FOUNDATION INVESTIGATION AND DESIGN REPORT

REHABILITATION OF HIGHWAY 21
FROM BAYFIELD TO GODERICH, ONTARIO

CULVERT AT STATION 10+267

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

MTO GEOCRES NO. 40P12-17

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 x1.2 x 27.05 m	BH G28 and BH G29	Replace south west concrete retaining wall with CIP concrete retaining walls. Construct CIP concrete	Two boreholes (southwest and northeast retaining walls)

Station	Existing Culvert		Boreholes Drilled	Proposed Work	Foundation Investigation Requirement
	Type	Dimension			
				wingwall at northeast.	
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 m 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 m 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 Cutline 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 culvert extension at Station 10+267.

The factual results of the soil conditions encountered in the boreholes and laboratory tests (without design discussion and recommendations) culvert extension at Station 10+267 are presented in a separate report titled "Foundation Investigation Report".

2.0 SITE AND PROJECT DESCRIPTION

The investigated culvert site (at Station 10+267) is located about 680 m south of Bayfield River Road, near 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 residential 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 0.9 m wide x 0.9 m high x 38.5 m long, concrete rigid frame structure with open footing. Preliminary Drawing No. 04/2012 (Sheet S2) indicated that the height of the existing embankment at the culvert location was about 6.5 m above the surrounding grade, and the existing road embankment would be widened to the west. Accordingly, the existing culvert may require extension due to road/ embankment widening on the west side of Highway 21. Detail of the culvert extension(s) was not available at the time of preparation of this report.

At the time of field work, the investigated area was 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 Highway 21 Culvert Recommendations Table, two (2) boreholes were advanced at mid shoulder on each side of Highway 21. The as-drilled borehole locations are presented on Drawing No. 2. Each borehole was extended to a depth of about 12.7 m below the existing granular surface, to elevations of about 178.9 m in BH G22 and about 178.7 m in BH G23.

The fieldwork was performed on 6 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 # 101, Sta. 10+194.134, El 188.250 m).

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, grain size analysis, Liquid and Plastic Limits, in-situ water content determination, and soil corrosivity analysis. Testing to determine the corrosivity 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 (22);
- 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 tests are shown in Appendix B.

5.0 SUB-SURFACE CONDITIONS

The investigation results indicated that the soil profile at the borehole locations consisted predominantly of surficial sand and gravel fill underlain by fill soils comprising silty clay / clayey silt and silty sand / sandy silt. The fill soils were underlain by native deposit consisting of clayey silt / silty clay, extending to termination depths of the boreholes at elevations of about 178.9 m in

Borehole BH G22, and about 178.7 m in Borehole BH G23.

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 Fill Soils

5.1.1 Sand and Gravel FILL

Sand and gravel fill was encountered at the existing surface in both boreholes which were drilled through the shoulders. The measured thickness of the sand and gravel fill was about 700 mm (Elevation 190.9 m) in Borehole BH G22, and about 400 mm (Elevation 190.9 m) in BH G21.

Two SPT N-values measured in the sand and gravel fill were 15 and 13 blows per 0.3 m. The moisture contents measured in the sand and gravel fill were 8 % and 6 %.

5.1.2 Silty Clay / Clayey Silt / Silty Sand / Sandy Silt FILL

Silty clay / clayey silt fill was encountered below the sand and gravel fill in both boreholes. In Borehole BH G22, silty sand / sandy silt fill was encountered sandwiched between two deposits of silty clay / clayey silt fill. The fill soils extended to about 7.6 m (Elevations 184.0 m in BH G22 and 183.7 in BH G23) below the existing grade in both boreholes (BH G22 and BH G23).

The fill soils were brown / grey in color and contained trace gravel, cobbles / boulders, organic matter and debris (wood / straw).

SPT N-values measured in the silty clay / clayey silt / silty sand / sandy silt fill ranged from 10 to 39 blows per 0.3 m and the measured moisture contents ranged from 13 % to 27 %.

5.2 Clayey Silt / Silty Clay

Native clayey silt / silty clay was encountered below the fill soils in both boreholes. The clayey silt /silty clay extended to the termination depths of about 12.7 m below the existing grade at elevations of about 178.9 m in Borehole BH G22, and about 178.7 m in Borehole BH G23.

The clayey silt / silty clay was brown / grey in color, and contained trace sand and gravel. The SPT 'N'-values measured within the clayey silt / silty clay ranged from 12 to 74 blows per 0.3 m indicating stiff to hard consistency. The measured moisture contents in the clayey silt / silty clay ranged from 12 % to 17 %.

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 G22	SS 8	7.6 - 8.1 (184.0 - 183.5)	1	3	52	44	31	16	15	CL
BH G22	SS 10	10.7 - 11.1 (180.9 - 180.5)	0	4	76	20	19	13	6	CL-ML
BH G23	SS 8	7.6 - 8.1 (183.7 - 183.3)	1	3	53	43	30	15	15	CL
BH G23	SS 11	12.2 - 12.7 (179.1 -178.6)	4	12	41	43	27	14	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 (Appendix B).

5.3 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling in the open boreholes. Groundwater was measured at a depth of about 10.8 m below the existing grade (elevation 180.5 m) in Borehole BH G23. Borehole BH G22 was dry on completion. 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.

5.4 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 10 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. S2), dated April 2012, for Culvert No. 2 at Station 10+267.
IV. Contract Drawings (CS Submission), Contract No. 2012-3028

The project comprises road / embankment widening on the west side of the existing road to accommodate an additional lane, which may be carried out:

- With culvert extension; or
- No culvert extension, but with retaining wall.

The existing culvert at this location is a concrete, rigid frame structure with open footing (CRF-OF), which is 0.9 m high, 0.9 m wide and 38.5 m long. The invert elevations of the culvert at the outlet and inlet are 183.85 m and 183.84 m respectively. The road embankment at the culvert is approximately about 6.5 m above the surrounding grades. Currently, no headwall or wingwall is in place adjacent to the culvert inlet/outlet.

The following sections discuss the geotechnical aspects of the proposed road / embankment widening on the west side of Highway 21 and culvert extension options. The recommendations should be reviewed if there are changes in the detail design.

6.1 Comparison of Culvert Extension and No Culvert Extension Options

A comparison of these options is provided in Table 6.1.

Table 6.1 - Comparison of Culvert Extension and No Culvert Extension Options

Option	Description	Advantages	Disadvantages	Risks / Consequences	Cost Comparison
Culvert extension	Existing 900 x 900 CRF-OF culvert will be extended to accommodate the widened embankment without the use of a headwall / wingwalls.	Minimum excavation of the existing slope. New embankment at the extended culvert can be constructed from the toe to the top of the new embankment. Traffic protection / shoring may not be required. Lane closure may not be required.	Will require dewatering and/or water flow diversion during construction. Excavation adjacent to and below the existing culvert foundation will be required to install the new culvert section.	Differential settlement could result in poor hydraulic flow (low spots) and ponding within the culvert. May require special permits from the related conservation authority due to disruption of water flow in the creek.	Medium to high
No culvert extension	Retaining wall will be constructed above and on either side of existing culvert to support the widened embankment. (RSS walls, or similar gravity-type walls)	Construction is relatively simple. No need to excavate to the existing footing elevations. RSS walls are flexible type of structure and can accommodate minor relative settlement. Does not significantly interfere with creek water flow. Does not extend beyond the extent of the existing embankment toe.	RSS Wall requires specialised contractor according to MTO's DSM. Lane closure may be required	Temporary shoring may be required for the installation of walls.	low to medium

6.2 Culvert Extension

If the culvert extension option is chosen, the following recommendations should be considered.

The foundation of the existing culvert lies below the elevation of about 183.5 m, and the new foundations are anticipated to be at or below the same grade. Very stiff to hard clayey silt / silty clay is likely to be encountered at the founding elevation.

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

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)	Factored Geotechnical Resistance at ULS[1] (kPa)
BH G22	Hard clayey silt / silty clay	7.6 m (±) and below	184.0 m (±) and below	300	450
BH G23	Stiff clayey silt / silty clay	7.6 - 9.0 m (±)	183.7 - 182.3 m (±)	150	225
	Hard clayey silt / silty clay	9.1 m (±) and below	182.3 m (±) and below	300	450

Note: [1] A resistance factor of Φ = 0.5 has been applied to the values provided.

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

Table 6.3 - Summary of Geotechnical Parameters

Soil Stratum	Bulk Unit Weight of Soil, γ (kN/m^3)	Angle of Internal Friction (degree)	Earth Pressure Coefficient[1]		
			At-rest, K_o	Active, K_a	Passive, K_p
Existing cohesive fill	18	28	0.53	0.35	2.0
Existing granular fill	21	32	0.47	0.30	2.0
Stiff to hard 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 relationships. 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 (*Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting*) and OPSS 1004 (*Material Specifications for Aggregates – Miscellaneous*) and OPSD 810.010 (*Rip-rap treatment for sewer and culvert outlets*). Scour protection should be designed by an experienced engineer.

For construction of culvert 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 (*Backfill, backfill transition and cover for the concrete culvert*). The excavation and groundwater control are discussed in Section 6.6.

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

6.3 No Culvert Extension, but with Retaining Wall

If the existing culvert is not extended, a retaining wall (e.g., RSS, cast-in-place retaining wall, or gravity-type retaining walls) will be required to support the widened embankment. Based design drawing, the base of the retaining wall would be at an approximate elevation of 184.0 m, and the height of proposed wall would be 4.5 to 5.0 m.

Cast-in-place concrete or gravity-type retaining walls (e.g., Retained Soil System (RSS) walls) are feasible, from the geotechnical viewpoint.

