



April 17, 2014

**GEOTECHNICAL INVESTIGATION AND DESIGN  
REPORT**

**Proposed Feedermain and  
Trunk Sewer Crossing Highway  
401, Between Toronto Street  
and Rudell Road  
Newcastle, Ontario**

**Submitted to:**  
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REPORT

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**Distribution:**

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### ATTACHMENTS

List of Abbreviations & Symbols  
Record of Borehole Sheets (BH10 to BH12)  
Drawing 1 – Borehole Locations and Soil Strata Plan

### APPENDICES

#### APPENDIX A

Important Information and Limitations of this Report

#### APPENDIX B

Figures 1 to 6 – Plasticity Charts and Grain Size Distributions

#### APPENDIX C

In-Situ Hydrogeological Testing Results



### 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM to provide geotechnical engineering services and a limited hydrogeological assessment in support of the design of the proposed 600 mm diameter concrete pressure pipe (CPP) feedermain and 1050 mm diameter CPP trunk sewer pipe installations along Toronto Street and Rudell Road in Newcastle, Ontario. As part of the assignment, this geotechnical investigation was to obtain the information of the existing subgrade soil and groundwater conditions at the site by means of a limited number of shallow boreholes to provide geotechnical engineering recommendations in support of the design of the proposed feedermain and trunk sewer crossing Highway 401. Authorization to proceed with this investigation was given by Mr. Doug Timms of AECOM, in an e-mail dated August 23, 2012. Concurrent with this program, Golder has also been retained to undertake a geotechnical study along the remainder of the feedermain and trunk sewer alignment, the results of which will be reported separately.

In order to assess the need to obtain a Permit To Take Water (PTTW) for temporary construction dewatering from the Ontario Ministry of the Environment (MOE), a limited hydrogeological investigation has been carried out in conjunction with the current geotechnical investigation and the results are summarized in this report.

The factual data, interpretations and recommendations contained in this report pertain to a specific project as described in the report and are not applicable to any other project or site location. If the project is modified in concept, location or elevation, or if the project is not initiated within eighteen (18) months of the date of the report, Golder should be given an opportunity to confirm that the recommendations are still valid. In addition, this report should be read in conjunction with the "Important Information and Limitations of This Report" attached in Appendix A of this report. The reader's attention is specifically drawn to this information, as it is essential for the proper use and interpretation of this report.

This report addresses only the geotechnical (physical) aspects of the subsurface conditions at this site. The geo-environmental (chemical) aspects of the subsurface conditions, including the consequences of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources, are outside the terms of reference for this investigation.

### 2.0 PROJECT AND SITE DESCRIPTION

The proposed feedermain and trunk sewer alignment extends northerly from Toronto Street (south of Highway 401) to Rudell Road (north of Highway 401), as shown on the Borehole Location and Soil Strata Plan, Drawing 1, attached. It is understood that trenchless methods will be utilized for crossing below Highway 401 for both the feedermain and trunk sewer installations.

At the Highway 401 crossing location, the highway is about 40 m wide (from edge of shoulder to edge of shoulder). The terrain in the study area is uneven with ground surface elevations ranging between approximately 88.0 m to 93.5 m, referenced to geodetic datum. Two ditches were observed at the proposed crossing location at the toes of the north and south highway embankments. A soil stockpile was observed on the south side of Highway 401, extending from the Highway 401 property line to about 70 m south of the property line. The top of the soil stockpile is approximately 5.0 m above the surface of Highway 401 and the Highway 401 surface is approximately 3.0 m below the existing ground surface to the north of the highway, as shown on the Drawing 1. The north and south highway embankment ditches were about 1 m below the edges of the shoulders.



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It is understood that the existing soil stockpile will be removed prior to the construction of the feedermain and trunk sewer.

### 3.0 INVESTIGATION PROCEDURES

The field work for the proposed feedermain and trunk sewer crossing of Highway 401 was carried out on September 28 and October 1, 2012, during which time two boreholes (BH10 and BH11) were located within the MTO Right of Way (ROW) and one borehole (BH12) was located immediately north of the MTO ROW. The boreholes were advanced at the site using both a truck-mounted and a track-mounted drill rig supplied and operated by Strong Soil Search Ltd. from Pickering, Ontario, as shown on the Borehole Locations and Soil Strata Plan 1, attached.

Boreholes BH10 and BH11 were advanced using 200 mm outside diameter (O.D.) continuous flight hollow stem augers, to depths of 15.7 m and 12.8 m, respectively, below the existing ground surface. Borehole BH12 was advanced using 115 mm outside diameter (O.D.) continuous flight solid stem augers to a depth of 14.2 m below existing ground surface. Soil samples were obtained at 0.75 m and 1.5 m intervals of depth, using 50 mm O.D. split-spoon samplers advanced using an automatic hammer, in accordance with the Standard Penetration Test (SPT) procedure (ASTM 1586).

The groundwater conditions in the open boreholes were observed during the drilling operations. Nested 50 mm diameter monitoring wells and 19 mm diameter piezometers were installed in Boreholes BH10 and BH12 and nested 19 mm diameter piezometers were installed in Borehole BH11 as shown on the Record of Borehole Sheets. The screened portions of the wells/piezometers are surrounded by a sand pack, and the un-slotted pipe sections were backfilled with bentonite pellets.

The field work was monitored on a full-time basis by a member of Golder's engineering staff who arranged for the clearance of underground utility services, directed the sampling and in situ testing operations and logged the boreholes. The soil samples were identified in the field, placed in labelled containers and transported to Golder's laboratories in Whitby and Mississauga for further examination, natural water content testing and soil classification testing.

The staked borehole locations in the field and their corresponding geodetic elevations were provided by AECOM. It is understood that the elevations are referenced to geodetic datum.

The borehole locations (MTM NAD83 northing and easting coordinates), the ground surface elevations (referenced to geodetic datum) are summarized in the following table. MTM NAD83 coordinates and ground surface elevations are also presented on the Record of Borehole sheets.

Borehole	Northing (m)	Easting (m)	Ground Surface Elevation (m)
BH10	4864433.1	692877.8	93.5
BH11	4864485.2	692853.1	88.1
BH12	4864521.6	692841.7	92.4



## **4.0 REGIONAL PHYSIOGRAPHY AND GEOLOGY**

### **4.1 Regional Physiography**

The site is located within the physiographic region of Southern Ontario known as the Iroquois Plain (Chapman, L.J. and Putnam, D.F., 1984, *The Physiography of Southern Ontario*, 3rd Edition). Clay plains are identified as the physiographic landform present at the site. Soils in this area are referred to as Newcastle loam, and are reported as glaciolacustrine sediments deposited in low lying areas.

### **4.2 Regional Geology**

According to surficial geology mapping (Brennand, T.A., 1997, *Surficial Geology of the Oshawa Area*, NTS 30M/15, Southern Ontario; Geological Survey of Canada, Open File 3331, Scale 1:50,000), the surficial geology in the vicinity of the site generally consists of a glaciolacustrine deposits of silt and clay underlain by glacial till with a sandy silt to sand matrix (i.e., the Bowmanville Till). The bedrock underlying the unconsolidated overburden is indicated to consist of shale of the Whitby Formation overlying limestone of the Trenton Group. The depth to bedrock is indicated to be approximately 20 m to 30 m below ground surface (bgs).

### **4.3 Site Stratigraphy**

As previously noted, two boreholes (BH10 and BH11) were located within the MTO Right of Way one borehole (BH12) was located immediately north of the MTO ROW at Highway 401 utility crossing location. The locations of these boreholes are shown on Borehole Locations and Soil Strata Plan, Drawing 1.

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are provided on the Record of Borehole sheets and in Appendix B following the text of this report. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling, observations of drilling progress and the results of Standard Penetration Tests (SPTs). These boundaries, 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, an approximately 100 mm thick layer of topsoil was encountered at the ground surface at the locations of Boreholes BH10 and BH12. Fill materials were encountered in all of the boreholes and extended to depths ranging from 1.4 m to 4.3 m below existing ground surface; the native soils encountered below the fills generally consisted of silty clay and glacial tills ranging in gradations from clayey silt till to silty sand till. Boulders and/or cobbles were encountered in the glacial tills at various depths. The shallow groundwater levels were measured at depths ranging from 1.8 m to 8.2 m below existing ground surface in the monitoring wells/piezometers installed in the boreholes on October 9, 2012. The shallow groundwater levels were at depths ranging from 0.4 m to 6.4 m below existing ground surface on October 24 and December 3, 2012.

A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

#### **4.3.1 Topsoil**

A layer of topsoil was encountered at the ground surface in all of the boreholes with the exception of Borehole BH11. The thickness of the topsoil layer was measured of about 100 mm at the borehole locations.



### 4.3.2 Fill Material

Fill materials consisting of dark brown/black clayey silt to silty clay containing varying amounts of sand and gravel and brown/dark brown/grey sandy silt to sand and gravel containing varying amounts of clay were encountered below the topsoil or at ground surface in all of the boreholes. The fill materials included topsoil inclusions, asphalt/metal fragments and organics. The bottom of the fill material was encountered between approximate Elev. 86.7 m and Elev. 91.0 m and its thickness varied from about 1.3 m to 4.2 m.

Standard penetration tests carried out within the silty clay to clayey silt fills gave N values of 8 blows and 13 blows per 0.3 m of penetration, indicating a firm to stiff consistency. Standard penetration tests carried out within the sandy silt to silty sand and sand and gravel fills gave "N" values ranging from 2 blows per 0.3 m of penetration to 43 blows per 0.3 m of penetration, indicating a very loose to dense compactness.

The in-situ water contents of the fill samples ranged from about 4 percent to 48 percent.

### 4.3.3 Silty Clay

A deposit of brown to grey silty clay containing trace to some sand and gravel was encountered below the fill materials in all of the boreholes advanced at the site. The silty clay deposit extended to elevations between approximate Elev. 85.2 m and Elev. 86.4 m, with the thicknesses ranging from about 1.5 m to 5.7 m.

SPT N-values measured within the silty clay deposit ranged from 5 blows per 0.3 m of penetration to 11 blows per 0.3 m of penetration; the measured N-values indicate a firm to stiff consistency.

The measured water contents of the silty clay samples ranged from approximately 15 percent to 36 percent.

The result of one Atterberg limit test performed on a selected sample of the silty clay is provided on Figure 1. The test results yielded a liquid limit of about 42 percent; a plastic limit of about 19 percent and a plasticity index of about 23 percent. The result of one grain one size distribution test carried out on a sample of the silty clay material is provided on Figure 2 and is also summarized on the Record of Borehole sheet.

### 4.3.4 Silty Clay Till

A deposit of brown silty clay till, containing trace to some sand and gravel was encountered below the silty clay in Borehole BH10. The silty clay till was encountered between approximate Elev. 86.4 m and Elev. 84.9 m and the thickness of the till was about 1.5 m.

One SPT N-value measured within the silty clay till deposit was 12 blows per 0.3 m of penetration; the measured N-values indicate a stiff consistency.

