



April 2013

## PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

### Culvert 18 Extension Highway 427 Widening from Albion Road to Highway 7, City of Vaughan and Regional Municipality of York G.W.P 2229-09-00(e)

**Submitted to:**

McCormick Rankin, a member of MMM Group  
2655 North Sheridan Way  
Mississauga, ON  
L5K 2P8



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REPORT





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## **PRELIMINARY FOUNDATION REPORT - CULVERT 18 EXTENSION**

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# **PART A**

**PRELIMINARY FOUNDATION INVESTIGATION REPORT  
CULVERT 18 EXTENSION  
HIGHWAY 427 WIDENING FROM ALBION ROAD TO HIGHWAY 7  
CITY OF VAUGHAN AND REGIONAL MUNICIPALITY OF YORK  
G.W.P. 2229-09-00(e)**



### 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by McCormick Rankin, a member of MMM Group (MRC) on behalf of the Ministry of Transportation, Ontario (MTO) to provide preliminary foundation engineering services for the future widening of the Highway 427 from Albion Road to Highway 7 (approximately 2.3 km) in the City of Vaughan and the City of Toronto in the Regional Municipality of York, Ontario.

This report addresses the results of a preliminary foundation investigation carried out for the proposed extension of Culvert 18, located 0.4 km north of Highway 407. It is understood that a culvert extension is only required on the west side of Highway 427 as the culvert on the east side of the highway currently extends beyond the proposed widening.

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. 2009-E-0075 dated September 2010, and in Section 5.8 of the *Technical Proposal* for this assignment.

### 2.0 SITE DESCRIPTION

Culvert 18 is located approximately 0.4 km north of the centerline of Highway 407 in the City of Vaughan and in the Regional Municipality of York, Ontario (see the key plan on Drawing 1). As discussed above it is understood that a culvert extension is only required on the west side of Highway 427 (upstream end) as the culvert on the east side of Highway 427 currently extends beyond the proposed widening, therefore only the site at the upstream end is described. In general, the terrain in this area is relatively flat and is surrounded by vacant land or farm land. The existing culvert consists of a single-cell box culvert and is approximately 2450 mm x 1850 mm in size. Highway 427 is at about Elevation 179 m and the invert of the culvert is at about Elevation 174 m. At the upstream end (west end) there are existing gabion walls along the channel, which are about 1.5 m high above the culvert invert. From Highway 427 the ground slopes down at a gradient of about 2 horizontal to 1 vertical (2H:1V). At the time of the investigation the culvert was dry.

Based on visual observation during Golder's site visit, the existing culvert and adjacent embankment side slopes appear to have performed satisfactorily from a geotechnical/foundations perspective.

### 3.0 INVESTIGATION PROCEDURES

The field work for this subsurface investigation was carried out in December 2012, during which time two boreholes (Boreholes 12-01 and 12-02) were advanced using track-mounted CME-75 drill rigs, supplied and operated by Geo-Environmental Drilling Inc. of Milton, Ontario. Borehole 12-01 was advanced through the shoulder of the 427 N – 407W Ramp on the west side of Highway 427, and Borehole 12-02 was advanced just south of the gabion wall south of the culvert near the inlet.

Soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers driven by an automatic hammer, in accordance with the Standard Penetration Test (SPT) procedure.



## PRELIMINARY FOUNDATION REPORT - CULVERT 18 EXTENSION

The groundwater conditions were observed in the open borehole during and immediately following the drilling operations and a piezometer was installed in Borehole 12-02 to permit monitoring of the water level at this location. The piezometer consists of 25 mm diameter PVC pipe, with a slotted screen sealed at a select depth within the borehole. The borehole and annulus surrounding the piezometer pipe above the screen sand pack were backfilled to the surface with bentonite pellets/grout. Piezometer installation details and water level readings are described on the Record of Borehole sheets following the text of this report. Borehole 12-01 was backfilled with bentonite upon completion, in accordance with Ontario Regulation 903 (as amended Ontario Regulation 372).

The field work was supervised on a full-time basis by a member of Golder's technical staff who located the borehole in the field, directed the drilling, sampling, and in situ testing operations, and logged the borehole. The soil 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 testing and grain size distribution analyses were carried out on selected soil samples.

The borehole location was measured on-site relative to the existing culvert and site features, and the ground surface elevation was obtained from the digital terrain model for the site, provided by MRC. The locations of the boreholes including MTM NAD83 northing and easting coordinates and ground surface elevations referenced to geodetic datum, are summarized below and are shown on Drawing 1.

Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation	Borehole Depth
12-01	4,846,478.4	294,115.9	178.3 m	15.8 m
12-02	4,846,477.9	294,104.3	176.5 m	12.8 m

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

The Highway 427 study area lies within the Peel Plain physiographic region, as delineated in *The Physiography of Southern Ontario*<sup>1</sup>.

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 is typically comprised of clayey silt to silty clay, with occasional sand to silt zones; it is mapped in this area as the Halton Till. 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

<sup>1</sup> Chapman, L.J. and D.F. Putnam. *The Physiography of Southern Ontario*, Ontario Geological Survey Special Volume 2, Third Edition, 1984. Accompanied by Map P.2715, Scale 1:600,000.



and clay and uppermost till deposits in this area overlie and are interbedded with stratified deposits of sand, silt and clay. The study area is underlain by Ordovician shales of the Georgian Bay Formation.

### 4.2 Subsurface Conditions

As part of the subsurface investigation, two boreholes were advanced in the vicinity of the Culvert 18. 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 following the text of this report. The results of geotechnical laboratory testing are also presented on Figures 1 to 8. The stratigraphic boundaries shown on the borehole records and on the interpreted stratigraphic sections 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 fill overlying a deposit of organic silty clay at the borehole through the embankment. The fill and silty clay are underlain by a till deposit consisting of silty clay to clayey silt with sand to sand and silt that contains granular till interlayers. The till deposit is underlain by a deposit of sand and silt, which in turn is underlain by clayey silt and silty sand.

A more detailed description of the soil deposits encountered in the boreholes is provided in the following sections

#### 4.2.1 Fill

The fill comprising the roadway embankment consists mainly of cohesive soil but varies in composition from clayey silt to silty clay to silty sand. Approximately 0.6 m of silty sand fill was encountered immediately below the ground surface in Borehole 12-01 (advanced through the shoulder of 427N – 407W Ramp). Immediately below the ground surface in Borehole 12-02 and underlying the silty sand fill in Borehole 12-01, clayey silt to silty clay fill was encountered to depths of 2.7 m and 1.5 m below ground surface (Elevation 175.6 m and 175.0 m), respectively. Rootlets and/or organics were noted in cohesive portions of the fill in Borehole 12-02 to a depth of 1.5 m below ground surface (Elevation 175.0 m).

Based on field observations, the silty clay to clayey silt portion of the fill material contains trace to some sand and gravel. Atterberg limits testing was completed on one sample of the silty clay fill, and measured a plastic limit of 15 per cent, a liquid limit of 37 per cent, and a plasticity index of 21 per cent. These test results, which are plotted on a plasticity chart on Figure 1, confirm that the fill material consists of silty clay of medium plasticity. The water content measured on samples of the silty clay to clayey silt fill material varied from 8 per cent to 31 per cent.

The measured SPT “N” values within the silty clay to clayey silt portion of the fill material range from 6 to 12 blows per 0.3 m of penetration, suggesting a firm to stiff consistency.

Based on field observations, the silty sand portion of the fill contains some gravel and trace clay. The water content measured on one sample of the silty sand fill material was 8 per cent.

The measured SPT “N” value within the silty sand portion of the fill material was 5 blows per 0.3 m of penetration, indicating a loose relative density.





### 4.2.2 Organic Silty Clay

Underlying the fill in Borehole 12-01 a deposit of organic silty clay was encountered at a depth of 2.7 m below ground surface (Elevation 175.6 m) and extended to a depth of 4.6 m below ground surface (Elevation 173.7 m).

Based on field observations, the silty clay contains some sand, trace gravel and also contains organics and rootlets to a depth of 3.8 m below ground surface (Elevation 174.5 m). The organic content measured on a sample of the silty clay was 8 per cent; therefore the deposit is classified as organic silty clay. Atterberg limit testing was completed on one sample of the silty clay, and measured a plastic limit of 19 per cent, a liquid limit 48 per cent, and a plasticity index of 29 per cent. These test results, which are plotted on a plasticity chart on Figure 2, confirm that the material consists of organic silty clay of medium plasticity. The water content measured on samples of the organic silty clay material were 25 per cent and 26 per cent.

The measured SPT “N” values within the organic silty clay material were 7 and 8 blows per 0.3 m of penetration, suggesting a firm to stiff consistency.

### 4.2.3 Clayey Silt Till and Sand and Silt Till

A till deposit that generally consists of clayey silt to silty clay till underlain by sand and silt till was encountered underlying the fill in Borehole 12-02 and the organic silty clay in Borehole 12-01. The surface of the clayey silt to silty clay till deposit was encountered at 4.6 m depth below ground surface (Elevation 173.7 m) in the borehole advanced through the shoulder of the 427N – 407W Ramp and at 1.5 m depth below ground surface in Borehole 12-02 (advanced near the inlet of the culvert). The clayey silt to silty clay portion of the till deposit was 1 m thick in Borehole 12-01 and 2.2 m thick in Borehole 12-02. The portion of the till deposit that consisted of sand and silt was encountered underlying the clayey silt to silty clay till and extended to a depth of 7.1 m in Borehole 12-01 and 12-02 (Elevation 171.2 m and 169.4 m, respectively).

