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PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

Mullet Creek Culvert Extension Highway 401 Widening from East of Credit River to Trafalgar Road, Regional Municipalities of Peel and Halton W.O. 07-20021

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REPORT





Table of Contents

PART A – PRELIMINARY FOUNDATION INVESTIGATION REPORT

1.0 INTRODUCTION.....	1
2.0 SITE DESCRIPTION.....	1
3.0 INVESTIGATION PROCEDURES	1
4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS	2
4.1 Regional Geology	2
4.2 Subsurface Conditions.....	3
4.2.1 Surficial Clayey Silt	3
4.2.2 Clayey Silt Till	4
4.2.3 Gravelly Sand	4
4.2.4 Shale Bedrock.....	4
4.3 Groundwater Conditions	5
5.0 CLOSURE.....	6

PART B – PRELIMINARY FOUNDATION DESIGN REPORT

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS.....	7
6.1 General.....	7
6.2 Foundation Options	7
6.3 Box Culvert Extensions.....	8
6.3.1 Founding Elevations.....	8
6.3.2 Geotechnical Resistance/ Reaction	8
6.4 Open Footing Culvert Extensions and Shallow Foundations for Wing Walls/Retaining Walls	9
6.4.1 Founding Elevations.....	9
6.4.2 Geotechnical Resistance/ Reaction	10
6.5 Culvert Bedding, Backfill and Erosion Protection.....	10
6.6 Approach Embankments	11
6.6.1 Subgrade Preparation and Embankment Construction.....	11
6.6.2 Embankment Stability	11
6.6.3 Embankment Settlement.....	12



PRELIMINARY FOUNDATION REPORT - MULLET CREEK CULVERT EXTENSION

6.7	Construction Considerations.....	13
6.7.1	Excavation	13
6.7.2	Groundwater and Surface Water Control.....	13
6.7.3	Subgrade Protection	14
6.8	Recommendations for Further Work in Detail Design.....	14
7.0	CLOSURE.....	15

REFERENCES

TABLES

Table 1	Comparison of Foundation Alternatives
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DRAWINGS

Drawing 1	Mullet Creek Culvert – Borehole Locations and Soil Strata
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FIGURES

Figure 1	Static Global Stability – Highway 401 Embankment Widening
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APPENDIX A Borehole Records

Lists of Abbreviations and Symbols
Records of Boreholes 11-401 and 11-402

APPENDIX B Laboratory Test Results

Figure B1	Grain Size Distribution Test Results – Clayey Silt Till
Figure B2	Plasticity Chart – Clayey Silt Till
Figure B3	Grain Size Distribution Test Result – Gravelly Sand
Table B1	Point Load Test on Rock Samples



**PRELIMINARY FOUNDATION REPORT - MULLET CREEK
CULVERT EXTENSION**

PART A

**PRELIMINARY FOUNDATION INVESTIGATION REPORT
MULLET CREEK CULVERT EXTENSION
HIGHWAY 401 WIDENING FROM EAST OF CREDIT RIVER TO TRAFALGAR
ROAD, REGIONAL MUNICIPALITIES OF PEEL AND HALTON
W.O. 07-20021**



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by URS Canada Inc. (URS) on behalf of the Ministry of Transportation, Ontario (MTO) to provide preliminary foundation engineering services for the future widening of Highway 401 from east of the Credit River in the Regional Municipality of Peel to Trafalgar Road (approximately 9.7 km) in the Regional Municipality of Halton, Ontario.

This report addresses the results of the subsurface investigation carried out for the proposed southward and northward extensions of the existing Mullet Creek culvert structure.

The terms of reference and scope of work for the foundation engineering services are outlined in MTO's Request for Proposal (RFP) for Assignment No. 2008-E-0015 dated February 2010, and in Section 5.8 of the *Technical Proposal* for this assignment.

2.0 SITE DESCRIPTION

The Mullet Creek culvert (MTO Structure Site No. 24-253/C) crosses under Highway 401 approximately 250 m east of Derry Road West, in the Regional Municipality of Peel, Ontario. The existing structure consists of an open footing culvert, with a width of 6.1 m, a length of about 65 m and a height of about 1.5 m. The original culvert has been extended as part of a 1977 contract by about 5.5 m to the south.

In general, the natural ground surface within the floodplain in this area is relatively flat at about Elevation 178.5 m, rising toward the west and east. Mullet Creek flows from north to south at the site. According to the *Grading, Paving and Drainage* drawing (Sheet 21 from Contract 77-47), the culvert invert at the Highway 401 centreline was designed to be at about Elevation 177.1 m. Based on a structural inspection in October 2010, it appears that the creek channel has eroded such that the top of the footings at the downstream (south) end are clearly exposed. The survey completed as part of URS's assignment indicates that the creek channel at the upstream (north) and downstream (south) end of the culvert is now at approximately Elevation 176.6 m and 176.4 m, respectively. The water depth in the creek was observed during the time of the investigation to be approximately 0.4 m. The regional flood level for Mullet Creek at this site is Elevation 180.15 m, and the flood level resulting from the 100-year storm is approximately Elevation 178.95 m.

Highway 401 has been constructed on embankment fill that is approximately 4.5 m in height relative to the natural ground surface. The pavement grade is at about Elevation 183 m at the structure site. The Highway 401 embankment side slopes are oriented at approximately 2 to 3 horizontal to 1 vertical (2H:1V to 3H:1V) in the immediate vicinity of the culvert.

3.0 INVESTIGATION PROCEDURES

The field work for this subsurface investigation was carried out in September 2011, during which time two boreholes (Boreholes 11-401 and 11-402) were advanced using a track-mounted CME-55 drill rig, supplied and operated by Geo-Environmental Drilling Inc. of Milton, Ontario. The borehole locations are shown on Drawing 1: Boreholes 11-401 and 11-402 were advanced in the southwest and northeast quadrants of the structure site, respectively.



PRELIMINARY FOUNDATION REPORT - MULLET CREEK CULVERT EXTENSION

Boreholes 11-401 and 11-402 were advanced to termination depths of 13.6 m and 10.6 m below ground surface, respectively using 108 mm inner diameter hollow stem augers through the overburden and the upper weathered portion of the bedrock, and rock coring in the bedrock. . Soil samples were obtained at 0.75 m and 1.5 m intervals of depth in the boreholes, using a 50 mm outside diameter split-spoon sampler driven by an automatic hammer in accordance with the Standard Penetration Test (SPT) procedure. Samples of the bedrock were obtained using an NQ-size rock core barrel.

The groundwater conditions were observed in the open boreholes during and immediately following the drilling operations and a standpipe piezometer was installed in Borehole 11-402 to permit monitoring of the groundwater level. The piezometer consists of a 50 mm diameter PVC pipe, with a slotted screen sealed within a sand filter pack at a selected depth interval within the borehole. Above the sand filter pack and piezometer screen, the annulus surrounding the piezometer pipe was backfilled to the ground surface with bentonite pellets. The piezometer installation details and water level readings are indicated on the borehole record contained in Appendix A. The remaining borehole (Borehole 11-401) was backfilled with bentonite pellets upon completion, in accordance with Ontario Regulation 903 (as amended).

The field work was supervised on a full-time basis by a member of Golder's staff who located the boreholes in the field, contacted public utility companies to locate the existing underground services and cleared the borehole locations, directed the drilling, sampling, and in situ testing operations, and logged the boreholes. The soil and rock samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for further examination and laboratory testing. Index and classification tests consisting of water content determinations, Atterberg limits tests and grain size distribution tests were carried out on selected soil samples. Point load tests were carried out on selected rock core specimens. The geotechnical laboratory testing was completed according to applicable MTO LS procedures.

The location of the boreholes and ground surface elevations were measured in the field by Callon Dietz, a licensed Ontario Land Surveyor. The borehole locations (referenced to the MTM NAD83 co-ordinate system) and ground surface elevations (referenced to geodetic datum) are summarized in the following table and are shown on Drawing 1.

Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
11-401	4,829,244.1	284,426.8	178.3	13.6
11-402	4,829,362.5	284,412.4	178.5	10.6

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

This section of Highway 401 is located in the Peel Plain close to the border of the South Slope physiographic region, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984).



PRELIMINARY FOUNDATION REPORT - MULLET CREEK CULVERT EXTENSION

The Peel Plain physiographic region covers the central portions of the Regional Municipalities of York, Peel and Halton. The general topography of this region consists of level to gently rolling terrain, sloping gradually southward toward Lake Ontario. A surficial till sheet, which generally follows the surface topography, is present throughout much of this area. The till, which is mapped in this area as the Halton Till, typically consists of clayey silt to silty clay, with occasional sand to silt zones. Shallow, localized deposits of loose sand and silt and/or soft clay can overlie this uppermost till sheet, and these represent relatively recent deposits, formed in small glacial meltwater ponds scattered throughout the Peel Plain and concentrated near river valleys. The recent sand, silt and clay and uppermost till deposits in this area overlie and are interbedded with stratified deposits of sand, silt and clay. The overburden within the majority of the Peel Plain area is underlain by shale bedrock of the Georgian Bay Formation which contains limestone interlayers.