The measured water content of a sample of the silty clay till was approximately 16 percent.

### 4.3.5 Sandy Silt to Silty Sand Till

A deposit of grey sandy silt to silty sand till containing varying amounts of gravel and clay was encountered in all of the boreholes. The sandy silt to silty sand till deposit was encountered below the silty clay till in Borehole BH10 and below the silty clay in Boreholes BH11 and BH12. Cobbles and boulders were inferred to be present within this deposit as evidenced by auger grinding during drilling. The sandy silt till to silty sand till was encountered at approximate elevations between 85.3 m and 84.9 m. All of the boreholes were terminated in the till deposit.



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SPT N-values measured within the sandy silt till to silty sand till deposits generally ranged from 4 blows per 0.3 m of penetration to greater than 100 blows per 0.13 m of penetration; the measured N-values indicate a loose to very dense compactness.

The measured water contents of the sandy silt till to silty sand till samples ranged from about 7 percent to 11 percent.

The results of three grain size distribution tests carried out on selected samples of the silty sand till deposit are provided on Figures 3, 4 and 5 and are summarized in the Record of Borehole sheets.

### 4.3.6 Groundwater Conditions

The groundwater levels were noted during and upon completion of the drilling operations. A total of two 50 mm diameter monitoring wells and four 19 mm diameter piezometers were installed during the subsurface investigation at the site. Monitoring wells were installed in Boreholes BH10 and BH12 and piezometers were installed in all of the boreholes. The water levels measured in these monitoring wells/piezometers on October 9, 2012 varied from approximately 1.8 m to 8.2 m below existing ground surface. The water levels measured in these monitoring wells/piezometers on October 24 and December 3, 2012 varied from approximately 0.4 m to 6.4 m below the existing ground surface. Details of the installations as well as the measured water levels are shown on the Record of Borehole sheets.

As part of the geotechnical investigation, a total of 3 boreholes were drilled on September 28, 2012 and October 1, 2012. Three bi-level (or nested) wells/piezometers were installed in these geotechnical boreholes. The depth to groundwater was measured in the monitoring wells and piezometers on October 9, 2012, October 24, 2012 and December 3, 2012. Based on the ground surface elevation data provided by AECOM, a summary of groundwater elevation monitoring data is provided in the table below:

Borehole I.D.	Ground Surface Elevation	October 9, 2012		October 24, 2012		December 3, 2012	
	(m asl)	(m bgs)	(m asl)	(m bgs)	(m asl)	(m bgs)	(m asl)
BH10-A (Deep)	93.50	6.5	87.7	6.42	87.09	nm	nm
BH10-B (Shallow)	93.50	5.8	87.00	5.61	87.90	nm	nm
BH11-A (Deep)	88.10	8.2	79.9	nm		1.70	86.40
BH11-B (Shallow)	88.10	1.8	86.3	nm		0.40	87.70
BH12-A (Shallow)	92.42	8.1	84.3	2.72	89.70	nm	nm
BH12-B (Deep)	92.42	5.7	86.7	3.68	88.74	nm	nm

**Notes:**

m bgs      meters below ground surface  
m asl      meters above mean sea level  
nm        not measured

From the above table, on October 9, 2012, groundwater elevations ranged from 79.9 m asl (BH11A) to 87.7 m asl (BH10A); and groundwater levels relative to ground surface ranged from 1.8 m bgs (BH11-B) to 8.2 m bgs (BH11A). However, static water level conditions may not have been present at many monitoring wells/piezometers (e.g., BH10-A, BH10-B, BH11-A, BH12-A, BH12-B) on that date, eight days or more following the drilling program. On October 24, 2012 and December 3, 2012, groundwater elevations ranged from 86.40 m





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asl (BH11A) to 89.70 m asl (BH12-A); and groundwater levels relative to ground surface ranged from 0.40 m bgs (BH11-B) to 6.42 m bgs (BH10-A). Downward vertical hydraulic gradients were observed at all locations with a bi-level installation with the exception of Borehole BH11. It should be noted that Borehole BH11 was drilled close to a drainage ditch. Water from the ditch may have temporarily elevated the groundwater levels at this location. It also should be noted that the water level data reflect the shallow groundwater conditions encountered in the monitoring wells/piezometers during the time of the field investigation and seasonal fluctuations should be anticipated.

### 5.0 DISCUSSION

This section of the report provides geotechnical engineering information related to the design of the proposed feedermain and trunk sewer where the utilities cross below Highway 401. The following comments and recommendations are based on our interpretation of the borehole information and on our understanding of the project requirements. The information of the report is provided for the guidance of the design engineers. Where comments are made on construction, they are provided only in order to highlight aspects of construction which could affect the design of the project. Contractors bidding on or undertaking any work at the site should examine the factual results of the investigation, satisfy themselves as to the adequacy of the information for construction and make their own interpretation of the factual data as it affects their proposed construction techniques, schedule, equipment capabilities, costs, sequencing and the like.

#### 5.1 General

Conventional open trench construction is not feasible for the crossing of the highway, as significant disruptions to traffic flow along the highway would be required.

Pipe ramming is also not considered to be feasible for this crossing due to the relatively long crossing distance and the potential presence of boulders within the soil deposits. In addition to the length of the required pipe ramming sections, it would be difficult to maintain the intended alignment below the highway using pipe ramming methods. Conventional tunnelling is not considered appropriate for the highway crossing because the equipment to provide human access would necessitate a tunnel much larger in diameter than would be required for the feedermain and trunk sewer pipes. Micro-tunnelling is also considered to be impractical due to the lack of local experience and appropriately equipped local contractors which would result in very high mobilization costs, for a relatively short tunnel section.

Horizontal directional drilling (HDD) is also not considered to be an option for the installation of the proposed feedermain and trunk sewer pipes as HDD methods are not suitable for the installation of concrete pressure pipes.

Therefore, the Jack and Bore tunnelling method is considered to be the preferred alternative for the installation of the feedermain and trunk sewer crossing below Highway 401. The Jack and Bore method would form a horizontal borehole through the ground, from a sending pit to a receiving pit, by means of a rotating cutting head and an auger while simultaneously jacking a steel casing with the boring operation, which would provide a cased liner space for installing the feedermain and trunk sewer pipe.

Since not all potential aspects relating to the specific equipment and installation methods selected by the pipe installation contractor can be identified at this time, it should be clearly understood that contractors bidding on the project will be solely responsible for independently reviewing and confirming the feasibility of installing the feedermain and trunk sewer crossing below Highway 401 by Jack and Bore installation methods and confirming



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the suitability of the contractor's equipment and proposed construction procedures for this purpose and for the ground conditions that are documented for the site.

As noted above, the width of the existing Highway 401 at the crossing location from the edge of shoulder to the edge of shoulder is about 40 m. The elevations of the Highway 401 pavement surface and the drainage ditches at the crossing locations are about Elev. 89.0 m and Elev. 88.0 m, respectively.

Based on the subsurface stratigraphy encountered at Boreholes BH10 and BH11 advanced on each side of the Highway 401 within the MTO ROW and Borehole BH12, located immediately north of the MTO ROW, fill materials consisting of clayey silt to silty clay and sandy silt to gravel and sand were encountered below topsoil or surficially in all of the boreholes and extended to depths ranging from 1.4 m to 4.3 m below existing ground surface (Elev. 89.2 m to Elev. 91.1 m); the native soils encountered below the fills generally consisted of silty clay, and glacial tills ranging in gradations from clayey silt till to silty sand till. Boulders and/or cobbles were encountered in the glacial tills at various depths. The shallow groundwater levels measured in the monitoring wells and piezometers installed in the boreholes ranged from 0.4 m to 6.4 m below existing ground surface on October 24 and December 3, 2012.

Based on the final profile drawing provided by AECOM in an email dated November 7, 2013, the proposed feedermain and trunk sanitary sewer invert depths at the Highway 401 crossing would be approximately 6 m and 9 m below the existing pavement surface, respectively. Based on the subsurface conditions identified in the boreholes advanced at the site, it is anticipated that the steel casing would be installed mainly within the compact silty sand to sandy silt till containing cobbles and boulders. Loose silty sand to sandy silt till deposits could also be encountered at the invert elevation along the proposed alignment. Groundwater control during construction within the tills could be handled, if necessary, by pumping from properly constructed and filtered sumps. However, more significant groundwater seepage would be expected from the sandy silt to silty sand layers within the glacial tills. Depending upon the actual thickness and extent of the sandy silt to silty sand layers and the finalized invert depths, some form of positive groundwater control may be required, in addition to pumping from sumps.

A "public digging" (i.e. test pitting) during the tender stage may be carried out at the crossing locations to allow prospective bidders to assess the subsurface conditions and determine the type of groundwater control required, consistent with their equipment capabilities and the actual groundwater conditions at that time. The locations of the test pits should be determined in consultation with the geotechnical engineer. It noted that groundwater control measures that extract more than 50,000 L/day of water are subject to a PTTW, as regulated by the MOE.

### 5.2 Pipe Jacking and Boring

The pipe Jack and Bore method involves drilling a near horizontal borehole from a jacking pit with a rotating cutter head and jacking a casing or liner to support the borehole walls. The casing is pushed by a jacking system through a thrust block that uniformly distributes the thrust load on the casing cross-section. The direction of the auger head can only be controlled using a rudimentary steering system where minor adjustments can be made should it be necessary or on encountered partial obstruction or difficult to penetrate soils. One of the advantages of using the Jack and Bore method for the utility installation is that the augers can be manually removed to permit clearing of obstructions such as cobbles and boulders. Further, the auger can be adapted to use rock-cutting teeth. However, the steering ability and grade control is somewhat limited. Where the Jack and Bore method is proposed, sufficient rig power, as well as suitable tools including cutting heads appropriate for the installation of the feedermain and trunk sewer for the anticipated ground conditions should be used to



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complete the undercrossing installations. The Jack and Bore may be used provided adequate consideration is given to the presence of cobbles and boulders that may affect alignment and tolerances with this method of feedermain and trunk sewer installation. Where necessary, overcutting and/or adjustments to the directional path may be required to assist with the installation process through the hard/very dense tills, if required. The size of steel liner should be sufficient to allow manual removal of large sized boulders in the steel liners. In soft or unstable ground conditions, boring and jacking operations are performed simultaneously to minimize ground loss. Lubrication may be provided to reduce the friction between the casing and the borehole walls. The characteristics of the surrounding soil should be considered in selecting the appropriate lubricant.

Based on the borehole data as noted above, it is anticipated that the boring operations will generally encounter the loose to compact silty sand to sandy silt till containing cobbles and boulders. The Jack and Bore operations should be continued without stoppage until completed. To reduce (but not eliminate) loss of ground and associated disturbance, consideration should be given to jacking the liner as far as practical, prior to augering. It is recommended that the auger cutting head be maintained a full casing diameter, or at least 0.5 m, behind the leading edge of the casing. However, the presence of cobbles and boulders in the till could make this difficult or impractical and deflection and/or refusal to penetration of the casing may occur if large obstructions are encountered. The volume of mucked soil should be monitored to provide an indication of the ground loss.

