



June 2015

## PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

**Structural Culvert Replacement  
Elliot-Laidlaw Drain, Site Number 19-651/C  
Highway 401 Interchange Improvements/  
Structural Replacements  
GWP 3054-11-00, Assignment No. 1 (3011-E-0046)  
Ministry of Transportation, Ontario - West Region**

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REPORT



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**PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT  
STRUCTURAL CULVERT REPLACEMENT - SITE NUMBER 19-651/C**

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**PART A**  
**PRELIMINARY FOUNDATION INVESTIGATION REPORT**

**STRUCTURAL CULVERT REPLACEMENT  
ELLIOT-LAIDLAW DRAIN, SITE NUMBER 19-651/C  
HIGHWAY 401 INTERCHANGE IMPROVEMENTS/STRUCTURAL REPLACEMENTS  
GWP 3054-11-00, ASSIGNMENT No. 1 (3011-E-0046)  
MINISTRY OF TRANSPORTATION, ONTARIO - WEST REGION**



## **1.0 INTRODUCTION**

Golder Associates Ltd. (Golder Associates) has been retained by Dillon Consulting Limited (Dillon) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations as part of the preliminary design and 30% detailed design work for GWP 3030-11-00, 3054-11-00, 3053-11-00, 3070-11-00, 3059-11-00, and 3055-11-00. The project involves the preliminary design and 30% detailed design for ten (10) bridges, including improvements at five (5) interchanges, and two structural culverts on Highway 401. The work for GWP 3054-11-00 includes replacement of the Pond Mills Road Overpass and C.N.R. Overhead, as well as culverts for the Tributary to Murray Drain and Elliot-Laidlaw Drain.

This report addresses the replacement of the Elliot-Laidlaw Drain structural culvert, Station 26+360, located approximately 350 metres west of Highbury Avenue South, in the City of London, Ontario (Site 19-651/C).

The purpose of the foundation investigation is to explore the subsurface conditions at the location of the proposed structure upgrades by drilling boreholes and carrying out in situ testing and laboratory testing on selected samples. The terms of reference for the scope of work are outlined in the MTO's Request for Proposal and in Golder Associates' proposal P2-1132-0076-P01 dated September 10, 2012. The work was carried out in accordance with our Quality Control Plan for Foundations Engineering dated November 2012.



## 2.0 SITE DESCRIPTION

### 2.1 General

The subject structural culvert crosses Highway 401 immediately west of the Highbury Avenue interchange in the City of London, Ontario. The location of the site is shown on the Key Plan, Figure 1. For the purposes of this report, Highway 401 and the culvert are assumed to be oriented in an east-west direction and a north-south direction, respectively. This section of Highway 401 is currently a six lane divided highway oriented generally northeast-southwest. The areas adjacent to the culvert site consist of relatively flat-lying commercial lands. Site photographs are presented in Appendix B.

The existing Elliot-Laidlaw Drain culvert was constructed in 1953 and is a concrete, rigid frame, open footing culvert. The original 51.8 metre long structure was subsequently extended with open footing rigid frame extensions to the north and south in 1989, and a box culvert extension added to the north in 1993, for a total length of about 84 metres. The composite structure has a span of about 6.1 metres, height of 2.4 metres, and approximately 1.6 metres of soil cover. It is understood that full replacement of the Elliot-Laidlaw Drain culvert with a precast structure is being considered.

### 2.2 Site Geology

This project lies within the physiographic region known as the Westminster Moraine. The physiographic mapping indicates that the culvert site is situated on an undrumlinized till plane.<sup>1</sup> Geology mapping indicates that the surficial material consists of Port Stanley silty clay till and clayey silt till, in places covered by thin patches of lacustrine silt.<sup>2</sup>

The rock formation in the area of the culvert site is described as medium brown, microcrystalline limestone of the Dundee Formation which belongs to the Hamilton Group of Middle Devonian Age.<sup>3</sup> The bedrock surface is estimated to be at about elevation 210 metres, some 60 metres below ground surface.

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<sup>1</sup> Chapman, L.J. and Putnam, D.F., 1984: The Physiography of Southern Ontario, Third Edition. Ontario Geological Survey, Special Volume 2.

<sup>2</sup> Dreimanis, A., 1963: Pleistocene Geology of the St. Thomas Area (East Half), Southern Ontario. Ontario Department of Mines, Preliminary Geological Map 238, scale 1:50,000.

<sup>3</sup> Sanford, B.V., 1969: Geology, Toronto-Windsor Area, Ontario. Geological Survey of Canada, Map 1263A, scale 1:250,000.



### 3.0 INVESTIGATION PROCEDURES

The field work for the investigation was carried out on May 13 and 16, 2013, during which time 3 boreholes were drilled at the locations shown on the Borehole Location Plan, Drawing 1. The table below summarizes the borehole locations, ground surface elevations at the borehole locations, and borehole depths.

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
701	4 755 898	412 253	269.5	11.1
702	4 755 904	412 261	270.4	12.6
703	4 755 964	412 241	270.5	11.0

The investigation was carried out using all-terrain drilling equipment supplied and operated by a specialist drilling contractor. Samples of the overburden were obtained at generally 0.75 metre intervals of depth in the boreholes using 50 millimetre outside diameter split spoon sampling equipment in accordance with the standard penetration test (SPT) procedures of ASTM D 1586. According to ASTM D1586, the SPT resistance, or N value, is defined as the number of blows required by a 63.5 kilogram hammer dropped from a height of 760 millimetres to drive a split-spoon sampler a distance of 300 millimetres, after an initial 150 millimetres of penetration. The split spoon samplers used in the investigation limit the maximum particle size that can be sampled and tested to about 38 millimetres. Therefore, particles or objects that may exist within the soils that are larger than this dimension will not be sampled or represented in the grain size distributions. The results of the SPT testing as presented on the Record of Borehole sheets and in Section 4.0 are unmodified (not standardized for hammer efficiency, borehole diameter, rod length, etc.).

The boreholes were terminated between 11.0 and 12.6 metres below the existing ground surface at the borehole locations. Groundwater conditions in the boreholes were observed throughout the drilling operations and a standpipe was installed in borehole 701 as indicated on the corresponding Record of Borehole sheet. The boreholes were backfilled in accordance with current MTO procedures and Ontario Regulation 903 (as amended).

The field work was monitored on a full-time basis by experienced Golder Associates staff members who also located the boreholes in the field, monitored the drilling, sampling, and in situ testing operations, and logged the boreholes. The samples were identified in the field, placed in labelled containers, and transported to our London laboratory for further examination and testing. Index and classification tests, consisting of water content determinations and grain size distribution analyses were carried out on selected samples. The results of the testing are shown on the Record of Borehole sheets and in Appendix A.

The locations of the boreholes are shown on the Record of Borehole sheets and on Drawing 1, attached.



## 4.0 SUBSURFACE CONDITIONS

### 4.1 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes, together with the results of the in situ testing and the laboratory testing carried out on selected samples, are provided on the attached Record of Borehole sheets following the text of this report and in Appendix A. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous samples and observations of drilling resistance and, therefore, may represent transitions between soil types rather than exact planes of geological change. Further, the subsurface conditions will vary between and beyond the borehole locations.

The boreholes drilled at the site generally encountered topsoil or pavement structure overlying granular and cohesive fill materials, overlying layers of silt and silty sand to sandy silt.

