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**FOUNDATION  
INVESTIGATION AND DESIGN REPORT  
CULVERTS AND RETAINING WALLS  
HIGHWAY 6 WIDENING  
BETWEEN HIGHWAYS 403 AND 5  
G.W.P. 19-95-01**

Submitted to:

URS Canada Inc.  
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## **PART A**

**FOUNDATION INVESTIGATION REPORT  
CULVERTS AND RETAINING WALLS  
HIGHWAY 6 WIDENING BETWEEN HIGHWAYS 403 AND 5  
G.W.P. 19-95-01**

## **1.0 INTRODUCTION**

Golder Associates Ltd. has been retained by URS Canada Inc. (URS) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for new bridge structures, a pedestrian tunnel, culverts, retaining walls, high fill embankments, high mast light poles, and overhead signs, associated with the widening of Highway 6 between Highways 403 and 5 near Dundas, Ontario.

This report addresses the culverts and retaining walls for this project, as follows:

- A new culvert located at approximately Station 11+615, extending from the west side of Highway 6 to the south side of York Road;
- An extension to the west end of the existing culvert that is located at approximately Station 11+860;
- New retaining walls between Plains Road and the Grindstone Creek valley, and along the south side of Old York Road adjacent to the Grindstone Creek valley;
- A new retaining wall at the west end of the culvert at Station 11+615; and
- A new retaining wall adjacent to the future E/W-S Ramp, immediately south of York Road.

A foundation investigation has been carried out to determine the subsurface conditions at the above-noted sites.

The terms of reference for the scope of work are outlined in Golder Associates' Proposal No. P01-1166, dated June 2000. The work has been carried out in accordance with Golder Associates' Quality Control Plan for Foundation Engineering Services, dated July 2000.

## **2.0 SITE DESCRIPTION**

This 2.5 km length of Highway 6, between Highway 403 and Highway 5 (Dundas Street), is located within the City of Burlington in the Regional Municipality of Halton, and the Towns of Dundas and Flamborough in the New City of Hamilton.

Highway 6 crosses the Niagara escarpment south of Highway 5, in the vicinity of Old Guelph Road. The escarpment crest is at about Elevation 215 m; above the crest, the ground surface rises northward to about Elevation 220 m near the north limit of the project at Highway 5. Below the crest, the ground surface declines from Elevation 215 m to about Elevation 147 m in the vicinity of York Road, and about Elevation 133 m near the south limit of the project.

Above Old Guelph Road, near-vertical rock cuts up to a maximum height of about 20 m have been constructed on either side of Highway 6. The upper portions of the cut are comprised mainly of dolostones and limestones, and are sub-vertical. From just north of Old Guelph Road at about Station 12+375 to approximately Station 12+525, the lower portion of the cuts is oriented at approximately 1.5 horizontal to 1 vertical. These lower slopes increase in height from north to south as the existing highway cuts through the escarpment, varying from less than 2 m to 3 m high at Station 12+525, to about 10 m high immediately north of Old Guelph Road.

Immediately south of Old Guelph Road, Highway 6 has been constructed on embankment fill which is up to about 15 m in height.

### **3.0 INVESTIGATION PROCEDURES**

Subsurface borehole investigations were carried out along Highway 6 in November 2002, May and June 2003, September 2003, and November 2004, during which time twelve boreholes (Boreholes C-2003-01 to C-2003-04, C-2004-01, C-3, NW-7, NW-8, RW-1, RW-2, RW-2A and RW-3) were advanced in the vicinity of the proposed culverts and retaining walls. The locations of the boreholes are shown on Drawing 1.

Due to drill rig access restrictions at the toe of the existing embankments and/or within the Grindstone Creek valley, Boreholes C-2003-01, C-2003-02, C-2003-04, RW-2, and RW-3 were advanced using tripod-mounted portable drilling equipment that was supplied and operated by Kodiak Environmental Drilling Ltd. of Oakville, Ontario. These boreholes were extended to depths of between 1.5 m and 2.0 m below the existing ground surface, to “refusal” (for the portable drilling equipment) within the hard till at the site; the boreholes were advanced via continuous sampling of the overburden. The samples were obtained using a 50 mm outside diameter split-spoon sampler, 0.75 m in length, which was advanced with a half-weight hammer in general accordance with the Standard Penetration Test (SPT) procedure.

