



FOUNDATION INVESTIGATION AND DESIGN REPORT

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

CULVERT REPLACEMENT AT STATION 11+187

**MINISTRY OF TRANSPORTATION ONTARIO - WEST REGION
PURCHASE ORDER NUMBER 3009-E-0022
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1.0 INTRODUCTION

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

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

Table 1.1- Culvert Details*

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

* From Culvert Summary Table provided by AMEC Design Team

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

As per Terms of Reference (TOR) in the Request for Proposal (Purchase Order Number: 3009-E-0022, dated March 2010), separate reports have been prepared for each culvert site. This report presents the results of foundation investigation together with design discussion and recommendations for the culvert at Station 11+187.

The factual results of the soil conditions encountered in the boreholes and laboratory tests (without design discussion and recommendations) for the culvert at Station 11+187 is presented in a separate report titled "Foundation Investigation Report".

2.0 SITE AND PROJECT DESCRIPTION

The investigated culvert site (at Station 11+187) is located about 227 m north of Bayfield River 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.

Based on the Culvert Summary Table provided in Table 1.1, the existing culvert at this location is a CSP type, 0.46 m diameter and 24.7 m long. From the drawing provided by MTO (ETR Plate No. 171-21/11-0), the existing fill cover over the culvert is 2.0 m \pm . AMEC Design Team recommended for the replacement of the existing culvert.

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

3.0 GEOLOGY

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

4.0 INVESTIGATION PROCEDURES

4.1 Field Investigation

In accordance with the Terms of Reference for this investigation, two (2) boreholes were advanced - one on each side of the existing culvert. Borehole BH G11 was drilled near the culvert outlet, while Borehole BH G12 was advanced near the culvert inlet and adjacent to the west shoulder. The borehole locations are presented on Drawing No. 2.

The fieldwork was performed on 16 May 2011 after acquiring all necessary permits for road occupancy, and obtaining clearance for underground utilities. The ground surfaces at the borehole locations were surveyed with reference to the nearest geodetic benchmark (BM HCP # 102, Sta. 10+449.955, El 197.134).

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

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

Upon completion of drilling, the boreholes were backfilled with bentonite in accordance with the general requirements of Ministry of the Environment Regulation 903.

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

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

4.2 Laboratory Tests

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

- In-situ water content determination (15);
- Grain size distribution analysis (3);
- Atterberg Limit tests (3); and
- Soil corrosivity (1).

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

5.0 SUB-SURFACE CONDITIONS

Based on the investigation results, the soil profile consisted predominantly of ground surface cover (topsoil or sand and gravel) underlain by native clayey silt deposit extending to the termination depths of the boreholes (elevations 188.5 m in BH G11 and 188.8 m \pm in BH G12). Borehole BH G12 drilled adjacent to the west shoulder encountered fill soils (silty sand and silty clay) between the sand and gravel fill and the native clayey silt.

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

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

5.1 Topsoil

Topsoil was encountered at the existing grade in Borehole BH G11 drilled adjacent to the culvert outlet. The measured thickness of topsoil was about 350 mm. The topsoil consisted primarily of organic matter with some rootlets and soils.

The thickness of topsoil could vary beyond the borehole location.

A single SPT N-value measured in the topsoil was 6 blows per 0.3 m. The water content determined within the topsoil was 28 %.

5.2 Fill Soils

Sand and Gravel Fill

Borehole BH G12 encountered sand and gravel fill at the existing grade. The measured thickness of the sand and gravel fill was about 600 mm. The sand and gravel fill contained trace silt.

A single water content determined within the sand and gravel fill was 7 %.

Silty Sand Fill

Silty sand fill was encountered below the sand and gravel fill in Borehole BH G12. The silty sand fill extended to about 0.8 m below the existing grade.

The silty sand was brown in color, and contained some gravel, and trace clay.

Silty Clay Fill

Silty clay fill was encountered below the silty sand fill in Borehole BH G12. The silty clay fill extended to about 2.7 m below the existing grade.

The silty clay fill was brown in color and contained trace gravel and organic matter. Pocket of peat was found in SS4.

The SPT 'N'-values measured within the silty clay fill ranged from 9 to 18 blows per 0.3 m. The measured moisture contents within the silty clay fill ranged from 17 % to 20 %.

5.3 Clayey Silt

Native clayey silt was encountered below the topsoil in Borehole BH G11, and the silty clay fill in Borehole BH G12. The clayey silt extended to the termination depths of the boreholes (elevations 188.5 m in BH G11 and 188.8 m \pm in BH G12).

The clayey silt was brown / grey in color, and contained trace to some sand and trace gravel. The SPT 'N' values of the clayey silt ranged widely from 15 to 67 blows per 0.3 m, indicating a very stiff to hard consistency. However, the SPT 'N' value of Sample SS1 was 6 blows per 0.3 m (firm in consistency). The measured moisture contents in the clayey silt ranged from 11 % to 23 %.

Grain size analyses and Atterberg Limit tests were completed on 3 samples of the clayey silt, and the results are presented in Table 5.1.

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

| Borehole No. | Sample No. | Depth (Elevation) (m) | Grain Size Distribution | | | | Atterberg Limit | | | USCS Modified Group Symbol |
|--------------|------------|------------------------------|-------------------------|----------|----------|----------|-----------------|---------------|------------------|----------------------------|
| | | | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Liquid Limit | Plastic Limit | Plasticity Index | |
| BH G11 | SS 2 | 0.7 - 1.2 (194.3 - 193.8) | 0 | 7 | 60 | 33 | 37 | 16 | 21 | CI |
| BH G11 | SS 7 | 6.1 - 6.6 (189.0 - 188.5) | 3 | 14 | 53 | 30 | 27 | 13 | 14 | CL |
| BH G12 | SS 6 | 4.6 - 5.1 (192.3 - 191.8) | 2 | 14 | 54 | 30 | 30 | 14 | 16 | CL |

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

5.4 Groundwater Conditions

Groundwater conditions in the open boreholes were observed during and on completion of drilling. Groundwater was measured at a depth of about 4.9 m below the existing grade (elevation 192.0 m \pm) in Borehole BH G12, while Borehole BH G11 was dry on completion.

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.

6.0 DISCUSSION AND RECOMMENDATIONS

In preparation of this report, the following drawings were forwarded to AMEC:

- Hwy 21 Culvert Summary Table, dated 3 January 2011.
- MTO Drawing related to the culvert at 11+187 (ETR Plate No. 171-21/11-0).
- Cross-section at Station 11+187

Based on the Culvert Summary Table provided to the Design Team, the existing culvert at Station 11+817 is CSP type, 0.46 m in diameter and 24.7 m long. The invert elevations of the culvert are 194.23 m (inlet) and 193.80 m (outlet). Based on the ETR Plate for the area, the existing fill cover over the culvert is 2.0 m \pm . AMEC Design Team recommended for replacement of the existing culvert.

Based on the investigation results, the soil profile consisted predominantly of ground surface cover (topsoil or sand and gravel) underlain by native clayey silt deposit extending to the termination depths of the boreholes (elevations 188.5 m in BH G11 and 188.8 m \pm in BH G12). Borehole BH G12 drilled adjacent to the west shoulder encountered fill soils (silty sand and silty clay) below the sand and gravel fill. Groundwater was measured at a depth of about 4.9 m below the existing grade (elevation 192.0 m \pm) in Borehole BH G12, while Borehole BH G11 was dry on completion. Stratigraphic cross-sections at the culvert are shown in Drawing No. 3.