The locations and elevations of the boreholes, together with the interpreted stratigraphic profiles, are shown on Drawing 1. Detailed descriptions of the subsurface conditions encountered in the boreholes are provided on the Record of Borehole sheets and are summarized in the following sections.

#### 4.1.1 Topsoil

Approximately 210 millimetres of surficial topsoil was encountered in borehole 701 and approximately 90 millimetres of buried topsoil was encountered in borehole 702 beneath the pavement structure.

Materials designated as topsoil in this report were classified solely based on visual and textural evidence. Testing of organic content or for other nutrients was not carried out. Therefore, the use of materials classified as topsoil cannot be relied upon for support and growth of landscaping vegetation.

#### 4.1.2 Pavement Structure

Approximately 120 and 150 millimetres of asphalt was encountered at the ground surface in boreholes 702 and 703, respectively. The asphalt was underlain by about 240 and 150 millimetres of granular base material which was underlain by about 1160 and 120 millimetres of granular subbase material in boreholes 702 and 703, respectively. The granular sub-base materials were noted to contain cobbles. A single measured N value from standard penetration testing carried out in the granular subbase material was 29 blows per 0.3 metres.





### **4.1.3 Fill**

Fill materials were encountered in borehole 701 beneath the topsoil and in boreholes 702 and 703 beneath the pavement structure. The fill materials varied in gradation from sand and gravel, sandy silt, clayey silt, to silty clay. Measured N values in the fill materials ranged from 8 blows per 0.3 metres to 34 blows per 0.3 metres. Water contents of samples of the fill materials were between about 7 and 13 per cent. The results of grain size determinations carried out on samples of the fill materials are shown on Figure A-1.

### **4.1.4 Sandy Silt to Silty Sand**

Loose to very dense sandy silt to silty sand was encountered in boreholes 701 and 702 underlying the fill materials and in borehole 703 underlying the upper layer of silt. The sandy silt to silty sand layers were encountered between elevations 263.2 and 265.5 metres and were about 1.5 to 4.4 metres thick.

Measured N values in the sandy silt to silty sand ranged from 9 to 89 blows per 0.3 metres, more typically in the range of 14 to 29 blows. Water contents of samples of the sandy silt to silty sand ranged from about 19 to 25 per cent. The results of grain size determinations carried out on samples of the silty sand to sandy silt are shown on Figures A-2 and A-3.

### **4.1.5 Silt**

Layers of compact to dense silt were encountered in borehole 703 underlying the fill materials and in each of the boreholes underlying the sandy silt to silty sand. The upper layer of silt in borehole 703 was encountered at about elevation 265.5 metres and was about 2.3 metres thick. The lower layers of silt were encountered at between about elevations 260.5 and 261.6 metres. Each of the boreholes was terminated in the silt after exploring for about 2.1 to 2.7 metres.

Measured N values in the silt ranged from 16 to 36 blows per 0.3 metres. Water contents of samples of the silt ranged from about 19 to 27 per cent. The silt in borehole 702 was noted to contain clayey silt seams and layers, which is reflected in the grain size distribution by a higher clay content than is representative of the silt layer. The results of grain size determinations carried out on samples of the silt and silt with clayey layers are shown on Figure A-4.



## 4.2 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling and sampling. Also, a standpipe was installed in borehole 701. A summary of the encountered and measured groundwater levels and the water levels in the drain is provided in the table below.

Borehole	Ground Surface Elevation (m)	Encountered Groundwater Elevation (m)	Installation	Measured Groundwater Elevation (m)		Elevation of Water Level in Drain (m)	
				June 5, 2013	June 20, 2013	May 13, 2013	May 16, 2013
701	269.5	265.7	Standpipe	266.2	266.6	266.1	266.3
702	270.4	265.8	-	-	-		
703	270.5	265.9	-	-	-		

Based on the observed groundwater levels, the surrounding topography, and water levels in the drain, the groundwater level is inferred to be about elevation 266.5 metres. Groundwater levels are expected to fluctuate seasonally and are expected to be higher during periods of sustained precipitation or during spring snow melt conditions and will be influenced by the water levels in the municipal drains.

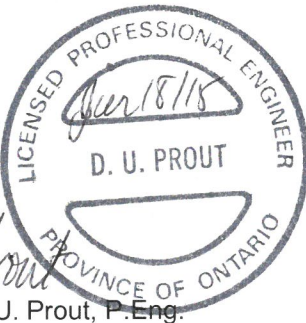


## 5.0 MISCELLANEOUS

This investigation was carried out using equipment supplied and operated by Lantech Drilling Services Inc., an Ontario Ministry of Environment licensed well contractor. The field operations were supervised by Mr. Brett Thorner, E.I.T. under the direction of Mr. David J. Mitchell.

The laboratory testing was carried out at Golder Associates' London laboratory under the direction of Mr. Chris M. Sewell. The laboratory is an accredited participant in the MTO Soil and Aggregate Proficiency Program and is certified by the Canadian Council of Independent Laboratories for testing Types C and D aggregates. This report was prepared by Ms. Nicole A. Gould, P.Eng. under the direction of the Project Engineer, Ms. Dirka U. Prout, P.Eng. and the Team Leader, Dr. Storer J. Boone, P.Eng. This report was reviewed by Mr. Azmi M. Hammoud, P.Eng. An independent audit of this report was carried out by Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

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**PART B**

**PRELIMINARY FOUNDATION DESIGN REPORT**

**STRUCTURAL CULVERT REPLACEMENT**  
**ELLIOT-LAIDLAW DRAIN, SITE NUMBER 19-651/C**  
**HIGHWAY 401 INTERCHANGE IMPROVEMENTS/STRUCTURAL REPLACEMENTS**  
**GWP 3054-11-00, ASSIGNMENT No. 1 (3011-E-0046)**  
**MINISTRY OF TRANSPORTATION, ONTARIO - WEST REGION**



## **6.0 ENGINEERING RECOMMENDATIONS**

### **6.1 General**

This section of the report provides our recommendations on the foundation aspects of the design of the replacement and/or rehabilitation of the Elliot-Laidlaw Drain culvert, at Station 26+360, located approximately 350 metres west of Highbury Avenue South, respectively, in the City of London, Ontario (Site 19-651/C). The recommendations are based on our interpretation of the factual information obtained during the investigation. It should be noted that the interpretation and recommendations are intended for use only by the design engineer. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods, and scheduling.

Full replacement of the Elliot-Laidlaw Drain culvert with a precast structure is being considered. No grade raise at the Elliot-Laidlaw Drain culvert has been indicated. It is anticipated that the replacement culvert invert elevation will be similar to those of the existing structure. Consideration may also be given to replacing the culvert with an open bottom structure founded on shallow strip footings.

### **6.2 Existing Structure**

The existing culvert was constructed in 1953 and is a concrete, rigid frame, open footing culvert. The original 51.8 metre long structure was subsequently extended with open footing and box culvert extensions, to a total length of about 84 metres. The composite structure has a span of about 6.1 metres, height of 2.4 metres, approximately 1.6 metres of soil cover, and an invert elevation of about 267.0 metres.

### **6.3 Foundations**

The subsurface conditions encountered during the investigation generally consisted of topsoil or pavement structures overlying granular and cohesive fill materials, overlying layers of silt and sandy silt to silty sand. The groundwater level is inferred to be about elevation 266.5 metres.