The South Slope region slopes gradually downward towards Lake Ontario. The overburden immediately below ground surface within the South Slope generally consists of clayey silt till and silty clay till and at depth consists of alternating deposits of dense lacustrine sands and silts and overconsolidated lacustrine clays and clay tills overlying the bedrock.

4.2 Subsurface Conditions

As part of the current subsurface investigation, two boreholes were advanced near the north and south ends of the existing culvert. The borehole locations, ground surface elevations and interpreted stratigraphic conditions are shown on Drawing 1. The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are given on the borehole records contained in Appendix A. The results of geotechnical laboratory testing are also presented on Figures B1 to B3 and Table B1 contained in Appendix B. The stratigraphic boundaries shown on the borehole records and on the interpreted stratigraphic section on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

In summary, the subsoil conditions encountered at the site consist of a surficial deposit of clayey silt overlying a deposit of clayey silt till which contains a layer of gravelly sand. Shale bedrock was encountered below the clayey silt till or gravelly sand in both boreholes. A more detailed description of the soil deposits and bedrock encountered in the boreholes is provided in the following sections.

4.2.1 Surficial Clayey Silt

A 1.5 m thick surficial clayey silt deposit was encountered in Borehole 11-402, extending to a depth of about 1.5 m (Elevation 177.0 m). The deposit consists of clayey silt containing trace to some sand and trace quantities of organic matter.

The measured SPT “N” values within the clayey silt deposit are 9 blows and 11 blows per 0.3 m of penetration, indicating a stiff consistency. The measured water content on one sample of the deposit is 13 per cent.



4.2.2 Clayey Silt Till

A deposit of clayey silt till was encountered below the surficial clayey silt in Borehole 11-402, and immediately below the ground surface in Borehole 11-401. The deposit extends to a depth about 7.6 m (Elevation 170.7 m) in Borehole 11-401 near the south end of the culvert, and to a depth of approximately 3.7 m (Elevation 174.8 m) in Borehole 11-402 near the north end of the culvert..

This till deposit consists of clayey silt with sand, containing trace to some gravel. The results of three grain size distribution tests carried out on selected samples of the deposit are shown on Figure B1 in Appendix B. Atterberg limits testing was carried out on three selected samples of the deposit and measured plastic limits of 14 per cent to 18 per cent, liquid limits of 19 per cent to 32 per cent, and plasticity indices 5 per cent to 14 per cent. The test results, which are plotted on a plasticity chart on Figure B2 in Appendix B, confirm that the deposit is comprised of clayey silt of low plasticity. The measured water content on selected samples of the till deposit ranged from 8 per cent to 15 per cent.

The measured SPT “N” value within the clayey silt till deposit range from 10 blows to 57 blows per 0.3 m of penetration. The lowest SPT “N” values of 10 blows and 14 blows per 0.3 m of penetration were measured immediately below the surface of the till in the two boreholes, with all remaining SPT “N” values above 21 blows per 0.3 m of penetration. These results indicate that the upper 0.75 m of the till deposit has a stiff consistency; below this depth, the deposit is very stiff to hard, with the consistency increasing with depth.

4.2.3 Gravelly Sand

A 0.6 m to 0.7 m thick interlayer or layer of gravelly sand was encountered within or below the clayey silt till in Boreholes 11-401 and 11-402, respectively. The surface of this layer was encountered at depths of about 3.7 m (Elevation 174.6 m and 174.8 m) below ground surface.

The gravelly sand contains some silt, and trace to some clay. The result of a grain size distribution test carried out on one selected sample of the layer is shown on Figure B3 in Appendix B. The measured water content on two samples of the gravelly sand was 4 per cent and 8 per cent.

The measured SPT “N” values within the gravelly sand till were 31 blows and 90 blows per 0.3 m of penetration, indicating a dense to very dense relative density.

4.2.4 Shale Bedrock

Bedrock was encountered below the gravelly sand or clayey silt till deposit at a depth of 7.6 m (Elevation 170.7 m) in Borehole 11-401 near the south end of the culvert, and at a depth of 4.3 m (Elevation 174.2 m) in Borehole 11-402 near the north end of the culvert.

Based on the bedrock core samples, the bedrock generally consists of reddish brown to grey shale, containing fossiliferous limestone interbeds. The upper 1.7 m to 1.9 m portion of the bedrock is described as weathered, based on being able to penetrate this portion of the bedrock by augering and split-spoon sampling. Below this depth, the recovered bedrock core samples are described as slightly to moderately weathered, laminated, grey, and weak to medium strong. The Rock Quality Designation (RQD) measured on the core samples is typically between about 0 and 65 per cent, indicating a rock mass of



PRELIMINARY FOUNDATION REPORT - MULLET CREEK CULVERT EXTENSION

very poor to fair quality. The Total Core Recovery (TCR) and Solid Core Recovery (SCR) of the recovered samples typically range between 73 per cent and 100 per cent, and 30 per cent and 72 per cent, respectively.

Point load strength tests were performed on two selected samples of rock core. Diametral point load strength index values are shown on the Record of Drillhole Sheets and on Table B1 in Appendix B following the text of this report. The point load index (Is_{50}) results from the diametral tests carried out on the two samples of shale bedrock were 0.3 MPa and 1.9 MPa. The point load index (Is_{50}) results from the axial tests carried out on the two samples of the shale bedrock were approximately 1.9 MPa and 2.8 MPa. The estimated uniaxial compressive strength (UCS) values for the tested samples are based on a relationship between Is_{50} and UCS which is given by a correlation factor (C) in accordance with ASTM D5731-08 (*Standard Test Method for Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classification*).

Based on the laboratory point load test results, as summarized in Tables B1 in Appendix B, and in accordance with Table 3.5 from CFEM (2006), the shale bedrock within the depth of exploration is classified as generally weak to medium strong (R2, 5 MPa < UCS < 25 MPa to R3, 25 MPa < UCS < 50 MPa), with strong limestone interbeds (R4, 50 MPa < UCS < 100 MPa), excluding the upper weathered zones.

4.3 Groundwater Conditions

Boreholes 11-401 and 11-402 were “dry” on completion of the overburden drilling, as noted on the borehole records contained in Appendix A. However, the gravelly sand layer and the shale bedrock are water-bearing.

A standpipe piezometer was installed in Borehole 11-402 to monitor the groundwater level at the site; this piezometer is sealed into the gravelly sand layer and the upper weathered portion of the shale bedrock. The water level measured in the piezometer is summarized in the following table:

Borehole Number	Ground Surface Elevation	Depth to Water Level	Groundwater Elevation	Date
11-402	178.5 m	0.4 m	178.1 m	November 2, 2011

The groundwater level should be expected to fluctuate seasonally and should be expected to rise during wet periods of the year.



PRELIMINARY FOUNDATION REPORT - MULLET CREEK CULVERT EXTENSION

5.0 CLOSURE

This Preliminary Foundation Investigation Report was prepared by Mr. Chris Sternik and Mr. Mehdi Mostakhdemi, M.Sc., M.Eng. and reviewed by Ms. Lisa Coyne, P.Eng., a senior geotechnical engineer and Principal with Golder. Mr. Ty Garde, P.Eng., a Designated MTO Foundations Contact for Golder, conducted an independent review of this report.

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PART B

**PRELIMINARY FOUNDATION DESIGN REPORT
MULLET CREEK CULVERT EXTENSION
HIGHWAY 401 WIDENING FROM EAST OF THE CREDIT RIVER TO
TRAFALGAR ROAD, REGIONAL MUNICIPALITIES OF PEEL AND
HALTON
W.O. 07-20021**



6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides preliminary foundation design recommendations for the proposed north and south extension of the existing Mullet Creek culvert, which is located under Highway 401 about 250 m east of Derry Road. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during this preliminary subsurface investigation. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to carry out the preliminary design of the culvert extensions. Further investigation and analysis will be required during detail design.

Where comments are made on construction, they are provided to highlight those aspects that could affect the future detail design of the project, and for which special provisions may be required in the Contract Documents. Those requiring information on construction aspects should make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.2 Foundation Options

Based on the planning study completed to date for Highway 401 from east of the Credit River to Trafalgar Road, it is understood that the future widening will consist of three additional lanes in both the eastbound and westbound directions on Highway 401, potentially in a core-collector system configuration. The existing Mullet Creek culvert will require extensions of approximately 20 m to 25 m on both the north and south sides of Highway 401.