At the time of preparation of this report, no detail design information with regard to the replacement culvert was available. It may be possible that the replacement culvert would be installed at the same location as or parallel and adjacent to the existing culvert. The feasibility of replacing the culvert by means of a trenchless method (e.g., pipe ramming) is considered in this report.

Considering the existing culvert size, location and soil conditions, open cut and trenchless technology (tunnelling) could be considered for the installation of the culvert replacement at the site. The geotechnical considerations for these methods are discussed in the following sections.

6.1 Open Cut Method

The existing culvert could be replaced by the open cut method with the following considerations.

6.1.1 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 / Silty clay fill

Type 3

Firm to stiff clayey silt
Very stiff to hard clayey silt

Type 3
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. If open cut excavation cannot be carried out due to space restriction, temporary shoring will be required. The temporary shoring is discussed in Section 6.1.4.

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 fill and native 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.

6.1.2 Dewatering and Drain / Ditch Diversion

Based on the groundwater conditions encountered in Borehole BH G11 (Section 5.4), the groundwater would likely be encountered at an elevation of 192.0 m \pm , which is below the invert elevation of the existing culvert. Excavation to replace the existing culvert is unlikely to encounter groundwater. Groundwater seepage, if any, is expected to be slow through the silty clay / clayey silt soils, and could be dewatered using a system of sumps and pumps. High rates of seepage may occur from surface water / silty sand fill, and dewatering effort could require an increased number of sumps and pumps.

At the time of field work, water was noted in the drain / ditch. Provision must be made to divert water flows from one side of the highway to the other during construction.

For phased construction (i.e., replace one portion of the culvert at a time), the drain flow can be collected from the upstream side and pumped / diverted to the downstream side. The hoses could be run through the portion of the culvert still in place, and then routed around to the north or south limit of the construction excavation for the portion under construction. If the highway were closed entirely to traffic, the drain flows could be pumped / diverted around the excavation.

Given the variations in drain flow and depending on the extent of the work area, a cofferdam (earth dyke) or sheet-piling could be required to prevent drain flows from entering the work area and/or reducing the groundwater inflow into the excavation.

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

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

6.1.3 Traffic Protection and Temporary Detours

The following scenarios could be considered for construction:

- Scenario 1 - reduction of traffic to one-lane using staged open cut construction and provide a temporary detour;
- Scenario 2 - reduce traffic to one-lane using traffic protection (sheet-piling) with no temporary detour required; or
- Scenario 3 - close the road entirely to traffic and provide an alternate route.

It is recommended that practical aspects including traffic protection and temporary detours for the replacement of culvert should be as per contract design.

6.1.4 Temporary Shoring

The width of the open cut will likely be limited and supporting the sideslopes using a system of shoring may be required. The temporary shoring of the excavation should conform to OPSS 539: "Construction Specification for Temporary Protection Systems".

The temporary shoring system should be designed to resist the lateral earth, surcharge and hydrostatic pressure which could occur during construction. Bracings should also be installed within the shoring system to minimize movements of the soils. The design of temporary shoring should be carried out in accordance with Canadian Foundation Engineering Manual, 4th edition. Soil types and parameters for design considerations are summarized in Table 6.1.

Table 6.1 - 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 |
| Silty Sand fill | 18 | 30 | 0.50 | 0.33 | 2.0 |
| Silty clay fill | 18 | 28 | 0.53 | 0.35 | 2.0 |
| Clayey silt | 20 | 28 | 0.53 | 0.35 | 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.

6.1.5 Bedding

The data from the boreholes suggests that the invert level of the proposed replacement culvert would likely be within the silty clay / clayey silt soils. The replacement culvert should be founded on undisturbed native clayey silt below any existing fill. Fill soil, if encountered below the proposed culvert invert level, should be removed and replaced with compacted clean fill soils. The replacement culvert should be provided with granular bedding or lean concrete. The bedding should consist of a well graded granular material such as Granular 'A' or better. The minimum bedding thickness shall be in accordance with OPSD 802.010. The thickness of the bedding may, however, have to be increased if wet or weak (soft to firm, or loose) subgrade conditions are encountered. Cut-off walls below the culvert invert should be considered to prevent erosion below the culvert, particularly if granular bedding is used.

6.1.6 Backfilling

Based on visual and tactile examination of the soil samples, and the measured moisture contents of the soil samples, the on-site excavated silty sand / clayey silt fill and native clayey silt could be generally be re-used as backfill provided their moisture contents at the time of construction are at or near optimum. All soils will likely require reconditioning prior to reuse (i.e. drying of the soil).

Backfill and cover for the replacement culvert should conform to OPSD 802.010 (*Flexible Pipe Embedment and Backfill, Earth Excavation*), while the frost treatment, where required, should follow OPSD 803.030 (*Frost Treatment – Pipe Culverts, Frost Penetration Line Below Bedding Grade*) and OPSD 803.031 (*Frost Treatment – Pipe Culverts, Frost Penetration Line between Top of Pipe and Bedding Grade*).

The reconstruction of the embankment slopes should match the existing slopes, with a maximum slope of 2H:1V.

6.2 Tunnelling Methods

Tunnelling procedures depend upon a number of factors, the most important of which are the groundwater conditions and the soil type through which the tunnel must pass. The following geotechnical factors should be considered for the selection of tunnelling method:

- i. The proposed tunnelling method should cause minimal disturbance to the existing highway and its usage.
- ii. The proposed tunnelling method would not cause instability of the existing highway embankments.
- iii. The proposed tunnelling method should consider suitable means of groundwater dewatering during the tunnelling work, if it is encountered.
- iv. A minimum soil cover (height of soil over the culvert crown) of 2.0 m should be maintained during tunneling except at the entrance and exit where applicable.

In view of the short length of culvert and soil conditions encountered at the site, the following two tunnelling methods may be considered, although other tunnelling methods (e.g., horizontal directional drilling) may also be considered, if applicable.

6.2.1 Jacking and Boring

Jacking and boring could be used directly at the existing culvert location by jacking a steel pipe with a larger diameter than the existing culvert, or nearby location.

This technique forms a horizontal bore hole from a drive shaft / pit to a reception shaft / pit by means of rotating cutting head. Spoil is transported back to the drive shaft / pit by helical auger flights rotating inside a steel casing. The casing is jacked in place simultaneously with the augering operation. After the installation of the steel casing, a new culvert pipe will be installed inside the casing and the gap between the casing and the pipe will be grouted.

Based on the soil condition encountered in Boreholes BH G11 and BH G12, the alignment of proposed pipe jacking and boring tunnelling will likely pass through the existing fill soil (silty sand / silty clay) and/or the native clayey silt. The invert level of the replacement culvert is likely to be above the groundwater level (Section 6.1.2). It is cautioned that soil/groundwater condition between and beyond the borehole locations may be different and that cobbles / boulders may be encountered. The groundwater level may also vary seasonally and perched water may be present. The anticipated tunneling condition is 'firm' according to Tunnelman's Ground Classification. Should silt and / or sand seams / lenses or weak zones be encountered during tunnelling, some local instability or seepage could occur.