The remaining boreholes (Boreholes C-2003-03, C-2004-01, C-3, NW-7, NW-8, RW-1 and RW-2A) were advanced to depths ranging from 5.2 m to 15.4 m with solid stem augers, using truck-mounted and track-mounted drill rigs supplied and operated by Master Soil Investigations Ltd. of Toronto, Ontario, Geo-Environmental Drilling Inc. of Milton, Ontario and Walker Drilling Ltd. of Utopia, Ontario. In these boreholes, samples of the overburden were obtained at 0.75 m and 1.5 m intervals of depth using 50 mm outside diameter split-spoon samplers in accordance with the Standard Penetration Test procedure.

The water level in the open boreholes was observed throughout the drilling operations, and a 20 mm diameter standpipe piezometer was installed in Boreholes NW-7 and RW-1 to monitor the groundwater level at the site. Details of the piezometer installation are shown on the relevant borehole records. Where no piezometer was installed, the boreholes were backfilled using bentonite pellets, mixed in places with soil cuttings; a surface seal of bentonite was placed in all of the boreholes.

The borehole investigations were supervised on a full-time basis by a member of Golder’s staff who located the boreholes in the field, directed the drilling, 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 laboratory in Mississauga for further examination. Index and classification tests consisting of water content determinations, Atterberg limit testing and grain size distribution analyses were carried out on selected soil samples.

The borehole locations and ground surface elevations were determined relative to known surface features or to points staked in the field by Callon Dietz, Ontario Land Surveyors. The MTM NAD83 northing and easting coordinates and the geodetic ground surface elevations are shown on the borehole records and on Drawing 1, and are summarized in the following table:

<b><i>Borehole No.</i></b>	<b><i>Ground Surface Elevation (m)</i></b>	<b><i>MTM NAD83 Northing (m)</i></b>	<b><i>MTM NAD83 Easting (m)</i></b>
C-2003-01	149.2	4,795,862.2	271,801.5
C-2003-02	141.7	4,795,761.2	271,973.8
C-2003-03	145.8	4,795,771.7	272,029.4
C-2003-04	137.8	4,795,733.6	272,053.6
C-2004-01	144.8	4,795,738.0	271,894.0
C-3	148.0	4,795,753.1	271,931.1
NW-7	145.4	4,795,513.3	272,096.9
NW-8	146.3	4,795,536.1	272,025.1
RW-1	145.7	4,795,657.1	272,113.9
RW-2	143.5	4,795,698.2	272,086.6
RW-2A	147.1	4,795,692.4	272,073.9
RW-3	140.3	4,795,728.7	272,049.3



## **4.0 SITE GEOLOGY AND STRATIGRAPHY**

### **4.1 Regional Geological Conditions**

This 2.5 km section of Highway 6 traverses the Niagara Escarpment, which separates the lower Iroquois Plain to the south from the Flamborough Plain to the north, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, Third Edition, 1984). In the vicinity of the Escarpment itself, covering much of the study area for this project, the Halton Till of the Peel Plain physiographic region is present, according to the *Urban Geology of Canadian Cities* (Karrow and White, 1998).

The escarpment crest is located just north of Old Guelph Road, and well-jointed and bedded sedimentary bedrock consisting of dolostone, limestone, sandstone and shale is exposed in the existing Highway 6 cut. Typically, natural talus intermixed with rubbly glacial debris covers the lower slopes of the escarpment. Below the escarpment, the bedrock consists of shale.

The Halton Till of the Peel Plain physiographic region typically ranges in composition from a dense, reddish clayey silt to silt till to a grey, plastic clayey silt to silty clay till. This Halton Till is the lowest and oldest soil deposit encountered in excavations in the area north of Hamilton, and it typically rests directly on the bedrock. Commonly, there is a transition zone of residual soil and/or disturbed bedrock at the contact between the Halton Till and the shale.