Based on the grading, paving, drainage and structural drawings for the existing culvert, it consists of a 6.1 m wide by 1.5 m high open footing culvert with the invert at about Elevation 177 m. The existing culvert is supported on strip footings with a width of about 2 m, founded about 1.2 m below the culvert invert, at approximately Elevation 175.8 m.

From a foundation perspective, either box culverts or “open footing” (shallow foundation) concrete culverts are feasible for the north and south extension of the existing culvert.. Shallow foundations will provide sufficient bearing resistance and acceptable settlement performance for support of associated wing walls/retaining walls; deep foundations will not be required. Both pre-cast concrete elements (box culvert segments or footing elements) and cast-in-place concrete elements are feasible from a foundations perspective.

Although it is recognized that the culvert extensions will likely be required to match the existing culvert, in accordance with the Terms of Reference set out in the *Request for Proposal* for this assignment, this section of the report presents advantages, disadvantages and geotechnical recommendations for both box culvert extensions and open footing culvert extensions.

The advantages and disadvantages associated with both box culvert and open footing culvert extension options are summarized in Table 1 following the text of this report. From a foundations perspective, pre-cast box culvert extensions are preferred over cast-in-place open footing culvert extensions based on the following:



PRELIMINARY FOUNDATION REPORT - MULLET CREEK CULVERT EXTENSION

- Pre-cast box culvert extensions minimize the depth of excavation and groundwater control requirements as compared with open footings.
- Pre-cast box culvert segments can often be installed more expeditiously than cast-in-place open footing culverts, resulting shorter durations for dewatering and surface water pumping.
- Pre-cast box culvert segments are more tolerant of the total and differential settlement that will result under the widened highway embankment loading.

It is noted, however, that if box culvert extensions do not satisfy fisheries requirements related to channel substrate, open footing culvert extensions are geotechnically feasible for this site. Recommendations for both box culvert extensions and shallow foundation (open footing) culvert extensions are provided in the following sections.

6.3 Box Culvert Extensions

6.3.1 Founding Elevations

It is not necessary to found box culvert extensions at the standard depth for frost protection purposes, as box structures are tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur. Box culvert extensions should, however, be founded below any existing fill and surficial organic materials, if encountered. The table below provides the recommended founding elevation and subexcavation requirements for the box culvert extensions, based on an assumed base slab thickness of 500 mm, and assuming that the upstream and downstream extensions are founded deeper than the original culvert invert as a result of the observed creek bed erosion at the site. It is recommended that the box culvert segments be placed on a minimum thickness of 300 mm of granular bedding meeting the material requirements of Ontario Provincial Standard Specification (OPSS) 1010 Granular A.

Proposed Culvert Invert Elevation	Highest Base Slab Founding Elevation	Subgrade Elevation for Granular Bedding	Founding Stratum
176.6 m (Upstream)	176.1 m	175.8 m	Very stiff to hard clayey silt till
176.4 m (Downstream)	175.9 m	175.6 m	

Surface water control will be required during excavation and construction of the culvert extensions; in addition, it is expected that some groundwater control will be required. These aspects are discussed further in Section 6.7.

6.3.2 Geotechnical Resistance/ Reaction

For preliminary design, box culvert extensions placed on the properly prepared subgrade, at or below the founding elevation identified above, should be designed based on the following factored geotechnical resistance at Ultimate Limit States (ULS) and geotechnical reaction at Serviceability Limit States (SLS):



PRELIMINARY FOUNDATION REPORT - MULLET CREEK CULVERT EXTENSION

Culvert Span	Factored Geotechnical Resistance at ULS	Geotechnical Reaction at SLS*
6.1 m	400 kPa	250 kPa

*For 25 mm of settlement.

The preliminary geotechnical resistances should be reviewed if the culvert span or founding elevation differs significantly from that given above. In addition, the preliminary geotechnical resistance/reactions values provided above will have to be re-evaluated and modified as necessary during detail design, based on future additional subsurface investigation within the culvert extension areas along with their associated wing walls/retaining walls.

6.4 Open Footing Culvert Extensions and Shallow Foundations for Wing Walls/Retaining Walls

6.4.1 Founding Elevations

Strip footings for open footing culvert extensions, and for any associated concrete wing walls/retaining walls, should be founded at a minimum depth of 1.2 m below the lowest surrounding grade to provide adequate protection against frost penetration. In addition, the footings should extend below any unsuitable soils, where these are present. The following table provides the recommended preliminary founding elevation for strip footings for the proposed culvert extensions, assuming that the upstream and downstream extensions are founded deeper than the original culvert invert as a result of the observed erosion at the site. Based on the conditions encountered in Boreholes 11-401 and 11-402, no additional subexcavation is expected to be required at this preliminary stage.

Proposed Culvert Invert Elevation	Maximum (Highest) Footing Founding Elevation	Founding Stratum
176.6 m (Upstream) 176.4 m (Downstream)	175.4 m (Upstream) 175.2 m (Downstream)	Very stiff clayey silt till

Due to the observed erosion and the lower invert elevations planned for the culvert extensions, excavations for footings for the extensions will extend below the existing culvert footings. Appropriate measures will be required during construction to support the soils below the existing culvert footings during excavation, to prevent undermining of the culvert footings.

The footing subgrade will be susceptible to loosening and degradation on exposure to water and construction traffic. As discussed further in Section 6.7, it is recommended that a 100 mm thick concrete working slab be placed on the inspected and approved footing subgrade, to protect the subgrade from degradation and to form a working mat for construction of the footings for the culvert extensions.

Groundwater and surface water control will be required for excavation and construction of open footing culvert extensions, including potential dewatering of the gravelly sand/bedrock aquifer to maintain an adequate factor of



PRELIMINARY FOUNDATION REPORT - MULLET CREEK CULVERT EXTENSION

safety against base failure in the temporary excavations for culvert footings, as discussed further in Section 6.7 (Construction Considerations).

6.4.2 Geotechnical Resistance/ Reaction

For preliminary design, strip footings placed on the properly prepared subgrade, at or below the founding elevation identified above, should be designed based on the following factored geotechnical resistances at ULS and geotechnical resistances at SLS.

Founding Stratum	Footing Width	Factored Geotechnical Resistance at ULS	Geotechnical Reaction at SLS*
Very stiff clayey silt till	2 m (match existing culvert footing) to 3 m	325 kPa	275 kPa

* For 25 mm of total settlement for the given footing width.

For wingwalls/retaining walls that may be associated with the culvert extensions, the structural engineer must ensure that the selected footing width is sufficient to resist overturning.

The preliminary geotechnical resistances/reactions should be reviewed if the culvert footing widths and/or founding elevation differ significantly from that given above. In addition, these preliminary geotechnical resistances/reactions are provided for loads applied perpendicular to the surface of the footings; where applicable, inclination of the load should be taken into account in accordance with Section 6.7.4 of the *Canadian Highway Bridge Design Code (CHBDC 2006)* and its *Commentary*.

The preliminary geotechnical resistance/reaction values provided above will have to be re-evaluated and modified as necessary during detail design, based on future additional subsurface investigation within the culvert extension areas along with their associated wing walls/retaining walls.

6.5 Culvert Bedding, Backfill and Erosion Protection

For a box culvert extension, the bedding levelling pad and backfill requirements should be in accordance with provincial standards and the manufacturer's requirements. As discussed in Section 6.3, it is recommended that box culvert extensions be provided with at least 300 mm of OPSS 1010 Granular A material for bedding purposes.

Backfill and cover for concrete culverts should be completed in accordance with provincial standards. Backfill to culvert walls should consist of granular fill meeting the requirements of OPSS 1010 Granular A or Granular B Type II, but with less than 5 per cent passing the No. 200 sieve. The culvert extensions should be designed for the full overburden pressure and live load, assuming that the fill has a unit weight of 22 kN/m³ for Granular A, and 21 kN/m³ for Granular B Type II or select earth fill above and/or surrounding the culvert.

To prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring) or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of



fine soil particles), a concrete cut-off wall should be provided at the upstream end of box culvert extensions, while a clay seal should be provided at the upstream end of open footing culvert replacements or extensions. Given the observed creek bed erosion at the culvert site, provision should be made for scour and erosion protection (suitable non-woven geotextiles and/or rip-rap or rock protection) at the culvert inlet and outlet, including in front of any wing walls/retaining walls adjacent to the creek channel.

6.6 Approach Embankments

6.6.1 Subgrade Preparation and Embankment Construction

It is recommended that all topsoil/organic material, existing fill, and surficial loose or soft to firm native soils be stripped from the footprint of the proposed Highway 401 embankment widening. The depth and extent of stripping should be assessed during detail design when additional subsurface information will be available for the widened embankment areas. Additional fill for construction of the embankment widening could consist of clean earth fill or granular fill. From a geotechnical/foundations perspective, both earth and granular fill will provide good compatibility with the existing embankment fill materials. To reduce erosion of the embankment side slopes due to surface water runoff, placement of topsoil and seeding or pegged sod is recommended as soon as practicable after construction of the embankments.