Provision for handling groundwater seepage during tunneling should be discussed and a contingency plan should be in place prior to commencement of tunneling work. At this site, groundwater seepage, if any during tunnelling, may be handled by gravity drainage and pumping from open sumps and pumps (Section 6.1.2). The tunnelling alignment should be provided with a gentle gradient so that water seepage into the opening can be directed away from the tunnel face. If there is a possibility of loss of soils due to high groundwater seepage into the tunnel, proper measures(s) should be implemented (e.g., installing a shield at the tunnel face, grouting the soils around the tunnel prior to excavation, etc.). As a minimum and as a preventive measure against development of flowing or running condition and to maintain stability of the tunnel face, a plug of soil should be left inside the front end of the tunnel casing at all times. The size of the plug depends on the soil and groundwater condition encountered the time of tunnelling. If unexpected high groundwater flow is encountered and/or loss of soil through the tunnel is excessive, the tunnel operation should be stopped immediately and remedial measures should be taken to stabilize the tunnel face. Potential gap between the tunnel casing and the soil, after the completion of tunnelling, should be grouted to reduce settlements.

Cobbles and boulders should be expected within the fill and native soils.

The construction of the tunnel should comply with OPSS 416: "*Construction Specification for Pipeline and Utility Installation by Jacking and Boring*".

The work should be carried out by specialized contractor experienced with such jack and bore work.

The soil parameters presented in Section 6.1.4 are also applicable with this method. Further, the following soil parameters may be used preliminary design purposes:

- Adhesion between the steel casing and surrounding soil: 50 kPa.
- Modulus of Elasticity, E, for the surrounding soil: 30 MPa.

6.2.2 Pipe Ramming

Pipe ramming could be used directly at the location of the existing culvert or nearby by ramming a steel pipe with a larger diameter than the existing culvert, or nearby location.

The pipe ramming is an established and widely used trenchless method for installation of steel pipes and casings. In operation, pipe ramming method utilizes a pneumatic tool to hammer the pipe into the ground. The spoils inside the pipe can be removed either during or after the installation. The pipe ramming method is applicable in a wide variety of soils and frequently used under railway and road embankments where pipe installation is required for relatively short lengths. Pipe ramming operation generates vibrations to the soil and noise.

This method is feasible for cohesionless and cohesive soils.

Discussion provided for jacking and boring in Section 6.2.1 is also applicable with this method.

6.2.3 Concluding Remarks

Based on the requirements of the project and the soil conditions, any of the two tunnelling methods may be used. The steel casing may be used directly as the new culvert if acceptable by the designer. Tunnelling method to be selected should cause minimum disturbance to Highway 21.

It is recommended that practical aspects for the best suited/economical method of installation be discussed with experienced tunnel contractors prior to commencement of the tunnelling work.

6.3 Comparison of the Construction Techniques

A comparison of the construction techniques (open cut and tunnelling) are provided in Table 6.2.

Table 6.2 - Comparison of Construction Methods

| Construction Technique | Description | Advantages | Disadvantages | Risks / Consequences | Cost Comparison |
|---|---|--|---|---|-----------------|
| Open Cut | Open cut or shored excavation to replace existing CSP culvert. | <ul style="list-style-type: none"> Use of standard excavation and construction equipment. - No specialist contractor is required. - Maintain the existing culvert location. | <ul style="list-style-type: none"> Disruption to traffic by opening only one lane or road closure. - Will require roadside protection (trench box or similar) to maintain traffic flow. A sliding trench box can be used. Traffic signalling will be required for one lane traffic. - Temporary dewatering and / or detouring of the existing water way will be required. - Will require rebuilding of embankment fills and road. | Excavation sideslopes may not be stable during construction due to rainfall, groundwater, etc. | Low to Medium |
| Tunnelling by Jacking and Boring / Pipe Ramming | <ul style="list-style-type: none"> - Boring underneath the embankment and jacking/ramming a new pipe into place. - Will require jacking and receiving pits. | <ul style="list-style-type: none"> - No disruption to traffic flow. | <ul style="list-style-type: none"> - Requires specialist contractor and specialized equipment. - Will require dewatering of jacking and receiving pits. - Temporary diversion of water way into and out of proposed replacement culvert location. | <ul style="list-style-type: none"> - Soil condition based on limited borehole data. - Risk of encountering cobbles / boulders, which may complicate jacking and boring / ramming operations. - Jacking and boring / ramming through wet to saturated fine grained soil may result in construction difficulties with the stability of the bore face. - Jacking and boring / ramming below embankment soils may result in settlement within embankment. | Medium to High |

Based on the above comparison of the construction techniques, the open cut method would likely be less costly. However, if interrupting the traffic on Highway 21 is to be avoided, tunnelling should be considered.

6.4 Entry / Receiver Pits

In constructing the tunnels, pits are required on both ends. The pits for the liner installation are expected to be at or below a depth of about 1 m to 2 m below the existing culvert invert. The soils to be excavated may consist of fill soils (silty sand / silty clay) and native clayey silt deposit. Subgrade materials for supporting tunnelling equipment at the pits would likely consist of native stiff to very clayey silt. Groundwater and dewatering is discussed in Sections 6.1.1 and 6.1.2 respectively. Geotechnical reaction of 100 kPa (SLS) and geotechnical resistance of 150 kPa (factored ULS) are recommended for consideration when the equipment is founded on native undisturbed soil. The exposed base of the entry / receiver pits should be covered with a mud slab to protect the subgrade from disturbance, and to provide a stable platform for pipe jacking/ramming operation.

6.5 Settlement Monitoring

During tunnelling, the ground over and in the vicinity of the tunnel alignment may experience settlement. Good workmanship and site control is the most effect way to reduce settlements to practical minimum. It is recommended that ground movement during tunnelling be monitored. This is to confirm that the tunnelling process does not cause any significant impact on the existing soil and groundwater conditions. If any adverse effect of tunnelling is identified by the monitoring program, the tunneling process can be modified accordingly.

Settlement monitoring should follow the MTO Settlement Monitoring Guidelines – Tunnelling, which is attached in Appendix D of this report. As per the guideline, a maximum settlement of 10 mm relative to baseline readings should be considered as review level, at which the method, rate or sequence of construction and/or ground stabilization measures should be reviewed and/or modified to mitigate further ground displacement. Furthermore, an alert level of a maximum settlement of 15 mm relative to baseline readings is recommended, at which stage the construction operation should be stopped, and measures to secure the site and to mitigate further movement should be immediately taken to ensure public safety and maintenance of traffic flow.

6.6 Soil Corrosivity

One soil sample (BH G12 - SS 4) 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 6.3.

Table 6.3 - Results of Corrosivity Test

| Soil Sample No. | pH | Electrical Conductivity $\mu\text{mho/cm}$ | Resistivity (ohms-cm) | Chloride ($\mu\text{g/g}$) | Sulphate ($\mu\text{g/g}$) |
|-----------------|-----|--|-----------------------|------------------------------|------------------------------|
| BH G12 - SS 4 | 7.6 | 951 | 1100 | 470 | <20 |

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

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

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

6.7 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 Station 11+187 on Highway 21, near Bayfield, Ontario.

The information presented in this report is complete within AMEC's terms of reference. If there are any further questions concerning this report, please do not hesitate to contact the undersigned.