The clayey silt to silty clay till deposit contains with to some sand and trace gravel. The result of grain size distribution tests completed on two selected samples of the clayey silt to silty clay till is shown on Figure 3 and Atterberg limits testing was conducted on three selected samples of the clayey silt to silty clay till, and measured plastic limits 12 per cent to 18 per cent, liquid limits 23 per cent to 36 per cent, and plasticity indices between 9 per cent and 20 per cent. These test results, which are plotted on a plasticity chart on Figure 4, confirm that the till deposit consists of clayey silt to silty clay of low to medium plasticity. The natural water content measured on samples of the clayey silt to silty clay till range from 7 per cent to 18 per cent, near the plastic limit of the till soil.

The sand and silt portion of the till contains trace to some gravel and trace clay. The results of grain size distribution tests completed on two selected of the sand and silt till are shown on Figure 5.

The measured SPT “N” values within the clayey silt to silty clay portion of the till generally range from 20 blows per 0.3 m of penetration to 70 blows per 0.23 m of penetration, suggesting a very stiff to hard consistency. The measured SPT “N” values within the sand and silt portion of the till were 62 and 81 blows per 0.3 m of penetration and 50 blows per 0.15 mm of penetration, indicating a very dense consistency.

### 4.2.4 Clayey Silt

A 1.5 m thick deposit of clayey silt was encountered Borehole 12-02 only, between the overlying till deposit and the underlying sand and silt deposit. The surface of the deposit was encountered at a depth of 5.6 m below ground surface (Elevation 170.9 m) and extended to a depth of 7.1 m below ground surface (Elevation 169.4 m).





The deposit of clayey silt contains thin layers of fine sand. The natural water content measured on a sample of the clayey silt is 15 per cent.

One SPT “N” value of 37 blows per 0.3 m of penetration was measured within the clayey silt deposit, suggesting a hard consistency.

### 4.2.5 Sand and Silt

A deposit of sand and silt was encountered underlying the till deposit in both boreholes advanced for the culvert extension. The surface of the sand and silt deposit was encountered at a depth of 7.1 m below ground surface in Borehole 12-01 and 12-02 (Elevation 171.2 m and 169.4 m, respectively). The deposit extends to depths of 13.2 m and 10.2 m below ground surface (Elevations 165.1 m and 166.3 m) in Boreholes 12-01 and 12-02, respectively.

The deposit of sand and silt contains trace clay. The results of grain size distribution tests completed on two selected samples of the cohesionless deposit are shown on Figure 6. The natural water content measured on samples of the silty sand to sandy silt to silt range from 10 per cent to 24 per cent.

The measured SPT “N” values within the deposit of sand and silt range from 60 blows per 0.3 m of penetration to 96 blows per 0.28 m of penetration, indicating a very dense relative density.

### 4.2.6 Clayey Silt

A deposit of clayey silt was encountered below the sand and silt deposit in Borehole 12-01 and 12-02; the surface of this deposit was encountered a depth of 13.2 m below ground surface and 10.2 m below ground surface (Elevation 165.1 m and 166.3 m, respectively). The base of the deposit extends to a depth of 12.5 m below ground surface (Elevation 164.0 m) in Borehole 12-02. Borehole 12-01 terminated within the clayey silt deposit at a depth of 15.8 m below ground surface (Elevation 162.5 m).

The deposit of clayey silt contains trace sand and is laminated with sandy silt to silty sand interlayers. The results of grain size distribution tests completed on one selected sample of the clayey silt deposit is shown on Figure 7. Atterberg limits testing was conducted on two selected samples of the deposit of clayey silt, and measured plastic limits of 15 per cent and 16 per cent, liquid limits of 25 per cent and 27 per cent, and plasticity indices of 10 per cent and 11 per cent. These test results, which when plotted on a plasticity chart on Figure 8, confirm that the deposit consists of clayey silt of low plasticity. The natural water content measured on samples of the clayey silt range from 20 per cent to 22 per cent, which were generally above the corresponding plastic limit values.

The measured SPT “N” values within the silty clay to clay range from 21 to 50 blows per 0.3 m of penetration, suggesting a very stiff to hard consistency.

### 4.2.7 Silty Sand

A deposit of silty sand was encountered underlying the clayey silt deposit in Borehole 12-02. The surface of this deposit was encountered at a depth of 12.5 m below ground surface (Elevation 164.0 m). The borehole terminated within this deposit, penetrating it for a thickness of 0.3 m.

The silty sand contains trace clay. One SPT “N” value of 34 blows per 0.3 m of penetration was measured within the silty sand deposit, indicating a dense relative density.



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### 4.3 Groundwater Conditions

Details of the water levels observed in the open boreholes at the time of drilling are summarized on the borehole records following the text of this report. In general, the sand and silt deposit was observed to be water-bearing during the drilling operations, although Borehole 12-01 was dry upon completion of drilling. A standpipe piezometer was installed in Borehole 12-02 to monitor the groundwater levels at the site. The water levels measured in the standpipe piezometer in Borehole 12-02 are summarized in the table below:

Borehole Number	Stratum Sealed Into	Piezometer Tip Elevation (m)	Depth to Water Level (m)	Water Elevation (m)	Date
12-02	Sand and Silt	169.0	4.7	171.8	Upon Completion of Drilling
			3.7	172.8	January 8, 2013
			4.4	172.8	January 21, 2013

Groundwater levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

### 5.0 CLOSURE

This Preliminary Foundation Investigation Report was prepared by Ms. Sandra McGaghran, P.Eng. a senior geotechnical engineer and Associate with Golder. Mr. Fintan Heffernan, P.Eng., the Designated MTO Foundations Contact for Golder, conducted an independent review of this report.

**GOLDER ASSOCIATES LTD.**

Sandra McGaghran, P.Eng.  
Senior Geotechnical Engineer, Associate

Fintan J. Heffernan, P.Eng.  
Designated MTO Foundations Contact

SMM/FJH/sm

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# **PART B**

**PRELIMINARY FOUNDATION DESIGN REPORT  
CULVERT 18 EXTENSION  
HIGHWAY 427 WIDENING FROM ALBION ROAD TO HIGHWAY 7  
CITY OF VAUGHAN AND REGIONAL MUNICIPALITY OF YORK  
G.W.P. 2229-09-00(e)**



## **6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS**

### **6.1 General**

This section of the report provides preliminary foundation design recommendations for the proposed extension of the west end of Culvert 18 under consideration for the widening of Highway 427 northbound and southbound lanes. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during this 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 extension. Further investigation and analysis will be required during detail design, once the configuration of the proposed culvert extension is finalized, to confirm and expand on the preliminary foundation recommendations provided in this report.

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 the aspects of construction 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 for Culvert Extension**

#### **6.2.1 Foundation Options**

It is understood that extension of Culvert 18 is only required on the west side of Highway 427 as the culvert on the east side of the highway currently extends beyond the proposed widening. Details regarding the existing culvert and the potential extension length are provided in the following table.

<b>Location</b>	<b>Existing Culvert Inside Dimensions and Type</b>	<b>Proposed Extension Length</b>	<b>Invert Elevation Upstream/Downstream</b>
Culvert 18	2450 mm x 1850 mm Single Box Culvert	13 m – West	174 m / 173.7 m

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

Either box culverts or “open footing” (shallow foundation) concrete culverts are feasible for the extension of the west end of Culvert 18. Deep foundations are not required, as shallow foundations will provide sufficient bearing resistance and acceptable settlement performance. Both pre-cast concrete elements (box culvert segments or footing elements) and cast-in-place concrete elements are also feasible from a foundations perspective.

The advantages and disadvantages associated with both the pre-cast box culvert and cast-in-place 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 - CULVERT 18 EXTENSION

- Pre-cast box culvert extensions minimize the depth of excavation 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 surface water pumping.
- Pre-cast box culvert segments are more tolerant of total and differential settlement that will result from the Highway 427 embankment widening at the culvert location.

It is noted, however, that a box culvert extension may not satisfy fisheries requirements related to channel substrate, in which case an open footing culvert is geotechnically feasible (though not preferred from a geotechnical perspective).

Recommendations for box culvert extension and shallow foundation (open footing) culvert extension are provided in the following sections.

### 6.3 Box Culvert Extension

#### 6.3.1 Founding Elevations

It is not necessary to found box culvert extensions at the standard depth for frost protection purposes, as the 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 organic materials. The table below provides recommended founding elevations and subexcavation requirements for box culvert extension, based on an assumed base slab thickness of 250 mm. In addition, it is recommended that the box culvert segments be placed on a minimum thickness of 300 mm of granular bedding material.

Culvert	Potential Culvert Invert Elevation Upstream	Borehole	Subexcavation Required?	Highest Base Slab Founding Elevation Upstream	Founding Stratum
Culvert 18	174 m	12-02	No	173.7	Very stiff to hard Clayey Silt Till to Silty Clay Till

Based on the founding levels and subsurface conditions in Borehole 12-02, no subexcavation requirements have been identified at this preliminary stage.