### **4.2 Site Stratigraphy**

The detailed subsurface soil and groundwater conditions encountered in the boreholes advanced during this investigation, together with the results of the laboratory tests carried out on selected soil samples, are given on the borehole records and on Figures 1 to 4 following the text of this report. The stratigraphic boundaries shown on the borehole records are in most instances inferred from non-continuous sampling, observations of drilling progress and the results of Standard Penetration Tests. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. The subsurface conditions will vary between and beyond the borehole locations.

Below the existing Highway 6 embankment fill (where present), the predominant native soil deposit at the site is a clayey silt till that grades with depth to a residual soil. A thin layer of surficial clayey silt to silty clay was encountered atop the till at some borehole locations. The following table summarizes the subsurface conditions at each of the proposed retaining wall or culvert sites; the subsections (Sections 4.2.1 to 4.2.3 and 4.3) provide further information on the major soil deposits and the groundwater conditions encountered in the boreholes.

<i>Location / Boreholes</i>	<i>Subsurface Conditions</i>
<p><b>Culvert Extension at Station 11+800 (Highway 6)</b></p> <p>The existing natural ground surface in the vicinity of this proposed culvert extension is at about Elevation 149 m to 150 m, and the existing Highway 6 grade is at about Elevation 154 m to 155 m. One shallow borehole (Borehole C-2003-01) was drilled within the limits of the extension using portable equipment.</p>	<p>The native soils at this site consist of soft to firm clayey silt containing trace quantities of organics, overlying stiff to hard clayey silt till. The surface of the hard clayey silt till (with measured Standard Penetration Test “N” values greater than 30 blows per 0.3 m of penetration) was encountered below Elevation 148 m in the borehole.</p>
<p><b>Culvert at Station 10+615 (Highway 6) and Retaining Wall at West End of Culvert</b></p> <p>The existing ground surface along this proposed culvert varies as follows, from the west side of Highway 6 to the south side of York Road:</p> <ul style="list-style-type: none"> <li>• about Elevation 143 m to 144 m on the west side of the highway;</li> <li>• about Elevation 148 m on the existing Highway 6 embankment;</li> <li>• about Elevation 138 m to 144 m on the east side of the highway, in the area north of York Road; and</li> <li>• about Elevation 146 m to 147 m on and immediately south of the existing York Road embankment.</li> </ul> <p>A total of five boreholes were drilled along the length of this proposed culvert: three shallow boreholes (one at each end and one in the area between Highway 6 and York Road) were advanced using portable drilling equipment, due to sloping ground and difficult access conditions at these locations; two deeper boreholes were drilled using truck-mounted drilling equipment on Highway 6 and York Road to supplement the subsurface information obtained from the shallow boreholes.</p>	<p>About 5.3 m of fill was encountered in the borehole advanced through the existing Highway 6 embankment; this fill consists of about 0.6 m of asphalt and compact sand and gravel, overlying about 4.7 m of soft to firm clayey silt fill. About 2.6 m of fill was encountered in the borehole advanced through the existing York Road embankment; this fill consists of about 0.6 m of asphalt and sand and gravel, overlying about 2 m of firm to very stiff silty clay fill.</p> <p>A 0.5 m to 1.4 m thick layer of silty clay was encountered at ground surface in the boreholes advanced east of Highway 6 and south of York Road, and below the embankment fill in the borehole advanced through York Road. The base of this layer was encountered in the boreholes between Elevation 136.4 m and 142.8 m. This layer has a very soft to firm consistency, based on measured SPT “N” values that range from 1 to 5 blows per 0.3 m of penetration.</p> <p>Below the Highway 6 embankment fill (western portion of the culvert) or the thin silty clay layer (eastern portion of the culvert), a deposit of stiff to hard clayey silt till was encountered in all of the boreholes. The measured SPT “N” values within the till range from 6 to 120 blows per 0.3 m of penetration, but are typically between 20 and 40 blows per 0.3 m of penetration, indicative of a generally very stiff to hard consistency. It is noted that the lowest SPT “N” values of 6 and 13 blows per 0.3 m of penetration were measured at the surface of the till deposit in two of the boreholes.</p>