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

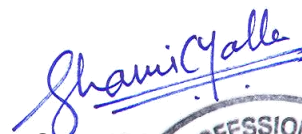
This report was prepared by Mohammad Mollah, M.Eng., P.Eng., and was reviewed by Dr. Prapote Boonsinsuk, Ph.D., P.Eng.

Sincerely,

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



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



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Project Manager



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



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

LIMITATIONS OF REPORT

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

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

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

This report was prepared specifically for the culvert at Station 11+187 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 416 (Nov/08) | Construction Specification for Pipeline and Utility Installation by Jacking and Boring |
| 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 |
| Drawings | |
| OPSD 208.010 | Benching of Earth Slopes |
| OPSD 802.010 | Flexible Pipe Embedment and Backfill, Earth Excavation |
| OPSD 803.030 | Frost Treatment – Pipe Culverts, Frost Penetration Line Below Bedding Grade |
| OPSD 803.031 | Frost Treatment – Pipe Culverts, Frost Penetration Line between Top of Pipe and Bedding Grade |
| OPSD 810.010 | Rip-rap treatment for sewer and culvert outlets |

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**



CLIENT LOGO



CLIENT

**MINISTRY OF
TRANSPORTATION ONTARIO
WEST REGION**

TITLE
CULVERT LOCATION PLAN

PROJECT
REHABILITATION OF HIGHWAY 21 - FROM BAYFIELD TO GODERICH, ONTARIO
PURCHASE ORDER NUMBER: 3009-E-0022, WP 834-93-00, GEOCREs No.: 40P12-24

DWN BY:
KW

CHK'D BY:
PB

PROJECTION:
-

DATUM:
-

REV. NO.:
A

SCALE:
AS SHOWN

DATE:
JANUARY 2013

PROJECT NO.:
TP110076

DRAWING No.
1



SCALE



AMEC Environment & Infrastructure,
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CLIENT LOGO



CLIENT

MINISTRY OF
TRANSPORTATION ONTARIO
WEST REGION

TITLE

BOREHOLE LOCATION PLAN

DWN BY:

KW

DATUM:

-

DATE:

JANUARY 2013

PROJECT

REHABILITATION OF HIGHWAY 21 - FROM BAYFIELD TO GODERICH

CHK'D BY:

PB

REV. NO.:

A

PROJECT NO:

TP110076

PROJECTION:

-

SCALE:

AS SHOWN

DRAWING No.