6.3.1 Comparison of Retaining Wall Options

A comparison of the feasible retaining wall structures is provided in Table 6.4.

Table 6.4 - Comparison of Retaining Wall Structure Options

Option	Description	Advantages	Disadvantages	Risks / Consequences	Cost Comparison
Cast-in-place concrete retaining wall	Typically, cantilever, reinforced-concrete, retaining wall.	Durable and low maintenance. Not susceptible to erosion by water flow and ice forces. No specialized contractor is needed. Can be constructed as integral part of culvert header.	Rigid structure which may show minor cracks. Labour intensive for placing reinforcing bars and formwork. Possible need more time for construction to allow for curing concrete.	Temporary slope excavated into the existing road embankment may have to stand up longer before backfilling.	Medium to high
Gravity Type retaining wall-Gabion	Gabions are rectangular steel baskets filled with stone and stacked on one another.	Construction is relatively simple. Flexible type of structure Drain freely.	Gabions are labour-intensive in order to properly place stones inside the gabion baskets. Steel cages may not be stable in long term. Gabion may be subject to erosion by creek water flow and ice forces.	Maintenance or replacement may be frequent. Possibly too high for a 5 m high retaining wall.	Low to medium
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	Possibly too high for a 5 m high retaining wall.	Low to medium

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. Labour intensive for construction. Reinforcing strips may not be durable.	May require some maintenance	Medium

Considering the length and height of the new retaining walls at this site, cast-in-place concrete retaining wall may be suitable, from the geotechnical viewpoint, because it can be an integral part of the culvert header and its resistance to scouring is high. A RSS retaining wall may be preferred due to lower cost. If an RSS wall is preferred, it should be protected against scouring.

6.3.2 Foundations

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 retaining wall.

Stiff to hard clayey silt / silty clay is likely to be encountered at the founding elevation, although Borehole BH G23 indicates that some sub-excavation to remove fill soils could be required. Sub-excavation may also be required to remove any topsoil, loose / soft soils, and / or otherwise deleterious materials, if any. If sub-excavation is required, the grade could be restored by placing lean concrete or compacted 20 mm crusher-run limestone (or approved similar) up to the proposed founding elevation.

The design frost penetration depth of 1.2 m should be considered in the design of the retaining wall.

For sliding resistance, the following un-factored coefficient of friction should be considered at the base of wall:

- Granular fill and cohesive subgrade : 0.44
- Concrete and Granular fill: 0.44

- Concrete and cohesive subgrade : 0.38

A resistance factor of 0.8 should be considered.

The backfilling for retaining 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, in accordance to OPSS 1860 (*Material Specification for Geotextiles*) 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.

If retained soil system (RSS) wall is selected, the design of the RSS wall should be carried out as per the manufacturer's specifications based on the type of wall selected. Ministry of Transportation's (MTO) RSS Design Guidelines, including the Non Standard Special Provision for RSS (January 2008) included therein, and/or Special Provision to OPSS - SSP599S23, should be used for the design, supply and construction of the RSS, in addition to any contract requirements and RSS manufacturer's standards. RSS Wall requires specialised contractor according to MTO's DSM.

All excavations should be carried out in accordance with the Occupational Health and Safety Act and Regulations for Construction Projects. The excavation and dewatering are discussed in details in Section 6.6.1.

***Excavations to replace fill / incompetent soils with lean concrete or compacted granular fill below the proposed wall should be carried out carefully to ensure that the existing foundation of the adjacent culvert is not compromised*.**

A small cofferdam (earth dyke) may be required to keep water flow from entering the work area. Dewatering plans must also consider any flow from the road side ditches that enter into the culvert.

A traffic protection (temporary shoring system) and lane closure will likely be required if the existing embankment toe has to be deeply excavated for the construction of the RSS wall.

6.4 Embankment Widening Construction

Based on the cross-section of Highway 21 at the culvert location (Sheet 165 of the Contract Drawing), the existing roadway is approximately 7 m wide, and runs on top of an embankment built up approximately about 6.5 m above the surrounding grades. The cross-section drawing also shows that the roadway will be widened by approximately 3.5 m on the west side of the roadway. The widening would require placement of up to about 4.5 m thick new fill over the existing slope surface and toe areas.

The embankment widening should be constructed with compacted engineered fill at 2H:1V (or flatter) side slopes. The construction should be carried out in accordance with OPSS 206 (*Construction Specification for Grading*). Backfill should be placed according to OPSS 206 and compacted according to OPSS 501 (*Construction Specification for Compactin*g). Bonding between the existing embankment fill and new fill should be achieved as per OPSD - 208.010 (*Benching of Earth Slopes*). The selection, placement and compaction of the fill should be carried out under a geotechnical control program.

All topsoil, organic matters, soft / loose and unsuitable soils should be removed from an area within a plane extending, from the footprint of the proposed widening, upwards at a slope of 1H:1.5V as per OPSS 501. Topsoil should also be stripped from existing slope prior to placement of new embankment fill. The subgrade preparation will require stripping of a minimum of 300 mm surficial fill soils (Elevation 184.5 m) under the footprint area of the embankment widening and replacement with compacted engineered fill. If deeper excavation is required during construction, a temporary shoring system (trench box / sheet piles / soldier piles and lagging) may be required. The stripping / removal of the soft / loose soil at the embankment toe should be carried out such that any instability to the existing road embankment is prevented.

After stripping, the exposed subgrade should be inspected. Any soft spots identified during stripping and/or re-compacting should be sub-excavated and replaced with compacted engineered fill. Care should be exercised to minimize disturbance to the subgrade during preparation and the construction of embankment.

The fill soils used for the proposed embankment widening should consist of approved, clean granular fill (e.g. Select Subgrade Materials - OPSS 1010). The compaction should comply with OPSS 501.

Provided that the new fill is properly compacted on the existing embankment side slope, its post-construction settlement should not exceed 40 mm.

The construction of the road embankment widening will likely require the closure of southbound traffic lane, unless a construction detour can be provided. Proper traffic control is necessary, if one traffic lane is closed.

Proper erosion control measures of the existing and new embankment surfaces should be implemented, both during construction and on a permanent basis. This can be achieved by immediate seeding or sodding (OPSS 572 - *Construction Specification for Seed and Cover*) or equivalent.

6.5 Retained Soil System (RSS) Design

The option of embankment widening including construction of a retaining wall without culvert extension has been selected in the detail design. For the retaining wall, a RSS wall has been proposed. The details of the widening, including RSS wall, are shown in Sheet 165A (General Arrangement, Station 10+267) and Sheet 207A (General Arrangement, Retained Soil System) of the Addendum to Contract Drawing prepared April 2, 2013. Global slope stabilities were carried out for three different critical sections along RSS walls, as follows (refer to Figure D1 in Appendix D):

- *Section from intersection of Highway 21 and Jowett's Grove Road to approximate Station 10+250 of Highway 21*: Global stability analysis was carried out for the RSS wall at approximate Station 10+241 (Highway 21) at the location of the Culvert No. 1, which is discussed in the separate report prepared for Culvert No. 1 at Station 10+241 (*Geocres No. 40P-16*).
- *Section from approximate Station 9+950 in Jowett's Grove Road to its intersection with Highway*: Global stability analysis was carried out for the RSS wall at approximate Station 9+958 at the location of the proposed retaining/header wall, which is discussed in the separate report prepared for Culvert No. 1 at Station 10+241 (*Geocres No. 40P-16*)..
- *Section from approximate Station 10+250 to the end of RSS wall at Station 10+280 on Highway 21*: Global stability analysis was carried out for the RSS wall at approximate Station 10+267 (Highway 21) at the location of Culvert No. 2, which is discussed in this section.

6.5.1 Slope Stability Analysis

A global slope stability analysis was carried for the proposed embankment widening with RSS retaining wall for section from Station 10+250 to the end of RSS wall at Station 10+280 on Highway 21 (refer to Figure D1, Appendix D). The analysis was carried for the proposed embankment widening with RSS retaining wall over and just beside the culvert at approximate Station 10+267, which represents a critical area within the road section analyzed. The analysis was carried out 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. The analysis has been carried out to determine the minimum reinforcing strip width of RSS wall required for the global stability of the wall and embankment. Additional stability analysis for non-circular slip surface over the culvert top (Station 10+267) was also carried out.

For the analysis at this location, a reinforcing strip width equal to the height of the wall (6.8 m) has been considered for global stability. For internal stability of the RSS wall including overturning and sliding, the width of reinforcing strip within the RSS wall is to be designed by the RSS wall supplier/designer in accordance with "*RSS Design Guidelines, MTO*" (refer to Section 6.3.2).

As per Sheet 165A (General Arrangement, Station 10+267) and Sheet 207A (General Arrangement, Retained Soil System) of the Addendum to Contract Drawing prepared in April 2, 2013, the height of the proposed retaining wall is about 5.8 m above the top of the culvert, with the toe of RSS about 0.6 above the top of the culvert. The embedment of wall below the toe is about 0.3 at the culvert location. For the slope stability analysis beside the culvert, the wall is considered to be founded on the native soil, which gives a total wall height of about 6.8 m. If the actual footing elevation and/or the wall height is/are significantly different in the final RSS wall design, a slope stability analysis should be carried out based on the actual design. The top of the embankment (road) is proposed to be widened by about 7 m at the culvert location.