It is emphasized that the resulting performance of the completed pipe crossing will largely be dependent upon construction procedures and techniques. Ground movements (heave or settlement) associated with the work should be monitored during installation and, if necessary, the construction method should be altered to control ground movements and minimize disturbance to the overlying Highway 401. Where adequate provisions are not included to ensure face stability of the bore to minimize ground loss, detrimental surface settlement could occur, adversely impacting Highway 401 and any existing underground services present. Therefore, full-time inspection by a geotechnical engineer should be considered during the course of the Jack and Bore operations underneath the Highway 401 roadway.

### 5.3 Sending/Receiving Pits

Based on the groundwater conditions encountered in the boreholes during drilling and the water levels measured in the monitoring wells and piezometers installed in the boreholes, the anticipated pit invert elevation will generally be below the local water table at the site. Groundwater control during excavation within the glacial tills and the cohesive silty clay can be handled, as required, by pumping from properly constructed and filtered sumps located within the excavations. However, more significant groundwater seepage may be expected from the fill materials and native cohesionless soils. Depending upon the actual thickness and extent of these soils, the prevailing groundwater level at the time of construction and the pit invert elevation, some form of positive groundwater control, in addition to pumping from sump may be required to maintain the stability of the base and side slopes of the excavations in these areas.

Excavation of the sending and receiving pits must be carried out in accordance with the Occupational Health and Safety Act for construction activities. Conventional open cuts can be utilized to construct the sending/receiving pits where sufficient space is available to construct side slopes not steeper than 1H:1V. Care should be taken to direct surface runoff away from the open excavations and all excavations should be carried out in accordance with the Occupational Health and Safety Act and Regulations for Construction Projects. According to the Act, the existing fills, silty clay and loose till deposits would be classified as Type 3 soils, and the native compact to very dense till deposits would be classified as Type 2 soils above the groundwater tables. However, should excavations extend into the loose sandy silt to silty sand till below ground water levels, the soils would be classified



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as Type 4 and unless supported by shoring or other approved retaining method, the excavations will require side slopes of 3H:1V. Where space limitations do not permit the construction of 1H:1V excavation side slopes, which may be the case near the existing roadway, temporary shoring will be required to support the side slopes of the sending and/or receiving pits.

The excavation support system should be designed to resist the lateral earth pressures of the soils. It is common practice for a specialist contractor to design and install the excavation support system. The design of the shoring system should be reviewed by a geotechnical engineer from a geotechnical perspective.

It is anticipated that the excavation bases will likely be constructed in the silty sand to sandy silt till. Groundwater seepage into the excavation should be expected and pumping from properly filtered sumps within the excavation may be required. All surface drainage water should be directed away from the excavations. A levelling mat of compacted granular materials and/or lean concrete may be necessary to improve the working base, especially if the wet zones are exposed.

### 5.3.1 Supported Excavations

Due to the space restrictions, an excavation support system, such as braced soldier piles and lagging walls, is likely to be required for the sending and receiving pits. The temporary support system should be designed to resist the lateral earth, water and surcharge loadings, as described in the Canadian Foundation Engineering Manual (4<sup>th</sup> edition), Section 26.10.3 for braced retaining structures. For the subsoil conditions at this site, the unfactored rectangular earth pressure distribution ( $p$  in  $\text{kN/m}^2$ ; constant with depth) can be calculated as follows assuming level ground behind the excavation:

$$p = 0.25 \gamma' H + \text{Surcharge}$$

Where

$$H = \text{height of the excavation}$$

$\gamma'$  = effective soil unit weight, where  $\gamma' = 21 \text{ kN/m}^3$  above groundwater level and  $\gamma' = 11 \text{ kN/m}^3$  below groundwater level.

A triangular component of pressure must also be added for hydrostatic pressures acting below the groundwater table (i.e.  $p_w = \gamma_w h_w$ ).

It is recommended that the soldier piles be installed in pre-augered holes with the lower end below the base of the excavation socketed and grouted into the auger hole. Passive toe restraint to soldier piles socketed into the compact to very dense silty sand to sandy silt till deposit below the base of the excavation may be determined using a triangular pressure distribution acting over an equivalent width equal to three times the pile socket diameter. The unfactored passive pressure,  $p_p$  in  $\text{kN/m}^2$ , in front of the soldier pile sockets or in front of the sheetpile wall may be calculated using the formula given below, assuming the coefficient of passive lateral earth pressure,  $K_p$ , and the effective unit weight of the soil below the water table,  $\gamma'$ , for the soil in front of the piles given below:



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$$p_p = 0.5 K_p \gamma' H$$

where

H = depth of the pile measured from the bottom of the excavation

$$K_p = 3.2$$

$$\gamma' = 10 \text{ kN/m}^3$$

For soldier piles design, full passive resistance will be mobilized only where the width of soil in front and behind the piles is equal to or greater than eight piles diameters. The top 0.5 m should be ignored to count for the disturbance caused by the construction activities.

The maximum spacing of soldier piles should be limited to 2.5 m for 75 mm timber lagging and to 3.0 m for 100 mm lagging. A factor of safety of at least 2.0 should be applied to the passive resistance in the design of the temporary support system.

Care should be taken to direct surface water away from the open excavations and all excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA).

### 5.4 Obstructions

Boulders are commonly encountered in the overburden soils/tills of southern Ontario. The specific presence of boulders can significantly affect the selection of equipment and progress of construction works, especially in trenchless drilling or boring. The soils at the site are glacially derived, and thus, contain boulders (rock of such a size that it is unable to pass through a 0.3 m square opening); sizes much larger than this should be anticipated at this site. Further, boulders within the till deposits can originate from the igneous and metamorphic rocks of the Canadian Shield which can have unconfined compressive strengths of up to 250 MPa. Therefore, suitable equipment will be required to remove any boulders encountered during drilling or boring.

### 5.5 Settlement and Settlement Monitoring

The installation of the proposed feedermain and trunk sewer using jack and bore methods may result in ground displacements of the soil located above and adjacent to the proposed pipes. The magnitude of such displacements is highly dependent on the construction procedures utilized. For the proposed feedermain and trunk sewer installation, a provision for monitoring is required to be included in the contract documents as per MTO's document "Guideline for Foundation Engineering – Tunnelling Specialty for Corridor Encroachment Permit Application" (April 2008). Ground displacement at the proposed Highway 401 crossing is not expected to affect the safe operations of the highway traffic since the intended alignments will have at least 5 m of overburden cover. Provided that appropriate construction procedures, workmanship and inspections are specified and implemented, the potential ground displacement at the ground surface during pipe installation, above the proposed pipes, is estimated to be nominal.

An inspection, instrumentation and ground monitoring program is necessary on this project to;

- Document the effects of the feedermain and trunk sewer installation on the overlying highway;



## GEOTECHNICAL INVESTIGATION AND DESIGN REPORT PROPOSED FEEDERMAIN AND TRUNK SEWER CROSSING

- Obtain prior warning of ground movements that could occur due to the construction methods and equipment or unforeseen ground conditions;
- Verify the contractor's compliance with the ground movement limits imposed in the Contract; and
- Allow adjustments to be made to the Jack and Bore methods such that the ground movement limits established are not exceeded.

The proposed monitoring program for the feedermain and trunk sewer pipes crossing of Highway 401 is consistent with the "Appendix – Settlement Monitoring Guideline-Tunneling" including in the above noted guideline and is summarized below:

- A series of surface monitoring points and in-ground monitoring points (minimum depth below ground surface of 1.5 m) should be installed along the intended feedermain and trunk sewer alignment. The in ground monitoring points should be installed at spacings of about 5 m beyond the north and south limits of the highway including the shoulders. A deep monitoring point should be installed about 1.5 m above the top of the steel casing at both ends of the feedermain and trunk sewer alignment, near the highway shoulder.
- Surface monitoring points (reflectors) should be installed directly over the alignment along the centreline of the pipeline where it crosses the highway. The surface monitoring points should be installed on the pavement, Highway 401 median, north and south shoulders within the limits of the highway. The maximum spacing between such points should not exceed 5 m along the pipeline alignment.
- Prior to the start of construction all monitoring points should be read a minimum of two times to provide a baseline.
- The monitoring points should be surveyed a minimum of three times per day during installation of the jack and bore activities, while jack and bore within the limits of, or approaching the limits of the highway, including during shut-down periods and weekends. An allowance should be made for more frequent monitoring (up to every 4 hours) should observations dictate.
- The surface monitoring points should be read and recorded during the construction period and after construction for a period of at least two weeks, provided that further settlement has ceased.

Monitoring of the instrumentation on this project will be constrained by the continuous and high traffic volume and the limited periods during which access to the highway can be obtained. The elevation of the top of the monitoring points would have to be read using conventional precision levelling equipment. By necessity, monitoring points on the road must be read remotely and the use of EDM equipment reading reflectors installed on the highway is suggested. A specialist surveying firm should be retained to confirm the set-up and to carry out the monitoring during construction; their equipment and procedures must be capable of surveying the settlement point elevation to within  $\pm 1$  mm of the actual elevation.

The following procedure should be followed if settlement levels of 10 mm (Review Level) and 15 mm (Alert Level) are reached:

- If the Review Level is reached the contractor would be required to provide a formal plan that states what is going to be done to ensure that the Alert Level is not reached; and





## GEOTECHNICAL INVESTIGATION AND DESIGN REPORT PROPOSED FEEDERMAIN AND TRUNK SEWER CROSSING

- If the Alert Level is reached, the contractor shall stop drilling and MTO would have the authority to order that the contractor alter the drilling methods prior to continuing with the installation.

In addition to ground movement monitoring, the feedermain and trunk sewer alignment (line and grade) should be carefully monitored and the as-drilled hole alignment should be submitted to the owner for approval.

### 6.0 LIMITED HYDROGEOLOGICAL ASSESSMENT

As part of the limited hydrogeological investigation carried out in conjunction with the geotechnical investigation, the following scope of work has been carried out:

- Measure the depth to groundwater in the monitoring wells/piezometers on two separate dates. Conduct single-well response testing (i.e., rising head tests) in 50 mm diameter monitoring wells installed as part of the concurrent geotechnical investigation, to estimate the bulk hydraulic conductivity; and
- Estimate temporary construction dewatering requirements to facilitate installation of the proposed feedermain and trunk sewer along the Site alignment and assess the potential need to obtain a PTTW for dewatering rates in excess of 50,000 L/day.