<i>Location / Boreholes</i>	<i>Subsurface Conditions</i>
<p><b>Retaining Wall Adjacent to Plains Road / York Road</b></p> <p>The proposed retaining wall east of Plains Road is located at and near the crest of the Grindstone Creek valley. The existing ground surface along the proposed wall length varies from approximately Elevation 145.7 m at the south end (about Station 10+620), to 145.1 m at the north end (about Station 10+740), with a low point of about Elevation 143.4 m in the middle of the wall.</p> <p>Four boreholes were drilled along or adjacent to the proposed wall alignment: two shallow boreholes were drilled using portable drilling equipment at the centre and north ends of the wall, due to the sloping ground conditions at these locations; and two deeper boreholes were drilled near the centre and at the south end of the wall, using track-mounted drilling equipment.</p>	<p>A clayey silt till deposit was encountered below a thin (less than 200 mm thick) topsoil layer in all of the boreholes. The upper 0.5 m of the till deposit is stiff, based on measured SPT “N” values of 8 to 13 blows per 0.3 m of penetration. Below this, the clayey silt till is very stiff to hard, based on measured SPT “N” values that range from 17 to 72 blows per 0.3 m of penetration; the typical range of SPT “N” values within the till in these boreholes is about 20 to 40 blows per 0.3 m of penetration. The clayey silt till is underlain by a hard (SPT “N” values generally greater than 100 blows per 0.3 m of penetration) clayey silt till / residual soil deposit, that was encountered below approximately Elevation 135.5 m in the deep borehole advanced at the south end of the wall.</p>
<p><b>Retaining Wall Adjacent to EW-S Ramp</b></p> <p>The existing ground surface along this retaining wall varies from approximately Elevation 146 m to 148 m. Two boreholes (Boreholes NW-7 and NW-8) were advanced along this retaining wall.</p>	<p>About 0.4 m of compact crushed limestone or sand and gravel fill was encountered overlying 0.7 m and 2.5 m of firm to stiff clayey silt fill in the boreholes; in one of the boreholes, the fill is underlain by surficial silty clay. The surface of the till deposit that underlies the fill and surficial silty clay was encountered at 2.1 m and 3.1 m depth in the boreholes. This till has a very stiff to hard consistency, based on measured SPT “N” values of 17 to 50 blows per 0.3 m of penetration.</p>

#### 4.2.1 Fill

Fill, typically associated with the existing Highway 6 or York Road embankments, was encountered in Boreholes C-2003-03, C-2004-1, C-3, NW-7, and NW-8. The fill ranges from about 1.1 m to 5.3 m in thickness, as encountered in the boreholes that are included in this report. The thickest areas of fill are located within the existing Highway 6 “high fill embankment” north of York Road.

The fill composition is variable, but typically consists of either crushed limestone or sand and gravel immediately below asphalt pavement, or clayey silt to silty clay containing trace to some sand and trace to some gravel, shale and limestone fragments; trace organics were also noted within the clayey fill in Boreholes C-2004-01, NW-7, and NW-8. It is noted that cobbles and boulders have been inferred within the embankment fill during drilling (although not within the boreholes that are included as part of this report), particularly within the “high fill embankment”

section north of York Road, based on grinding of the augers and/or resistance to penetration of the sampler.

The measured Standard Penetration Test (SPT) “N” values within the existing embankment fill range from 3 to 16 blows per 0.3 m of penetration within the clayey silt to silty clay portions of the fill; these results indicate that the consistency of the fill is variable, ranging from soft to very stiff, although the cohesive portions of the till are typically firm to stiff as encountered in these boreholes. Two measured SPT “N” values of 11 and 12 blows per 0.3 m of penetration were measured within the sand and gravel fill in Boreholes NW-7 and NW-8, indicating that this material has a compact relative density.

#### **4.2.2 Surficial Clayey Silt to Silty Clay**

Approximately 0.5 m to 1.0 m of clayey silt to silty clay was encountered immediately below the existing fill in Borehole C-2003-03 and NW-8, and about 0.9 m to 1.4 m of clayey silt to silty clay was encountered immediately below ground surface in Boreholes C-2003-01, C-2003-02 and C-2003-04. This surficial clayey silt contains trace to some sand, trace gravel, and trace organics. The result of a grain size distribution test on a selected sample of this deposit is shown on Figure 1.