Table 6.5 summarizes the soil parameters used for the global stability analysis. These conservative soil parameters were considered based on the soil conditions encountered in Boreholes BH G22 and BH G23. Groundwater was encountered in Borehole BH G23 at an elevation of about 180.5 m. For the slope stability analyses, the groundwater was assumed to be just above the invert of the culvert, which would be at an elevation of about 184.0 m, to account for potentially highest groundwater level. Granular fill has been considered for the proposed widening, as shown in Sheet 165A of the Contract Drawing. For the analysis, it has been assumed that there is no perched water behind the wall. Proper drainage system should be constructed to avoid accumulation of water behind the wall.

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

Table 6.5 - Summary of Soil Parameters

Soil Type	Unit Weight (kN/m^3)	Total Stress		Effective Stress	
		c (kPa)	Φ (deg)	c' (kPa)	Φ' (deg)
Existing cohesive fill (stiff to hard)	18	50	0	0	28

Soil Type	Unit Weight (kN/m^3)	Total Stress		Effective Stress	
		c (kPa)	Φ (deg)	c' (kPa)	Φ' (deg)
Hard clayey silt/ silty clay	20	100	0	0	28
Granular Fill	21	0	32	0	32
Retained Soil System	23	0	35	0	35
RSS retaining wall (for circular slip surface)*	24	200	38	200	38

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

The results of the slope stability analysis are presented in Appendix D. Table 6.6 summarizes the results of slope stability analysis.

Table 6.6: Results of Slope Stability Analysis

Analyzed Section (Station)	Calculated Minimum Factor of Safety	
	Total Stress Analysis (Short Term)	Effective Stress Analysis (Long Term)
10+267 (circular slip surface)	2.3 (Figure No. D1)	1.5 (Figure No. D2)
10+267 (non-circular slip surface over the culvert)	1.6 (Figure No. D3)	

Generally, a minimum factor of safety of 1.3 is considered for a stable slope. Based on the results, the calculated minimum factor of safety is equal to or greater than 1.5. Therefore, the RSS wall should be stable, provided that the width of the reinforcing strip is equal to the height of wall. Additionally, on both sides of the culvert (beside and beyond the culvert), the RSS wall should be founded on competent native soil.

6.5.2 Design Considerations

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

- The RSS wall should be founded on native soil within this section (from approximate Station 10+250 to 10+270 on Highway 21. The wall height within this section would be generally about 7.0 (from top of the wall to the founding level). Recommendations provided in Section 6.3 should be followed for design of the RSS 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 RSS wall. As the Sheet 207A of the contract drawings, in the remaining portion of the wall at the north limit of the RSS wall (approximately Station 10+270 to 10+280), the RSS wall height varies from about 0.6 m to 4.0 m (top of the wall to founding level) and will possibly be founded on new fill, which as per Sheet 165A is proposed to be granular fill. Provided that the granular fill is compacted properly, a bearing capacity of 100 kPa (SLS) and 150 kPa (factored ULS) can be used for the granular fill. The founding subgrade for the wall should be inspected and verified by the Contract Administrator.

- The reinforcing strip length for the RSS wall should be equal to the height of the wall (about 0.6 m to 7.0 m). The RSS wall design should be carried out as per the manufacturer's specifications based on the type of wall selected. In addition to any contract requirements and the RSS manufacturer's standards, MTO's "*RSS Design Guidelines*" should be used for the design, supply and construction of the RSS. It should be noted that RSS wall requires specialised contractor listed in MTO's DSM.
- Adequate and proper drainage system should be provided behind the RSS wall to prevent accumulation of water behind wall. Otherwise, the minimum reinforcing strip length may have to be increased.
- Potential differential settlement between the RSS wall founded on top of the culvert and the RSS wall founded on native soil beside the culvert should be taken into consideration in the RSS wall design.

6.6 Other Construction Considerations

6.6.1 Excavation, Dewatering and Detouring

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:

Fill soils (silty clay / clayey silt / silty sand / sandy silt)	Type 3
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 culvert extension, and should be in accordance with OPSS 539 (*Construction Specification for Temporary Protection Systems*). The temporary shoring is discussed in Section 6.6.3.

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

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

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.

Provision must be made to divert water flows from one side of the road to the other during construction, if required.

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

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

6.6.2 Culvert Backfilling

The backfilling for culvert should 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 should be brought up simultaneously on each side of the culvert extension and operation of heavy equipment within 0.5 times the height of the culvert on (each side) should be restricted to minimize the potential for movement and / or damage of the culvert due to lateral earth pressure induced by compaction (OPSS 501 is referred for additional comments).

Backfill and cover for the culvert extension should conform to OPSD 803.010.

6.6.3 Temporary Shoring

Proper shoring in order to support the sides of excavation may be needed for the construction of the culvert extension, if open excavation cannot be used due to site restriction.

The temporary protection systems should comply with OPSS 539. 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 6.2).

6.6.4 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 (*Construction Specification for Topsoil*), OPSS 803 (*Construction Specification for Sodding*) and OPSS 804 (*Construction Specification for Seed and Cover*), as soon as possible. Where slopes are inclined at 2.H:1V or steeper, the slopes should be protected with erosion control blankets.

6.6.5 Construction Inspection

During installation of culvert extension, the road surface may experience settlement and / or horizontal movement. Good workmanship and site control is the most effective way to reduce settlements to practical minimum. It is recommended that ground movement during construction be monitored. This is to confirm that the culvert extension installation does not cause any significant impact on the existing soil and groundwater conditions. If any adverse effect of culvert extension is identified by the monitoring program, the construction can be modified accordingly.

6.7 Soil Corrosivity

To determine the soil corrosivity potential with respect to concrete and steel, one soil sample (BH G22 - SS 6) 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 6.7. The Certificate of Analysis is included in Appendix B.

Table 6.7 - Results of Corrosivity Test

Soil Sample No.	pH	Electrical Conductivity (µmho/cm)	Resistivity (ohm-cm)	Chloride (µg/g)	Sulphate (µg/g)
BH G22 – SS 6	7.6	292	3400	90	25

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 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 (if required).

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 10+267 on Highway 21, near Bayfield, Ontario.

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

This report was prepared by Mohammad Mollah, M.Eng., P.Eng., and 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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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 10+267 in Highway 21 near Bayfield, Ontario, as described in the report. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. AMEC Environment & Infrastructure, a Division of AMEC Americas Limited, accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

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

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

SCALE

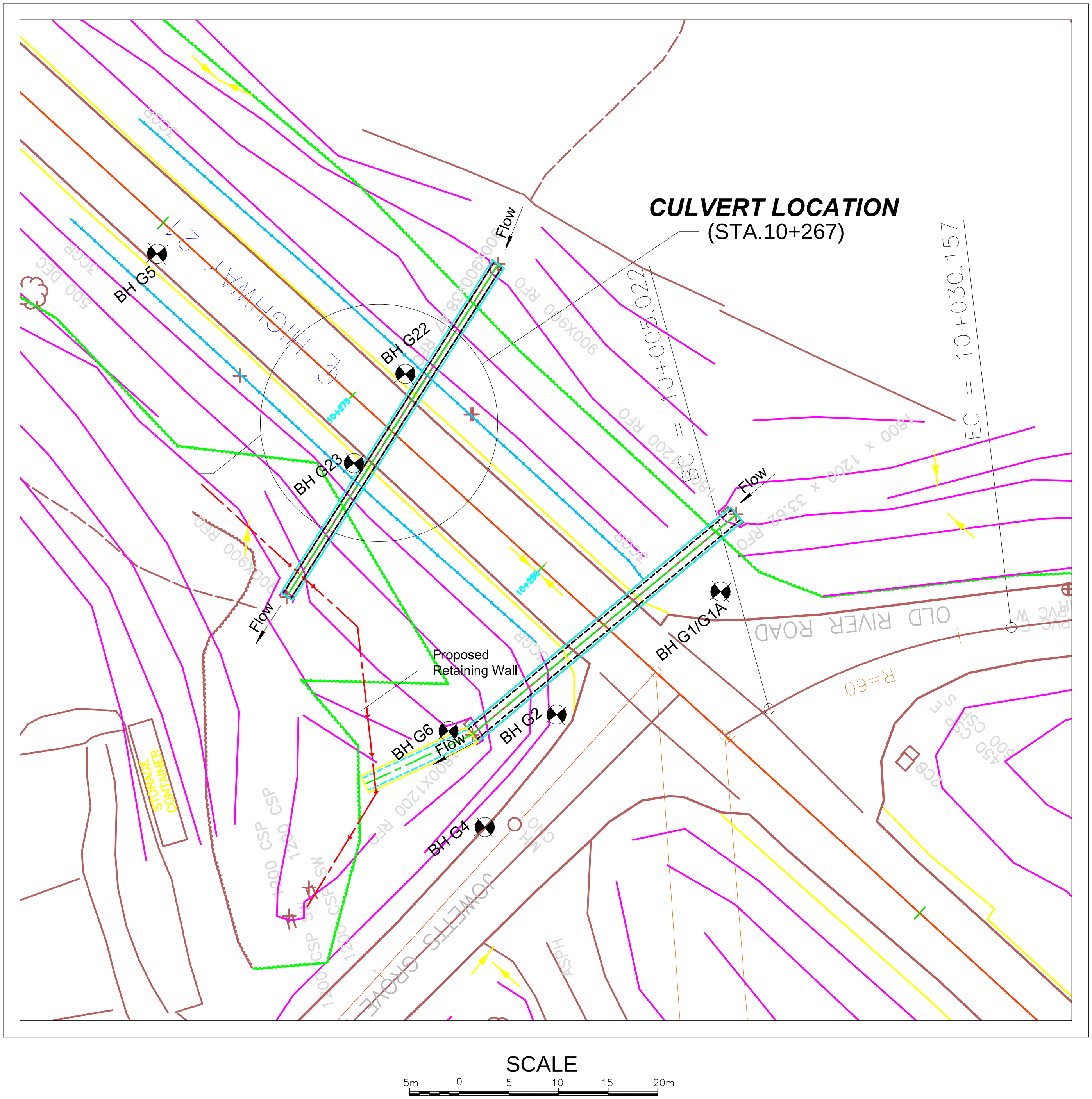
1500m 0 1500 3000 4500 6000m

LEGEND

● CULVERT LOCATION

AMEC Environment & Infrastructure, a Division of AMEC Americas Limited	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	CHK'D BY: PB	REV. NO.: A	PROJECT NO: TP110076
PURCHASE ORDER NUMBER: 3009-E-0022, WP 834-93-00 GEOCRES No.: 40P12-17	PROJECTION: -	SCALE: AS SHOWN	DRAWING No. 1