#### 6.1 Hydraulic Testing

Single well response testing (i.e., rising head tests) was carried out at BH10-A and BH12-B on October 24, 2012. Rising head tests were carried out by rapidly lowering the water levels by purging with a dedicated Waterra footvalve and tubing, and the resulting water level recovery was recorded with an electronic water level tape. The recovery data were analyzed using the Bouwer and Rice (1976) solution for unconfined aquifers. A summary of the hydraulic conductivity analysis from each rising head tests is provided in Appendix C, following the text of this report. The estimated bulk hydraulic conductivity values for soils in the vicinity of the monitoring well screens are provided in the table below:

Borehole ID	Screened Interval	Screened Unit	Estimated Bulk Hydraulic Conductivity
	(m bgs)		(cm/s)
BH10-A (Deep)	12.2 - 15.2	Silt to Silty Sand (Till)	$3 \times 10^{-5}$
BH12-A (Shallow)	7.0 - 8.5	Sandy Silt (Till)	$2 \times 10^{-6}$

**Notes:**

m bgs    metres below ground surface  
cm/s    centimetres per second

Based on the results of the rising head tests, the bulk hydraulic conductivity of the silty sand till to sandy silt till, was estimated to range in the order of  $2 \times 10^{-6}$  cm/s to  $3 \times 10^{-5}$  cm/s which is considered to be reasonable for this soil type.

#### 6.2 Construction Dewatering

The following provides an assessment of the potential for temporary construction dewatering to exceed 50,000 L/day, which requires a PTTW from the MOE.



## GEOTECHNICAL INVESTIGATION AND DESIGN REPORT PROPOSED FEEDERMAIN AND TRUNK SEWER CROSSING

It is anticipated that the proposed feedermain and watermain are to be installed using trenchless methods (i.e. Jack and Bore) at the Highway 401 crossing. The locations of the sending and received pits are not available at the time of preparing the report but likely located near boreholes BH10 and BH11. AECOM provided Golder with the final profile for the services at each of our borehole locations, which ranged from 6.0 m bgs to 9.0 m bgs for the Highway 401 crossing of the alignment.

Based on a review of the information obtained through this limited hydrogeological assessment, the site is characterized by various fill materials underlain by native glaciolacustrine deposits of silty clay underlain by glacial till. On October 24 and December 3, 2012, groundwater levels in the monitoring wells/ piezometers were generally observed at depths of 0.4 m bgs to 6.4 m bgs (or elevations 86.4 m asl to 87.9 m asl), and a downward vertical hydraulic gradient was present, although seasonal variation in groundwater levels should be expected. The hydraulic conductivity of the silty clay and till was estimated to be relatively low, and in the order of  $2 \times 10^{-6}$  cm/s to  $3 \times 10^{-5}$  cm/s.

Given the groundwater levels measured during this investigation (0.4 m bgs to 6.4 m bgs) servicing inverts in areas of open cut trenching are expected to be in the order of up to 6.1 m below groundwater levels. Groundwater inflow rates from native silty clay and till soils for a typical length of excavation using a daily cut and backfill method are not expected to exceed 50,000 L/day. Additional seepage from any localized medium- to coarse-textured units within the till or from any saturated portions of the overlying fill materials, can likely also be managed within this threshold, but may impact the project schedule.

Excavations for sending and receiving pits at the Highway 401 crossing are expected to be in the order of up to 6.1 m below groundwater levels. Given the low rates of groundwater inflow, it is expected that the pumping of groundwater plus precipitation for typical pit sizes can be managed under 50,000 L/day.

Groundwater control can likely be handled by passive techniques using conventional pumping equipment in sumps. Sumps should be properly constructed and filtered to prevent loss of ground. Prospective bidders should make their own assessment of subsurface conditions and determine the type of groundwater control required. Dewatering systems should be installed maintained by an MOE-licensed Water Well Contractor in accordance with applicable legislation. The responsibility for the design, equipment selection and operation of construction dewatering method for the proposed construction activities should entirely be that of the contractor.

### 7.0 PIEZOMETER AND MONITORING WELL DECOMMISSIONING

As noted, several monitoring wells and piezometers were installed in the boreholes to permit monitoring of the groundwater levels at the site. Ontario Regulation (O.Reg.) 903 amended by O.Reg. 128/03 of the Ontario Water Resources Act requires that monitoring wells and piezometers are properly abandoned/decommissioned by qualified personnel. It is recommended that the decommissioning of the piezometers be carried out as part of the construction activities at the site so that water level measurements can be taken immediately prior to construction. If requested, Golder could provide assistance to the owner in arranging for the decommissioning of the piezometers by a licensed water well drilling contractor.

### 8.0 MONITORING AND TESTING

Should changes be made to the proposed underground service alignments, inverts and their limits, this report should be reviewed by the geotechnical engineer to confirm that the subsurface information obtained and geotechnical design recommendations provided are sufficient.





## GEOTECHNICAL INVESTIGATION AND DESIGN REPORT PROPOSED FEEDERMAIN AND TRUNK SEWER CROSSING

In addition, the geotechnical aspects of the final design drawings and specifications should be reviewed by this office prior to tendering and construction, to confirm that the intent of this report has been met. During construction, sufficient inspections and in-situ materials testing should be carried out to confirm that the conditions exposed are consistent with those encountered in the boreholes and to monitor conformance to the pertinent project specifications.

### 9.0 CLOSURE

We trust that this report provides sufficient geotechnical engineering information for your current requirements. If you have any questions regarding the contents of this report or require additional information, please do not hesitate to contact this office.

Yours truly,

**GOLDER ASSOCIATES LTD.**

Alan Mohammad, P.Eng.  
Geotechnical Engineer



GM/DPSW/EW/DBL/CMK/TJG/sv/kv

Ty Garde, M.Eng., P.Eng.  
Principal, Senior Geotechnical Engineer



<https://capws.golder.com/sites/p211860151torontostfeedermain/reports/final/12-1186-0151a/12-1186-0151a rep 2014'04'16 geotechnical investigation and design report final.docx>

## 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
DO	Drive open
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

### III SOIL DESCRIPTION

#### (a) Cohesionless Soils

Density Index (Relative Density)	N 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

### 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 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):

An electronic cone penetrometer with a 60° conical tip and a projected 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.

### 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 test (LV-laboratory vane test)
$\gamma$	unit weight

Note:

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

# 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
$F$	factor of safety
$V$	volume
$W$	weight

## 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 stresses (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
*	Density symbol is $\rho$ . Unit weight symbol is $\gamma$ where $\gamma = \rho g$ (i.e. mass density x acceleration due to gravity)

### (a) Index Properties (con't.)

$w$	water content
$w_l$	liquid limit
$w_p$	plastic limit
$I_p$	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)

### (c) 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

### (d) Consolidation (one-dimensional)

$C_c$	compression index (normally consolidated range)
$C_r$	recompression index (overconsolidated range)
$C_s$	swelling index
$C_a$	coefficient of secondary consolidation
$m_v$	coefficient of volume change
$c_v$	coefficient of consolidation
$T_v$	time factor (vertical direction)
$U$	degree of consolidation
$\sigma'_p$	pre-consolidation pressure
OCR	Overconsolidation ratio = $\sigma'_p / \sigma'_{vo}$

### (e) 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

Notes: 1.  $\tau = c' + \sigma' \tan \phi'$

2. Shear strength = (Compressive strength)/2

PROJECT: 12-1186-0151AA

**RECORD OF BOREHOLE: BH10**

SHEET 1 OF 2

LOCATION: N 4864433.12; E 692877.76

BORING DATE: September 28, 2012

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa				WATER CONTENT PERCENT					
								nat V. + Q - ● rem V. ⊕ U - ○				Wp   — W —   Wi					
								20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>	10 <sup>-4</sup>	10 <sup>-3</sup>		
								20	40	60	80	12	24	36	48		
0		GROUND SURFACE		93.50													
		TOPSOIL (100 mm)		0.00													
		Silty sand, trace to some gravel, trace asphalt fragments, topsoil inclusions, zones of clayey silt (FILL)		0.10	1	SS	9						○				
		Compact to dense															
		Brown															
		Moist															
1						2	SS	43					○				
						3	SS	21					○				
2																	
						4	SS	16					○				
3		Clayey silt to silty clay, some sand, trace roots, zones of topsoil (FILL)		90.60													
		Stiff to firm		2.90										○			
		Black to dark brown			5	SS	13										
		Moist															
4																	
					6	SS	8								○		
		SILTY CLAY, trace sand		89.23													
		Stiff		4.27													
		Brown															
		Moist			7	SS	11							○			
5																	
					8	SS	10										
6																	
7																	
		SILTY CLAY, trace to some sand, trace gravel (TILL)		86.41													
		Stiff		7.09													
		Grey															
		Wet															
8																	
9		Sandy SILT to SILTY SAND, trace clay, trace to some gravel, cobbles and/or boulders inferred from auger resistance between depths of 11.2 m and 14.6 m (TILL)		84.89													
		Compact		8.61													
		Grey															
		Moist to wet															
10																	
									</								

DEPTH SCALE

1 : 50



LOGGED: AZ

CHECKED: AM

MIS-BHS 001 1211860151A.GPJ GAL-MIS.GDT 1/31/14 GPC.OCT. 2012

PROJECT: 12-1186-0151AA

## RECORD OF BOREHOLE: BH10

SHEET 2 OF 2

LOCATION: N 4864433.12; E 692877.76

BORING DATE: September 28, 2012

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION		
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m											
								SHEAR STRENGTH Cu, kPa				WATER CONTENT PERCENT						
								20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>	10 <sup>-4</sup>	10 <sup>-3</sup>			
								nat V. + Q - rem V. ⊕ U - ●				Wp   — W —   Wi						
								20	40	60	80	12	24	36	48			
10		--- CONTINUED FROM PREVIOUS PAGE ---																
11		Sandy SILT to SILTY SAND, trace clay, trace to some gravel, cobbles and/or boulders inferred from auger resistance between depths of 11.2 m and 14.6 m (TILL) Compact Grey Moist to wet																
	11			SS	11													
12				12	SS	17												
13																		
14								13	SS	20								
15																		
16		END OF BOREHOLE NOTES:		77.80														
				15.70														
17		1. Nested monitoring well/piezometer were installed at borehole location with shallow screen from 7.3 m to 8.8 m and deep screen from 12.2 m to 15.2 m																
		2. Water level measured in deep monitoring well at a depth of 6.5 m below ground surface, Oct. 9/12																
18		3. Water level measured in shallow piezometer at a depth of 5.8 m below ground surface, Oct. 9/12																
		4. Water level measured in deep monitoring well at a depth of 6.4 m below ground surface, Oct. 24/12																
19		5. Water level measured in shallow piezometer at a depth of 5.6 m below ground surface, Oct. 24/12																
20																		