The box culvert subgrade should be inspected by a Quality Verification Engineer to ensure that all existing fill and organic soils or other unsuitable material have been removed, in accordance with provincial standards.

Depending on the water level upstream of the culvert at the time of construction, some re-routing of the flow may be required prior to excavating for the culvert extension. Based on the water level measured in the standpipe installed in the borehole adjacent to the culvert (Elevation 172.8 on January 2013), excavations for the box culvert extension will likely be above the groundwater level (see Section 6.7.2 for further details).



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The subgrade for the box culvert replacements and extensions will be susceptible to loosening/softening and degradation on exposure to water and construction traffic. As discussed further in Section 6.7.3, as an alternative to the placement of 300 mm of granular bedding material on the native soil below the base slab, a 100 mm thick concrete working slab could be placed on the subgrade to protect it from degradation.

### 6.3.2 Geotechnical Resistance

The preliminary design for box culvert extensions placed on the properly prepared subgrade, at or below the founding elevation identified above, should be based on the following factored geotechnical resistance at Ultimate Limit States (ULS) and geotechnical reaction at Serviceability Limit States (SLS), for 25 mm of settlement:

Culvert	Culvert width	Factored Geotechnical Resistance at ULS	Geotechnical Reaction at SLS
Culvert 18	2.5 m	400 kPa	300 kPa

The ULS resistance and SLS reaction is dependent on the foundation size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed if the culvert width or founding elevation differs significantly from that given above.

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 at the potential culvert extension location.

## 6.4 Open Footing Culvert Extensions

### 6.4.1 Founding Elevations

Strip footings for open footing culvert extensions should be founded at a minimum depth of 1.4 m below the lowest surrounding grade to provide adequate protection against frost penetration, as per OPSD 3090.101 (*Foundation Frost Depths for Southern Ontario*). In addition, the footings should extend below any existing fill and surficial organic materials, where present. The following table provides recommended founding elevations for strip footings for the potential culvert extensions.

Culvert	Potential Culvert Invert Elevation Upstream	Highest Base Slab Founding Elevation Upstream	Founding Stratum
Culvert 18	174 m	172.6 m	Very Dense Sand and Silt Till

Based on the footing founding levels and subsurface conditions at the culvert site, no subexcavation requirements have been identified at this preliminary stage.



## PRELIMINARY FOUNDATION REPORT - CULVERT 18 EXTENSION

The footing subgrade should be inspected by a Quality Verification Engineer following excavation, to check that all existing fill and surficial organic soils or other unsuitable material have been removed, in accordance with provincial standards.

Depending on the water level upstream of the culvert at the time of construction, some re-routing of the flow may be required prior to excavating for the culvert extension. Based on the water level measured in the standpipe installed in the borehole adjacent to the culvert, excavations for the open footing culvert extension will likely be at or above the groundwater level (see Section 6.7.2 for further details).

The footing subgrade will be susceptible to loosening and degradation on exposure to water and construction traffic. As discussed further in Section 6.7.3, 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 culvert extension.

### 6.4.2 Geotechnical Resistance

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 resistance at Ultimate Limit States (ULS) and geotechnical reaction at Serviceability Limit States (SLS), for 25 mm of settlement:

Culvert	Founding Stratum	Footing Width	Factored Geotechnical Resistance at ULS	Geotechnical Reaction at SLS
Culvert 18	Very Dense Sand and Silt Till	0.6 m	350 kPa	350 kPa
		0.9 m	375 kPa	375 kPa
		1.2 m	400 kPa	400 kPa

The structural engineer must ensure that the selected footing width is sufficient to resist overturning for concrete retaining walls. These preliminary geotechnical resistances/reaction values 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 geotechnical resistances/reaction values should be reviewed if the selected footing width or founding elevation differs significantly from those given above. 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 at the potential culvert extension location.

## 6.5 Approach Embankments

It is understood that Highway 427 is to be widened by about 13 m at the culvert location, which would require placement of a vertical thickness of up to approximately 4.2 m of additional fill atop the existing embankment side slopes. This embankment widening to construct the culvert will induce some settlement in the foundation soils beneath the widening area.





### 6.5.1 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 embankment widening on the west side of Highway 427 at Culvert 18. 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.

### 6.5.2 Embankment Stability

Preliminary slope stability analyses have been performed for the widened embankment on the west side Highway 427 at Culvert 18 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 4.2 m high embankment widening, based on the subsurface conditions as encountered in Boreholes 12-01 and 12-02. 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 <sup>3</sup> )	Effective Friction Angle	Undrained Shear Strength (kPa)
Firm to Stiff Silty Clay to Clayey Silt Fill	19	28°	50
Organic Silty Clay	19	26°	50
Very Stiff to Hard Clayey Silt Till	21	30°	-
Very Dense Sand and Silt Till	21	36°	-

The preliminary stability analysis results indicate that the approximately 4.2 m high widened Highway 427 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 9. 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.

### 6.5.3 Settlement

The settlement analysis for culvert site was carried out using both hand calculations and the commercially-available program *Settle-3D* from Rocscience, using estimated consolidation parameters and elastic deformation moduli as given in the table below, based on correlations with the undrained shear strength, Atterberg limits and SPT "N" values and engineering judgement from experience with similar soils in this region of Ontario.



## PRELIMINARY FOUNDATION REPORT - CULVERT 18 EXTENSION

Soil Deposit	Bulk Unit Weight	Elastic Modulus	$P_c'$	$e_o$	$C_c$	$C_r$
New Embankment Fill	21 kN/m <sup>3</sup>	—	—	—	—	—
Firm to Stiff Silty Clay to Clayey Silt Fill	19 kN/m <sup>3</sup>	12 MPa	—	—	—	—
Organic Silty Clay	19 kN/m <sup>3</sup>	--	225 kPa	0.7	0.36	0.036
Very Stiff to Hard Clayey Silt Till	21 kN/m <sup>3</sup>	50 – 75 MPa	—	—	—	—
Very Dense Sand and Silt Till	21 kN/m <sup>3</sup>	100 MPa	-	-	-	-

The settlement of the foundation soils under the up to 4 m thickness of additional fill that be placed on the embankment side slope is estimated to be approximately 40 mm under the actual widening area, decreasing to less than 5 mm under the shoulder of the existing embankment and at the toe of the widened embankment. The connection between the existing culvert and the extension should be designed by the structural engineers to accommodate these deformations and stresses. For these relatively small predicted settlements, settlement mitigation measures are not required; this should be reassessed at the detail design stage following completion of additional borehole investigation at that time.

### 6.6 Culvert Bedding, Backfill and Erosion Protection

For a box culvert extension, the bedding levelling pad and backfill requirements should be in accordance with OPSS 422 (*Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut*) for pre-cast rigid frame culverts. Box culvert extensions should be provided with at least 300 mm of OPSS 1010 Granular A material for bedding purposes, or alternatively a 100 mm thick concrete working slab with 75 mm of bedding material.

Backfill and cover for concrete culverts should be completed in accordance with Ontario Provincial Standard Drawing (OPSD) 803.010 (*Backfill and Cover for Concrete Culverts*). 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 backfill and bedding should be placed and compacted in accordance with MTO's Special Provision SP105S21 (Amendment to OPSS 501). The fill depth during placement should be maintained equal on both sides of the culvert walls, with one side not exceeding the other by more than 500 mm. The culvert extensions should be designed for the full overburden pressure and live load, assuming that the embankment fill has a unit weight of 22 kN/m<sup>3</sup> for Granular A, and 21 kN/m<sup>3</sup> for Granular B Type II.

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. Clay seals should also be placed adjacent to the culvert inlet opening for both box culvert and open footing structure types. The clay material should meet the requirements of OPSS 1205 (*Material Specification for Clay Seal*). The clay seal should have a thickness of 1 m, and the seal should extend from a depth of 1 m below the scour level to a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and a minimum



vertical height equivalent to the high water level including treatment of the adjacent side slopes. Alternatively, a clay blanket may be constructed, extending upstream to a distance equal to three times the culvert height, and extending along the adjacent side slopes to a height of two times the culvert height or the high water level, whichever is higher.

At the time of the geotechnical investigation the channel/creek was dry; however if the water level in the channel/creek is sufficiently higher during flood periods, provision should be made for scour and erosion protection (suitable non-woven geotextiles and/or rip-rap) at the culvert inlet. The requirements for and design of erosion protection measures for the culvert inlet should be assessed by the hydraulic design engineer. As a minimum, rip-rap treatment for the culvert outlet should be consistent with the standard Treatment Type A presented in OPSP 810.010 (*Rip-Rap Treatment for Sewer and Culvert Outlets*), with the rip-rap placed above the flood level. Similarly, rip-rap should be provided over the full extent of the clay blanket if adopted, including the channel/creek side slopes and embankment fill slope adjacent to the culverts.

## 6.7 Construction Considerations

The following subsections identify future construction considerations 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

Temporary excavations for the culvert extensions will be made through the existing fill and are expected to terminate in very stiff to hard clayey silt/silty clay till for a box culvert option or to the very dense sand and silt till for open footing option. Excavation works must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act and Regulations for Construction Projects. The existing fill would be classified as Type 3 soil, while the native materials would be classified as a Type 2 soil, according to the OHSA. Where space permits, temporary open-cut excavations through these materials should be made with side slopes formed no steeper than 1H:1V, assuming proper groundwater and surface water control is in place.