The culvert replacement should be designed to withstand the appropriate weight of fill and traffic loading. If an open footing culvert design is selected, adequate cover for frost protection is required. Alternatively, if a box culvert design is selected, it is not necessary to found the culvert replacement at the standard depth for frost penetration protection purposes as pre-cast box culvert structures are tolerant of small magnitude movements related to freeze-thaw cycles should these occur. A box culvert replacement should, however, be founded below any existing fill and organic materials.



Based on the existing invert elevation, a box culvert may be founded at or below elevation 266.6 metres and shallow foundations for an open bottom culvert may be founded at or below elevation 265.8 metres.

It is anticipated that excavations to the elevations noted above may not fully penetrate the existing fill materials. If fill materials, organics, or loose or soft soils are observed in the base of culvert excavations, the excavations should be extended to the native sandy silt to silty sand or silt. The native soils were encountered between elevations 264.8 and 265.1 metres. It is anticipated that subexcavation to reach the native soils will likely not exceed 1.0 metre for shallow foundations and will be between about 1.1 and 1.8 metres for a box culvert.

For box culvert construction, areas of sub-excavation should be brought to design grade with engineered fill placed on the native sandy silt to silty sand or silt. The engineered fill should consist of OPSS Granular A or Granular B, Type II placed in maximum 300 millimetre loose lifts and compacted to at least 98 per cent of the standard Proctor maximum dry density. Shallow footings for an open bottom culvert should be founded on the native soils.

### Geotechnical Resistances

The compact to very dense sandy silt to silty sand and compact to dense silt at the site are suitable for support of the proposed culvert replacement. A box culvert and shallow footings for an open bottom culvert founded on the native soils may be designed using a factored geotechnical resistance at Ultimate Limit States (ULS) of 270 kilopascals (kPa) and a geotechnical reaction at Serviceability Limit States (SLS) of 180 kPa. A box culvert founded on engineered fill as described above may also be designed using a factored geotechnical resistance at ULS of 270 kPa and a geotechnical reaction at SLS of 180 kPa. The SLS values correspond to a maximum of 25 millimetres total settlement.

### Resistance to Lateral Forces

The resistance to lateral forces/sliding resistance between the culvert base or footings and the bedding or native soils should be calculated in accordance with Section 6.7.5 of the Canadian Highway Bridge Design Code (CHBDC). Assuming that the founding soils are not loosened/disturbed during excavation and footing construction, and the bedding and leveling pad are adequately constructed, the following angles of friction between the culvert concrete foundation and founding stratum, and corresponding unfactored coefficient of friction,  $\tan \delta$ , may be used:

Culvert Type	Interaction	Angle of Friction, $\delta$ (degrees)	Coefficient of Friction, $\tan \delta$
Open footing culvert	Cast-in-place concrete footing on: native sandy silt to silty sand	26	0.49
	native silt	26	0.49
Pre-cast box culvert	Pre-cast concrete on Granular A levelling pad	30	0.58



### ***Frost Protection***

Frost treatment in the form of a frost taper symmetrical about the culvert centreline must be provided in accordance with Ontario Provincial Standard Drawing (OPSD) 803.010 or 803.031, as appropriate. Shallow footings should be provided with a minimum of 1.2 metres of earth cover or thermal equivalent for frost protection purposes.

### **6.3.1 Bedding**

For a pre-cast box culvert, bedding should be placed on a properly prepared subgrade from which all frozen, soft, uncompacted fill, organic materials, or other deleterious materials have been removed. Subexcavated material below the design subgrade elevation should be replaced with compacted OPSS Granular A or Granular B, Type II fill material. It is recommended that the box culvert units be placed on a minimum thickness of 300 millimetres of compacted OPSS Granular A bedding material. A minimum 75 millimetre thick levelling course consisting of uncompacted Granular A or fine aggregates as specified in MTO Special Provision (SP) 422S01 may be placed on the bedding material.

### **6.3.2 Backfill and Cover**

Backfill, cover, and construction of the frost tapers (backfill transition) should be completed in accordance with OPSD 803.010 or 803.031, as appropriate. The excavations for the culvert replacement should exceed the culvert dimensions by at least one metre on each side to promote good workmanship and effective compaction of the fill.

The backfill should consist of free-draining, non-frost susceptible granular materials such as OPSS Granular A or Granular B, Type II but with less than 5 per cent passing the number 200 sieve placed and compacted in accordance with SP105S21. All bedding, backfill, and cover materials should be placed in accordance with OPSS 422, 501, and 902.

Heavy compaction equipment should not be used immediately adjacent to the walls of the culvert. The height of backfill adjacent to the culvert walls should be maintained as equal as possible on both sides of the walls during all stages of backfill placement with one side not exceeding the other by more than 500 millimetres.

## **6.4 Lateral Earth Pressures**

The lateral pressures acting on the proposed culvert will depend on the type and method of placement of the backfill materials, on the nature of the soil behind the backfill, on the magnitude of surcharge including construction loadings, on the freedom of lateral movement of the structure, and on the drainage conditions behind the walls.





The following recommendations are made concerning the design of the walls in accordance with the current CHBDC. It should be noted that these design recommendations and parameters assume level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- Select, free-draining granular fill meeting the specifications of OPSS Granular A or Granular B, Type II but with less than 5 per cent passing the No. 200 sieve should be used as backfill behind the walls. The fill should be compacted in loose lifts not greater than 200 millimetres in thickness. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill.
- A compaction surcharge equal to 12 kPa should be included in the lateral earth pressures for the structural design in accordance with CHBDC Figure 6.6.
- If the wall support does not allow lateral yielding (such is typically the case for a rigid concrete box culvert), at-rest earth pressures should be assumed for geotechnical design. The granular fill should be placed in a zone with a width equal to at least 1.2 metres behind the culvert walls (case (a) from commentary on CHBDC Figure C6.6).
- For Case (a), the restrained case, which is typical for box culvert walls, the pressures are based on the existing embankment fill materials, assuming a Select Subgrade Material (SSM) is used. The following parameters (unfactored) may be used:

Soil unit weight:	19 kN/m <sup>3</sup>
Coefficients of lateral earth pressure:	
'at rest' or restrained, $K_0$	0.50

- If the wall support allows lateral yielding (unrestrained structure, such as typically the case for wingwalls), active earth pressures may be used in the geotechnical design of the structure. The granular fill should be placed in a wedged shaped zone with a width equal to at least 1.2 metres at the footing level against a cut slope which begins at the footing level and extends upwards at a maximum inclination of 1 horizontal to 1 vertical (case (b) from commentary on CHBDC Figure C6.20).
- For walls backfilled using granular materials in accordance with case (b), the following parameters (unfactored) may be assumed:

	<u>GRANULAR A</u>	<u>GRANULAR B,</u> <u>TYPE II</u>
Fill unit weight:	22 kN/m <sup>3</sup>	21 kN/m <sup>3</sup>
Coefficients of lateral earth pressure:		
'active' or unrestrained, $K_a$	0.27	0.27
'passive', $K_p$	3.7	3.7





## 6.5 Construction Considerations

### 6.5.1 General

Care should be taken during construction to avoid disturbance of the subgrades prior to constructing foundations for the replacement culvert. All existing fill and any topsoil, organics, and soft or loose soils should be stripped from the proposed founding areas prior to placement of base materials. Subgrade preparation should be performed and monitored in accordance with OPSS 902.

It is recommended that the footing excavations be carried out such that the final 0.5 metres of excavation is completed with a geotechnical Quality Verification Engineer (QVE) on site. The prepared excavation bases should be inspected by the QVE. If shallow spread/strip footings are to be constructed, a working slab should be placed immediately after inspection to protect the founding materials.