DEPTH SCALE

1 : 50



LOGGED: AZ

CHECKED: AM

MIS-BHS 001 1211860151A.GPJ GAL-MIS.GDT 1/31/14 GPC OCT. 2012

PROJECT: 12-1186-0151AA

## RECORD OF BOREHOLE: BH11

SHEET 1 OF 2

LOCATION: N 4864485.19; E 692853.09

BORING DATE: October 1, 2012

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RESISTANCE, BLOWS/0.3m				k, cm/s					
								SHEAR STRENGTH Cu, kPa		nat V. + Q - rem V. ⊕ U -		WATER CONTENT PERCENT					
								20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>	10 <sup>-4</sup>	10 <sup>-3</sup>		
								20	40	60	80	12	24	36	48		
0		GROUND SURFACE		88.10													
		Sandy silt, some gravel, trace clay (FILL) Loose Grey Wet		0.00	1	SS	2										
				87.34													
1		Sand and gravel, some silt, zones of silty clay (FILL) Compact Grey Wet		0.76	2	SS	25										
				86.73													
		SILTY CLAY, trace to some sand, trace to some gravel Firm Grey Wet		1.37	3	SS	5										
2																	
					4	SS	5										
				85.20													
3		Sandy SILT, some clay, some gravel (TILL) Loose Grey Wet		2.90	5	SS	5										
4				84.06													
		Sandy SILT to SILTY SAND, trace to some clay, some gravel, cobbles and/or boulders inferred from auger resistance between depths of 5.3 m and 12.8 m (TILL) Compact to very dense Grey Wet		4.04	6	SS	10										
5																	
6																	
					7	SS	15										
7																	
8					8	SS	18										
9					9	SS	19										
10																	
		CONTINUED NEXT PAGE															

DEPTH SCALE

1 : 50



LOGGED: AZ

CHECKED: AM

MIS-BHS 001 1211860151A.GPJ GAL-MIS.GDT 1/31/14 GPC.OCT. 2012

PROJECT: 12-1186-0151AA

## RECORD OF BOREHOLE: BH11


SHEET 2 OF 2

LOCATION: N 4864485.19; E 692853.09

BORING DATE: October 1, 2012

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION		
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m											
								SHEAR STRENGTH Cu, kPa		nat V. + Q - ● rem V. ⊕ U - ○		WATER CONTENT PERCENT						
								20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>	10 <sup>-4</sup>			10 <sup>-3</sup>	Wp
								20	40	60	80	12	24	36	48			
10		--- CONTINUED FROM PREVIOUS PAGE ---																
11		Sandy SILT to SILTY SAND, trace to some clay, some gravel, cobbles and/or boulders inferred from auger resistance between depths of 5.3 m and 12.8 m (TILL) Compact to very dense Grey Wet																
	10			SS	17													
12																		
							</											

DEPTH SCALE

1 : 50



LOGGED: AZ

CHECKED: AM

MIS-BHS 001 1211860151A.GPJ GAL-MIS.GDT 1/31/14 GPC OCT. 2012

SHEET 1 OF 2

DATUM: Geodetic

CHECKED: AM



PROJECT: 12-1186-0151AA

## RECORD OF BOREHOLE: BH12

SHEET 2 OF 2

LOCATION: N 4864521.60; E 692841.72

BORING DATE: October 1, 2012

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m										
								SHEAR STRENGTH Cu, kPa				WATER CONTENT PERCENT					
												Wp — W — Wi					
							20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>	10 <sup>-4</sup>	10 <sup>-3</sup>			
							nat V. + Q - ● rem V. ⊕ U - ○										
							20	40	60	80	12	24	36	48			
10		--- CONTINUED FROM PREVIOUS PAGE ---															
11		Sandy SILT to SILTY SAND, some clay, some gravel (TILL) Compact Grey Wet															
	10			SS	4												
12																	
13																	
14		Sandy SILT, trace clay, some gravel (TILL) Dense Grey Wet		79.24 13.18													
15		END OF BOREHOLE NOTES:  1. Nested monitoring well/piezometer were installed at borehole location with shallow screen from 7.0 m to 8.5 m and deep screen from 10.7 m to 12.2 m.  2. Water level measured in shallow monitoring well at a depth of 8.1 m below ground surface, Oct. 9/12  3. Water level measured in deep piezometer B at a depth of 5.7 m below ground surface, Oct. 9/12  3. Water level measured in shallow monitoring well at a depth of 2.7 m below ground surface, Oct. 24/12  4. Water level measured in deep piezometer B at a depth of 3.7 m below ground surface, Oct. 24/12															
16																	
17																	
18																	
19																	
20																	

DEPTH SCALE

1 : 50



LOGGED: AZ

CHECKED: AM

MIS-BHS 001 1211860151A.GPJ GAL-MIS.GDT 1/31/14 GPC OCT. 2012

**METRIC**  
DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.

CONT No.  
WP No.

BOREHOLE LOCATIONS AND  
SOIL STRATA PLAN

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











SHEET



KEY PLAN  
N.T.S



LEGEND

-  Borehole
-  Piezometer/Well
-  Seal
-  Piezometer/Well
-  Standard Penetration Test Value
-  Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
-  WL in piezometer
-  WL in monitoring well

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
BH10	93.5	4864433.1	692877.8
BH11	88.1	4864485.2	692853.1
BH12	92.4	4864521.6	692841.7

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 design configuration as shown elsewhere in the Contracts Documents.

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

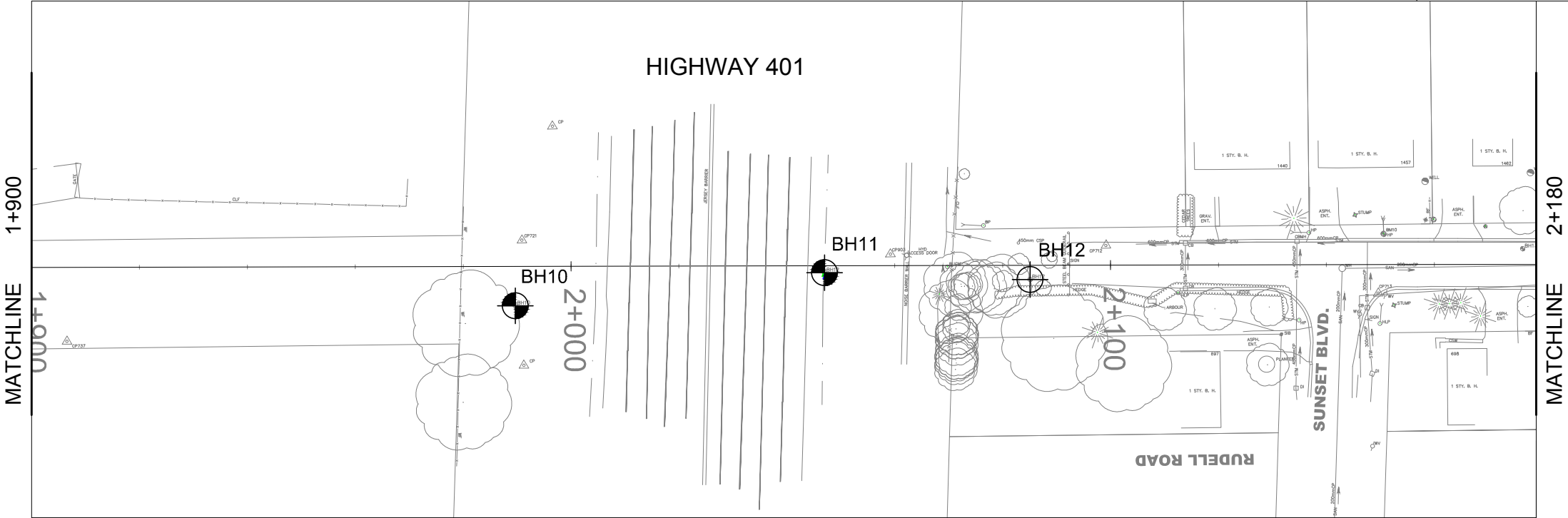
The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS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

REFERENCE

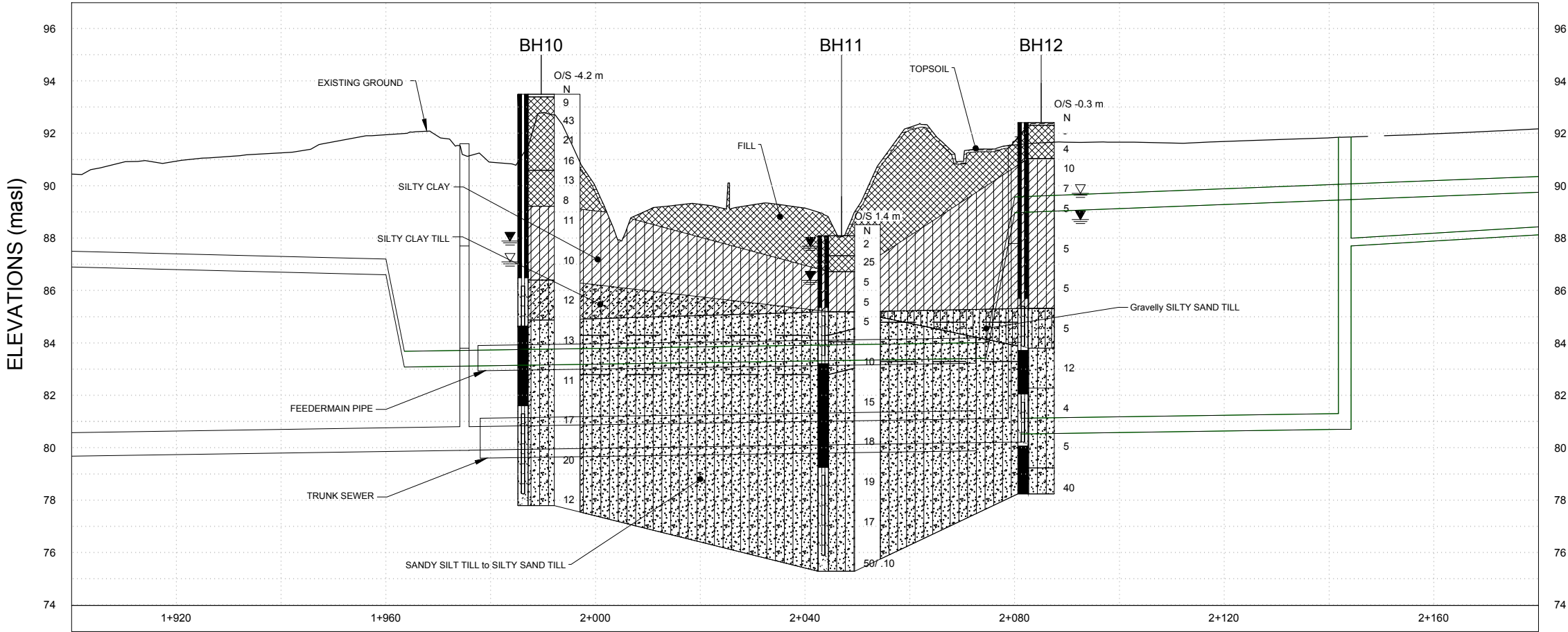
Base plan provided in digital format by AECOM, cad file: ACAD-60274699-BASE.dwg, received on October 25, 2012.

Profile provide in digital format by AECOM, cad file: 60274699.PROFILE FOR GOLDER.dwg, received on November 1, 2012.