6.6.2 Embankment Stability

Preliminary slope stability analyses have been performed for the widened Highway 401 embankment using the commercially available program SLIDE, produced by Rocscience Inc., to check that a minimum factor of safety of 1.3 is achieved for the proposed embankment heights and geometries under static conditions. This minimum factor of safety is considered appropriate for the widened highway embankments on this project, considering the design requirements and the available field and laboratory testing data.

The stability analyses were completed for an approximately 4.5 m high embankment widening, based on the subsurface conditions as encountered in Boreholes 11-401 and 11-402. The following parameters have been used in the preliminary stability analyses, based on field and laboratory test data as well as accepted correlations:

Soil Deposit	Bulk Unit Weight (kN/m ³)	Effective Friction Angle	Undrained Shear Strength (kPa)
Stiff surficial clayey silt	19	28°	75
Stiff to hard clayey silt till	20	32°	-
Dense to very dense gravelly sand	21	34°	-
Hard clayey silt till	21	35°	-



PRELIMINARY FOUNDATION REPORT - MULLET CREEK CULVERT EXTENSION

The preliminary stability analysis results indicate that the approximately 4.5 m high widened Highway 401 embankment with side slopes oriented no steeper than 2H:1V will have a factor of safety of at least 1.3 against global instability, assuming appropriate subgrade preparation and proper placement and compaction of the embankment fill materials. An example static global stability result is provided on Figure 1. This preliminary assessment of the stability of the approach embankments should be reviewed and confirmed based on the subsoil conditions encountered within the proposed embankment widening footprints during detail design.

6.6.3 Embankment Settlement

Based on the planning study completed to date, the existing 4.5 m high Highway 401 embankment will require widening by approximately 20 m to 25 m on both the north and south sides in this area.

Preliminary settlement analyses for the anticipated soil conditions below the widened Highway 401 embankment were carried out using both hand calculations and the commercially available computer program *Settle-3D* from Rocscience, using estimated elastic deformation moduli and consolidation parameters as given in the table below, based on correlations with the SPT “N” values and laboratory test results, and engineering judgement from experience with similar soils in this region of Ontario (Bowles, 1984; Kulhawy and Mayne, 1990; Peck et al., 1974).

Soil Deposit	Bulk Unit Weight (kN/m ³)	Elastic Modulus (MPa)
Embankment fill	21	-
Stiff surficial clayey silt	19	10
Stiff to hard clayey silt till	20	50
Dense to very dense gravelly sand	21	75
Hard clayey silt till	21	75

Based on this preliminary assessment, the settlement of the foundation soils under the widened 4.5 m high Highway 401 embankments is estimated to be less than about 25 mm. The settlement of the culvert itself under the widened embankment loading is expected to be less than this, as the existing culvert and new extensions would be founded below the stiff surficial clayey silt and the stiff upper portion of the till deposit. Further assessment of the differential settlement should be completed at the detail design stage, once the embankment geometry is confirmed.

The majority of this settlement is expected to occur relatively quickly during and immediately following construction of the embankment widening, based on the nature of the soils at the site. However, if the surficial clayey silt deposit has less stiff zones than that encountered in Borehole 11-402 as part of the preliminary investigation, there is potential for some slightly longer-term consolidation settlement within the surficial clayey silt deposit, and this could be variable across the embankment widening area. The estimated magnitude and rate of settlement should be reassessed based on the soil and groundwater conditions under the widened



embankments as determined during detail design, with particular emphasis on the thickness and properties of the surficial clayey silt deposit throughout the embankment widening areas.

6.7 Construction Considerations

The following subsections identify future construction issues that should be considered at this stage as they may impact the planning and preliminary design. Where applicable, Non-Standard Special Provisions (NSSP) should be developed during detail design for incorporation in the Contract Documents.

6.7.1 Excavation

The foundation excavations for the culvert extensions will extend through existing surficial stiff clayey silt, into stiff to hard clayey silt till. If space permits, open-cut excavations into these materials should be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act (OHSA) for Construction Activities. The existing surficial soil is classified as Type 3 soil, according to the OHSA. Temporary excavations (i.e. those that are open for a relatively short time period) through these materials should be made with side slopes no steeper than 1H:1V, assuming that proper groundwater control is in place in the glacial till deposits.

Due to the observed erosion and the lower invert elevations planned for the culvert extensions, excavations for footings for the extensions will extend below the existing culvert footings. Appropriate measures will be required during construction to support the soils below the existing culvert footings during excavation, to prevent undermining of the culvert footings.

6.7.2 Groundwater and Surface Water Control

Depending on the creek flow at the time of construction, the surface water flow could be passed through the culvert area by means of a temporary pipe, or diverted by pumping from behind a temporary cofferdam. Surface water should be directed away from the excavation areas, to prevent ponding of water that could result in disturbance and weakening of the clayey silt till subgrade.

The excavation for the culvert extension will extend through and into relatively less permeable cohesive soil deposits – the surficial clayey silt and clayey silt till. Groundwater seepage from these cohesive soils is expected to be relatively minor, and should be able to be handled by pumping from properly filtered sumps within or just outside the excavation for the extensions. However, there is potential for the excavation to encounter some “perched” groundwater at the base of the Highway 401 embankment fill. In addition, the groundwater level associated with the gravelly sand layer and the shale bedrock is relatively high (near the ground surface). If open footing culvert extensions are adopted, founded at approximately Elevation 175.8 m, there is a potential risk of instability at the temporary excavation base due to the groundwater pressure in the underlying aquifer(s), and some dewatering may be required to lower the groundwater pressure associated with this aquifer to maintain an adequate factor of safety against excavation base heave. If box culvert extensions are adopted, founded at a slightly higher elevation, it is anticipated that dewatering of the underlying aquifers will not be



required. This aspect will require further investigation, measurement of the variability in the groundwater level, and assessment of the factor of safety against excavation base failure at detail design.

6.7.3 Subgrade Protection

If open footing culvert extensions are adopted, the clayey silt till deposit that will be exposed at the foundation subgrade level will be susceptible to disturbance from construction traffic and/or ponded water. To limit this degradation, it is recommended that a concrete working slab be placed on the subgrade within four hours after preparation, inspection and approval of the footing subgrade. This requirement can be addressed with a note on the General Arrangement drawing and/or with an NSSP, which can be developed during the detail design stage.

6.8 Recommendations for Further Work in Detail Design

Additional boreholes will be required within the culvert extension and embankment widening areas during the future detail design stage of investigation, to further assess and/or confirm the subsurface conditions and the preliminary recommendations provided in this report, as follows:

- Culvert extensions:
 - Assessment of the thickness of the surficial clayey silt deposit, to confirm the founding elevation and bearing resistances for culvert extensions and associated wing walls/retaining walls.
 - Further assessment of the differential settlement between the existing culvert ends and the new extensions, based on more detailed existing embankment geometry information at the culvert location.
 - Further assessment of the groundwater level(s) associated with the gravelly sand and shale bedrock aquifers, and assessment of the potential requirement for dewatering to lower the groundwater pressure acting on the base of open footing excavations.
- Embankment widening:
 - Assessment of the depth and extent of stripping of topsoil/organics and fill materials within the footprint of the widened Highway 401 approach embankments.
 - Further assessment of the thickness, strength and consolidation/elastic compression properties of the surficial soils within the footprint of the widened embankments, particularly the surficial clayey silt deposit, to confirm the preliminary stability analyses and settlement estimates.

In addition, as the footings at the south end of the existing culvert have been exposed due to erosion/scour, remedial work will be required to protect these existing footings.

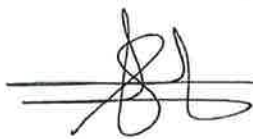


PRELIMINARY FOUNDATION REPORT - MULLET CREEK CULVERT EXTENSION

7.0 CLOSURE

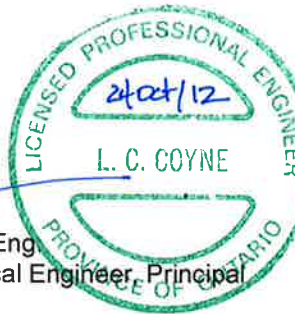

This Preliminary Foundation Design Report was prepared by Mr. Mehdi Mostakhdemi, M.Sc., M.Eng., and reviewed by Ms. Lisa Coyne, P.Eng., a geotechnical engineer and Principal with Golder. Mr. Ty Garde, P.Eng., a Principal and Designated MTO Foundations Contact for Golder, conducted an independent review of this report.

GOLDER ASSOCIATES LTD.