AMEC Environment & Infrastructure,
a Division of AMEC Americas Limited

CLIENT LOGO: Ontario

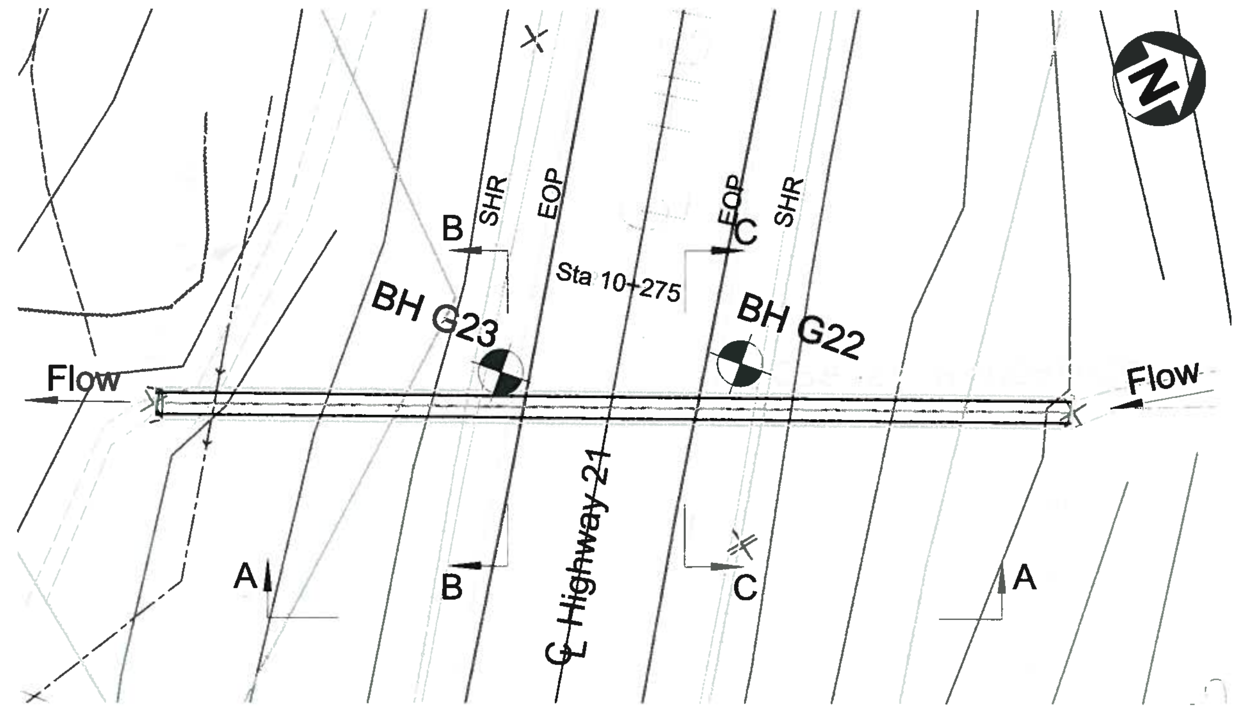
CLIENT: MINISTRY OF TRANSPORTATION ONTARIO WEST REGION

TITLE: BOREHOLE LOCATION PLAN

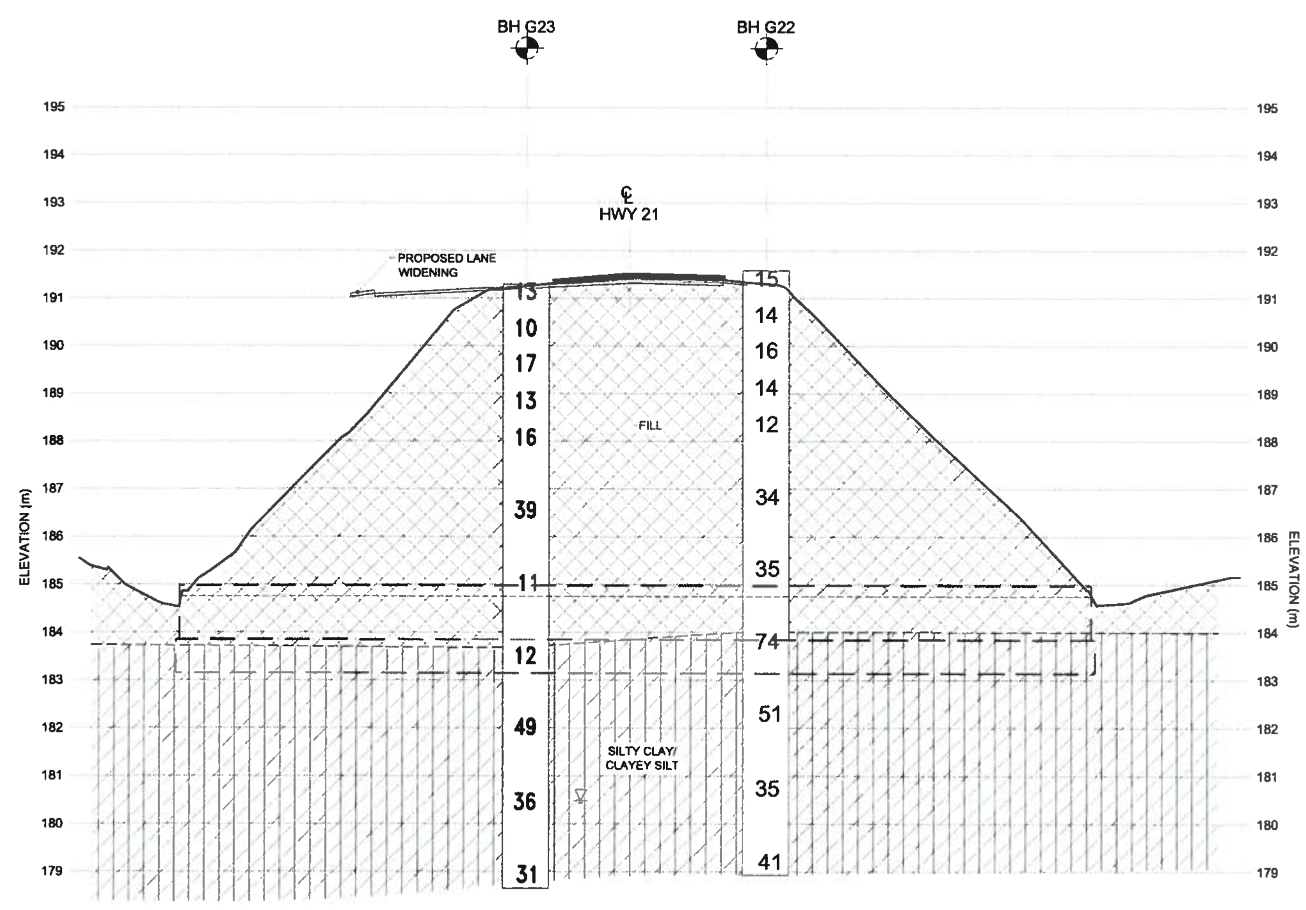
PROJECT: REHABILITATION OF HIGHWAY 21 - FROM BAYFIELD TO GODERICH

PURCHASE ORDER NUMBER: 3009-E-0022, WP 834-93-00, GEOCRES No. 40P12-17

DWN BY: KW	DATUM: -	DATE: JANUARY 2013
CHK'D BY: PB	REV. NO.: A	PROJECT NO: TP110076
PROJECTION: -	SCALE: AS SHOWN	DRAWING No. 2