2

PURCHASE ORDER NUMBER: 3009-E-0022, WP 834-93-00, GEOCREs No.: 40P12-24

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

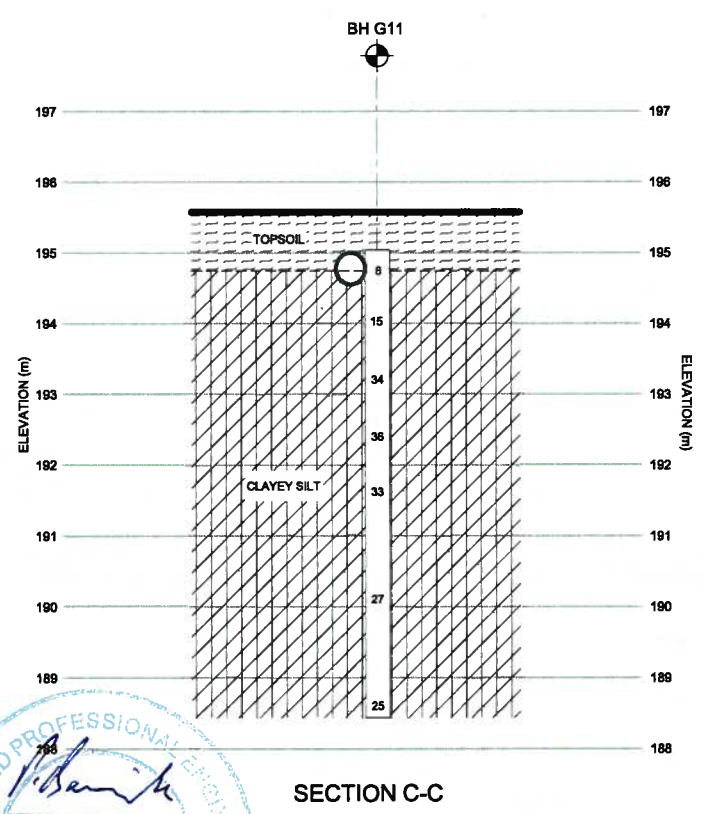
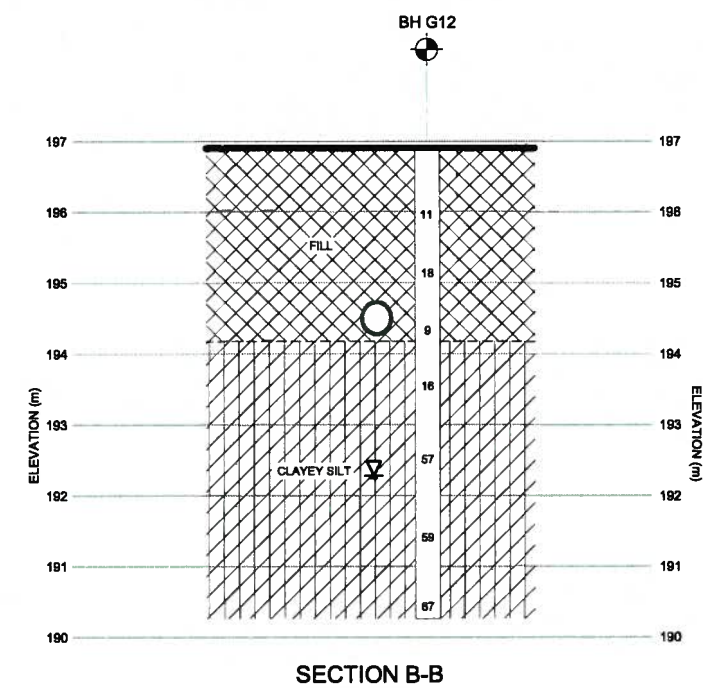
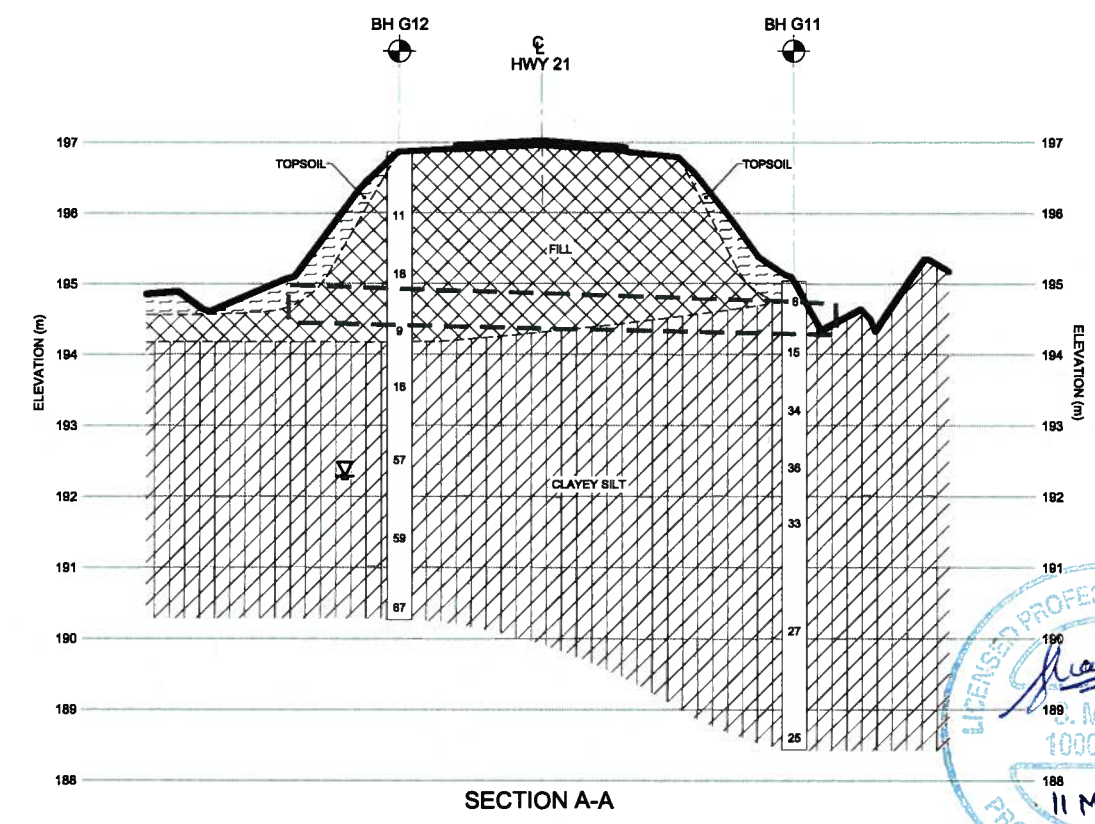
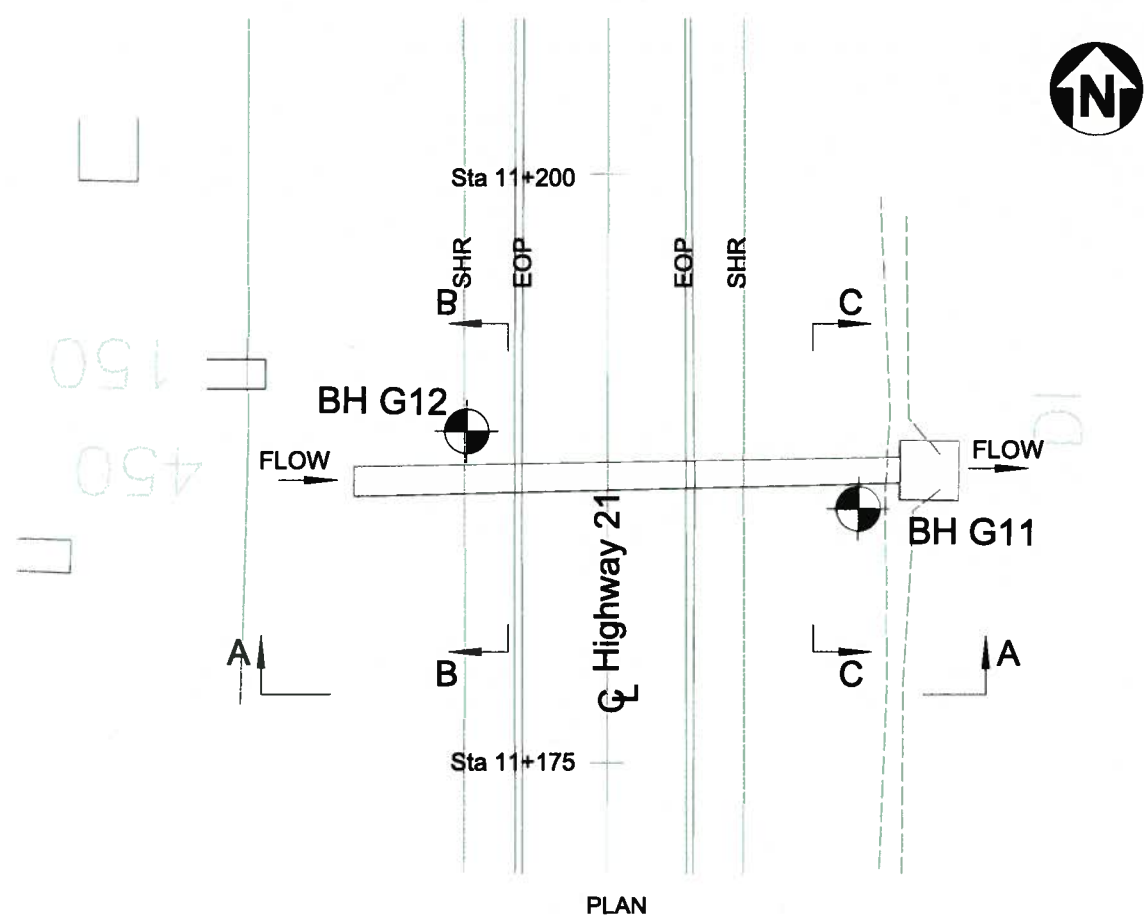
PURCHASE ORDER NUMBER:
3009-E-0022

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

REHABILITATION OF HWY 21 FROM BAYFIELD TO GODERICH
GEOCRES No.40P12-24
CULVERT AT STA 11+187
STRATIGRAPHIC CROSS SECTION

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

SHEET
1 OF 1

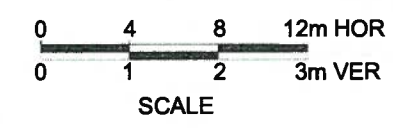
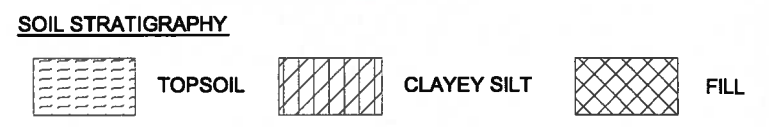


LEGEND

BOREHOLE LOCATION
 GROUNDWATER LEVEL AT TIME OF INVESTIGATION
EOP EDGE OF PAVEMENT
SHR SHOULDER ROUND

| DESCRIPTION | UTM COORDINATES | | ELEVATION (m) |
|-------------|-----------------|---------|---------------|
| | NORTHING | EASTING | |
| BH G11 | 4825220 | 443046 | 195.04 |
| BH G12 | 4825225 | 443028 | 196.86 |

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.