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PRELIMINARY FOUNDATION REPORT - MULLET CREEK CULVERT EXTENSION

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- Canadian Geotechnical Society, 2006. *Canadian Foundation Engineering Manual*, 4th Edition. The Canadian Geotechnical Society, BiTech Publisher Ltd., British Columbia.
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- Chapman, L.J., and Putnam, D.F., 1984. *The Physiography of Southern Ontario*, 3rd Edition. Ontario Geological Survey, Special Volume 2. Ontario Ministry of Natural Resources.
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- Ontario Geological Society, 1991. *Geology of Ontario*. Special Volume 4, Part 1. Eds. P.C. Thurston, H.R. Williams, R.H. Sutcliffe and G.M. Stott. Ministry of Northern Development and Mines, Ontario.
- Peck, R.B., Hanson, W.E., and Thornburn, T.H., 1974. *Foundation Engineering*, Second Edition, John Wiley and Sons, New York.

Ontario Provincial Standard Specifications (OPSS)

OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS 501	Construction Specification for Compacting
OPSS 539	Construction Specification for Temporary Protection Systems
OPSS 572	Construction Specification for Seed and Cover
OPSS 902	Construction Specification for Excavating and Backfilling Structures
OPSS 1002	Material Specification for Aggregates - Concrete
OPSS 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
OPSS 1205	Material Specification for Clay Seal

Ontario Provincial Standard Drawings (OPSD)

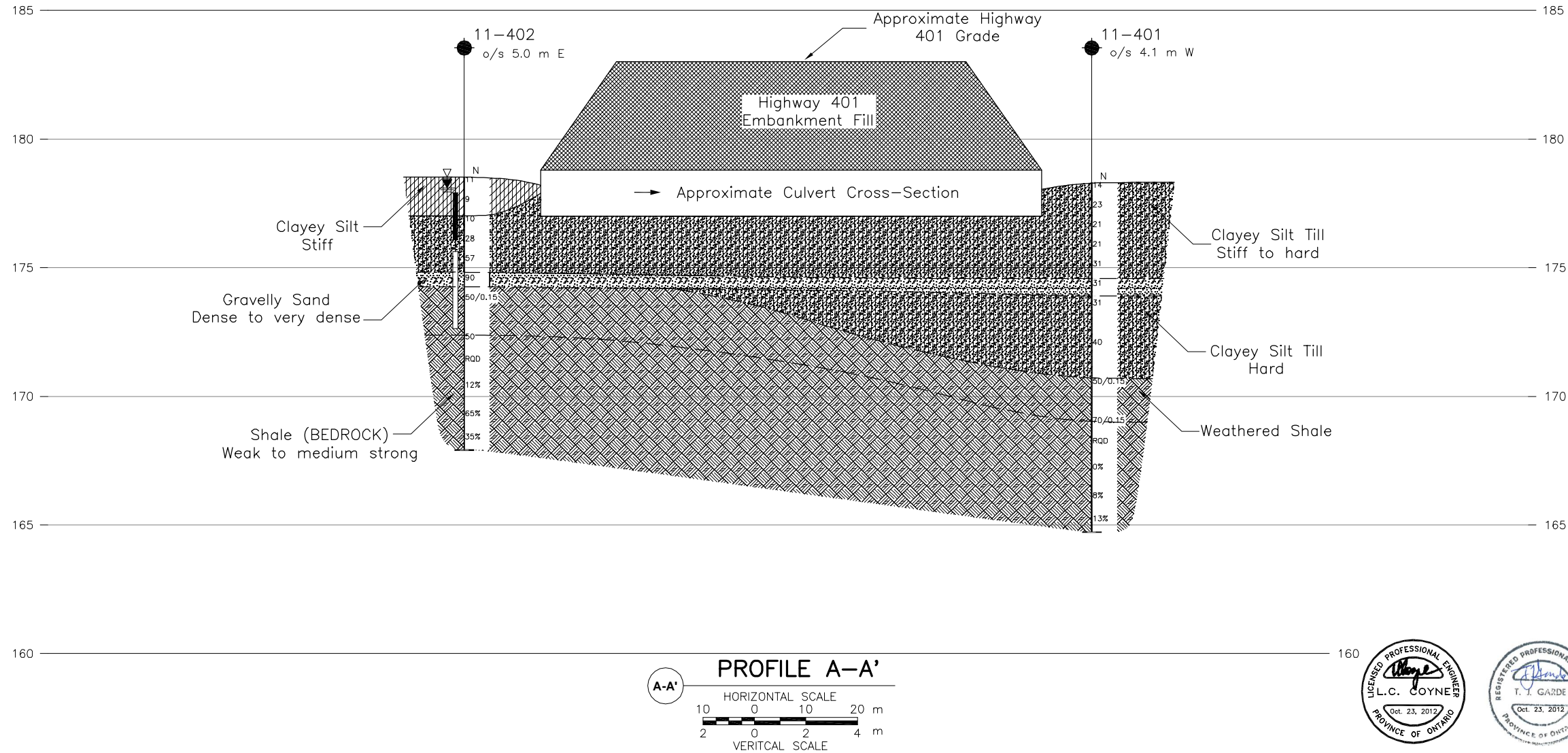
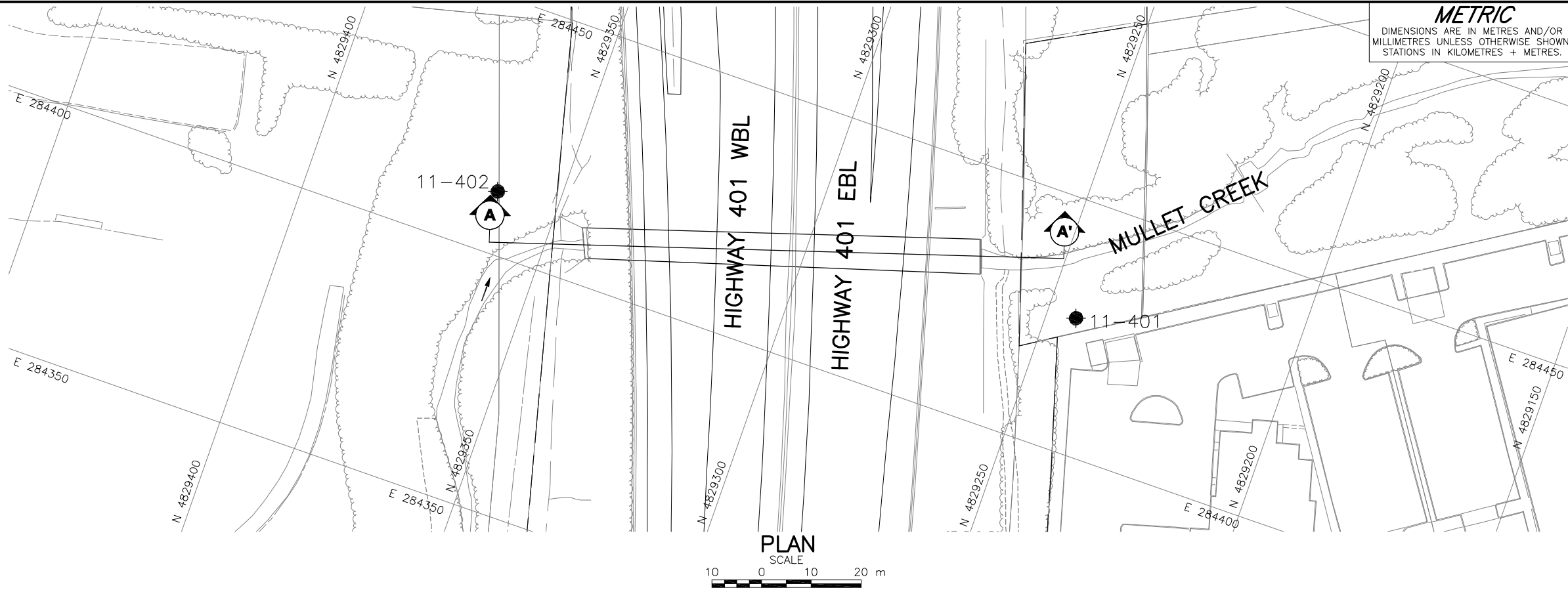
OPSD 803.010	Backfill and Cover for Concrete Culverts
OPSD 810.010	Rip-Rap Treatment for Sewer and Culvert Outlets
OPSD 3090.101	Foundation Frost Penetration Depths for Southern Ontario