The surficial clayey silt to silty clay has a very soft to firm consistency, based on measured SPT “N” values of 1 to 6 blows per 0.3 m of penetration. Atterberg limit testing was carried out on one sample of the deposit, and the result is plotted on a plasticity chart on Figure 2. This testing measured a plastic limit of 17 per cent and a liquid limit of 36 per cent, with a corresponding plasticity index of 19 per cent. This test result indicates that the tested sample is a silty clay of intermediate plasticity.

#### **4.2.3 Clayey Silt to Silty Clay Till and Till / Residual Soil**

A deposit of brown to red-brown or grey-brown till was encountered in all of the boreholes below the topsoil, existing embankment fill or surficial clayey silt to silty clay (where present). The till is typically comprised of clayey silt, although in places it grades to silty clay, and it contains trace to some sand and trace to some gravel, shale and limestone fragments. Below about 7.0 m and 10.2 m depth in Boreholes C-2003-03 and RW-1, respectively, the till grades to a residual soil deposit, which consists of clayey silt with a higher proportion of sand and gravel. The results of grain size distribution tests conducted on six samples of the clayey silt till and till / residual soil are shown on Figure 3. It is noted that the till is glacially derived and should, therefore, be expected to contain cobbles and boulders, although no such obstructions were encountered within the till in the boreholes advanced as part of this investigation.

Atterberg limit testing was carried out on twelve samples of the till and one sample of the residual soil, and the results are plotted on a plasticity chart on Figure 4. The testing on the till measured plastic limits of 13 to 18 per cent, and liquid limits of 26 to 37 per cent; the corresponding plasticity indices range from 9 to 19 per cent. The testing on the residual soil measured a plastic limit of 13 per cent, a liquid limit of 19 per cent, and a corresponding plasticity index of 6 per cent. These plasticity results indicate that the till and residual soil are predominantly a clayey silt of low plasticity; however, some portions of the till grade to a silty clay of intermediate plasticity, as encountered in Boreholes NW-7, NW-8, and RW-2.

The consistency of the clayey silt to silty clay till varies from firm to hard, based on measured SPT “N” values that range from 6 to greater than 100 blows per 0.3 m of penetration. However, the till is typically very stiff to hard, with the measured SPT “N” values typically in the range of 15 to 50 blows per 0.3 m of penetration. The lower measured SPT “N” values of 6 to 13 blows per 0.3 m of penetration were measured immediately below the ground surface, existing fill or surficial clayey silt to silty clay in Boreholes C-3 and RW-1 to RW-3.

The till/residual soil that was encountered at depth in Boreholes C-2003-03 and RW-1 has a hard consistency, based on measured SPT “N” values of 49 to greater than 100 blows per 0.3 m of penetration.

### 4.3 Groundwater Conditions

A standpipe piezometer was installed in Boreholes NW-7 and RW-1 to monitor the groundwater level at the site. The water levels measured in the piezometers approximately six weeks after installation is summarized in the following table:

<i><b>Borehole No.</b></i>	<i><b>Depth to Groundwater</b></i>	<i><b>Groundwater Elevation</b></i>	<i><b>Date of Measurement</b></i>
NW-7	1.4 m	144.0 m	November 1, 2003
RW-1	9.7 m	136.0 m	November 1, 2003

Based on the measurements summarized above as well as groundwater monitoring information from other piezometers installed as part of the Highway 6 widening study, the stabilized groundwater level at the site is typically between 1.5 m and 3 m below the natural ground surface. The groundwater table is deeper relative to the “tableland” in the vicinity of the Grindstone Creek channel (as is the case for Borehole RW-1).

It should be noted that groundwater levels are expected to fluctuate seasonally and are expected to rise during wet periods of the year.

## **5.0 CLOSURE**

This Foundation Investigation Report was prepared by Ms. Lisa Coyne, P.Eng., an Associate and Senior Engineer with Golder. Mr. Fintan J. Heffernan, P.Eng., a Designated MTO Contact for Golder, conducted an independent review of the report.