NO.	DATE	BY	REVISION
Geocres No.			
HWY. 401	PROJECT NO. 12-1186-0151A		DIST.
SUBM'D.	CHKD. AM	DATE: 12/13/2012	SITE:
DRAWN: GPC	CHKD. DW	APPD.	DWG. 1



PLAN



PROFILE



# **APPENDIX A**

## **Important Information and Limitations of this Report**



## IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

**Standard of Care:** Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

**Basis and Use of the Report:** This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder can not be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, Golder may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client can not rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

**Soil, Rock and Ground water Conditions:** Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.



## IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report. The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

**Sample Disposal:** Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

**Follow-Up and Construction Services:** All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

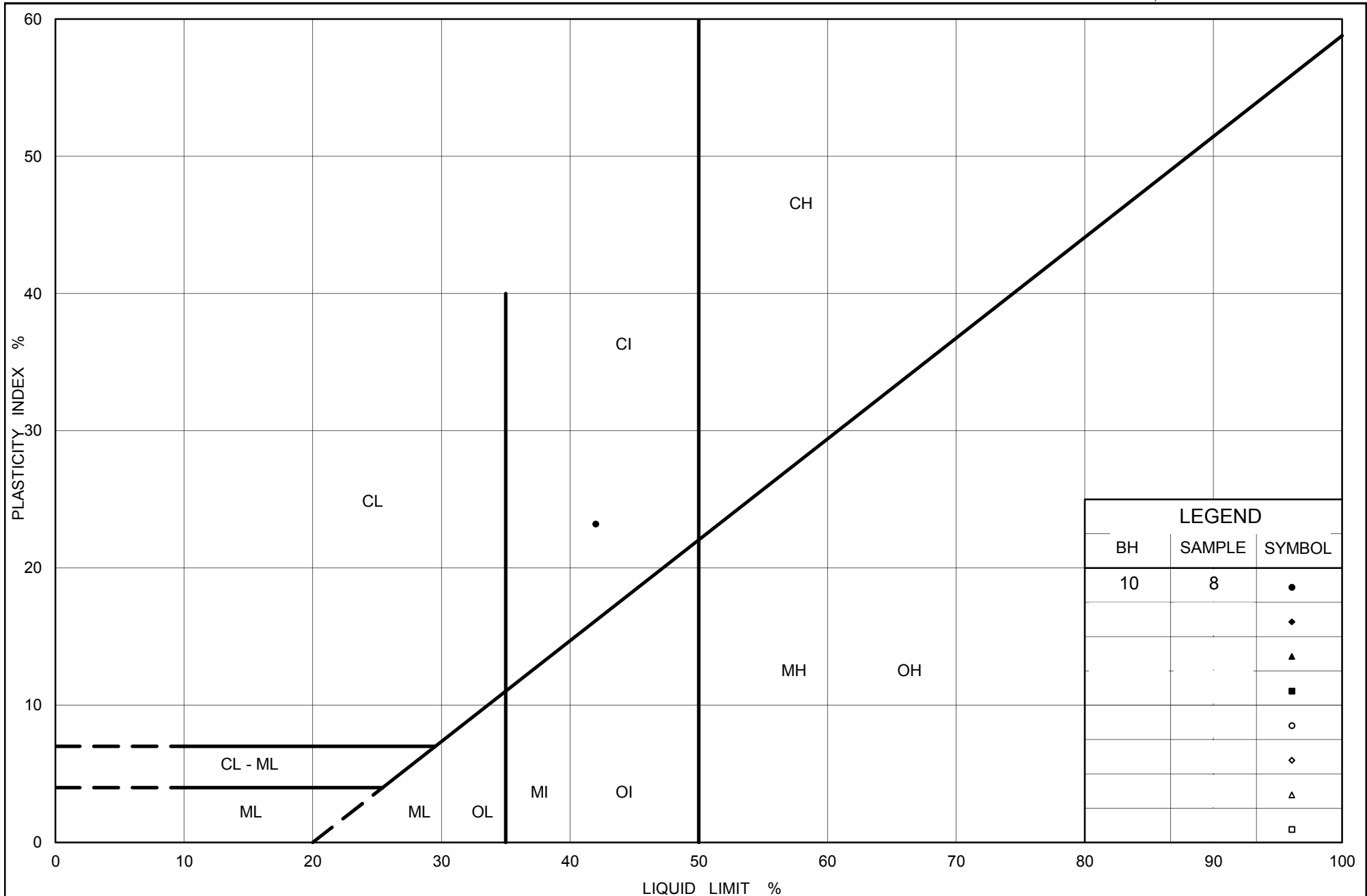
**Changed Conditions and Drainage:** Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.



# **APPENDIX B**

## **Figures 1 to 6 – Plasticity Charts and Grain Size Distributions**



Ministry of Transportation

Ontario

## PLASTICITY CHART SILTY CLAY

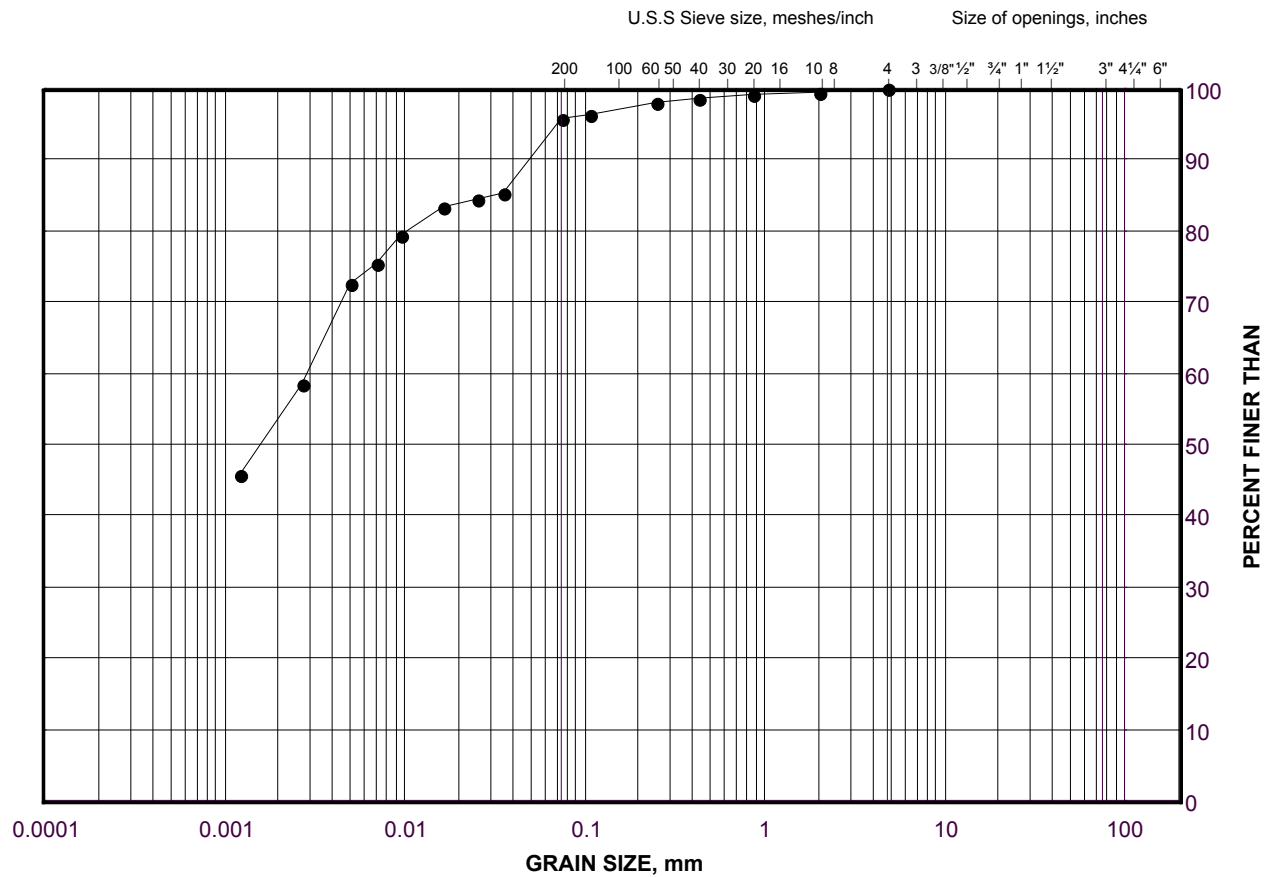
Figure No. 1

Project No. 12-1186-0151 (A)

Checked By: AM

# GRAIN SIZE DISTRIBUTION SILTY CLAY

FIGURE 2



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

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
•	10	8	6.10 - 6.40

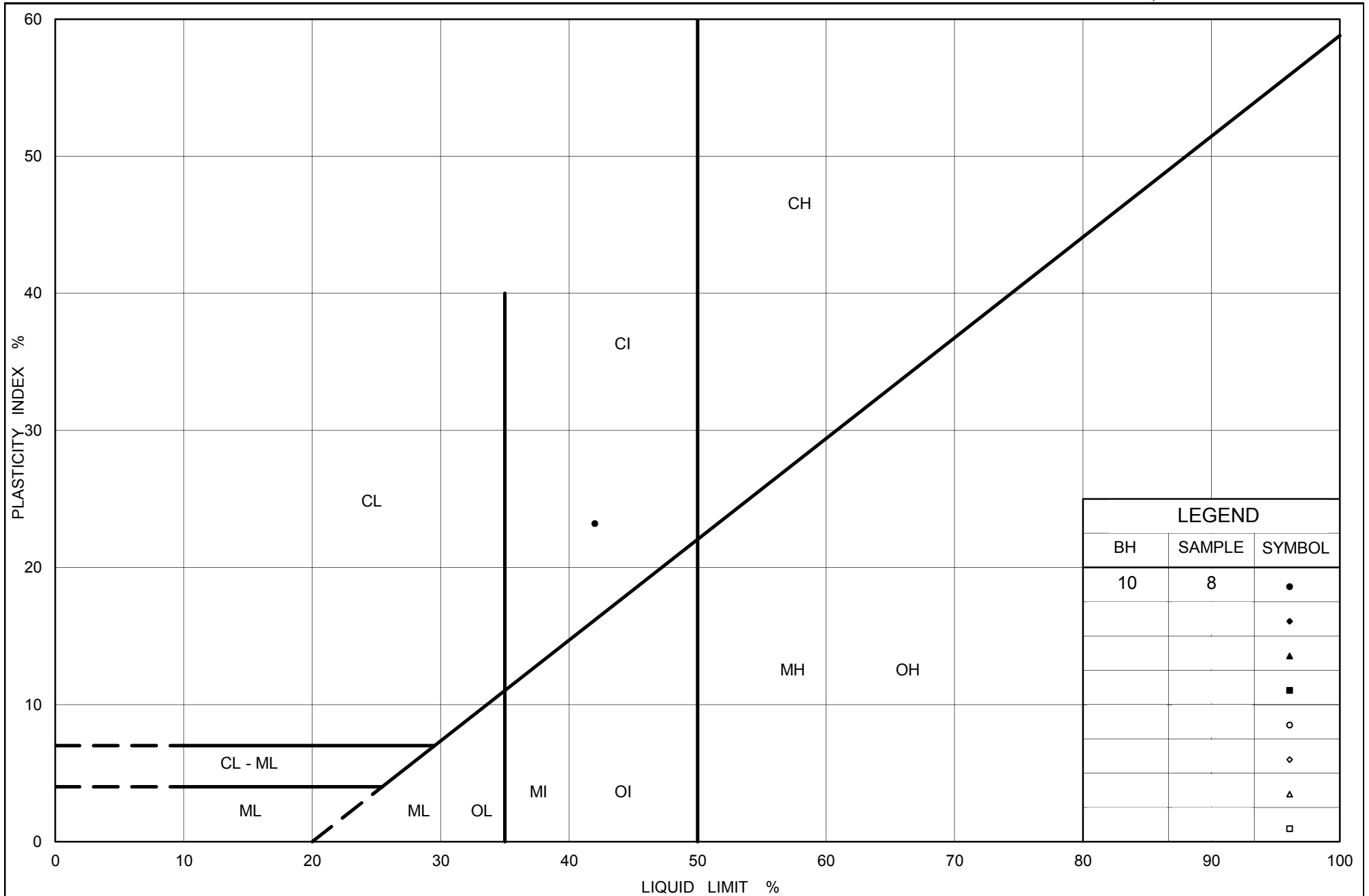
Project Number: 12-1186-0151(A)