PRELIMINARY FOUNDATION REPORT - MULLET CREEK CULVERT EXTENSION

TABLE 1
COMPARISON OF FOUNDATION ALTERNATIVES

Option	Advantages	Disadvantages	Risks/Consequences
Box culvert extension	<ul style="list-style-type: none"> ■ Minimizes depth of excavation, protection system and dewatering requirements compared to open footing option ■ Pre-cast box sections expected to allow faster construction than cast-in-place open footings, with shorter duration for dewatering and surface water pumping 	<ul style="list-style-type: none"> ■ Although shallower than for open footings, there is still potential for some groundwater seepage from the base of the embankment fill or cohesionless soil lenses within the till, requiring some dewatering ■ Greater disturbance to natural creek channel than for open footing culvert option 	<ul style="list-style-type: none"> ■ Base of excavation for new box culvert would be above founding level of existing open footing culvert, resulting in increased structural load on existing foundations and possible settlement at ends of existing culvert..Risk of disturbance of existing culvert founding soils is minimal.
Open footing culvert extension	<ul style="list-style-type: none"> ■ Would satisfy any fisheries requirements related to natural channel substrate, if applicable ■ Minimizes disturbance of creek channel during excavation, as compared with wider span for box culvert ■ May be feasible to build culvert extensions on pre-cast footing sections, to accelerate the construction schedule and reduce time for dewatering and surface water pumping 	<ul style="list-style-type: none"> ■ Excavation depths are greater than for box culvert extension option, resulting in increased excavation support and potential requirement for dewatering of underlying gravelly sand/shale aquifer ■ Cast-in-place footings may require a longer duration for construction, including dewatering and surface water pumping, as compared with pre-cast culvert segments or footing elements 	<ul style="list-style-type: none"> ■ Compatible with existing open footing culvert founding level, with some risk of disturbance of existing culvert founding soils. Minor differential settlement between culvert and extensions should be expected.



CONT No.
WO No. 07-20021

MULLET CREEK CULVERT
HIGHWAY 401 WIDENING
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

SHEET

KEY PLAN
SCALE
1.5 0 1.5 3 km

LEGEND

- Borehole - Current Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- WL in piezometer, measured on November 2, 2011
- WL upon completion of drilling
- Direction of flow

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
11-401	178.3	4829244.1	284426.8
11-402	178.5	4829362.5	284412.4

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the design configuration as shown elsewhere in the Preliminary Design Report.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

The complete Preliminary Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS, Drawing File Nos. ACAD-X-base1_to_Trafalgar.dwg and ACAD-Aerials_MTO ROW_Property Boundaries.dwg, received August 17, 2011 and August 29, 2011.

NO.	DATE	BY	REVISION

Geocres No. 30M12-348

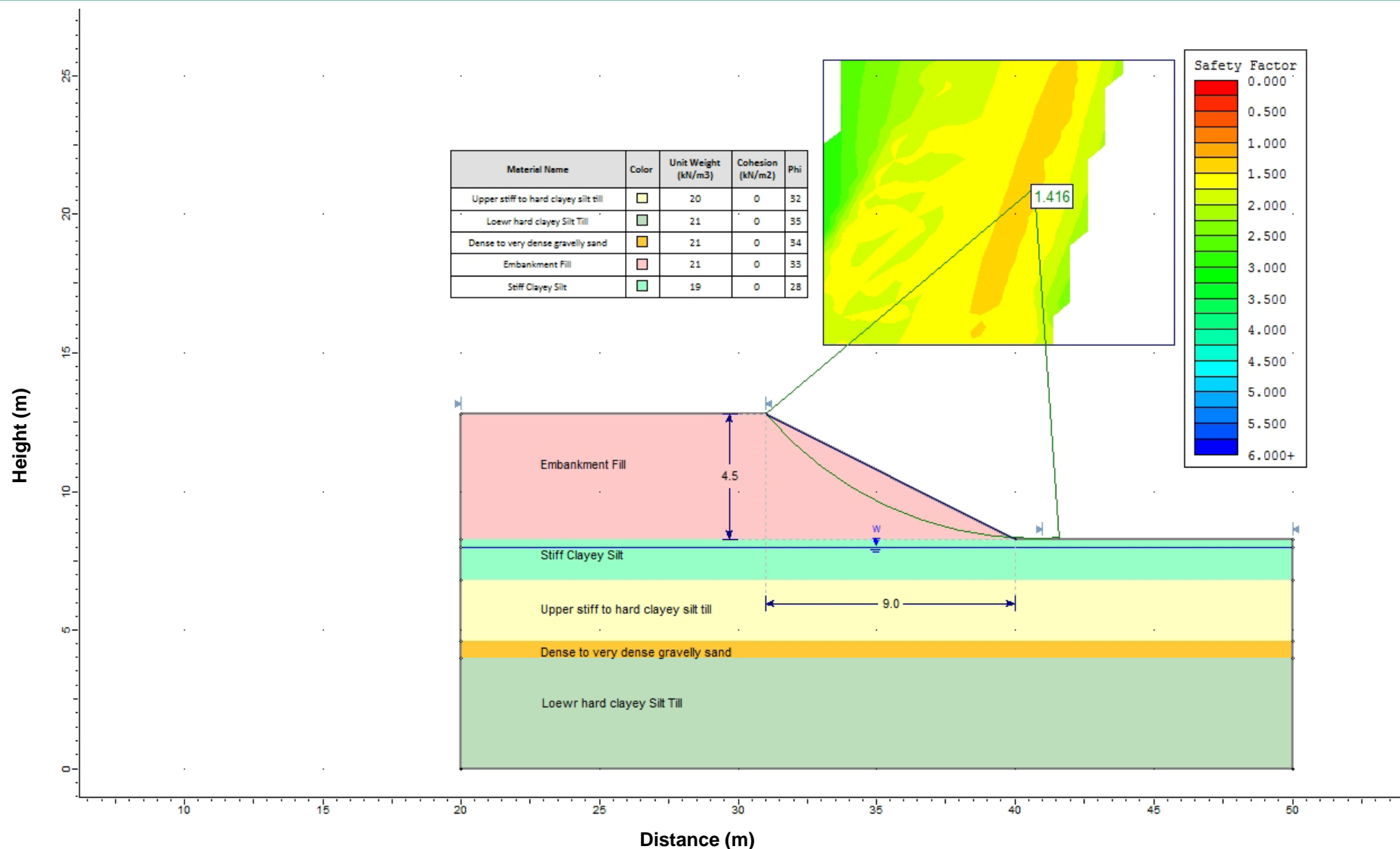
HWY. 401	PROJECT NO. 10-1111-0040	DIST.
SUBM'D. MM	CHKD. LCC	DATE: 10/23/2012
DRAWN: JFC	CHKD. MM	APPD. LCC

DWG. 1



Static Global Stability – Mullet Creek Culvert Highway 401 Embankment

Figure 1





APPENDIX A

Borehole Records



LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
SS	Split-spoon
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH:	Sampler advanced by hydraulic pressure
PM:	Sampler advanced by manual pressure
WH:	Sampler advanced by static weight of hammer
WR:	Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils Consistency

	c_u, s_u	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

V. MINOR SOIL CONSTITUENTS

Percent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (cohesionless) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand



LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
$\ln x$,	natural logarithm of x
\log_{10}	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
C_v	coefficient of consolidation (vertical direction)
C_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan \delta$
c'	effective cohesion
C_u, S_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

* Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$



LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERINGS STATE

Fresh: no visible sign of weathering

Faintly weathered: weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.

Completely weathered: rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

BEDDING THICKNESS

<u>Description</u>	<u>Bedding Plane Spacing</u>
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 m to 2 m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	Less than 6 mm

JOINT OR FOLIATION SPACING

<u>Description</u>	<u>Spacing</u>
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

<u>Term</u>	<u>Size*</u>
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: * Grains greater than 60 microns diameter are visible to the naked eye.

CORE CONDITION

Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

DISCONTINUITY DATA

Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

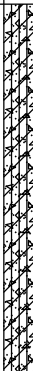
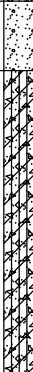


Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations

JN Joint	PL Planar
FLT Fault	CU Curved
SH Shear	UN Undulating
VN Vein	IR Irregular
FR Fracture	K Slickensided
SY Stylolite	PO Polished
BD Bedding	SM Smooth
FO Foliation	SR Slightly Rough
CO Contact	RO Rough
AXJ Axial Joint	VR Very Rough
KV Karstic Void	
MB Mechanical Break	

PROJECT <u>10-1111-0040</u>		RECORD OF BOREHOLE No 11-401		SHEET 1 OF 2		METRIC	
G.W.P. <u>07-20021</u>		LOCATION <u>N 4829244.1 ; E 284426.8</u>		ORIGINATED BY <u>SB/BM</u>			
DIST <u>Central</u> HWY <u>401</u>		BOREHOLE TYPE <u>Track-Mounted CME55, 108 mm I.D. Hollow Stem Augers</u>		COMPILED BY <u>MM</u>			
DATUM <u>NAD83, Geodetic</u>		DATE <u>September 6, 2011</u>		CHECKED BY <u>LCC</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)	
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × REMOULDED							
178.3	GROUND SURFACE							20 40 60 80 100		10 20 30						
0.0	CLAYEY SILT with sand, trace gravel (TILL) Stiff to hard Brown and grey Moist		1	SS	14											
			2	SS	23											
			3	SS	21											
	Becoming grey at a depth of 2.3 m		4	SS	21											
			5	SS	31											
174.6																
3.7	Gravelly SAND, some silt, trace clay Dense Brown		6	SS	31											
173.9	Wet															
4.4	CLAYEY SILT with sand, some gravel (TILL) Hard Brown Moist		7	SS	31											
			8	SS	40											
170.7																
7.6	Shale (BEDROCK) Weathered Reddish brown		9	SS	50/0.15											
169.0			10	SS	70/0.15											
9.3	Shale (BEDROCK) containing limestone interbeds															
	Bedrock cored between 9.3 m and 13.6 m. For bedrock coring details, refer to Record of Drillhole 11-401		1	RC	REC 75%									RQD = 0%		
			2	RC	REC 73%									RQD = 8%		
			3	RC	REC 100%									RQD = 13%		
164.7	END OF BOREHOLE															
13.6	NOTE: 1. Wet soils encountered at 3.7 m (Elev. 174.6 m), but borehole dry on completion of overburden drilling.															