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

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

| REVISIONS | | | | |
|-----------|----|-----|----|----------------|
| | | | | |
| | | | | |
| DESIGN | PB | CHK | PB | CODE CHBDC-06 |
| DRAWN | KW | CHK | HS | SITE 11+187 |
| | | | | CL 625-ONT |
| | | | | DATE JAN. 2012 |
| | | | | DWG 3 |

P:\GEO\Projects\2011\TP-Burlington\TP110076-HWY 2105-Foundations\Drawings\11TB112041 - Washburn Drain.DWG

APPENDIX A
RECORD OF BOREHOLES

EXPLANATION OF BOREHOLE LOG

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

GENERAL INFORMATION

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

SOIL LITHOLOGY

Elevation and Depth

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

Lithology Plot

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

Description

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

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

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

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

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

Soil Sampling

Sample types are abbreviated as follows:

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

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

Field and Laboratory Testing

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

Instrumentation Installation

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

Comments

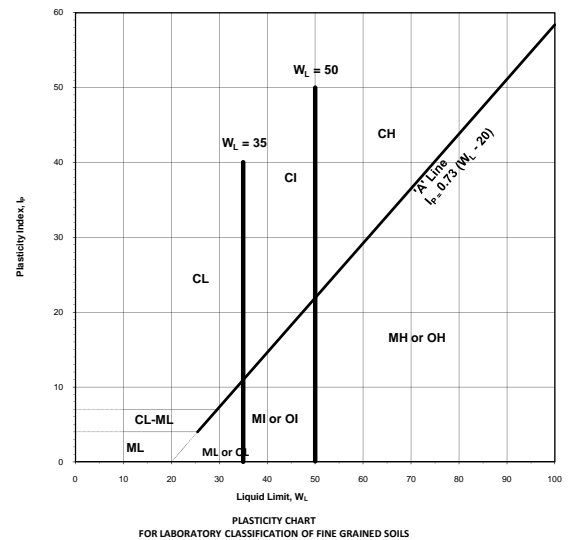
This column is used to describe non-standard situations or notes of interest.

MTC SOIL CLASSIFICATION
Based on MTC Soil Classification Manual



| MAJOR DIVISION | | | | GROUP SYMBOL | TYPICAL DESCRIPTION | INFORMATION REQUIRED FOR DESCRIBING SOILS | LABORATORY CLASSIFICATION CRITERIA | |
|--|---|--|---|--|---|---|--|--|
| COARSE GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 75µm) | GRAVELS MORE THAN HALF THE COARSE FRACTION LARGER THAN 4.75mm | CLEAN GRAVELS (LITTLE OR NO FINES) | WIDE RANGE IN GRAIN SIZE & SUBSTANTIAL AMOUNTS OF ALL INTERMEDIATE PARTICLE SIZES | GW | WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES | GIVE TYPE, NAME, IF NECESSARY, INDICATE APPROX % OF SAND & GRAVEL, MAX SIZE; ANGULARITY, SURFACE CONDITION, & HARDNESS OF THE COARSE GRAINS, LOCAL OR GEOLOGICAL NAME & OTHER PERTINENT DESCRIPTIVE INFORMATION, & SYMBOL IN PARENTHESIS. | $C_u = \frac{D_{60}}{D_{10}}$ <p>GREATER THAN 4;</p> $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ <p>BETWEEN 1 AND 3</p> | |
| | | | PREDOMINANTLY ONE SIZE OF A RANGE OF SIZES WITH SOME 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 | | NOT MEETING ALL GRADATION REQUIREMENTS FOR GW | |
| | | | 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 | <p>ATTENBERG LIMITS BELOW A-LINE OR I_p LESS THAN 4</p> <p>ABOVE A-LINE WITH I_p BETWEEN 4 AND 7 ARE BORDERLINE CASES REQUIRING USE OF DUAL SYMBOLS</p> | |
| | | | 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 | | <p>ATTENBERG LIMITS ABOVE A- LINE WITH I_p GREATER THAN 7</p> | |
| | | | PLASTIC FINES (FOR IDENTIFICATION PROCEDURES SEE CL BELOW) | SC | CLAYEY SANDS, POORLY GRADED SAND-CLAY MIXTURES | | | |
| FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT SMALLER THAN 75µm) | IDENTIFICATION PROCEDURE ON FRACTION SMALLER THAN 425µm | | | | | | <p>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:</p> <p>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</p> <p>USE GRAIN SIZE CURVE IN IDENTIFYING THE FACTORS AS GIVEN UNDER FIELD IDENTIFICATION</p> | |
| | LIQUID LIMIT LESS THAN 35 AND 50 | NONE | DRY STRENGTH (CRUSHING CHARACTERISTICS) | DILATANCY (REACTION TO SHAKING) | TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT) | | | |
| | | | NONE | QUICK | NONE | ML | | |
| | | MEDIUM TO HIGH | NONE TO VERY SLOW | | MEDIUM | CL | | |
| | | | SLOW | | SLIGHT | OL | | |
| | | SLIGHT TO MEDIUM | SLOW TO QUICK | | SLIGHT | MI | | |
| | | | HIGH | NONE | MEDIUM TO HIGH | CI | | |
| | LIQUID LIMIT BETWEEN 35 AND 50 | SLIGHT TO MEDIUM | VERY SLOW | | SLIGHT | OI | | |
| | | | SLOW TO NONE | | MEDIUM | MH | | |
| | | HIGH TO VERY HIGH | NONE | | HIGH | CH | | |
| | | | NONE TO VERY SLOW | | SLIGHT TO MEDIUM | OH | | |
| | | MEDIUM TO HIGH | | | | | | |
| | | | | | | | | |
| | 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 | | DEFINING RANGES OF PERCENTAGE BY WEIGHT OF MINOR COMPONENTS | | |
|---|-------------------------|---------|---|--|------------|
| GRAVEL | COARSE | PASSING | RETAINED | PERCENT | DESCRIPTOR |
| | | 75 mm | 26.5 mm | | |
| SAND | FINE | 26.5 mm | 4.75 mm | 40-50 | AND |
| | | 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 | |



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



AMEC Earth & Environmental,
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**MTC SOIL CLASSIFICATION MANUAL
ENGINEERING PROPERTIES OF SOIL**



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

RECORD OF BOREHOLE No. BH G11

| | | | |
|--|--|------------------|------------------|
| G.W.P. 834-93-00 | LOCATION Sta: 11+187, 1.5 m S of Culvert, 10.7 m Rt of CL of Rd. E 443046; N 4825220 | 1 OF 1 | ORIGINATED BY JF |
| DIST Goderich HWY 21 | BOREHOLE TYPE 150 mm diameter borehole (Solid Stem) | COMPILED BY SAL | |
| DATUM Geodetic | DATE May 16, 2011 - May 16, 2011 | CHECKED BY SM | |
| PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario | | JOB NO. TP110076 | |