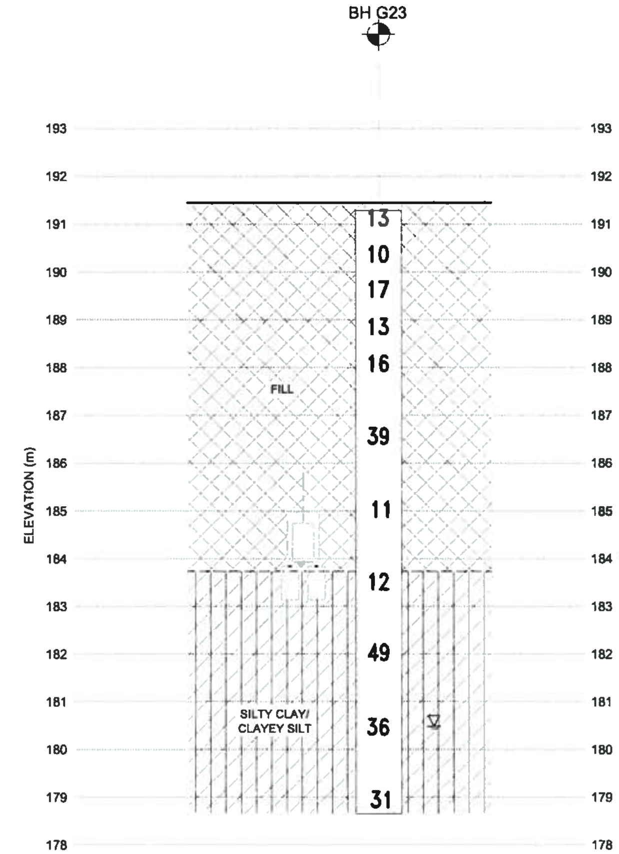


PLAN

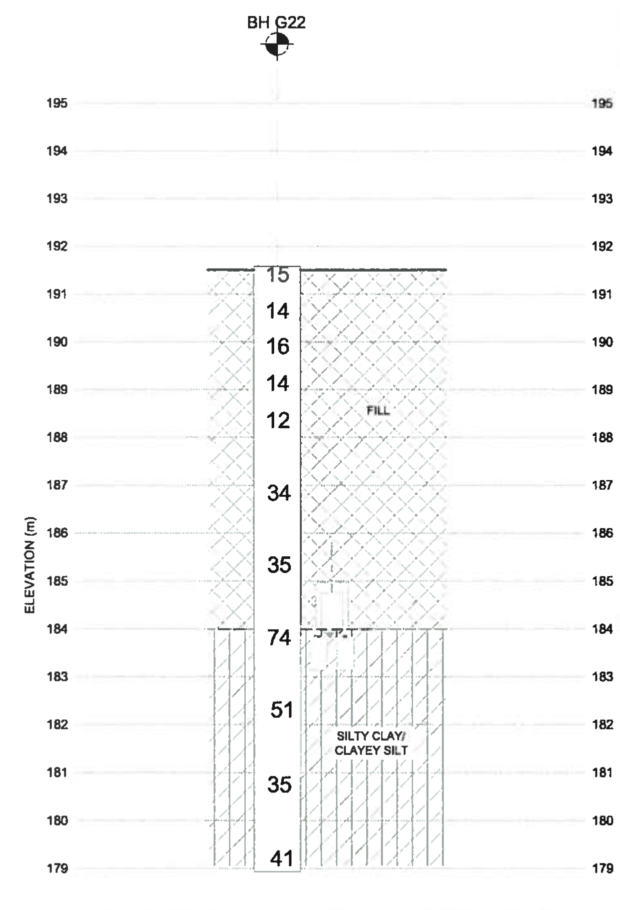


SECTION A-A

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



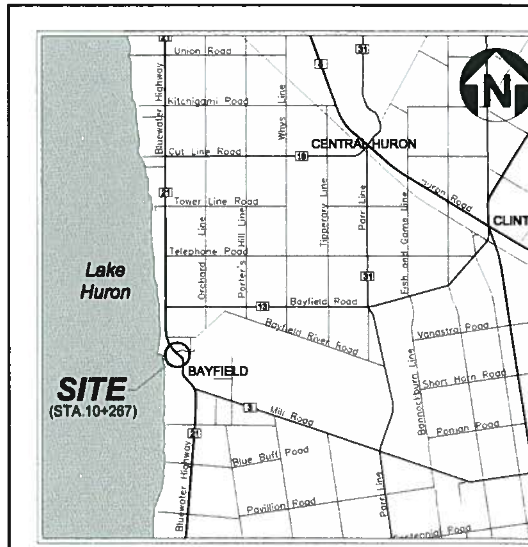
SECTION B-B



SECTION C-C

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.40P12-17 **CULVERT AT STA 10+267** STRATIGRAPHIC CROSS SECTION	**SHEET 1 OF 1**
amec AMEC Environment & Infrastructure, a Division of AMEC Americas Limited	



KEY PLAN

Approximate Scale

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17 Apr. 2013
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17 Apr. '13
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LEGEND

- BOREHOLE LOCATION
- GROUND WATER LEVEL AT TIME OF INVESTIGATION
- EOP EDGE OF PAVEMENT
- SHR SHOULDER ROUND

DESCRIPTION	UTM COORDINATES NORTHING	UTM COORDINATES EASTING	ELEVATION (m)
BH G22	4824423	443403	191.6
BH G23	4824422	443391	191.3

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

AMEC Reference: TP110076

DESIGN PB	CHK PB	CODE CHBDC-06	CL 625-ONT	DATE JAN. 2013	
DRAWN KW	CHK HS	SITE 10+267		DWG 3	

REVISIONS

P:\GEO\Projects\2011\TP-Burlington\TP110076-HWY 21\05-Foundation\Drawings....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.	$C_u = \frac{D_{60}}{D_{10}}$ 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		NOT MEETING ALL GRADATION REQUIREMENTS FOR GW
		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		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
			PLASTIC FINES (FOR IDENTIFICATION PROCEDURES SEE CL BELOW)	GC	CLAYEY GRAVELS, POORLY GRADED GRAVEL-SAND-CLAY MIXTURES		ATTERBERG LIMITS ABOVE A- LINE WITH Ip GREATER THAN 7
	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	$C_u = \frac{D_{60}}{D_{10}}$ GREATER THAN 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ BETWEEN 1 AND 3
			PREDOMINANTLY ONE SIZE OR A RANGE OF SIZES WITH SOME INTERMEDIATE SIZE MISSING	SP	POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES		NOT MEETING ALL GRADATION FOR SW
		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
			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

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

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

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

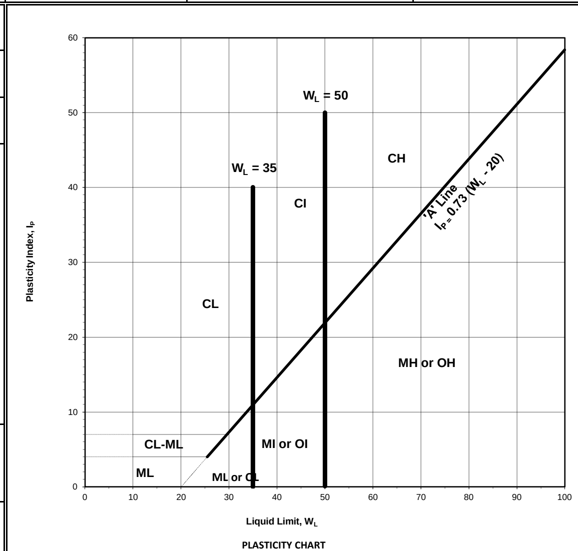
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT SMALLER THAN 75μm) — SILT AND CLAYS — IDENTIFICATION PROCEDURE ON FRACTION SMALLER THAN 425μm

	DRY STRENGTH (CRUSHING CHARACTERISTICS)	DILATANCY (REACTION TO SHAKING)	TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT)	GROUP SYMBOL	TYPICAL DESCRIPTION	INFORMATION REQUIRED FOR DESCRIBING SOILS
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.
	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	FOR UNDISTURBED SOILS AND INFORMATION ON STRUCTURE, STRATIFICATION, CONSISTANCY IN UNDISTURBED AND REMOLDED STATES, MOISTURE & DRAINAGE CONDITION.
	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 DIATOMECACOUS 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	

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
	FINE	425 μm	75 μm	10-20	SOME
FINES (SILT OR CLAY BASED ON PLASTICITY)		75 μm		1-10	TRACE

OVERSIZED MATERIAL

ROUNDED OR SUBROUNDED: COBBLES 75 mm TO 200 mm BOULDERS > 200 mm	NOT ROUNDED: ROCK FRAGMENTS > 75 mm ROCKS > 0.76 CUBIC METRE IN VOLUME



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

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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	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 G22

G.W.P. 834-93-00 LOCATION Sta. 10+267, NBL, 4.8m E of Rd C/L, 2.0m N of Culv. C/L, E443403 N4824423 ORIGINATED BY JF

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

DATUM Geodetic DATE 6 March 2012 - 6 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	WATER CONTENT (%)	SOIL VAPOUR READING (PPM)	GR	SA	SI	CL
191.6 / 0.0	brown **Sand and Gravel FILL** trace to some silt moist	1	SS	15	8	0				
190.9 / 0.7	brown **Silty Clay FILL** some sand, trace gravel	2	SS	14	15	0				
		3	SS	16	16	0				
	trace cobbles / boulders in SS 4	4	SS	14	16	0				
	--- light grey	5	SS	12	19	0				
187.0 / 4.6	brown **Silty Sand / Sandy Silt FILL** trace to some clay moist	6	SS	34	20	5				
185.5 / 6.1	grey **Silty Clay / Clayey Silt FILL** trace sand trace rootlets	7	SS	35	27	0				
184.0 / 7.6	brown / grey **CLAYEY SILT / SILTY CLAY** trace sand and gravel hard	8	SS	74	14	0	1	3	52	44
	rock fragment at spoon tip in SS9	9	SS	51	15	0				

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

Continued Next Page

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

Ontario

RECORD OF BOREHOLE No BH G22

G.W.P. 834-93-00 LOCATION Sta. 10+267, NBL, 4.8m E of Rd C/L, 2.0m N of Culv. C/L, E443403 N4824423 ORIGINATED BY JF

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

DATUM Geodetic DATE 6 March 2012 - 6 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
	grey **CLAYEY SILT / SILTY CLAY** trace sand and gravel hard					181						
		10	SS	35	11		12	0	.	4	76	20
					12	180						
178.9	rock fragment at spoon tip in SS 11	11	SS	41		179	15	0				
12.7	**End of Borehole** Groundwater level on 6 March 2012 : dry											