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

GTA-MTO 001 1011110040.GPJ GAL-GTA.GDT 10/22/12 DD

[illegible]

PROJECT		10-1111-0040		RECORD OF BOREHOLE No 11-402		SHEET 1 OF 2		METRIC				
G.W.P.		07-20021		LOCATION		N 4829362.5 ; E 284412.4		ORIGINATED BY				
DIST		Central HWY 401		BOREHOLE TYPE		Track-Mounted CME55, 108 mm I.D. Hollow Stem Augers		COMPILED BY				
DATUM		NAD83, Geodetic		DATE		September 6, 2011		CHECKED BY				
								LCC				
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC NATURAL LIQUID UNIT REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	W _p W W _L	WATER CONTENT (%)	γ	GR SA SI CL
178.5	GROUND SURFACE											
0.0	CLAYEY SILT, trace to some sand, containing rootlets Stiff Brown Moist		1	SS	11		178					
			2	SS	9							
177.0							177					
1.5	CLAYEY SILT with sand, trace to some gravel (TILL) Stiff to hard Grey Moist		3	SS	10							
			4	SS	28		176					
			5	SS	57		175					25 30 38 7
174.8												
3.7	Gravelly SAND, some silt, trace clay Very dense Grey Moist		6	SS	90		174					28 47 17 8
174.2												
4.3	Shale (BEDROCK) Weathered Reddish brown to grey Moist		7	SS	50/0.15		173					
172.3							172					
6.2	Shale (BEDROCK) containing limestone interbeds		8	SS	80							
	Bedrock cored between 6.2 m and 10.6 m. For bedrock coring details, refer to Record of Drillhole 11-402		1	RC	REC 88%		171					RQD = 12%
			2	RC	REC 100%		170					RQD = 65%
			3	RC	REC 95%		169					RQD = 35%
167.9							168					
10.6	END OF BOREHOLE											
NOTE: 1. Borehole dry on completion of overburden drilling. 2. Water level in monitoring well measured as follows: Date Depth (m) Elev. (m) 09/06/11 0.0 178.5 11/02/11 0.4 178.1												

PROJECT: 10-1111-0040

RECORD OF DRILLHOLE: 11-402

SHEET 2 OF 2

LOCATION: N 4829362.5 ; E 284412.4

DRILLING DATE: September 6, 2011

DATUM: NAD83, Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: Track-Mounted CME 55

DRILLING CONTRACTOR: Geo-Environmental Drilling Inc.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH	COLOUR % RETURN	JN - Joint FLT - Fault SH - Shear VN - Vein CJ - Conjugate	BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage	PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular	PO - Polished K - Slickensided SM - Smooth RO - Rough VR - Very Rough	MB - Mechanical Break BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.	NOTES
		Continued from Record of Borehole BH11-402		172.38									
7		SHALE (BEDROCK) with fossiliferous limestone beds Slightly to moderately weathered Laminated Reddish-brown to grey Weak to medium strong		6.15	1								(Axial)
8					2								
9													
10					3								
11		END OF DRILLHOLE		167.91									
12				10.62									
13													
14													
15													
16													