### 6.7.2 Groundwater and Surface Water Control

Control of the surface water will be necessary for the construction of the culvert extensions (depending on their founding elevation), to allow excavation and foundation construction to be carried out in dry conditions.

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 subgrade soils; further discussion on this aspect is provided in Section 6.7.3.

As discussed in Sections 6.3 and 6.4, the box culvert foundation excavations will be above the groundwater level at this site, and therefore groundwater control is not anticipated at this site. The foundation excavating for an open footing will be at or slightly below the groundwater level. Water inflow from the sand and silt till should be minor and could be handled by pumping from sumps located outside the founding area.



## PRELIMINARY FOUNDATION REPORT - CULVERT 18 EXTENSION

### 6.7.3 Subgrade Protection

The subgrade soils 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 During Detail Design

Should the recommended plan require the extension of this culvert, additional boreholes are recommended as close as practicable to the culvert extension during the future detail design stage of investigation, to further assess and/or confirm the subsurface conditions and the preliminary recommendations provided herein, as follows:

- Advance a borehole near the end of the proposed culvert extension;
- Assessment of the depth and extent of stripping of organics, fill materials and/or any soft/loose surficial materials within the footprint of the culvert extensions, and;
- Measure the undrained shear strength of the organic silty clay layer underlying the fill as encountered in Borehole 12-01.

Further assessment of the estimated magnitude of settlement under the widened Highway embankment.

## 7.0 CLOSURE

This Preliminary Foundation Design Report was prepared by Ms. Sandra McGaghran, P.Eng. a senior geotechnical engineer and Associate with Golder. Mr. Fin Heffernan, P.Eng., the Designated MTO Foundations Contact for Golder, conducted an independent review of this report.

GOLDER ASSOCIATES LTD.

Sandra McGaghran, P.Eng.  
Senior Geotechnical Engineer, Associate



Fintan J. Heffernan, P.Eng.  
Designated MTO Foundations Contact



SMM/FJH/sm

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## PRELIMINARY FOUNDATION REPORT - CULVERT 18 EXTENSION

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### Ontario Provincial Standard Specifications (OPSS)

- |           |  |
|-----------|--|
| OPSS 422  | Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut |
| 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 Depths for Southern Ontario    |

### Construction Design Estimating and Documentation (CDED) Special Provisions (SP)

- |          |   |
|----------|---|
| SP105S21 | Amendment to OPSS 501 – Construction Specification for Construction |
|----------|---|



## PRELIMINARY FOUNDATION REPORT - CULVERT 18 EXTENSION

**TABLE 1 – COMPARISON OF FOUNDATION ALTERNATIVES**

Option	Advantages	Disadvantages	Risks/Consequences
Box culvert extension	<ul style="list-style-type: none"><li>■ Minimizes depth of excavation, protection system and dewatering requirements compared to open footing option</li><li>■ Pre-cast box sections expected to allow faster construction than cast-in-place open footings, with shorter duration for dewatering and surface water pumping</li><li>■ More tolerant of differential settlement than open footing culvert</li></ul>	<ul style="list-style-type: none"><li>■ Greater disturbance to natural creek channel than for open footing culvert option</li></ul>	<ul style="list-style-type: none"><li>■ Some risk of disturbance of the subgrade during construction; can be mitigated with use of a concrete working slab</li><li>■ Limited risk related to settlement performance</li><li>■ Compatible with existing box culvert founding level, with some risk of disturbance of existing culvert founding soils. Minor differential settlement between culvert and extensions should be expected.</li></ul>
Open footing culvert extension	<ul style="list-style-type: none"><li>■ Would satisfy any fisheries requirements related to natural channel substrate, if applicable</li><li>■ May be feasible to build culvert extension on pre-cast footing sections, to accelerate construction schedule and reduce time for dewatering and surface water pumping</li><li>■ Minimizes disturbance of creek channel during excavation, as compared with wider span for box culvert</li></ul>	<ul style="list-style-type: none"><li>■ Excavation depths are greater than for box culvert option, resulting in increased excavation support and dewatering requirements</li><li>■ 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</li></ul>	<ul style="list-style-type: none"><li>■ Some risk of disturbance of the subgrade during construction; can be mitigated with use of a concrete working slab</li></ul>





## 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.).

<b>PH:</b>	Sampler advanced by hydraulic pressure
<b>PM:</b>	Sampler advanced by manual pressure
<b>WH:</b>	Sampler advanced by static weight of hammer
<b>WR:</b>	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 cm<sup>2</sup> 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 <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
$D_R$	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 <sub>4</sub>	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
$\gamma$	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

$\pi$	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

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\varepsilon$	linear strain
$\varepsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	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
$\gamma'$	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
$C_\alpha$	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
$\sigma'_p$	pre-consolidation stress
OCR	over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$

#### (d) Shear Strength

$\tau_p, \tau_r$	peak and residual shear strength
$\phi'$	effective angle of internal friction
$\delta$	angle of interface friction
$\mu$	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  $\rho$ . Unit weight symbol is  $\gamma$  where  $\gamma = \rho g$  (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1  
2

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

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

PROJECT <u>10-1111-0202</u>		<b>RECORD OF BOREHOLE No 12-01</b>		SHEET 1 OF 2		<b>METRIC</b>	
G.W.P. <u>2229-09-00(e)</u>		LOCATION <u>N 4846478.4 ;E 294115.9</u>		ORIGINATED BY <u>SB</u>			
DIST <u>Central</u> HWY <u>427</u>		BOREHOLE TYPE <u>200mm Outside Diameter Hollow Stem Augers</u>		COMPILED BY <u>TWB</u>			
DATUM <u>Geodetic</u>		DATE <u>December 11 and 12, 2012</u>		CHECKED BY <u>SMM</u>			

[illegible]

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Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3%</sup> STRAIN AT FAILURE

PROJECT		10-1111-0202		RECORD OF BOREHOLE No 12-01				SHEET 2 OF 2				METRIC					
G.W.P.		2229-09-00(e)		LOCATION		N 4846478.4 ; E 294115.9				ORIGINATED BY		SB					
DIST		Central		HWY		427		BOREHOLE TYPE		200mm Outside Diameter Hollow Stem Augers				COMPILED BY		TWB	
DATUM		Geodetic		DATE		December 11 and 12, 2012				CHECKED BY		SMM					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>		
								20	40	60	80	100					
162.5	END OF BOREHOLE		14	SS	21		163										
15.8	NOTE: 1. Borehole dry upon completion of drilling.																

PROJECT		10-1111-0202		RECORD OF BOREHOLE No 12-02		SHEET 1 OF 2		METRIC					
G.W.P.		2229-09-00(e)		LOCATION		N 4846477.9 ; E 294104.3		ORIGINATED BY		SB			
DIST		Central HWY 427		BOREHOLE TYPE		200mm Outside Diameter Hollow Stem Augers		COMPILED BY		TWB			
DATUM		Geodetic		DATE		December 12, 2012		CHECKED BY		SMM			
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT $\gamma$	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)			
176.5	GROUND SURFACE												
0.0	Clayey silt, trace sand and gravel, containing organics and rootlets (FILL) Firm Brown and grey Moist		1	SS	6								
			2	SS	6								
175.0													
1.5	CLAYEY SILT to SILTY CLAY, some sand, trace gravel (TILL) Very stiff to hard Brown to grey at a depth of 3.1 m Moist		3	SS	20								
			4	SS	80								
			5	SS	70/23								
172.8													
3.7	SAND and SILT, some gravel, trace clay (TILL) Very dense Grey Moist		6	SS	81								
			7	SS	62								
170.9													
5.6	CLAYEY SILT with thin layers of brown fine sand Hard Grey Moist		8	SS	37								
169.4													
7.1	SAND and SILT, trace clay Very dense Grey Moist to wet		9	SS	60								
			10	SS	69								
166.3													
10.2	CLAYEY SILT, trace sand, laminated with sandy silt and silty sand interlayers Hard Greyish brown Moist		11	SS	50								
			12A	SS	34								
164.0			12B	SS	34								
163.7	Silty SAND, trace clay Dense Grey Wet												
12.8	END OF BOREHOLE												

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

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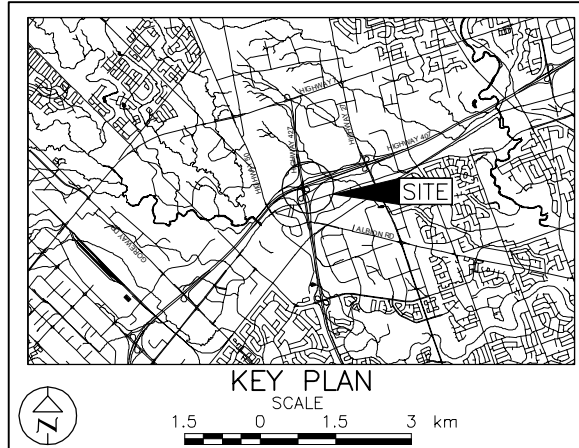
CONT No.
GWP No. 2229-09-00(e)

HIGHWAY 427 WIDENING  
CULVERT 18 EXTENSION






BOREHOLE LOCATIONS AND SOIL STRATA



**Golder Associates Ltd.**  
MISSISSAUGA, ONTARIO, CANADA



## LEGEND

- |   |  |
|---|--|
|  | Borehole – Current Investigation                                   |
|  | Seal   |
|  | Piezometer   |
| N   | Standard Penetration Test Value                                    |
| 16  | Blows/0.3m unless otherwise stated<br>(Std. Pen. Test, 475 j/blow) |
|  | WL in piezometer, measured on January 21, 2013                     |
|  | WL upon completion of drilling                                     |

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
12-01	178.3	4846478.4	294115.9
12-02	176.5	4846477.9	294104.3

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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 final configuration as shown elsewhere in the Preliminary Design Report.