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## **PART B**

**FOUNDATION DESIGN REPORT  
CULVERTS AND RETAINING WALLS  
HIGHWAY 6 WIDENING BETWEEN HIGHWAYS 403 AND 5  
G.W.P. 19-95-01**

## **6.0 ENGINEERING RECOMMENDATIONS**

### **6.1 General**

This section of the report provides geotechnical recommendations for the design of foundations for the proposed retaining walls and culverts. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation at this site. The interpretation and recommendations provided are intended only to provide the designers with sufficient information to design the structure foundations. As such, where comments are made on construction they are provided only in order to highlight those aspects which could affect the planning 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, scheduling and the like.

### **6.2 Culverts and Culvert Extensions**

Two structural culverts or extensions are proposed as part of this project to channel Grindstone Creek:

- A 15 m long, 3.0 m x 1.8 m concrete box extension will be constructed on the west side of Highway 6 at approximately Station 11+800. The existing culvert has an invert elevation of about 148.9 m at its outlet, and the extension is proposed to have its invert at Elevation 148.4 m.
- A concrete box culvert, approximately 190 m long and varying from 3.0 m x 1.8 m to 3.5 m x 1.25 m, will be constructed at about Station 10+615 (Highway 6), extending from west to east across Highway 6, then south across York Road. The proposed invert elevation for this culvert will vary from about Elevation 143.4 m at its inlet on the west side of Highway 6, to Elevation 138.0 m at its outlet on the south side of York Road.

#### **6.2.1 Subexcavation Requirements**

Based on the borehole results, the subsoils at these proposed invert elevations generally consist of stiff to hard clayey silt till. With the exception of the portion of the culvert south of York Road, as discussed below, no additional subexcavation (beyond that required to place 300 mm of granular bedding, as discussed in Section 6.2.3) is required for construction of the new culvert or culvert extension.

However, at the east end of the culvert at Station 11+615 (i.e. the portion of the culvert that extends south of York Road), there is up to about 1.5 m of very soft to firm surficial silty clay present below the proposed culvert invert elevation. This deposit extends from the existing ground surface immediately adjacent to the Grindstone Creek channel, down to about Elevation



136.4 m. In order to minimize settlement of the end of the culvert under the embankment loading to less than 25 mm, it is recommended that the surficial silty clay layer be subexcavated down to Elevation 136.3 m. The width to be subexcavated should be defined by lines extending from the outside edges of the culvert (and the east retaining wall, as discussed further in Section 6.4), outward and downward at 1 horizontal to 1 vertical. Based on the creek valley topography, it is recommended that the length of subexcavation extend over the flow splitter weir plus the southern/eastern 15 m of the culvert, where the existing ground surface is below Elevation 139 m adjacent to the Grindstone Creek channel. This subgrade should be inspected following subexcavation to ensure that all soft clayey materials have been removed, then the subexcavated area should be replaced with Granular “A” or Granular “B” backfill that is placed and compacted in accordance with the requirements of MTO’s Special Provision SP105S10.

### **6.2.2 Foundations**

If a concrete headwall is required for the culvert extension at Station 11+800, spread footings for the headwall may be designed based on a factored geotechnical resistance at Ultimate Limit States (ULS) of 400 kPa. This factored resistance at ULS is based on a footing width of about 2 m and a maximum founding elevation of 148.0 m, within the hard clayey silt till; the founding elevation should be adjusted downward as necessary to provide a minimum founding depth of 1.2 m below lowest surrounding grade, to provide adequate protection against frost penetration. The settlement of the box culvert extension and associated headwall (if any) under the applied embankment loading is discussed in Section 6.2.2, below.

Recommendations for the retaining walls that are required at either end of the culvert at Station 11+615 are provided separately in Sections 6.3 and 6.4.

Resistance to lateral forces / sliding resistance between the footings for the concrete headwall (if required) and the clayey silt till subgrade should be calculated in accordance with Section 6.7.5 of the *CHBDC*, using a coefficient of friction,  $\tan \phi'$ , of 0.45. This represents an unfactored value; in accordance with the *CHBDC*, a factor of 0.8 is to be applied in calculating the horizontal resistance.

### **6.2.3 Settlement**

Some settlement of the clayey silt till is expected beneath the culverts, due to the placement of between 3 m and 12 m of fill associated with the construction of the new or widened Highway 6, N-EW Ramp, EW-S Ramp, and York Road embankments.