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

Ontario

RECORD OF BOREHOLE No BH G23

G.W.P. 834-93-00	LOCATION Sta. 10+267, SBL, 5.0m W of Rd C/L, 2.0m N of Culv. C/L, E443391 N4824422	ORIGINATED BY	JF
DIST Goderich HWY 21	BOREHOLE TYPE 150 mm diameter borehole (Solid Stem)	COMPILED BY	DA
DATUM Geodetic	DATE 6 March 2012 - 6 March 2012	CHECKED BY	SM
PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario		JOB NO.	TP110076

SOIL PROFILE

ELEV / DEPTH (m)	DESCRIPTION
191.3 / 0.0	brown **Sand and Gravel FILL** trace to some silt moist
190.9 / 0.4	brown / grey **Silty Clay FILL** trace to some sand trace gravel moist trace cobbles / boulders in SS 2; trace organic matter in SS 5; trace straw in SS 6; trace organic matter and wood in SS 7
183.7 / 7.6	brown / grey **CLAYEY SILT** trace sand and gravel stiff to hard

SAMPLES

NUMBER	TYPE	"N" VALUES	ELEVATION (m, approx.)	WATER CONTENT (%)	SOIL VAPOUR READING (PPM)	GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	13	191	6	0	
2	SS	10		13	0	
3	SS	17		16	0	
4	SS	13		16	0	
5	SS	16	188	18	5	
6	SS	39		18	5	
7	SS	11	185	25	10	
8	SS	12		19	0	1 3 53 43
9	SS	49	182	13	0	

Chart headings: 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 (%) GR SA SI CL.

Continued Next Page

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

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RECORD OF BOREHOLE No BH G23

G.W.P. 834-93-00	LOCATION Sta. 10+267, SBL, 5.0m W of Rd C/L, 2.0m N of Culv. C/L, E443391 N4824422	ORIGINATED BY	JF
DIST Goderich HWY 21	BOREHOLE TYPE 150 mm diameter borehole (Solid Stem)	COMPILED BY	DA
DATUM Geodetic	DATE 6 March 2012 - 6 March 2012	CHECKED BY	SM
PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario		JOB NO.	TP110076

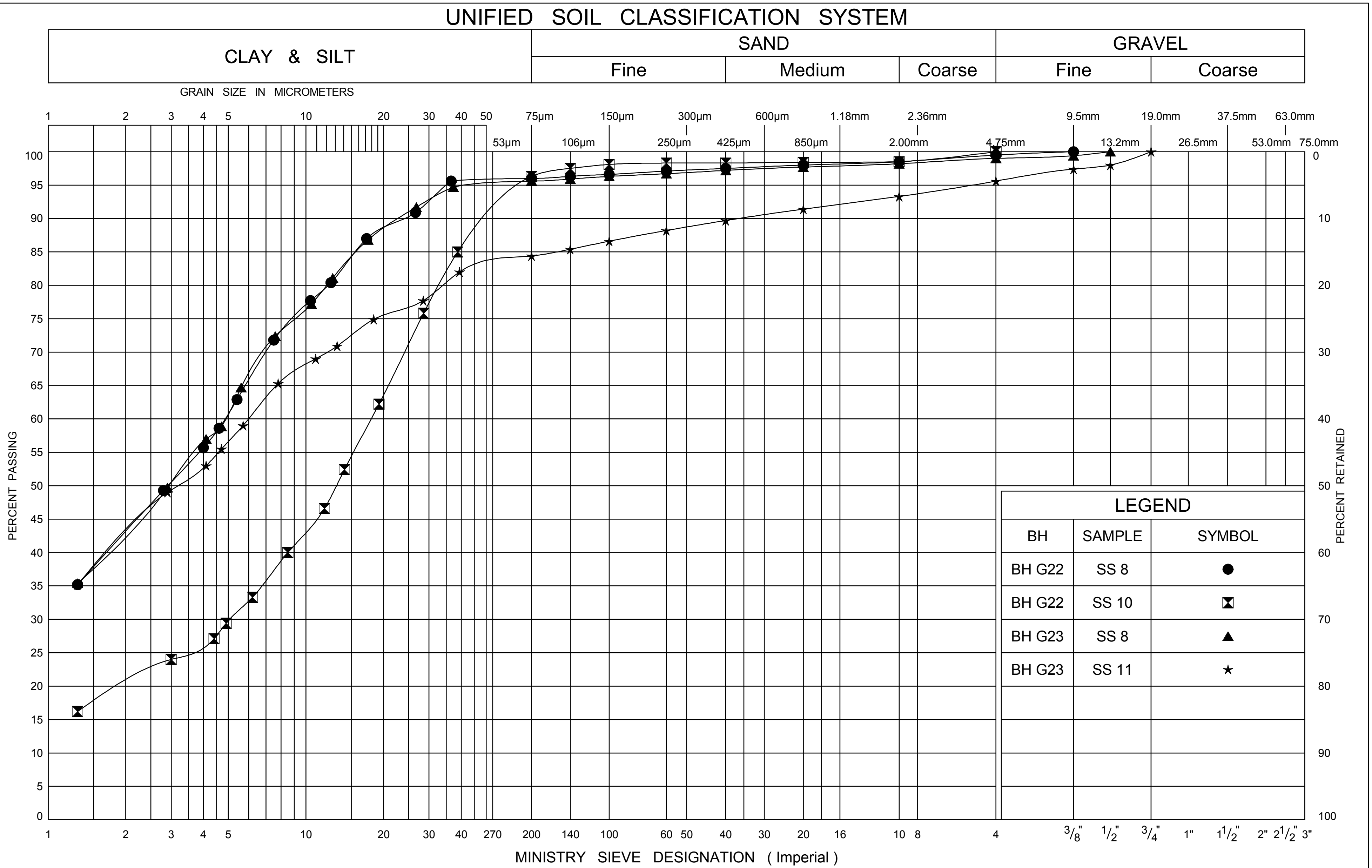
ELEV DEPTH (m)	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	DEPTH m	ELEVATION SCALE m	WATER CONTENT (%)	SOIL VAPOUR READING PPM	GR	SA	SI	CL
	brown / grey **CLAYEY SILT** trace sand and gravel stiff to hard						181						
		10	SS	36	▽	11	180	15	0				
178.7		11	SS	31		12	179	17	0	4	12	41	43
12.7	**End of Borehole** Groundwater level on 6 March 2012 was 10.8 m below the existing grade												