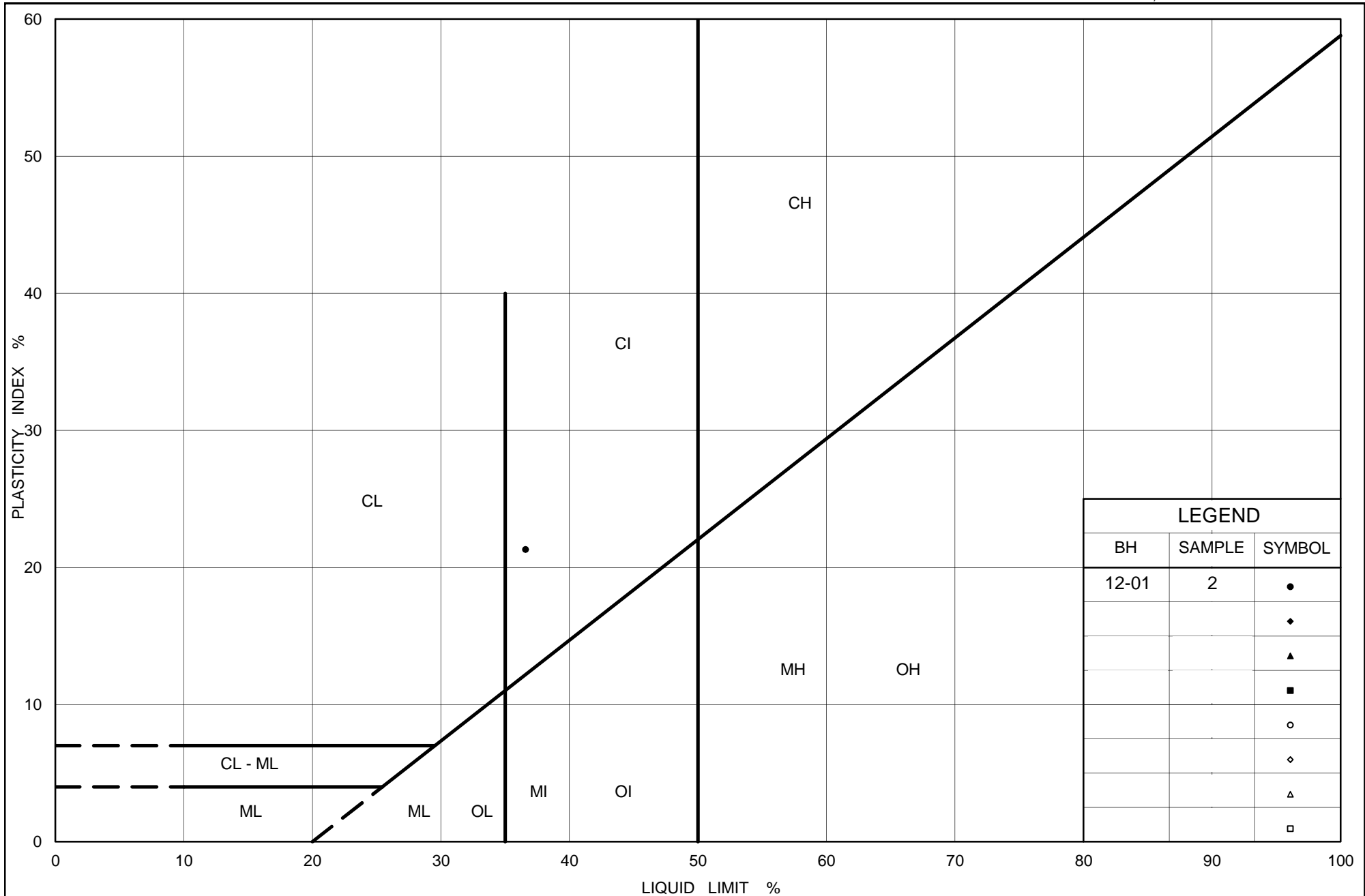
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

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

Culvert 18 provided in digital format by MRC, drawing file no.s DTM-CLV\_18.dwg., received January 08, 2013 and 3211001-base map-rds.dwg, received January 10, 2013

NO.	DATE	BY	REVISION		
Geocres No. 30M12-359					
HWY. 427		PROJECT NO. 10-1111-0202			SITE.
SUBM'D. SB		CHKD. SMM		DATE: Mar, 2013	
DRAWN: JFC		CHKD. SMM		APPD. FJH	
				DWG. 1	



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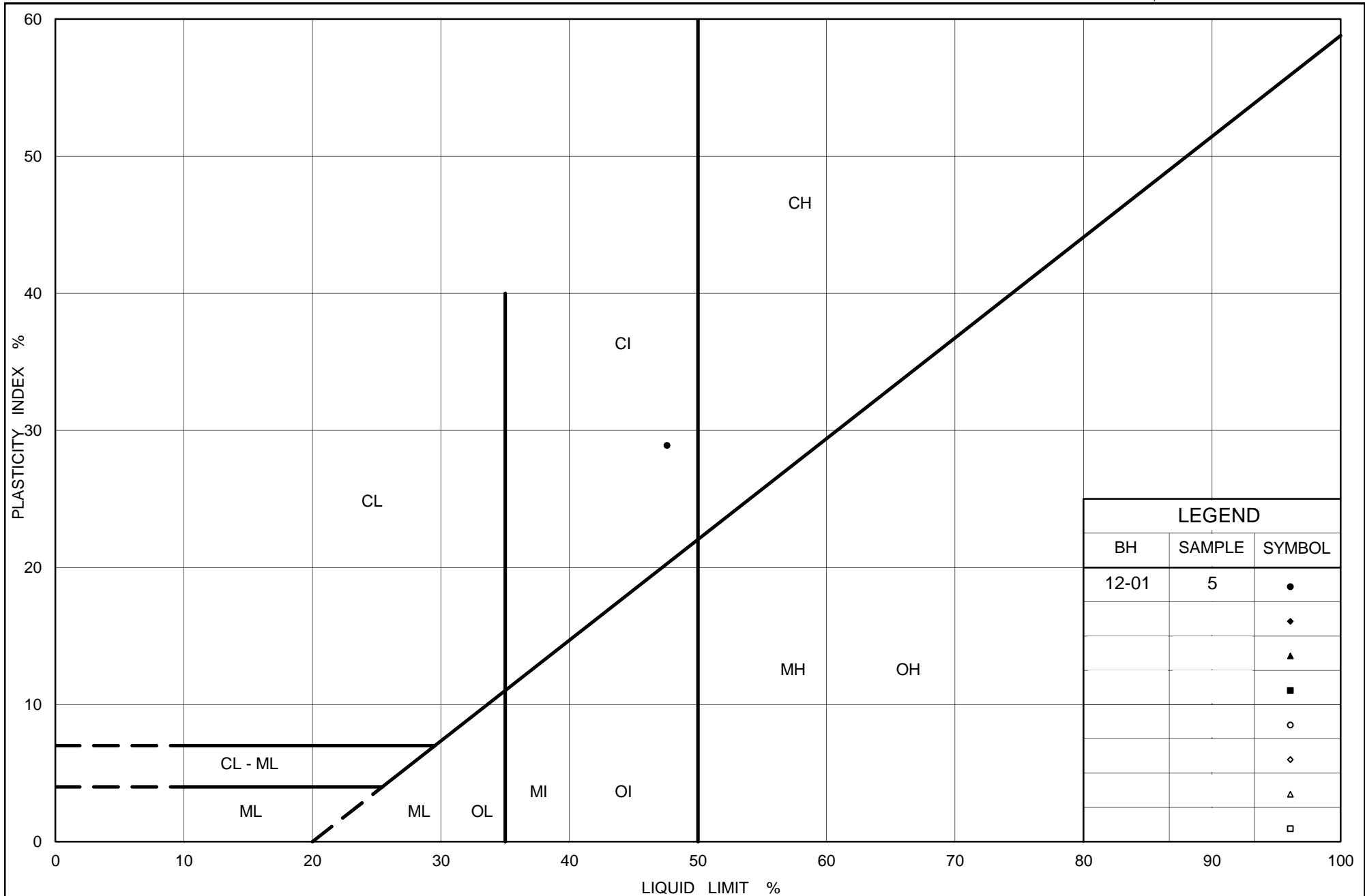
## PLASTICITY CHART Silty Clay Fill