### 6.5.2 Erosion and Scour Protection

Water flowing beneath a culvert could potentially cause undermining and scouring. Seepage flowing around the culvert walls has the potential to remove fines from the embankment fill and lead to piping and erosion. Therefore the replacement culvert must be designed with the appropriate end treatment to prevent undermining, scouring and piping. The native silts and sands encountered at the site are considered to be susceptible to piping. As required by the CHDBC, pre-cast concrete box culverts should be designed with cutoff walls, at least at the upstream end, to prevent undermining or possible collapse of the ends.

Erosion and scour protection for the culvert backfill and stream banks should be provided to protect the roadway, approach embankments, and culvert, as appropriate. In addition, sediment control such as silt fences and erosion control blankets may be required during construction and diversion/piping of the watercourse to minimize migration of fine particles should be carried out. Consideration could be given to using suitable non-woven geotextile and rip rap, as required, to provide erosion protection based on hydraulic requirements. Rip-rap treatment at the culvert outlets should be provided in accordance with OPSD 810.010.

### 6.5.3 Camber

Considering the relatively low cover for the proposed replacement culverts and the presence of compact to very dense granular soils below the founding elevations, the provision of camber for the replacement culvert is not required.



## 6.6 Excavations and Temporary Cut Slopes

Excavations for the replacement of the culvert will encounter topsoil and fill materials, silt, or sandy silt to silty sand. Temporary open cut slopes within these materials should be maintained no steeper than 1 horizontal to 1 vertical and localized sloughing and ground movements should be expected. All debris, cobbles, and boulders should be removed from slope surfaces. Where excavations extend below the groundwater level in granular soils, it may be necessary to use flatter slopes. All excavations should be carried out in accordance with the latest edition of the Ontario Occupational Health and Safety Act and Regulations for Construction Projects. Any existing embankment fill materials that may be encountered and the saturated native granular soils at the site would be classified as Type 3 soils. Effectively dewatered native granular soils would be classified as Type 2 soils.

Excavations for open bottom culvert strip footings or box culverts will extend below the inferred groundwater elevation 266.5 metres. Dewatering of excavations made into the saturated silt and sandy silt to silty sand may be required in order to construct the footings in the dry. Gravity methods such as wells are not considered to be effective in the silt and sandy silt to silty sand encountered at the site. Dewatering of these soils should be carried out using an eductors or vacuum well point system. Groundwater at the site may be controlled by using properly filtered sumps at the base of the excavation. Sumps should be maintained outside the actual footing limits. The volume of seepage from the native soils is expected to be low due to the low hydraulic conductivity. The estimated hydraulic conductivity of the silt is expected to be less than  $10^{-6}$  centimetres per second. The estimated hydraulic conductivity of the sandy silt to silty sand is expected to be in the order of about  $10^{-5}$  centimetres per second.

The existing culvert flows will need to be diverted/piped during construction. Surficial water seepage into the excavations should be expected and will be heavier during periods of sustained precipitation. Surface water should be directed away from the excavations at all times. The appropriate NSSP should be included in the contract documents to alert the contractor about the need for adequate control of surface and groundwater flows.

The exposed silt will be sensitive to disturbance from construction activities once exposed to moisture. Therefore, it will be essential to redirect surface water flow away from the excavations and construct all granular levelling pads or cast-in-place concrete footings during the same day the excavation is completed to the planned subgrade elevation.

### 6.6.1 Temporary Roadway Protection

Temporary roadway protection systems may be required where space is restricted and will not permit open cuts, to support the sides of the excavation and permit the use of vertical cuts. If protection systems are to be used during construction they are to be designed by the contractor and the limits of the systems are to be determined by the contractor.

Temporary support systems could consist of soldier piles and lagging where the H-piles would be driven to a suitable depth and horizontal lagging installed as the excavation proceeds or driven steel sheet piling. Support



to the systems could be in the form of struts and walers in the case of footing excavations or rakers and anchors in the case of roadway protection. The raker/anchor support must be designed to accommodate the loads applied from pressures and surcharge pressures from area line or point loads as well as the impact of sloping ground behind the system.



## **7.0 COMMENTS FOR DETAIL DESIGN**

Design options for the culvert upgrades include full culvert replacement with a pre-cast box culvert or an open footing culvert. A Foundation Design Report will need to be prepared during a future assignment to provide appropriate information for future Detail Design. Provided that the vertical and horizontal alignment of the proposed culvert do not vary significantly from the assumptions made within this report, the current investigation meets the MTO requirements for detail design of culverts, therefore, additional boreholes may not be required.

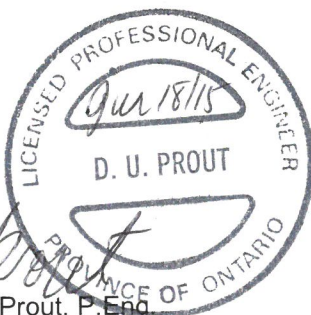
The preliminary recommendations given in this Preliminary Foundation Design report should be expanded upon and updated in the Foundation Design Report for detail design in accordance with MTO's standard requirements for foundation engineering assignments. Emphasis should be placed on provision of detailed recommendations for foundations for the culvert. An evaluation of the need for a Permit to Take Water and additional recommendations on dewatering will be required. If the approach embankments are to be modified, the stability of the altered embankments should be confirmed and the resulting settlement evaluated. If the culvert is to be replaced using staged construction and temporary roadway protection, the discussion on conceptual shoring alternatives must be expanded to include lateral earth pressures and detailed impact of ground conditions on shoring construction and design.



## 8.0 MISCELLANEOUS

This report was prepared by Ms. Nicole A. Gould, P.Eng. under the direction of the Project Engineer, Ms. Dirka U. Prout, P.Eng. and the Team Leader, Dr. Storer J. Boone, P.Eng. This report was reviewed by Mr. Azmi M. Hammoud, P.Eng. An independent audit of this report was carried out by Mr. Fintan J. Heffernan, P. Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

### GOLDER ASSOCIATES LTD.



Dirka U. Prout, P.Eng.  
Project Engineer



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

NG/DUP/AMH/FJH/cr

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n:\active\2012\1132 - geo\1132-0000\12-1132-0076 dillon-11 structures-3011-e-0046\ph 1000 gwp 3011-e-0046\ph 1001 fdns\rpts\vr05b structural culvert site 19-651c\1211320076-1001-r05b jun 17 15 (final) fdns a&b site 19-651c.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
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

### 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

### 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.) split spoon sampler for a distance of 300 mm (12 in.)

#### Consistency

	<u>kPa</u>	<u>psf</u>
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

#### (b) Cohesive Soils

#### Dynamic Cone Penetration Resistance; $N_d$ :

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

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

**WH:** Sampler advanced by static weight of hammer

**WR:** Sampler advanced by weight of sampler and rod

#### Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 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
$SO_4$	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.