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

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

APPENDIX B

LABORATORY TEST RESULTS



Ministry of Transportation

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GRAIN SIZE DISTRIBUTION

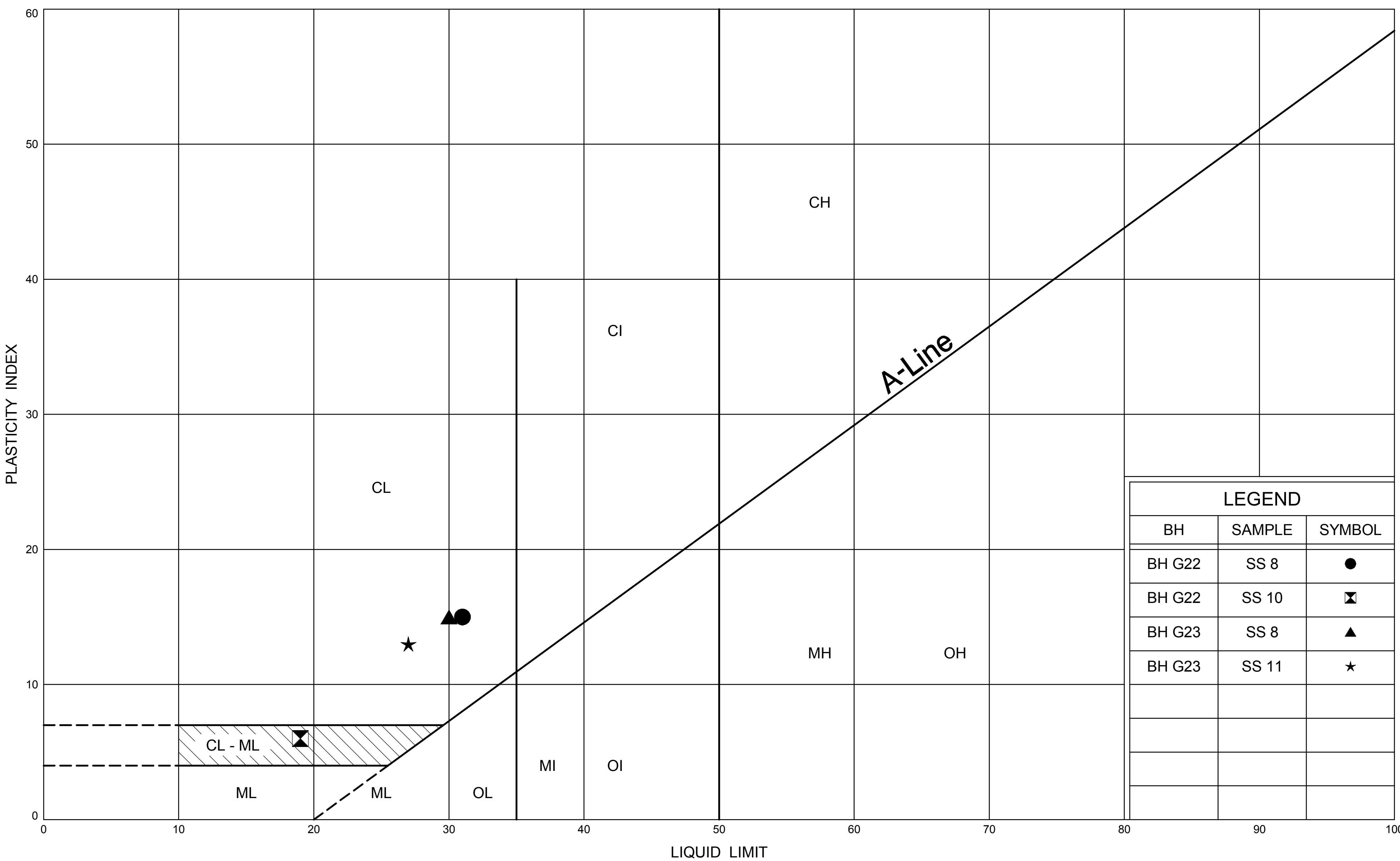
CLAYEY SILT / SILTY CLAY

Figure No. B 1

G.W.P. 834-93-00

Culvert at Sta. 10+267, Hwy 21, Bayfield to Goderich

ONTARIO MOT GRAIN SIZE TP110076-5-3 MTO.GPJ ONTARIO MOT.GDT 31/05/12



BH	SAMPLE	SYMBOL
BH G22	SS 8	●
BH G22	SS 10	⧗
BH G23	SS 8	▲
BH G23	SS 11	★

Ministry of Transportation
Ontario

PLASTICITY CHART
CLAYEY SILT / SILTY CLAY

Figure No. B 2

G.W.P. 834-93-00

Culvert at Sta. 10+267, Hwy 21, Bayfield to Goderich

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

Success Through Science®

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

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

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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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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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

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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

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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

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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]

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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, 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.

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APPENDIX C

SITE PHOTOGRAPHS

HIGHWAY 21, GODERICH, ONTARIO
(CULVERT AT Sta. 10 + 267)

PHOTOGRAPH NO. 1

Looking towards the existing culvert outlet area.

Overall view of the slope over the culvert.

PHOTOGRAPH NO. 2

Looking towards the existing culvert outlet area.

Culvert completely filled with debris

APPENDIX D

SLOPE STABILITY ANALYSIS RESULTS

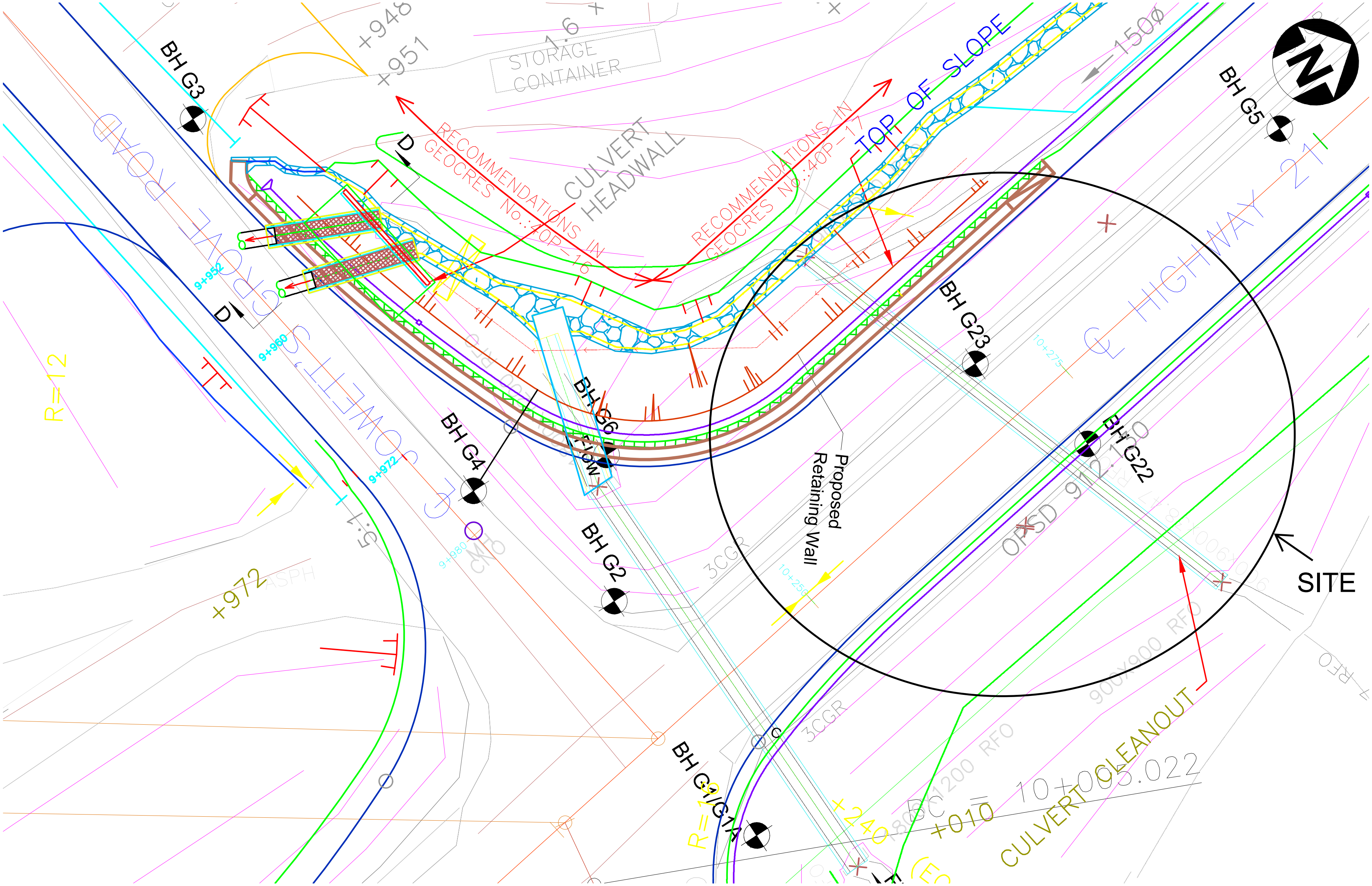
BH G3
BH G5
BH G23
BH G22
BH G4
BH S6
BH G2
BH G1/G1A
STORAGE CONTAINER
CULVERT HEADWALL
RECOMMENDATIONS IN GEOCRES No.:40P-16
RECOMMENDATIONS IN GEOCRES No.:40P-17
TOP OF SLOPE
HIGHWAY 21
Proposed Retaining Wall
SITE
CULVERT CLEANOUT
R=12
+972
+948
+951

Figure D1

TP110076 - Rehabilitation of HWY 21 from Bayfield to Goderich, ON
Culvert 2 - Sta. 10+267 (Total Stress Analysis)
C2-10+267 Retaining Wall (rev 15 Apr).gsz

Name: Granular Fill   Unit Weight: 21 kN/m³   Cohesion: 0 kPa   Phi: 32 °
Name: Retaining Wall   Unit Weight: 23 kN/m³   Cohesion: 200 kPa   Phi: 35 °
Name: Very Stiff to Hard Silty Clay/Clayey Silt (ST)   Unit Weight: 20 kN/m³   Cohesion: 100 kPa
Name: Existing Cohesive Fill (ST)   Unit Weight: 18 kN/m³   Cohesion: 50 kPa

Note: The soil parameters used for RSS wall are only for slope stability analysis to disregard slip surfaces through the wall.

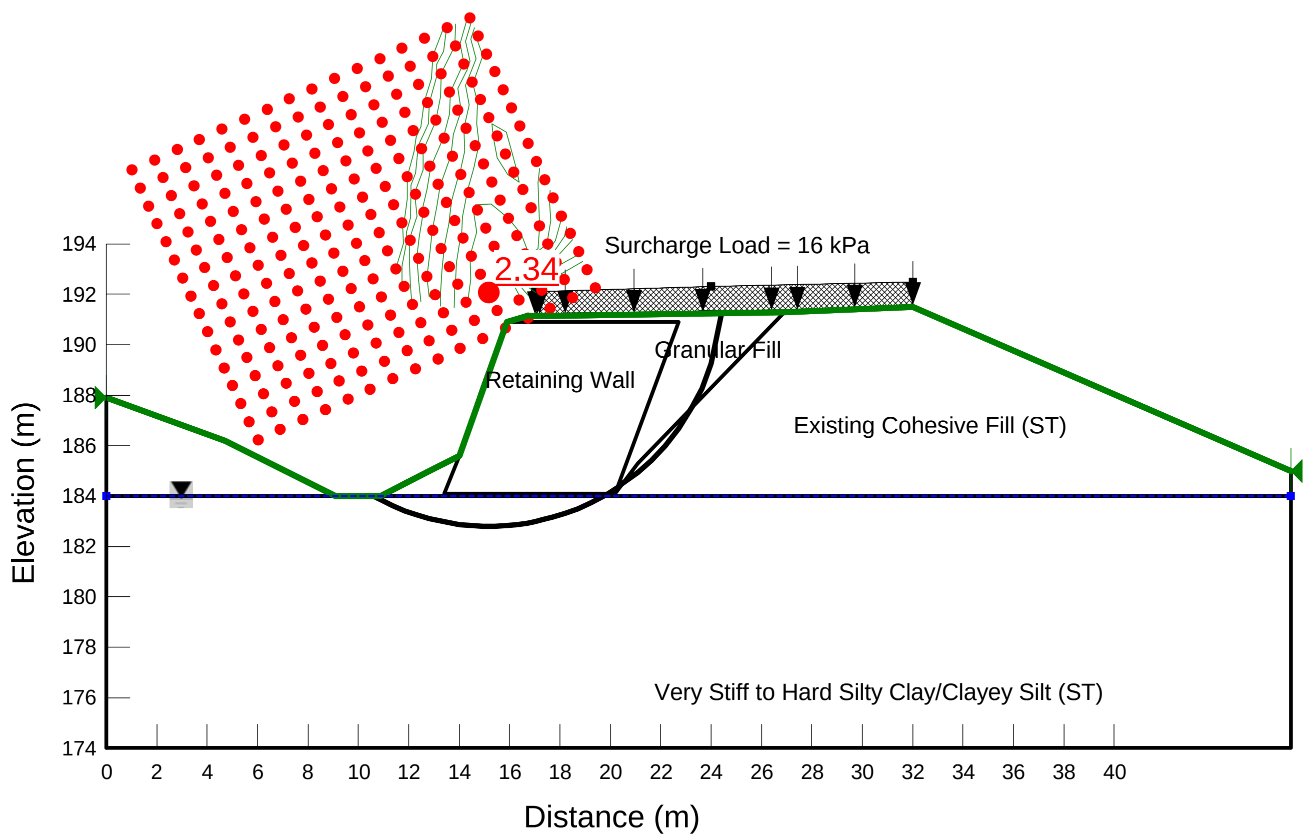

Figure D2 Slope Stability Analysis of Proposed Retaining Wall (beside Culvert) - Sta. 10+267 (Total Stress Analysis)