Figure No. 1

Project No. 10-1111-0202

Checked By: SMM





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## PLASTICITY CHART

### Organic Silty Clay

Figure No. 2

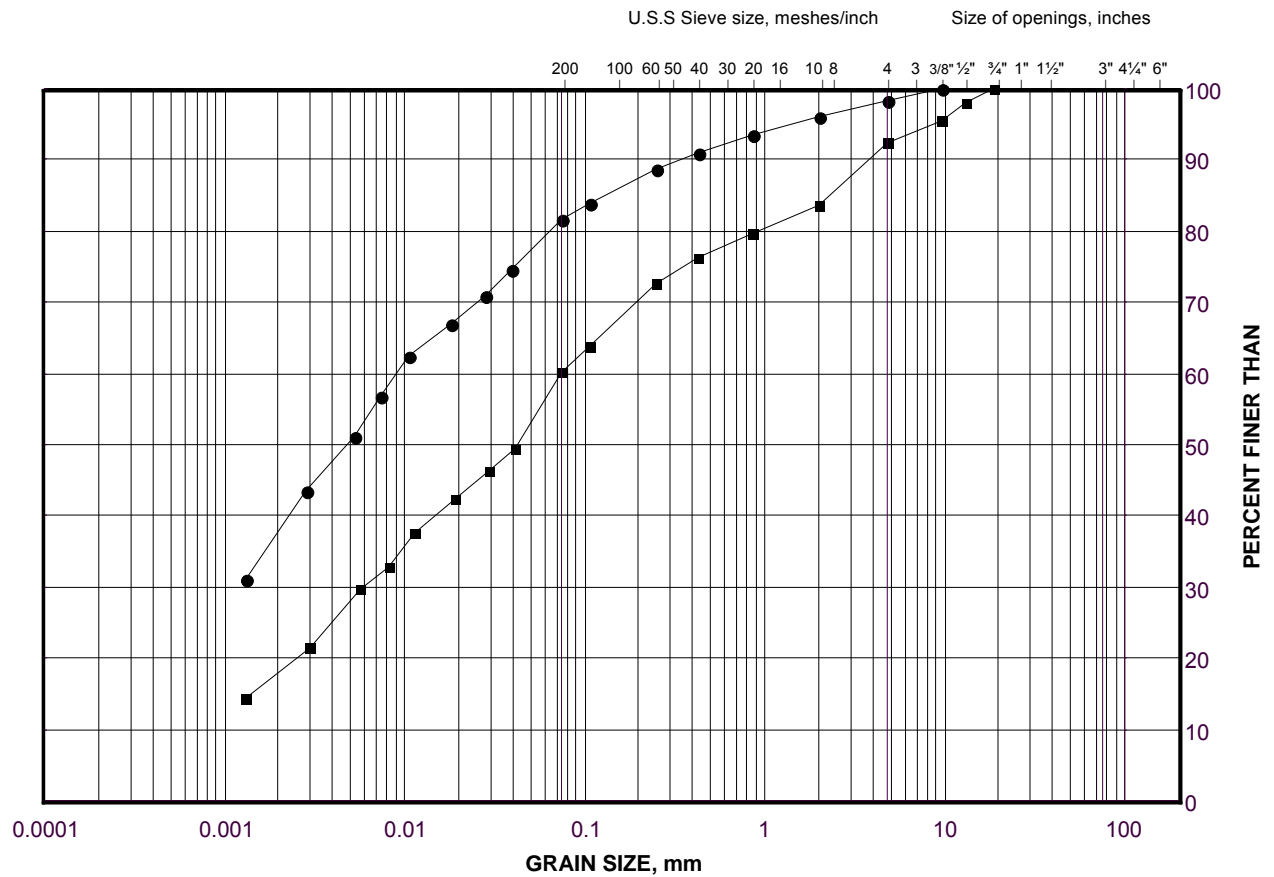
Project No. 10-1111-0202

Checked By: **SMM**

# GRAIN SIZE DISTRIBUTION

Clayey Silt with Sand Till to Silty Clay Till

FIGURE 3



SILT AND CLAY SIZES		FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED		SAND SIZE			GRAVEL SIZE		SIZE

## LEGEND

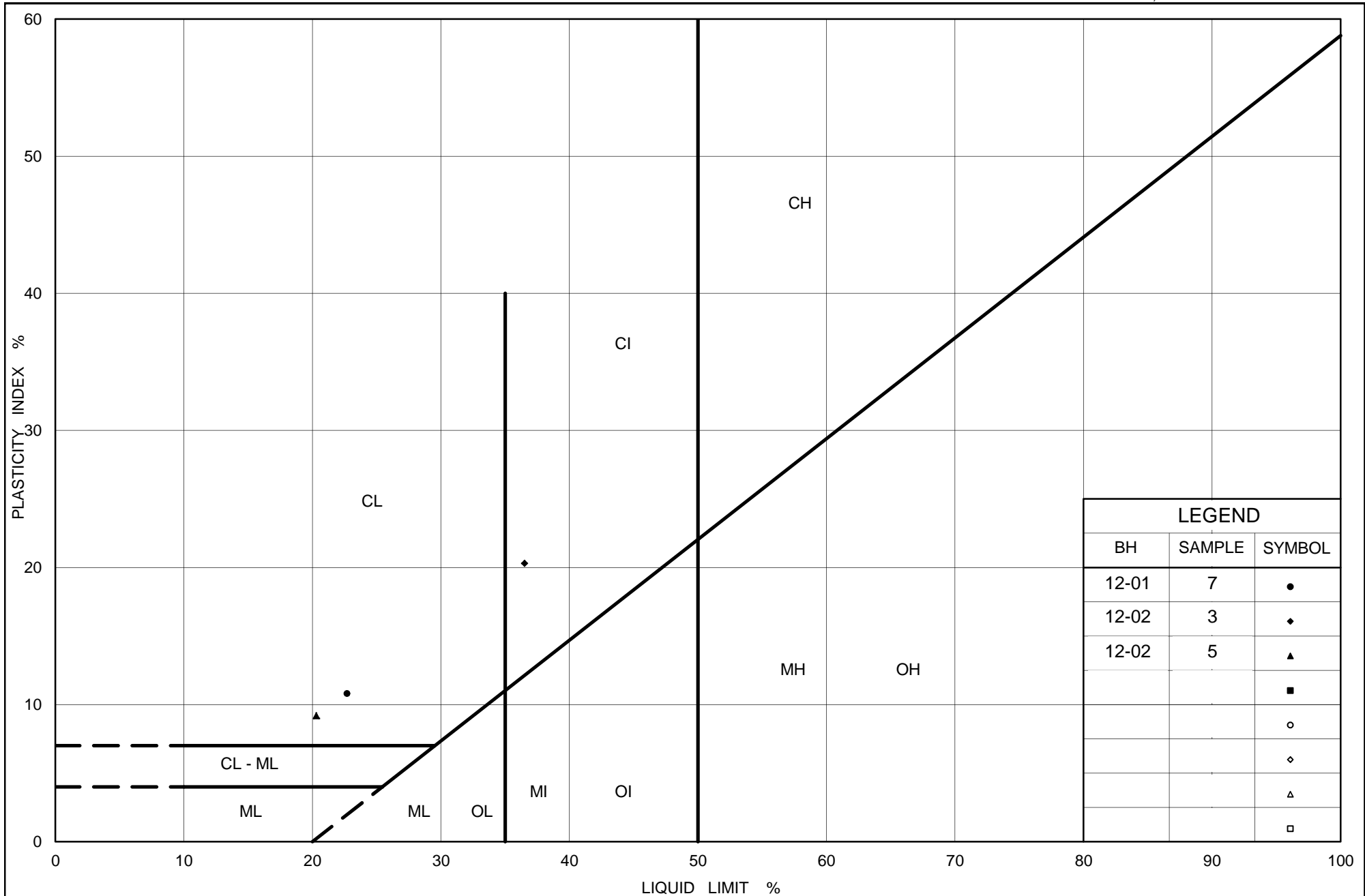
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	12-02	3	174.7
■	12-01	7	173.4

Project Number: 10-1111-0202

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Date: 01-Feb-13



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# PLASTICITY CHART Clayey Silt with Sand Till to Silty Clay Till