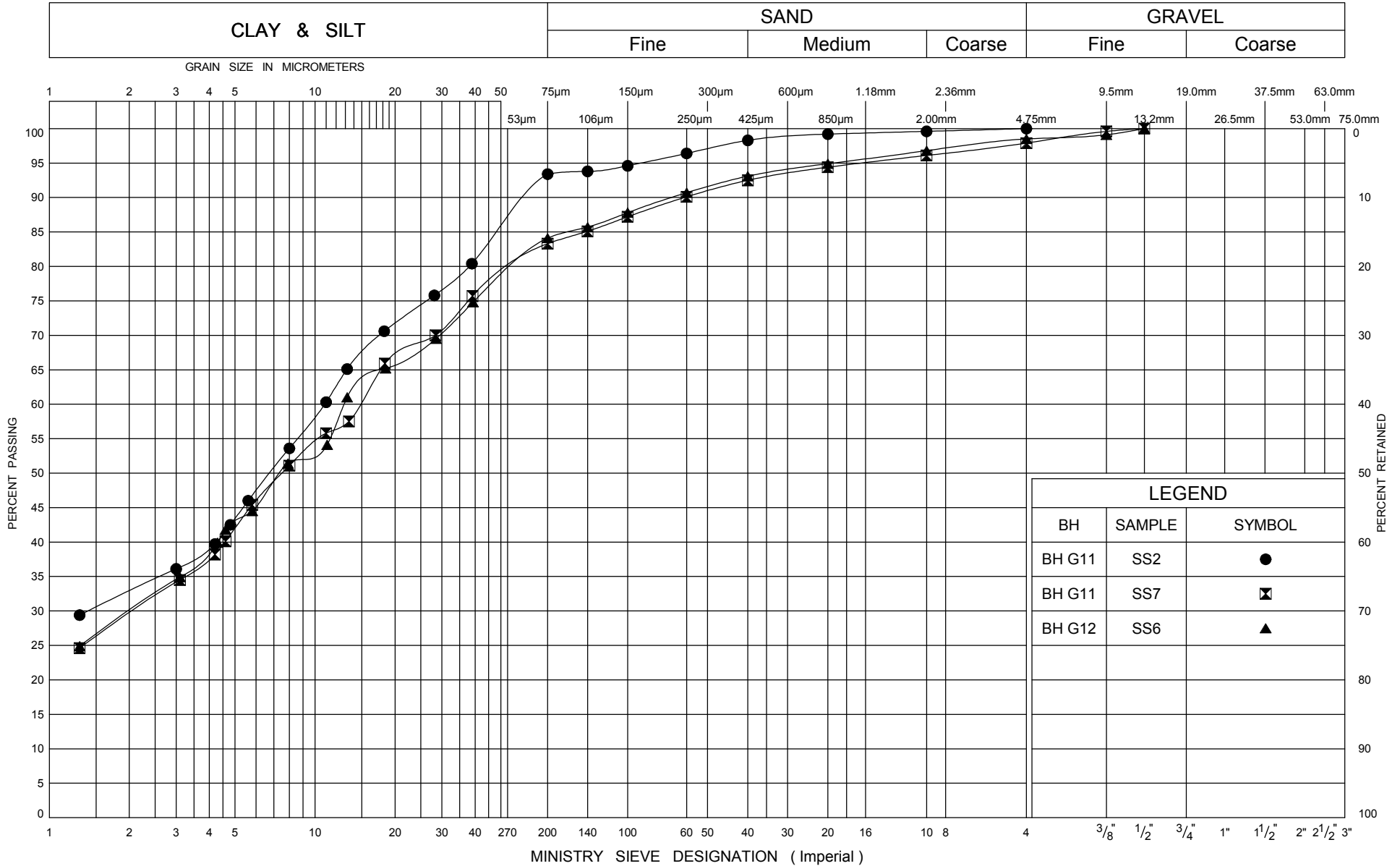
| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | DEPTH m | ELEVATION SCALE m | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | | SOIL VAPOUR READING | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|----------------------|---|------------|---------|------|------------|----------------------------|------------|-------------------------|---|--|--|--|--|--|--|--|------------------------|---|
| ELEV DEPTH (m) | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | | SHEAR STRENGTH kPa | | | | | WATER CONTENT (%) | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| 195.0 | | | | | | | | | | | | | | | | | | |
| 0.0 | about 350 mm TOPSOIL | | | | | | | | | | | | | | | | | |
| 194.7 | | | 1 | SS | 6 | | | | | | | | | | | | | |
| 0.4 | grey CLAYEY SILT trace sand firm to hard | | | | | | | | | | | | | | | | | |
| | | | 2 | SS | 15 | | 1 | 194 | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | 3 | SS | 34 | | | | | | | | | | | | | |
| | | | | | | | 2 | 193 | | | | | | | | | | |
| | | | 4 | SS | 36 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | grey | | 5 | SS | 33 | | 3 | 192 | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | 4 | 191 | | | | | | | | | | |
| | | | 6 | SS | 27 | | | | | | | | | | | | | |
| | trace cobbles / boulders | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | 5 | 190 | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | trace cobbles / boulders | | | | | | 6 | 189 | | | | | | | | | | |
| | | | 7 | SS | 25 | | | | | | | | | | | | | |
| 188.5 | | | | | | | | | | | | | | | | | | |
| 6.6 | End of Borehole | | | | | | | | | | | | | | | | | |
| | Groundwater level on 16 May 2011: borehole was dry | | | | | | | | | | | | | | | | | |

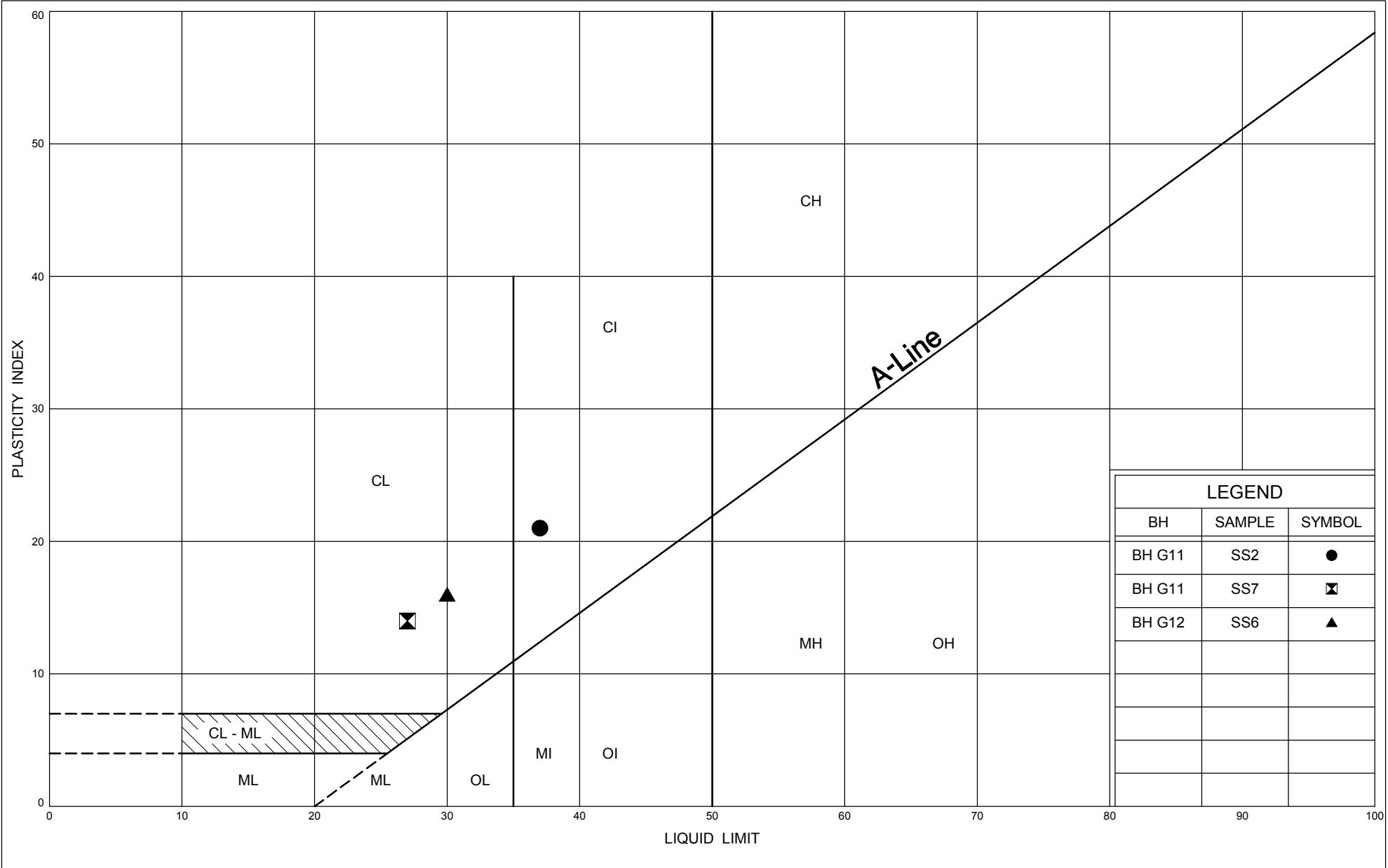
+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