## 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: $\Delta \sigma$
$\epsilon$	linear strain
$\epsilon_v$	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
$w_l$	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)

#### (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
$C_a$	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	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

- Notes:** 1  $\tau = c' + \sigma' \tan \phi'$   
 2 shear strength = (compressive strength)/2  
 \* density symbol is  $\rho$ . Unit weight symbol is  $\gamma$  where  $\gamma = \rho g$  (i.e. mass density x acceleration due to gravity)

# RECORD OF BOREHOLE No 701

1 OF 1

**METRIC**

PROJECT 12-1132-0076

W.P. 3030-11-00

LOCATION N 4755897.8 , E 412252.5

ORIGINATED BY BT

DIST HWY 401

BOREHOLE TYPE POWER AUGER, HOLLOW STEM

COMPILED BY LMK

DATUM GEODETIC

DATE May 13, 2013

CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ 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 ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE								
269.54	GROUND SURFACE							20	40	60	80	100				
0.00	TOPSOIL, sandy Brown						Cuttings									
0.21																
268.93	FILL, silty clay, trace sand, some gravel Compact Grey		1	SS	20		Granular bentonite									
0.61																
0.76																
268.23	FILL, sand and gravel, some silt															
1.31	FILL, silty sand, with gravel, some topsoil Brown		2	SS	21		268 Cuttings									
	FILL, sandy silt, some clay, some gravel, trace topsoil Compact Brown															
			3	SS	20		267						○			1 25 61 13
			4	SS	22								○			
265.88							266 Granular bentonite									
3.66	FILL, sand and gravel, trace silt, crushed Compact Grey		5	SS	14								○			
265.12																
4.42	SILTY FINE SAND TO SANDY SILT, trace gravel, with silty clay layers Compact Brown		6	SS	29		265						○			0 37 57 6
			7	SS	23		264									
			8	SS	16		263									
							Cuttings 262									
			9	SS	20											
							261									
260.70																
8.84	SILT, trace clay, trace sand Compact Brown		10	SS	23		260						○			0 4 89 7
							Standpipe 259 Filter sand									
258.41			11	SS	24											
11.13	END OF BOREHOLE															
	Groundwater encountered at about elev. 265.7m during drilling on May 13, 2013.															
	Water level measured in standpipe at elev. 266.24m on June 5, 2013.															
	Water level measured in standpipe at elev. 266.61m on June 20, 2013.															





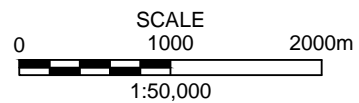
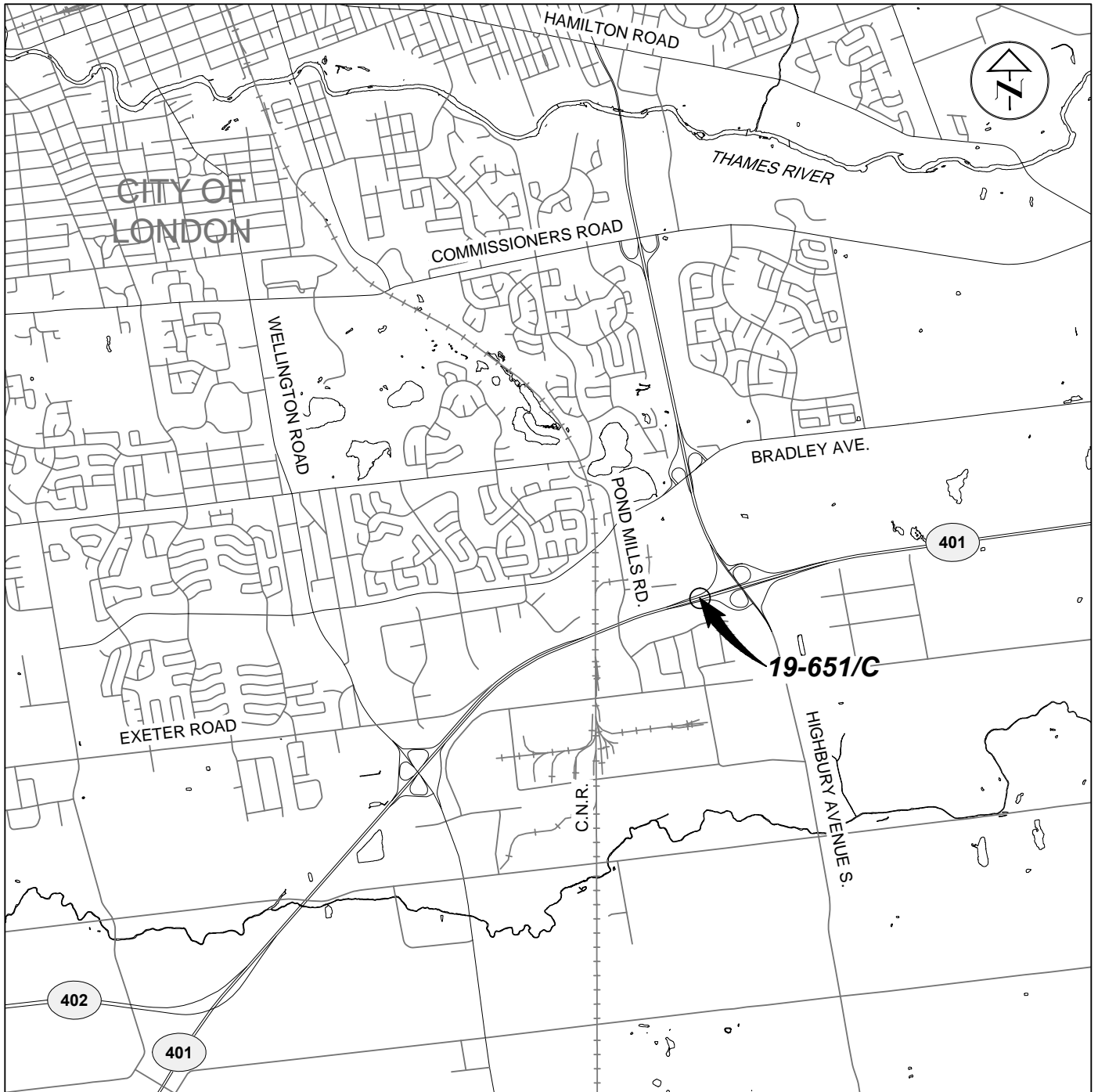
**RECORD OF BOREHOLE No 703**

1 OF 1

**METRIC**

PROJECT 12-1132-0076  
W.P. 3030-11-00 LOCATION N 4755964.4 , E 412240.7 ORIGINATED BY MA  
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE May 16, 2013 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ  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 (%)				
																		○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE		
270.48		PAVEMENT SURFACE						20	40	60	80	100									
0.00		ASPHALT																			
0.16		FILL, sand and gravel, trace silt, crushed Brown																			
0.27																					
269.81		FILL, sand and gravel, trace silt Brown		1	SS	12															
0.67																					
269.20		FILL, clayey silt, some sand, some gravel, trace topsoil Stiff Brown		2	SS	8															
1.28																					
268.80		FILL, sandy silt, some sand, trace gravel, trace topsoil Loose Brown		3	SS	27															
1.68																					
1.98		FILL, clayey silt, trace sand, trace gravel Stiff Brown		4	SS	24															
266.97		FILL, sandy silt, trace clay, some gravel to gravelly, trace topsoil Compact Grey		5	SS	9										26	24	42	8		
3.51																					
		FILL, sandy silt, some gravel, trace topsoil Loose Grey		6	SS	9											13	25	52	10	
265.45		SILT, trace to some clay, some sand Compact to very dense Grey		7	SS	57															
5.03																					
						8	SS	89													
						9	SS	22										0	17	77	6
263.16		SILTY FINE SAND, trace clay Loose Grey																			
7.32						10	SS	9										0	64	34	2
262.40																					
8.08		SANDY SILT Dense Grey		11	SS	47															
261.64																					
8.84		SILT, trace sand, with clayey silt layers Dense to compact Grey		12	SS	36											0	2	89	9	
				13	SS	21															
259.51		END OF BOREHOLE  Groundwater encountered at about elev. 265.9m during drilling on May 16, 2013.																			
10.97																					



## REFERENCE

PLAN BASED ON CANMAP STREETFILES V.2008.5.