Checked By: AM

**Golder Associates**

Date: 06-Dec-12





Ministry of Transportation

Ontario

# PLASTICITY CHART (CI) SILTY CLAY

Figure No. 3

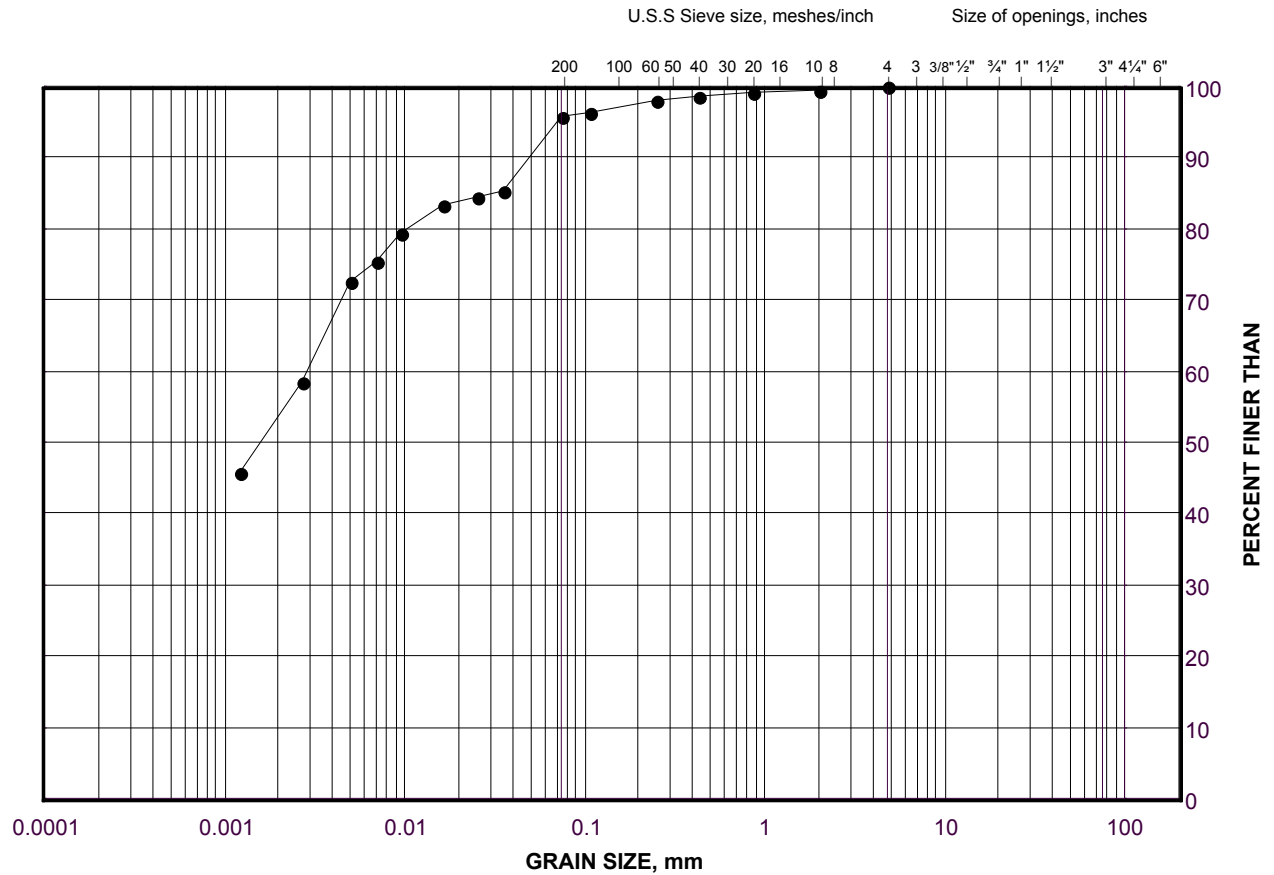
Project No. 12-1186-0151 (A)

Checked By: AM

# GRAIN SIZE DISTRIBUTION

(CI) SILTY CLAY

FIGURE 4



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

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
•	10	8	6.10 - 6.40

Project Number: 12-1186-0151 (A)

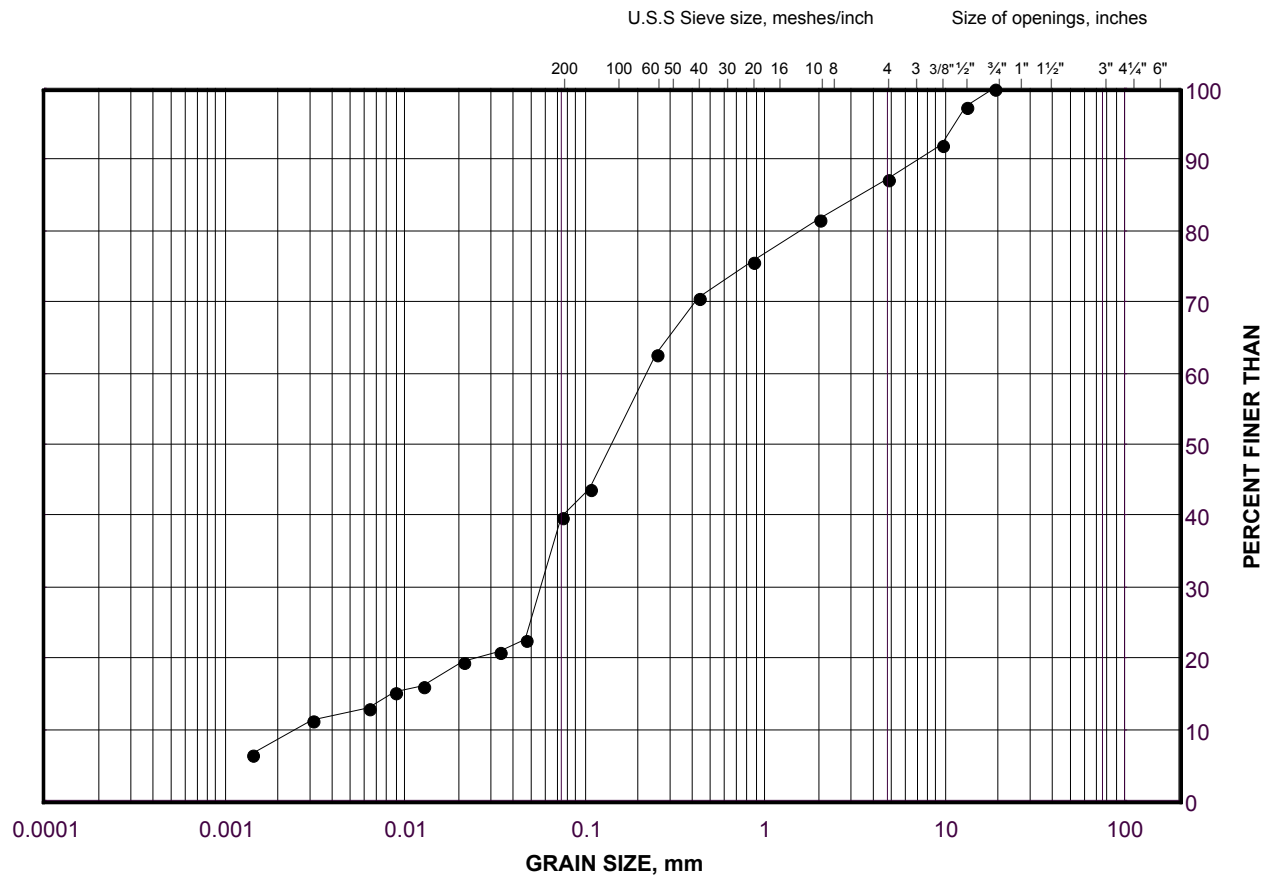
Checked By: AM

**Golder Associates**

Date: 20-Nov-12

# GRAIN SIZE DISTRIBUTION (SM) SILTY SAND (TILL)

FIGURE 5



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

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
•	10	12	12.20 - 12.60

Project Number: 12-1186-0151 (A)