DEPTH SCALE

1 : 50



LOGGED: SB/BM

CHECKED: MS

GTA-RCK 018 1011110040.GPJ GAL-MISS.GDT 10/22/12 DD



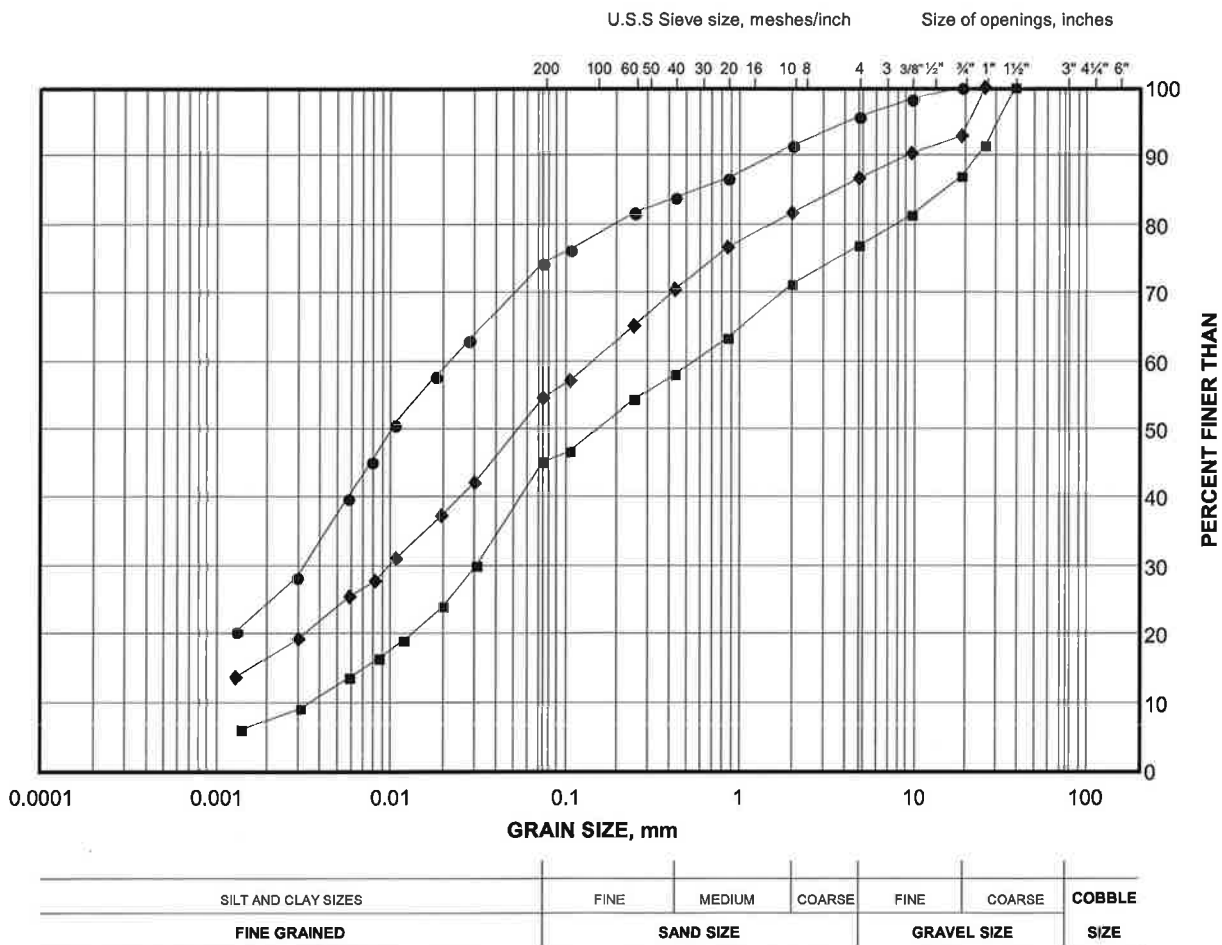
APPENDIX B

Laboratory Test Results

GRAIN SIZE DISTRIBUTION TEST RESULTS

Clayey Silt Till

FIGURE B1



LEGEND

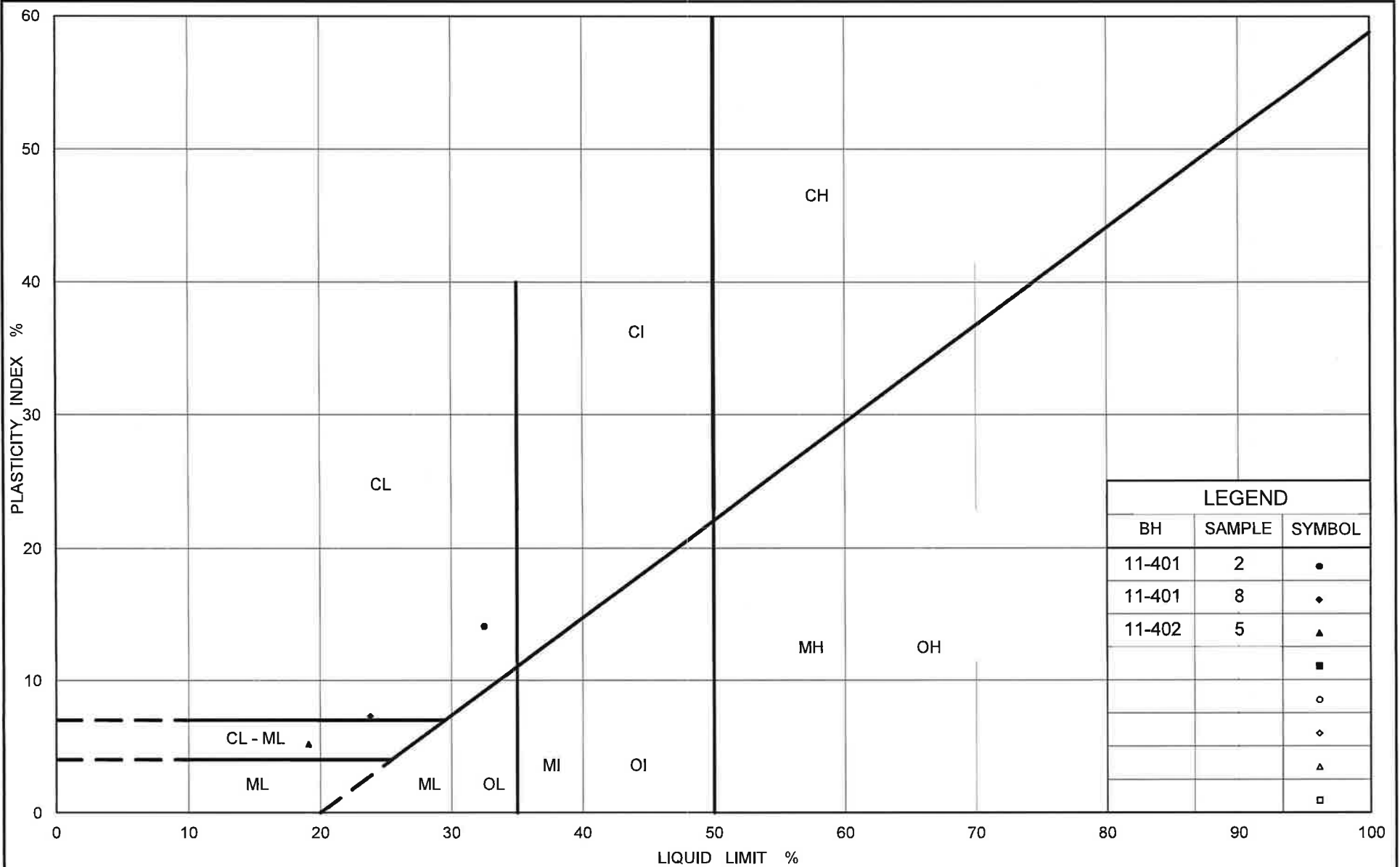
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	11-401	2	177.2
■	11-402	5	175.1
◆	11-401	8	171.9

Project Number: 10-1111-0040

Checked By: *W*

Golder Associates

Date: 09-Jul-12



Ministry of Transportation

Ontario

PLASTICITY CHART Clayey Silt Till

Figure No. B2

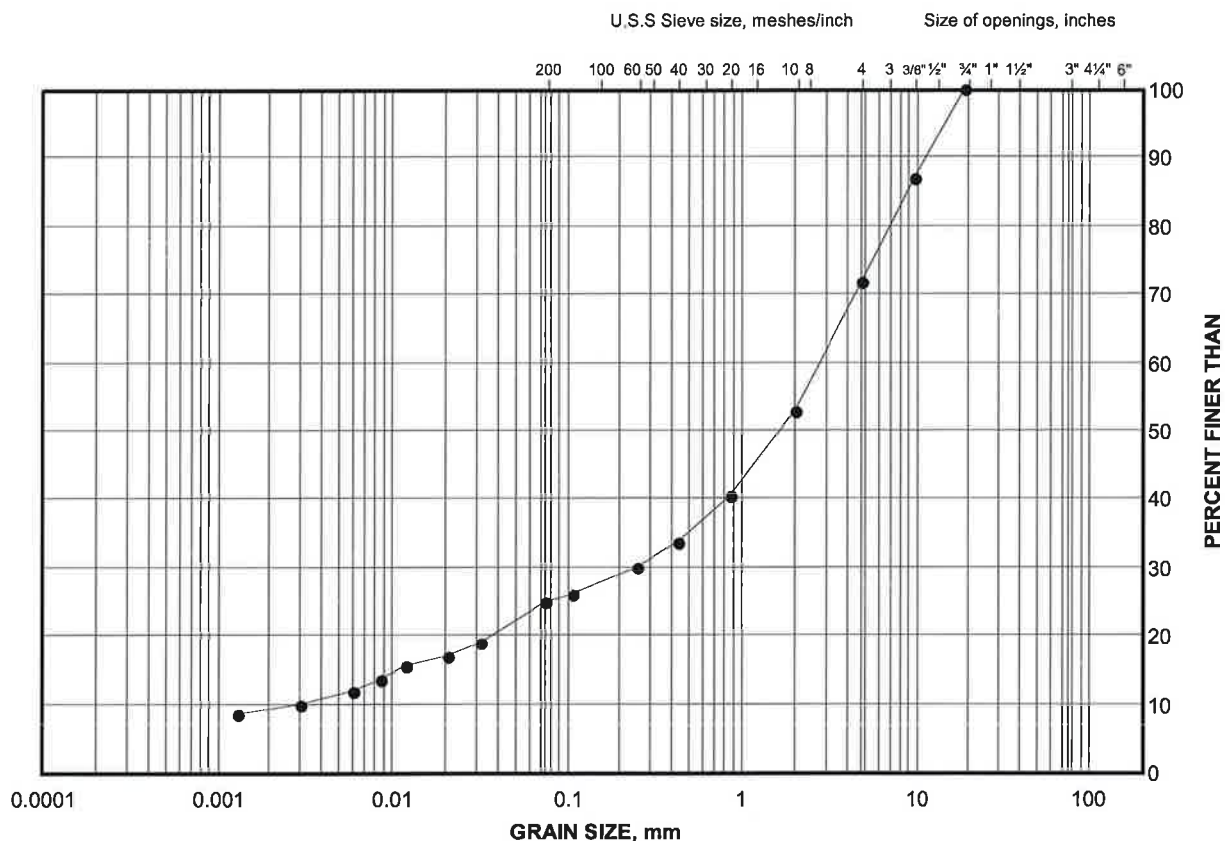
Project No. 10-1111-0040-4

Checked By: MM/LCC

GRAIN SIZE DISTRIBUTION TEST RESULT

Gravelly Sand

FIGURE B3



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	11-402	6	174.5

Project Number: 10-1111-0040

Checked By: *[Signature]*

Golder Associates

Date: 06-Jul-12

TABLE B1 - POINT LOAD TEST ON ROCK SAMPLES

PROJECT NO. 10-1111-0040-4

TITLE URS / Hwy 401 Widening / Halton Peel

DATE October, 2011

Borehole Number	Sample Depth (m)	Test Type	Core Length (mm)	Core ⁽²⁾ Diameter (mm)	Equivalent Diameter (mm)	Ram Pressure (kPa)	Load (P) (kN)	Is Axial (MPa)	Is Diametral (MPa)	Is (50mm) (MPa)	Approx. ⁽¹⁾ UCS (MPa)
11-401	9.98-10.05	A	15.01	46.10	29.68	3,360.00	3.19	3.616	-	2.859	66
11-401	12.75-12.79	D	36.61	45.63	-	1,030.00	0.98	-	0.469	0.450	9
11-402	6.76-6.83	A	20.50	46.69	34.91	2,880.00	2.73	2.240	-	1.906	44
11-402	8.16-8.23	D	41.88	46.85	-	660.00	0.63	-	0.285	0.277	6

⁽¹⁾ $Is_{50} \times C$ (actual value will have to be confirmed by UCS testing), from ISRM ("Suggested Methods for Determining Point Load Strength", International Society for Rock Mechanics Commission on Testing Methods, Int. J. Rock. Mech. Min. Sci. and Geomechanical Abstr., Vol 22, No. 2 1985, pp. 51-60.

⁽²⁾ Actual distance between point load cones at time of failure.

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