## NOTE

THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ACCOMPANYING TEXT.

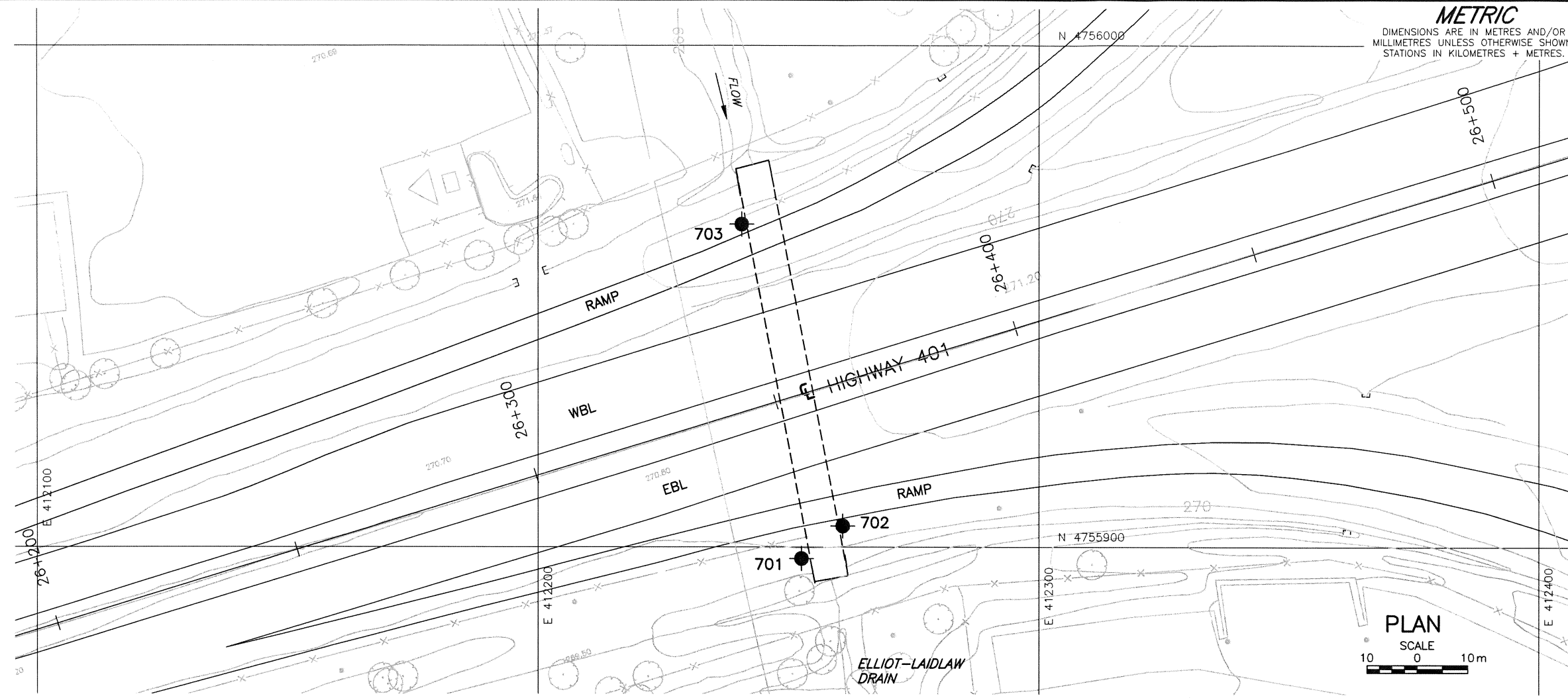
PROJECT  
STRUCTURAL CULVERT REPLACEMENT 19-651/C  
HIGHWAY 401 INTERCHANGE IMPROVEMENTS  
GWP 3054-11-00

TITLE

## KEY PLAN



PROJECT No. 12-1132-0076		FILE No. 1211320076-1001-F05B01	
CADD	LMK/WDF	Nov. 01/13	SCALE AS SHOWN REV. 0
CHECK			
			<b>FIGURE 1</b>

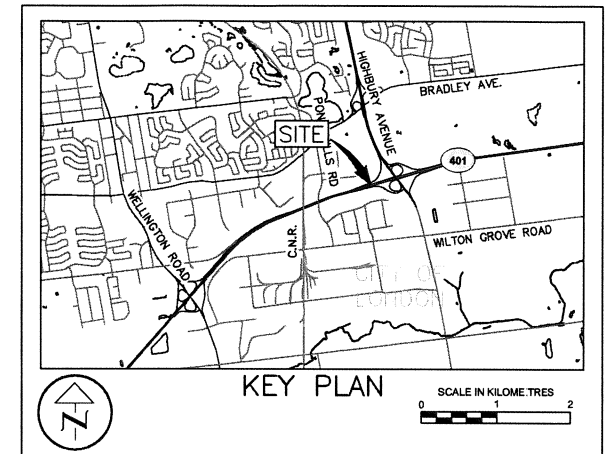


CONT No. WP No. 3054-11-00

STRUCTURAL CULVERT REPLACEMENT  
 STATION 26+360  
 HIGHWAY 401 IMPROVEMENTS  
 BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

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- LEGEND**
- Borehole - Current Investigation
  - ⊞ Seal
  - ⊞ Standpipe
  - N Standard Penetration Test Value
  - 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
  - ⊞ WL measured on June 20, 2013
  - ⊞ WL encountered during drilling

No.	ELEVATION	CO-ORDINATES (MTM ZONE 10)	
		NORTHING	EASTING
701	269.54	4 755 897.7	412 252.5
702	270.39	4 755 904.3	412 260.8
703	270.48	4 755 964.4	412 240.7