Figure No. 4

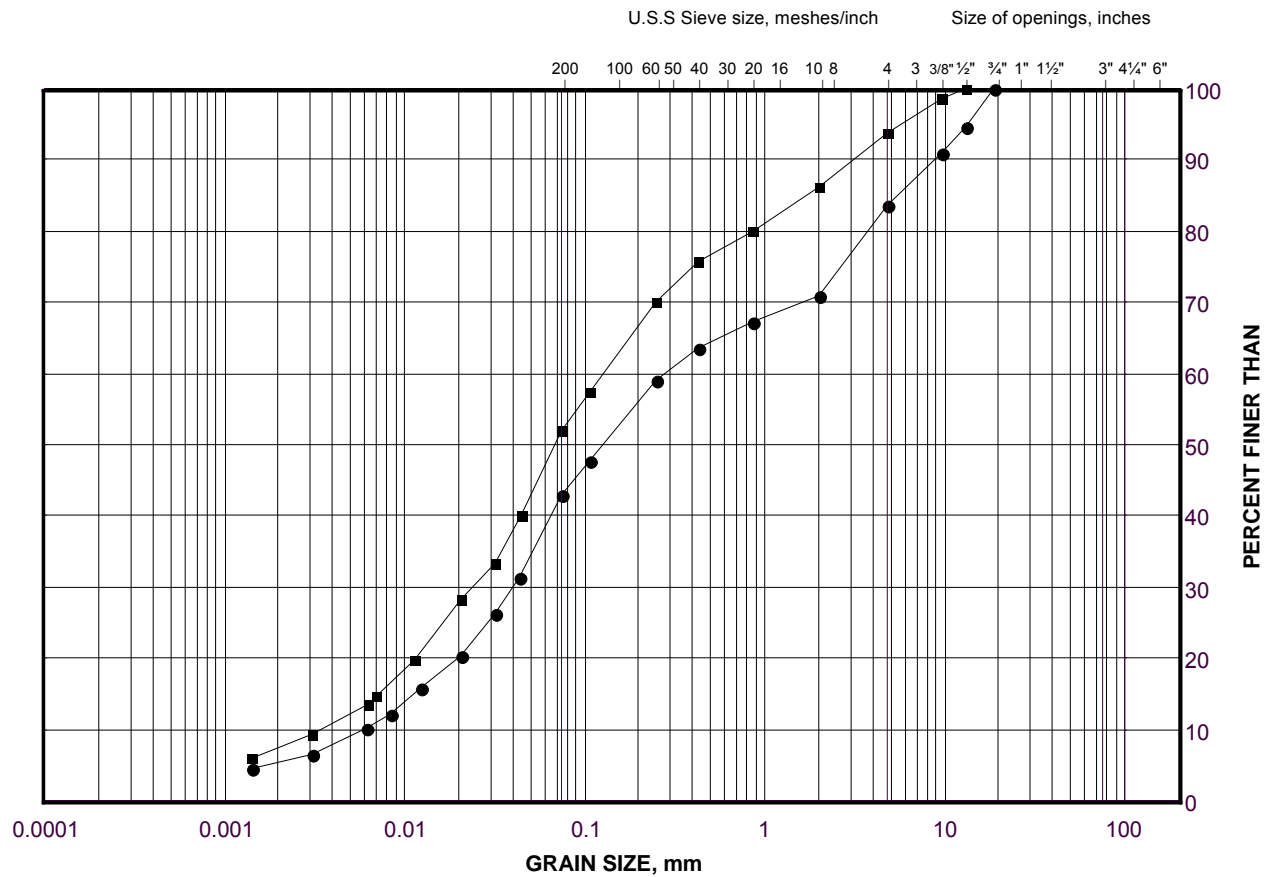
Project No. 10-1111-0202

Checked By: SMM

# GRAIN SIZE DISTRIBUTION

Sand and Silt Till

FIGURE 5



SILT AND CLAY SIZES		FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED		SAND SIZE			GRAVEL SIZE		SIZE

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	12-02	6	172.4
■	12-01	8	172.1

Project Number: 10-1111-0202

Checked By: SMM

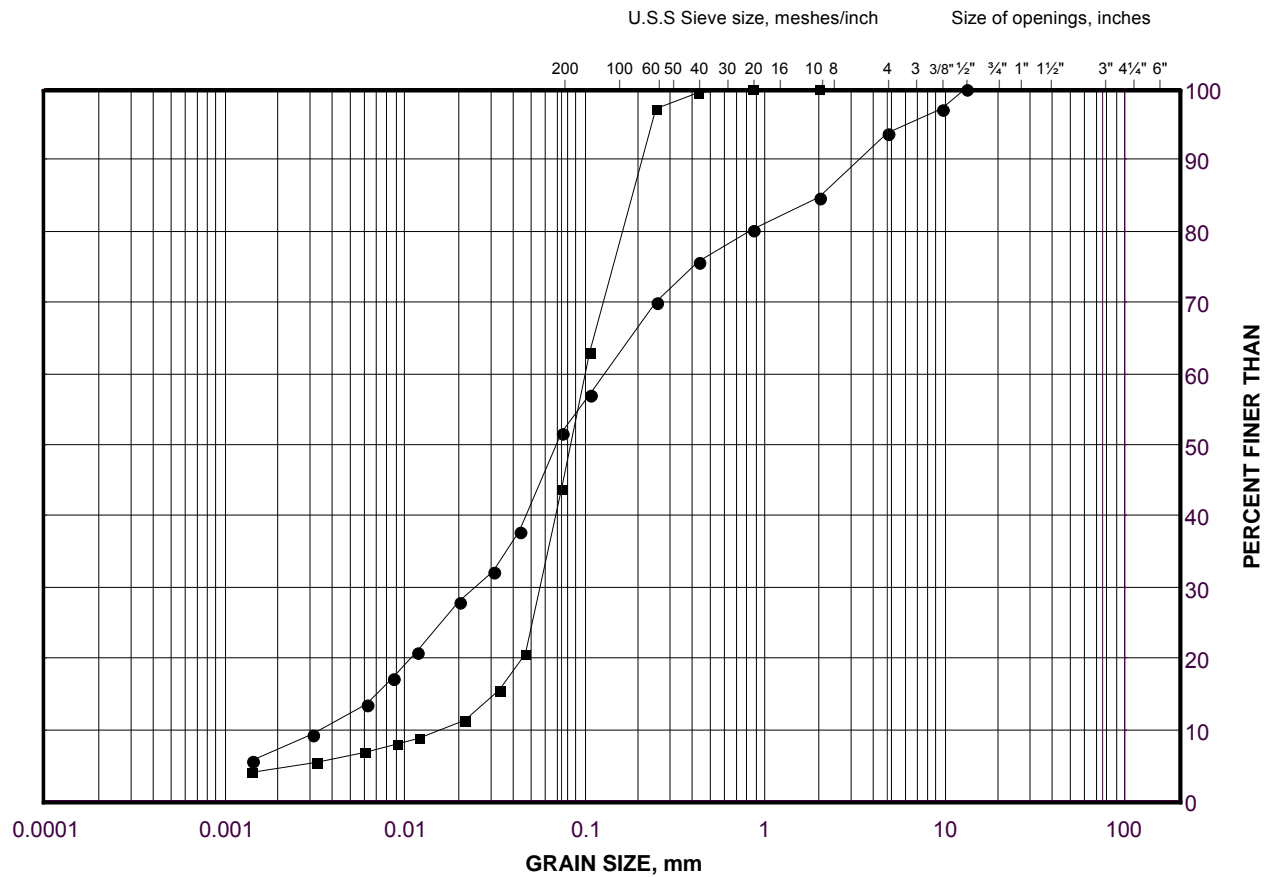
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# GRAIN SIZE DISTRIBUTION

Sand and Silt

FIGURE 6



SILT AND CLAY SIZES		FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED		SAND SIZE			GRAVEL SIZE		SIZE

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	12-01	10	168.8
■	12-02	9	168.6

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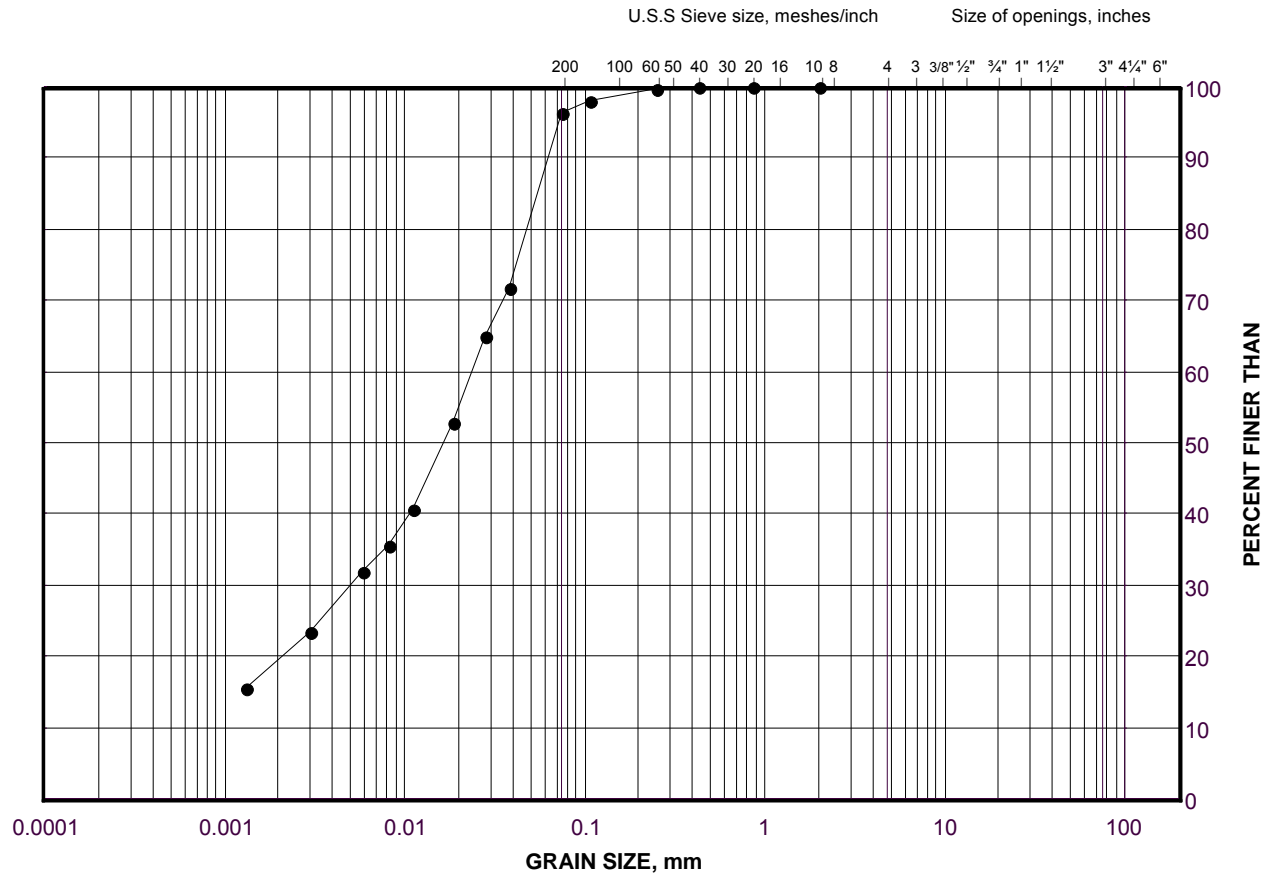
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# GRAIN SIZE DISTRIBUTION