APPENDIX B

LABORATORY TEST RESULTS

UNIFIED SOIL CLASSIFICATION SYSTEM





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

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

Report Date: 2011/06/06

CERTIFICATE OF ANALYSIS

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

Sample Matrix: Soil
 # Samples Received: 7

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

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

Encryption Key

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

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

=====

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

Total cover pages: 1

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

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

RESULTS OF ANALYSES OF SOIL

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

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

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

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

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

| | |
|-----------|--------|
| Package 1 | 20.3°C |
|-----------|--------|

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

GENERAL COMMENTS

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

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

QUALITY ASSURANCE REPORT

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

N/A = Not Applicable

RPD = Relative Percent Difference

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

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

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

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

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

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

Validation Signature Page

Maxxam Job #: B175937

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

A handwritten signature in black ink, appearing to read "Cristina Carriere".

CRISTINA CARRIERE, Scientific Services

=====

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

APPENDIX C

SITE PHOTOGRAPHS



Photograph No. 1: View of culvert inlet.



Photograph No. 2: View of culvert outlet.

APPENDIX D

SETTLEMENT MONITORING GUIDELINE

APPENDIX: SETTLEMENT MONITORING GUIDELINES - TUNNELING

The purpose of settlement monitoring is to prevent damage to existing utilities and highway structures along the tunnel alignment. Ground settlement include settlement due to lost ground and dewatering/drainage.

Instrumentation Arrays

All measurement points shall be installed and surveyed before the start of excavation to establish benchmarks/baseline.

Surface Monitoring Points

Surface monitoring points will be installed to cover the whole length of the tunnel with in the right of way under the jurisdiction of MTO (Figure 1).

Surface monitoring points will be located at not greater than 5m intervals along the tunnel alignment. The surface monitoring will be identified using paint marks on the pavement. Surface monitoring points installed on the unpaved right of way shall be founded below frost penetration depths. The interval and/or marking of the points should be changed with MTO's approval where traffic disruptions might occur.

The final instrumentation plan should be finalised when Contractor's proposed construction method is available.

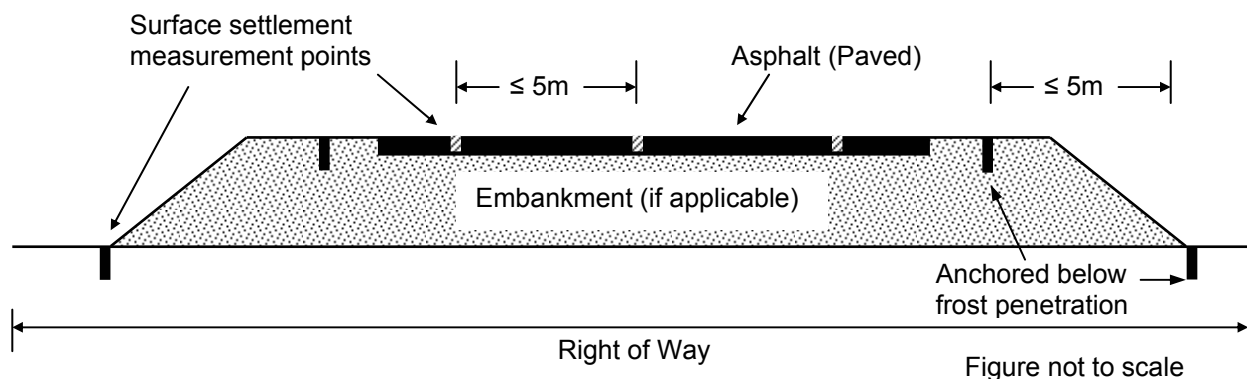


Figure 1: Typical configuration of surface settlement monitoring points along the tunnel alignment.

Condition Survey

A condition survey for the pavement will be carried out prior to commencement of construction and documented for the purpose of requirement of restoration. The condition survey shall document visible flaws such as cracks, distortions and deviations, heaves, and depressions. This surface survey will be completed during the installation of the monitors and again once the tunnel has been completed.

Reading Frequency

An average of at least two readings shall be taken to establish the initial conditions.

The reading and collection of data from the surface monitoring points shall be read and recorded by the Contractor during the construction period and after construction for period of at least 2 weeks provided that further settlement has stopped.

A minimum of three (3) sets of reading be taken daily, provided that movements are within anticipated limits. Otherwise, the frequencies should increase according to a pre-planned interval.

Monitoring of movements is required during work stoppages, such as during non-operation period (off-shifts) or weekends. A minimum of three (3) sets of readings should be taken daily.

Measurements of the monitoring points shall be reported promptly to MTO for review.

Data Collection and Data Transfer

A procedure is required to be established in consultation with MTO so that the monitoring data and the interpreted data will reach all parties as soon as necessary. The contract administrator/consultant and the Contractor should interpret monitoring data as needed for the purpose of on-going construction. The Foundation Engineer should be contacted for technical support to the prime Consultant in the interpretation of ground movements and review of the Contractor's response when Review and Alert Levels are reached.

Criteria for Assessment

The acceptable surface settlement (or heave) will be according to criteria as specified below.

Baseline Reading – A baseline reading of the instrumentation shall be taken prior to commencement of the work. An average of at least two initial readings shall be recorded as baseline reading.

Review Level – A maximum value of 10 mm relative to the baseline readings is suggested for this project. If this level is reached, the method, rate or sequence of construction, or ground stabilization measures should be reviewed or modified to mitigate further ground displacements.

Alert Level – A maximum value of 15mm relative to the baseline readings is suggested for this project. If this level is reached, the Contractor shall cease construction operations and to execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic.

Review of Contractor's Proposed Method

MTO, the Proponent's prime consultant and Foundation Engineer should review the Contractor's proposed method of construction. The proposed method should include a description of the potential loss of ground, and calculation of the maximum settlement in relation to the Contractor's procedure and equipment, alternative/remedial measures when review level of measurement is reached; and contingency/remedial measures when alert level of measurement is reached.

Contractor's Responsibility For Restoration and Warranty Provision

In addition to the monitoring program to assess the adequacy of the construction method to control potential ground movements and groundwater, the Contractor is responsible for reinstatement (such as surface paving) should movements or other surface distress occur, and provide a reasonable warranty period acceptable to MTO. Remedial measures shall be approved by MTO; however, MTO maintains the right to perform the maintenance at the proponent's expense.

Construction Monitoring

The Proponent shall retain a qualified Geotechnical Consultant to supervise the installation of surface settlement points on site and to provide direction, technical input and field inspection on this project.