**NOTES**

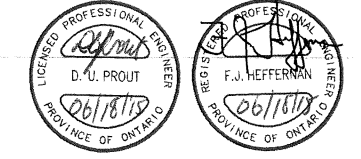
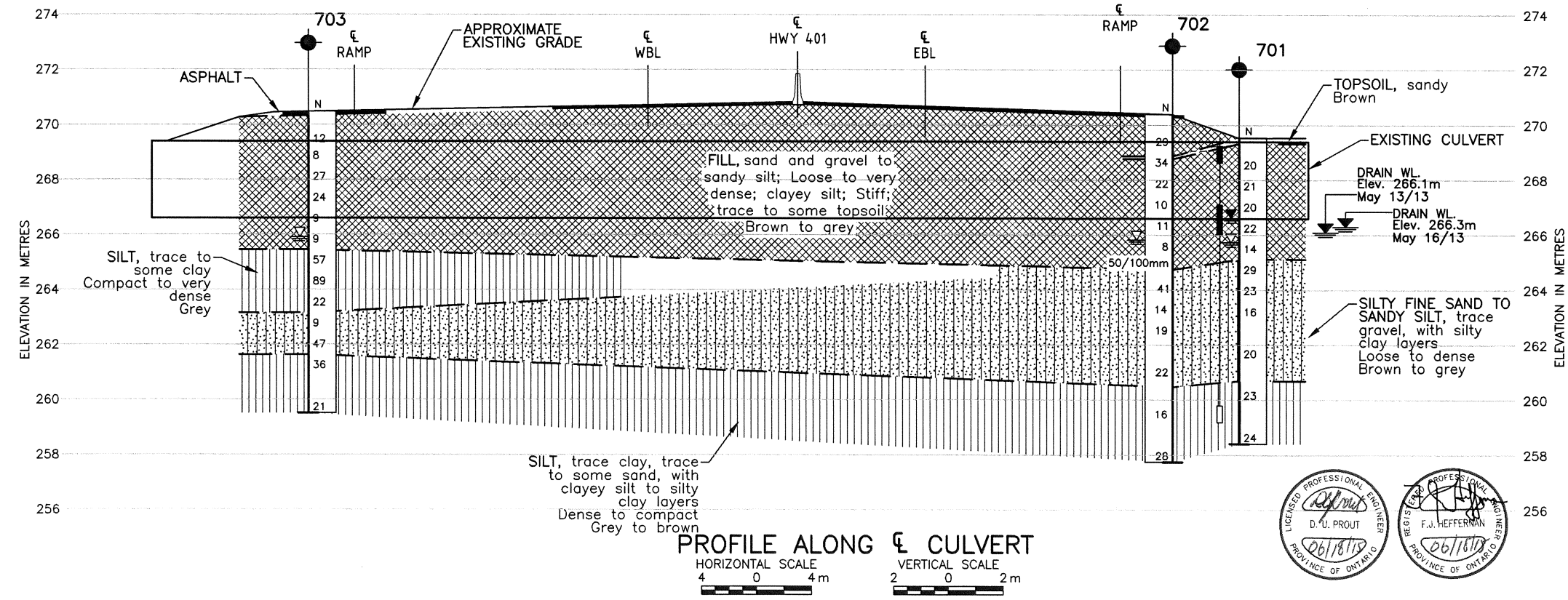
This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

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

**REFERENCE**

Base plans based on City of London Digital Mapping Disc 2011 (converted to MTM ZONE 11)

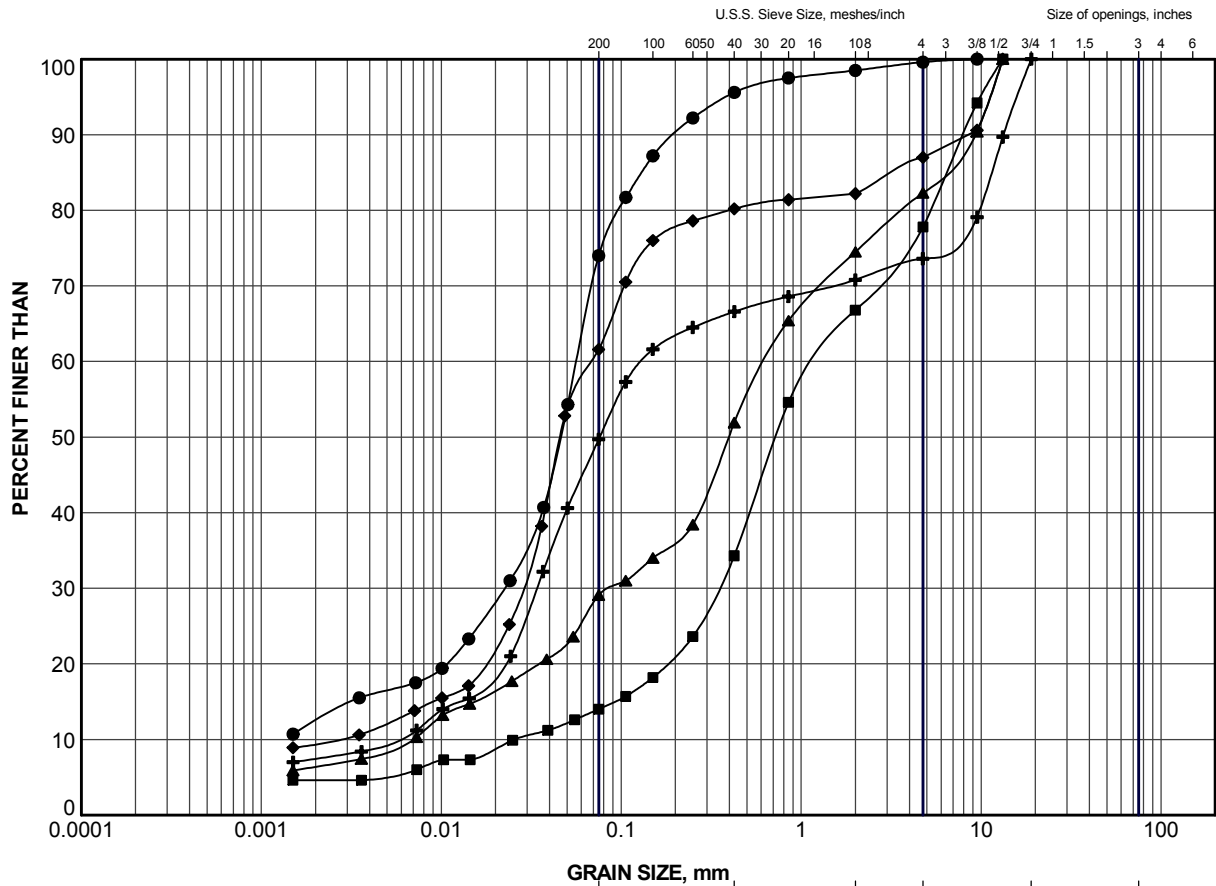
NO.	DATE	BY	REVISION
1	06/18/13	D.U. PROUT	Geocres No. 4014-159
2	06/18/13	F.J. HEFFERNAN	HWY. 401 PROJECT NO. 12-1132-0076 DIST.
3			SUBM'D. NG CHKD. NAG DATE: Aug. 08/13 SITE: 19-651/C
4			DRAWN: WDF/LMK CHKD. DUP APPD. FJH DWG. 1





# APPENDIX A

## Laboratory Test Data



CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

#### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	701	3	267.0
■	702	3	267.9
▲	702	5	266.4
+	703	4	267.4
◆	703	5	266.6