TP110076 - Rehabilitation of HWY 21 from Bayfield to Goderich, ON
Culvert 2 - Sta. 10+267 (Effective Stress Analysis)
C2-10+267 Retaining Wall (rev 15 Apr).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: 30 °
Name: Retaining Wall   Unit Weight: 23 kN/m³   Cohesion: 200 kPa   Phi: 35 °
Name: Existing Cohesive Fill   Unit Weight: 18 kN/m³   Cohesion: 0 kPa   Phi: 28 °

Note: The soil parameters used for RSS wall are only for slope stability analysis to disregard slip surfaces through the wall.

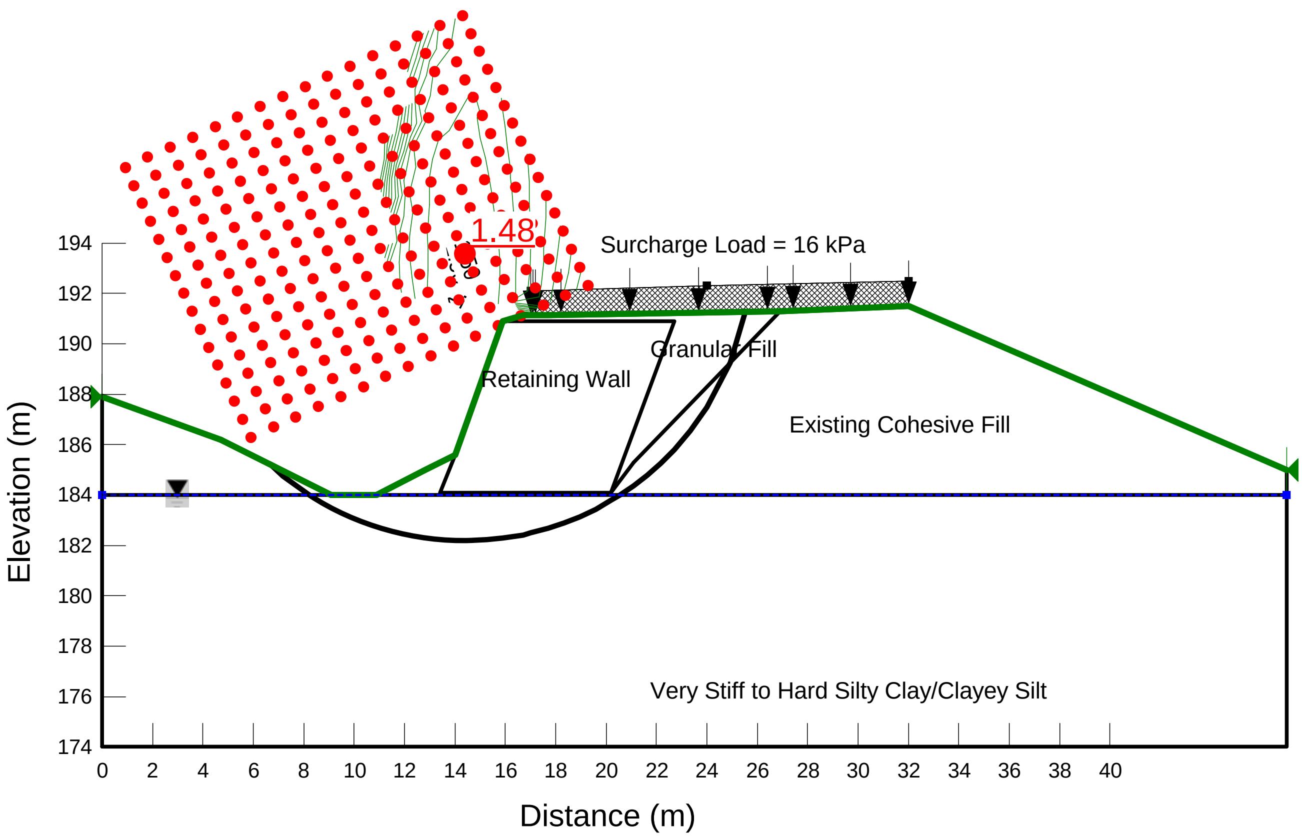

Figure D3 Slope Stability Analysis of Proposed Retaining Wall (beside culvert) - Sta. 10+267 (Effective Stress Analysis)

TP110076 - Rehabilitation of HWY 21 from Bayfield to Goderich, ON
Culvert 2 - Sta. 10+267 (Effective Stress Analysis)
C2-10+267 Retaining Wall (culvert) (rev 15 Apr).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: 30 °
Name: Retaining Wall Unit Weight: 23 kN/m³ Cohesion: 200 kPa Phi: 35 °
Name: Existing Cohesive Fill Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 28 °
Name: Culvert Unit Weight: 24 kN/m³ Cohesion: 200 kPa Phi: 38 °
Name: Granular Fill (Reduced) Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 21 °
Name: Existing Cohesive Fill (Reduced) Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 19 °

Note: (1) Soil parameters used for RSS wall are only for slope stability analysis
to diregard slip surfaces through the wall.
(2) Reduced friction angle used for fill material to consider the interface friction between
soil and concrete.

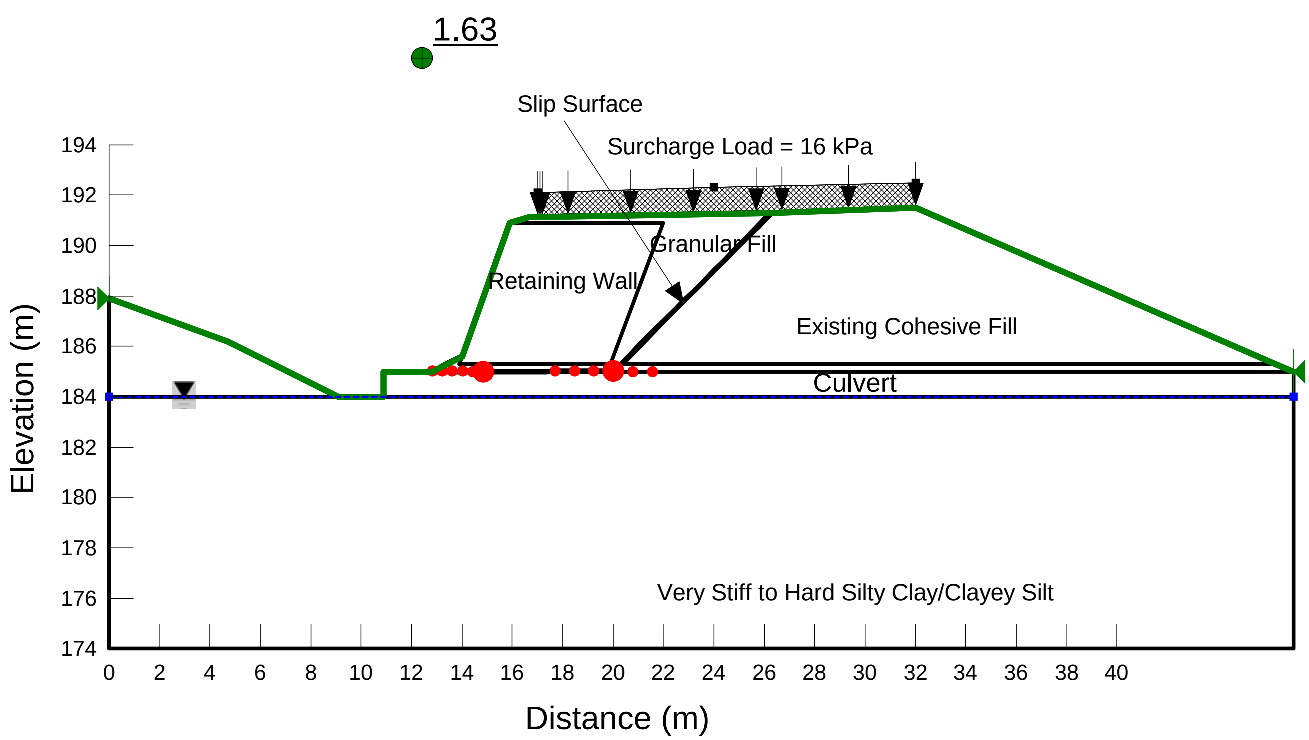

Figure D4 Slope Stability Analysis of Proposed Retaining Wall - Sta. 10+267
(Effective Stress Analysis - Non-circular slip surface)