Clayey Silt

FIGURE 7



## LEGEND

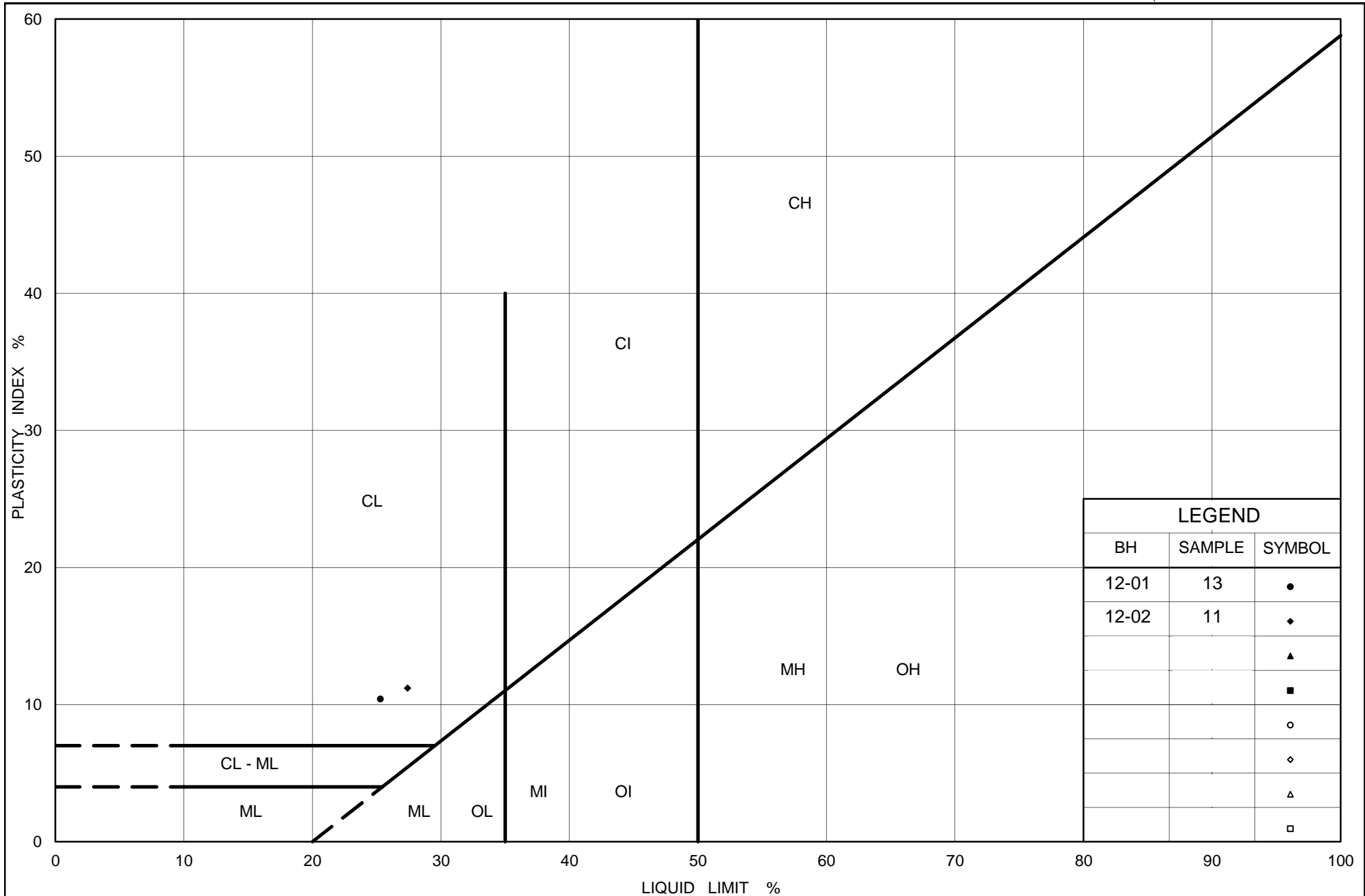
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	12-01	13	164.3

Project Number: 10-1111-0202

Checked By: SMM

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Date: 01-Feb-13



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## PLASTICITY CHART

### Clayey Silt

Figure No. 8

Project No. 10-1111-0202

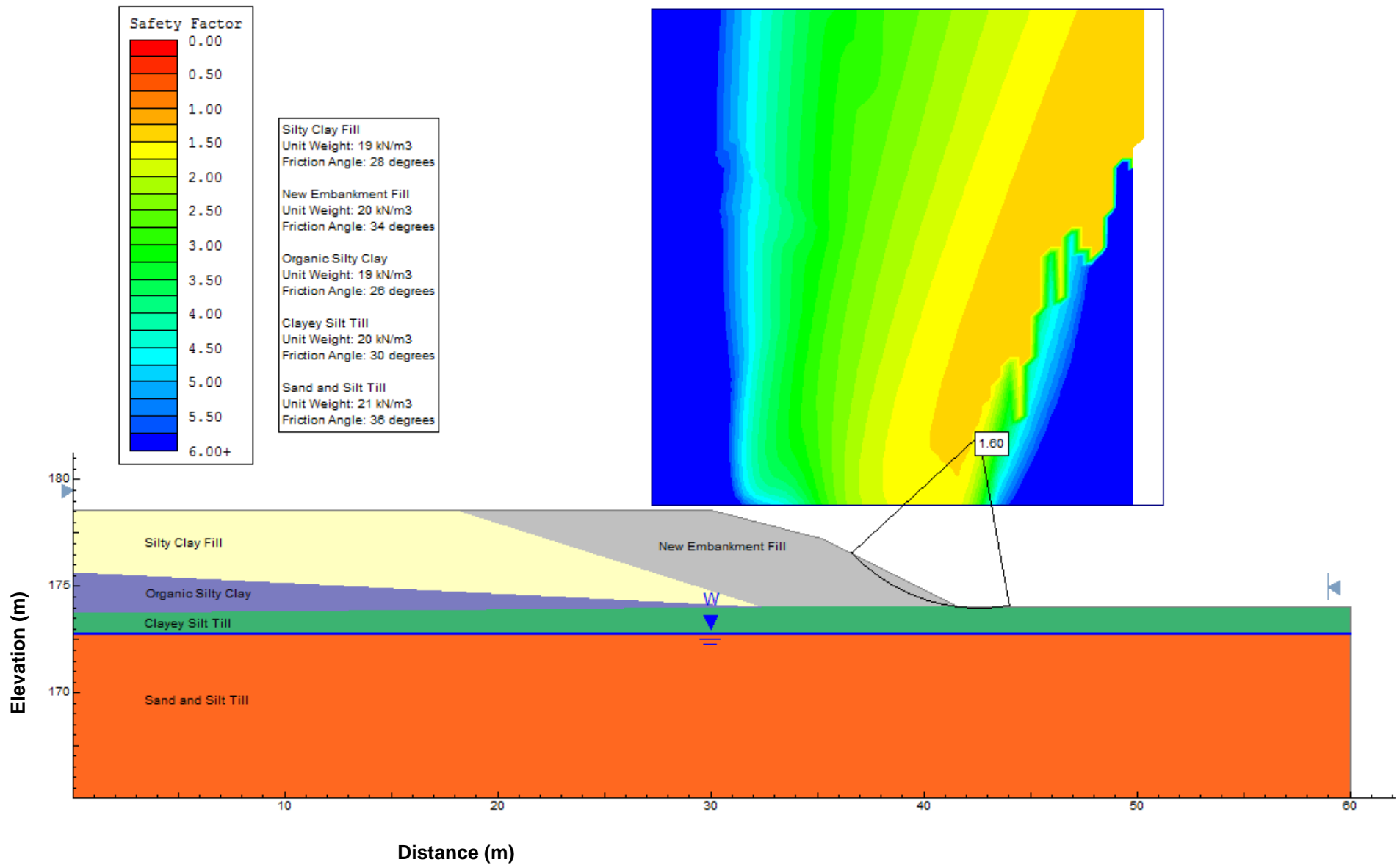
Checked By: SMM





## Static Global Stability – Culvert 18 – Highway 427 Widening

Figure 9



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[solutions@golder.com](mailto:solutions@golder.com)  
[www.golder.com](http://www.golder.com)

**Golder Associates Ltd.**  
**6925 Century Avenue, Suite #100**  
**Mississauga, Ontario, L5N 7K2**  
**Canada**  
**T: +1 (905) 567 4444**

