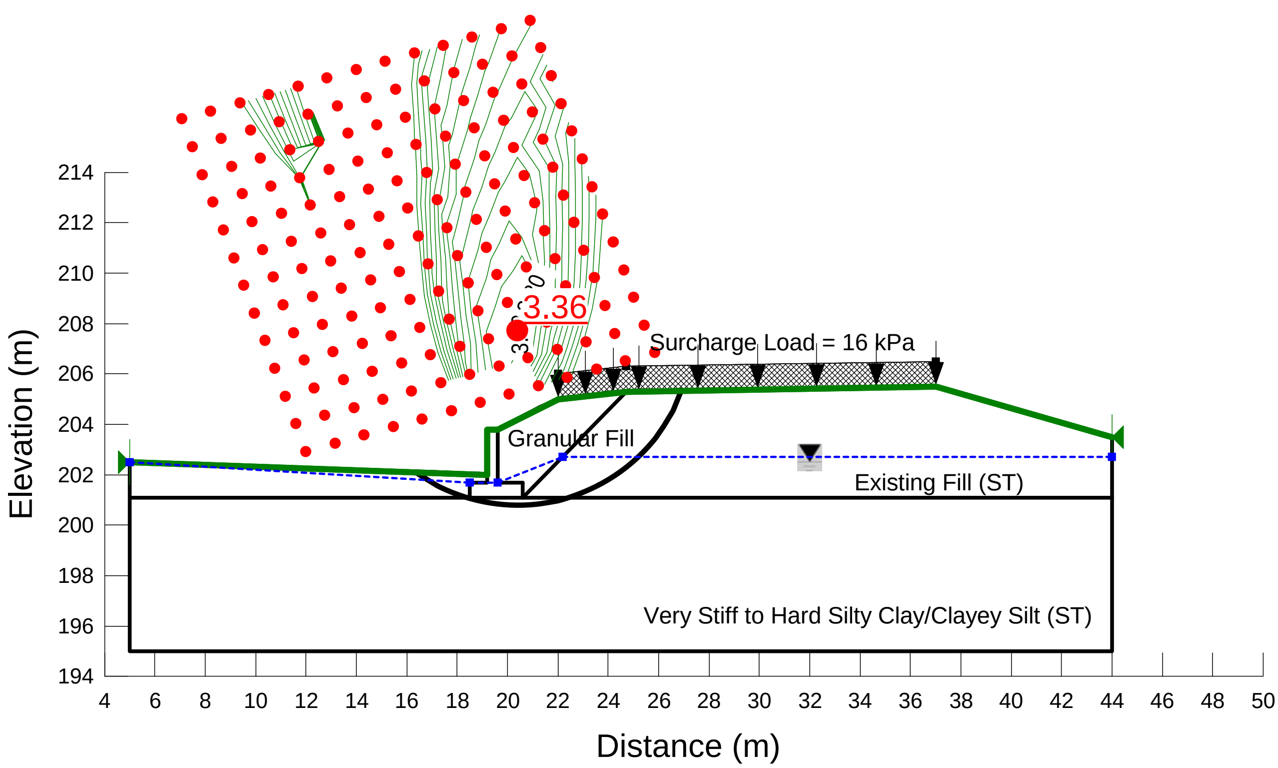

Figure D1 Slope Stability Analysis of Proposed Retaining Wall - Sta. 18+843
(Total Stress Analysis)

TP110076 - Rehabilitation of HWY 21 from Bayfield to Goderich, ON
Culvert 34 - Sta. 18+843 (Effective Stress Analysis)
C34-18+843 Retaining Wall (19 March 2013).gsz

Name: Granular Fill Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 32 °
Name: Very Stiff to Hard Silty Clay/Clayey Silt Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 28 °
Name: Retaining Wall Unit Weight: 23 kN/m³ Cohesion: 500 kPa Phi: 36 °
Name: Existing Fill Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 30 °

NOTE: For retaining wall, Cohesion = 500 kPa used only for slope stability modelling to disregard slip surface through the wall.

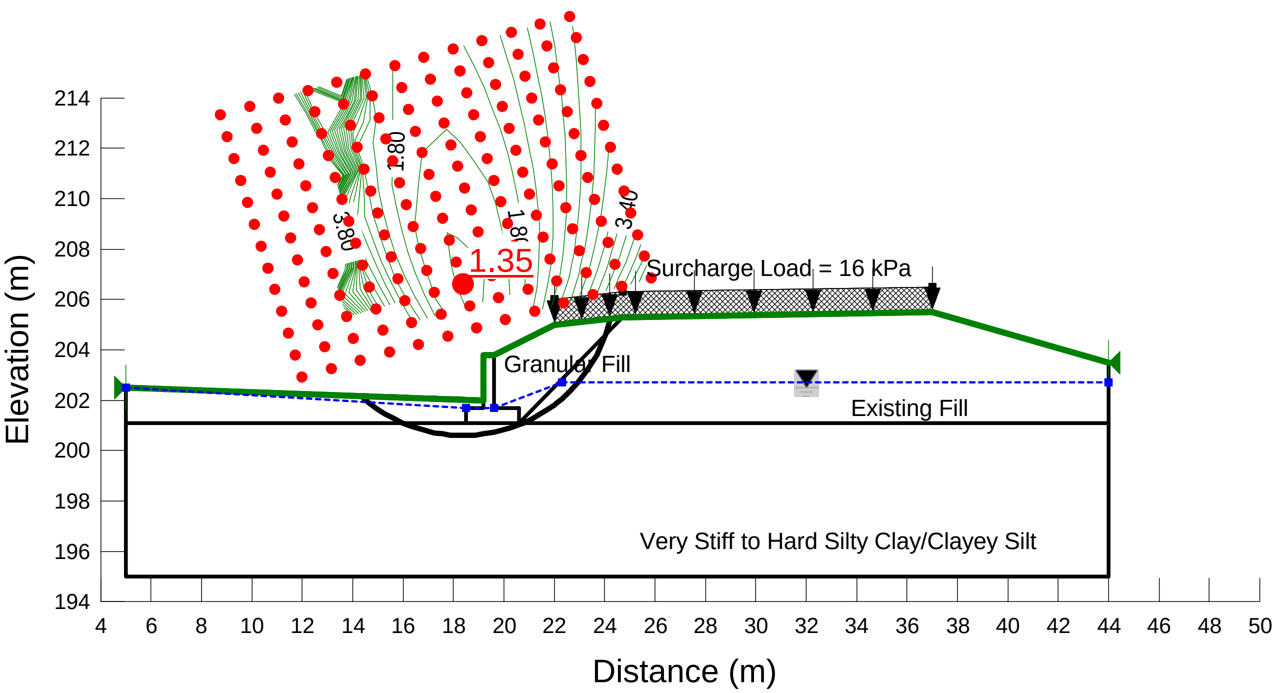

Figure D2 Slope Stability Analysis of Proposed Retaining Wall - Sta. 18+843
(Effective Stress Analysis)