PROJECT  
STRUCTURAL CULVERT REPLACEMENT 19-651/C  
HIGHWAY 401 INTERCHANGE IMPROVEMENTS  
GWP 3054-11-00

TITLE

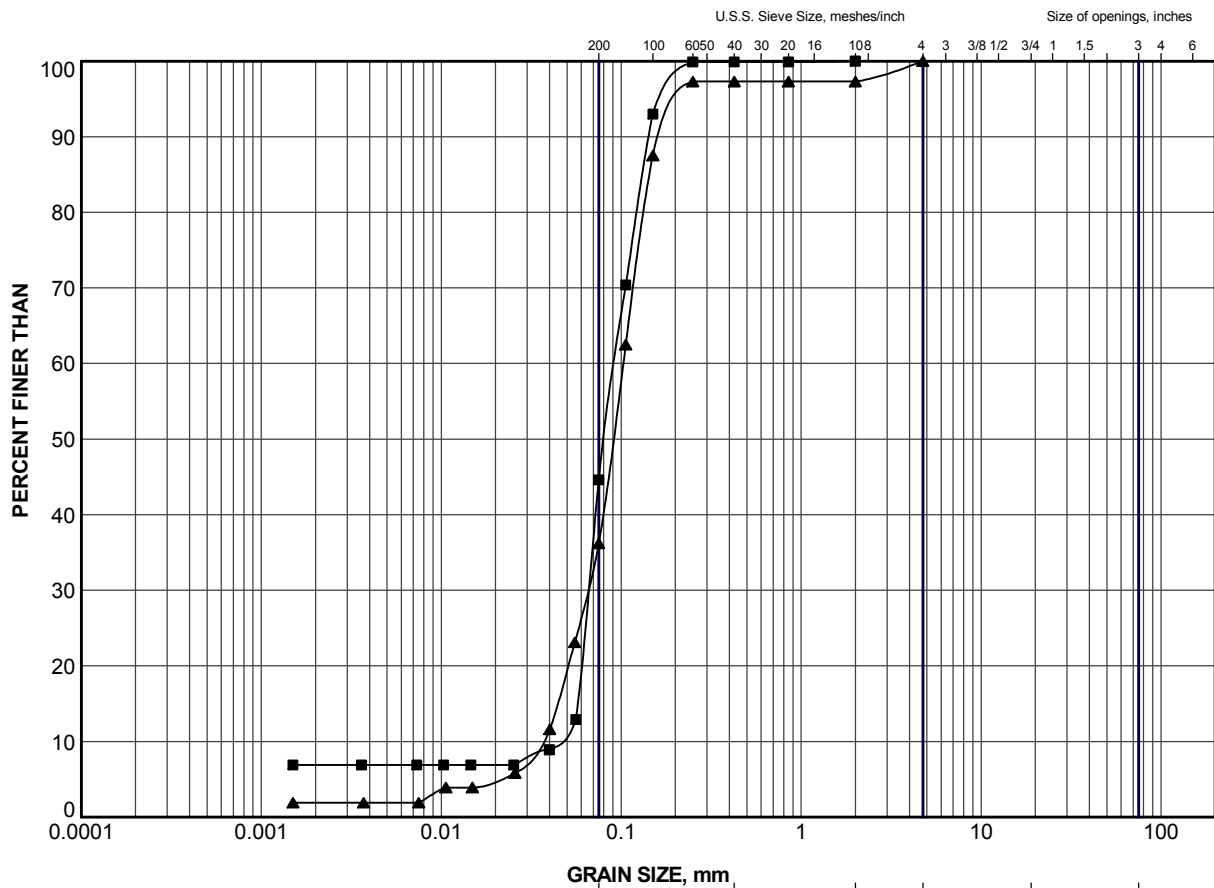
## GRAIN SIZE DISTRIBUTION FILL



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PROJECT No.	12-1132-0076	FILE No.	1211320076-1001-F05BA1
DRAWN	LMKWDF	Aug. 07/13	SCALE N/A REV.
CHECK			


**FIGURE A-1**

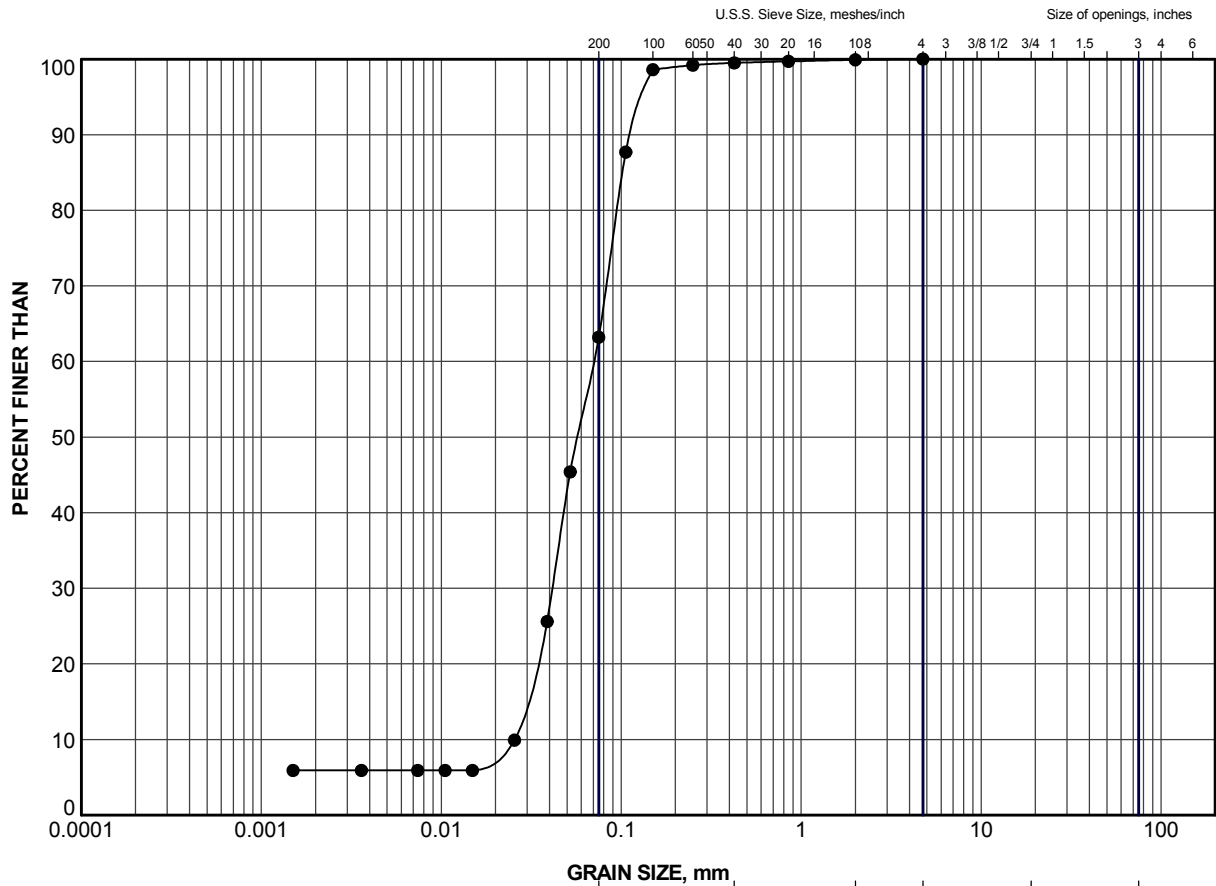


CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

#### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	701	6	264.7
■	702	10	262.5
▲	703	10	262.8

PROJECT				STRUCTURAL CULVERT REPLACEMENTS HIGHWAY 401 INTERCHANGE IMPROVEMENTS GWP 3054-11-00			
TITLE				GRAIN SIZE DISTRIBUTION SILTY FINE SAND			
PROJECT No. 12-1132-0076-1001				FILE No. 1211320076-1001-F050A2			
DRAWN MKWDF Aug. 07/13				SCALE N/A REV.			
CHECK				FIGURE A-2			
 <b>Golder Associates</b> LONDON, ONTARIO							









# APPENDIX B

## Photographs



## APPENDIX B SITE PHOTOGRAPHS



Photograph 1: Elliot-Laidlaw Drain, outlet, south end.



Photograph 2: N-W on ramp riding surface, looking south.

n:\active\2012\1132 - geo\1132-0000\12-1132-0076 dillon-11 structures-3011-e-0046\ph 1000 gwp 3011-e-0046\ph 1001 fdns\rpts\r05b structural culvert site 19-651c\1211320076-1001-r05b jun 16 15 (final) app b-site photos.docx

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