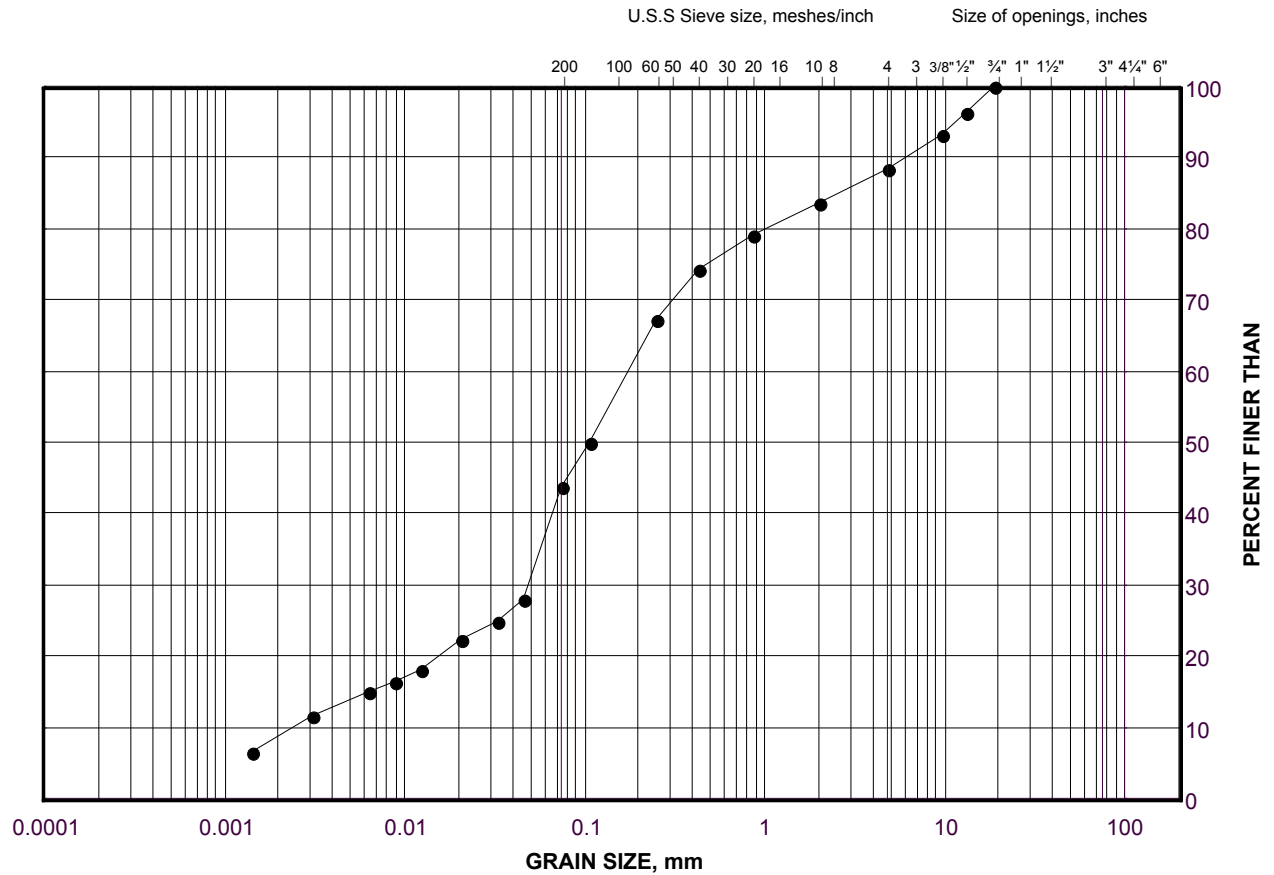
Checked By: AM

**Golder Associates**

Date: 20-Nov-12

# GRAIN SIZE DISTRIBUTION (SM) SILTY SAND (TILL)

FIGURE 6



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

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
•	11	6	4.60 - 5.0

Project Number: 12-1186-0151 (A)

Checked By: AM

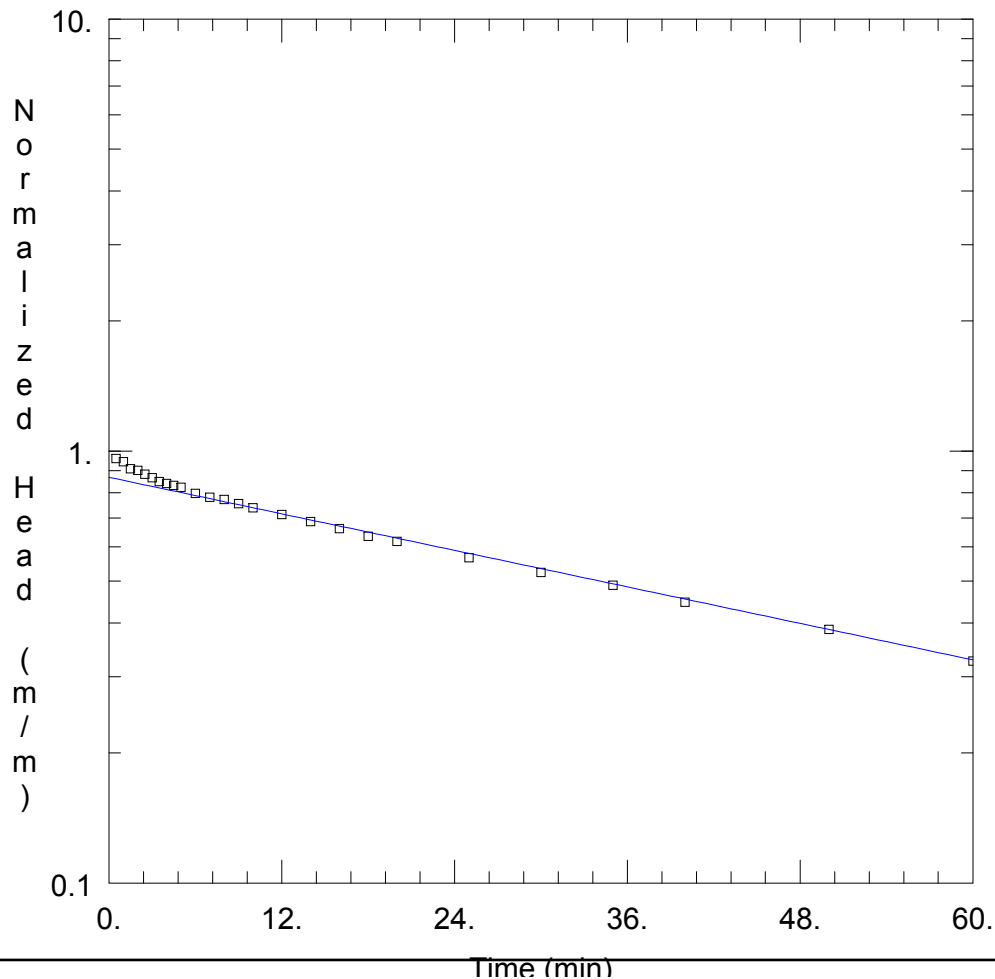
**Golder Associates**

Date: 20-Nov-12



# **APPENDIX C**

## **In-Situ Hydrogeological Testing Results**



### Time (min) WELL TEST ANALYSIS

Data Set: \...\12-1186-0151-bh10aaqt.aqt

Date: 12/11/12

Time: 12:48:26

### PROJECT INFORMATION

Company: Golder Associates

Project: 12-1186-0151

Location: Newcastle

Test Well: BH10A

Test Date: Oct 24, 2012

### AQUIFER DATA

Saturated Thickness: 7.1 m

Anisotropy Ratio ( $K_z/K_r$ ): 1.

### WELL DATA (BH10A)

Initial Displacement: -1.165 m

Static Water Column Height: 8.59 m

Total Well Penetration Depth: 9.285 m

Screen Length: 3.81 m

Casing Radius: 0.05 m

Well Radius: 0.1 m

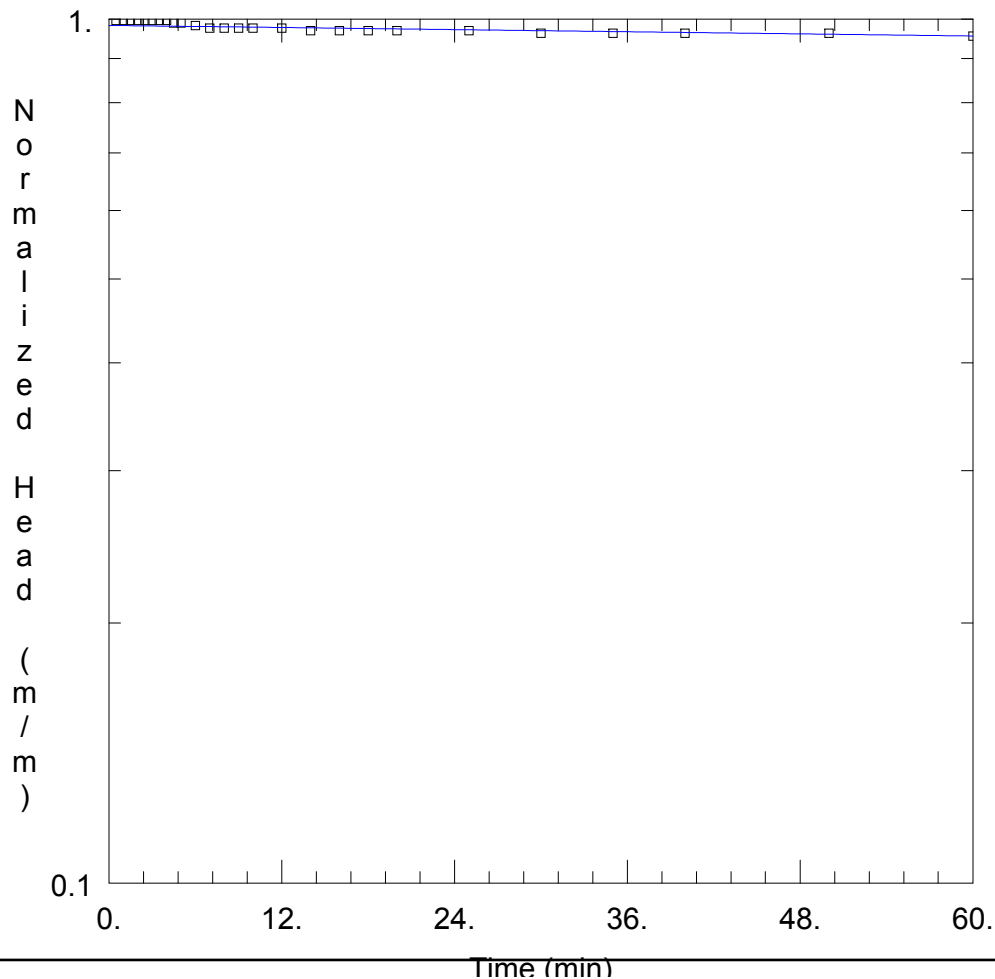
### SOLUTION

Aquifer Model: Unconfined

Solution Method: Bouwer-Rice

$K = 1.766E-5$  m/min

$y_0 = -1.013$  m



### WELL TEST ANALYSIS

Data Set: \...\12-1186-0151-bh12baqt.aqt

Date: 12/11/12

Time: 12:48:51

### PROJECT INFORMATION

Company: Golder Associates

Project: 12-1186-0151

Location: Newcastle

Test Well: BH12B

Test Date: Oct 24, 2012

### AQUIFER DATA

Saturated Thickness: 1.52 m

Anisotropy Ratio ( $K_z/K_r$ ): 1.

### WELL DATA (BH12B)

Initial Displacement: -1.465 m

Static Water Column Height: 5.97 m

Total Well Penetration Depth: 5.97 m

Screen Length: 1.98 m

Casing Radius: 0.05 m

Well Radius: 0.1 m

Gravel Pack Porosity: 0.

### SOLUTION

Aquifer Model: Unconfined

Solution Method: Bouwer-Rice

$K = 1.048E-6$  m/min

$y_0 = -1.44$  m

At Golder Associates we strive to be the most respected global company providing consulting, design, and construction services in earth, environment, and related areas of energy. Employee owned since our formation in 1960, our focus, unique culture and operating environment offer opportunities and the freedom to excel, which attracts the leading specialists in our fields. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees who operate from offices located throughout Africa, Asia, Australasia, Europe, North America, and South America.

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Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

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**T: +1 (905) 723 2727**