Settlement analyses for the foundation soils were carried out using the commercially available computer program Unisettle. The compression of the clayey silt till deposit was modelled using

elastic deformation moduli based on correlations with the measured SPT “N” values. The parameters used in the analyses are summarized in the following table:

<i>Soil Unit</i>	<i>Bulk Unit Weight</i>	<i>Elastic Modulus</i>
Embankment fill (range of parameters assumed for earth fill and granular fill)	20-22 kN/m <sup>3</sup>	—
Stiff to hard clayey silt till	21 kN/m <sup>3</sup>	40 MPa
Hard till/residual soil	21 kN/m <sup>3</sup>	150 MPa

Based on the above, the settlement of the foundation soils below these culverts as a result of the embankment loading is calculated to be approximately 5 mm to 20 mm. The majority of this compression is expected to occur within about three to six months of completion of the embankment construction. The greatest magnitude of settlement will occur where the culvert passes below the new high fill embankment for York Road. The maximum differential settlement, which is expected to be about 10 mm to 15 mm, will occur near the north and south toe of the new York Road high fill embankment; this differential settlement is expected to occur over a length of at least 5 m. West of this area under Highway 6, the maximum differential settlement is expected to be about 5 mm.

#### **6.2.4 Bedding and Backfill**

The bedding, backfill, and levelling pad requirements for the culverts should be in accordance with OPSD 803.010 and 803.020 for concrete box culverts.

The box culverts should be provided with a minimum of 300 mm of OPSS Granular “A” bedding, except for the portion of the culvert that extends south of York Road where subexcavation of approximately 1.5 m of very soft to soft surficial silty clay is required (as discussed in Section 6.2.1). The bedding should be placed and compacted in accordance with MTO’s Special Provision SP105S10.

Backfill to the culvert walls should consist of granular fill meeting the specifications for Ontario Provincial Standard Specification (OPSS) Granular “A” or Granular “B” Type II, but with less than 5 per cent passing the No. 200 sieve. The backfill should be placed and compacted in accordance with MTO’s Special Provision SP105S10. The fill depth during placement should be maintained equal on both sides of the culvert walls, with one side not exceeding the other by more than 500 mm.

Backfill above the culverts should also be carried out using Granular “A” or Granular “B” fill, to minimize differential settlements along the highway or ramp embankments that could arise as a result of the use of cohesive earth fill.

The culverts should be designed for the full overburden pressure and live load, assuming an embankment fill unit weight of 22 kN/m<sup>3</sup> for Granular “A” and 21 kN/m<sup>3</sup> for Granular “B” backfill above and surrounding the culvert.

### **6.2.5 Erosion Protection**

Consideration should be given to the use of suitable non-woven geotextile and rip-rap, clay seals or cut-off walls to provide erosion protection, based on the hydraulic requirements at the site.

In order to prevent surface water from flowing either beneath the culverts (potentially causing undermining and scouring) or around the culverts (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a clay seal or concrete cut-off wall could be provided at the upstream end of the new culvert at Station 10+615. If a clay seal is adopted, the clay material should meet the requirements of OPSS 1205, and the seal should be extended a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and a minimum vertical height equivalent to the high water level.

### **6.3 Retaining Wall at West End of Culvert at Station 10+615 (Highway 6)**

A new retaining wall is required along the N-EW Ramp at the west end of the new box culvert that is to be located at Station 10+615 (Highway 6), in order to prevent new embankment fills from encroaching on the Grindstone Creek channel and floodplain. The existing ground surface along the proposed retaining wall alignment varies from about Elevation 144.5 m to 147 m. The wall will be about 35 m in length and about 2 m to 4.5 m high relative to the existing ground surface.

It is understood that a concrete retaining wall is planned at this location. Based on the subsurface conditions at this site, it is recommended that the concrete retaining wall be supported on spread footings founded on the very stiff to hard clayey silt till deposit; since adequate bearing resistances and global stability can be achieved with the use of spread footings, and since shallow foundations are more cost-effective than deep foundations at this site, deep foundations are not recommended for support of this new concrete retaining wall.

#### **6.3.1 Spread Footings for Support of Concrete Wall**

Spread footings for this concrete retaining wall should be placed below the fill on the properly prepared, very stiff to hard clayey silt till deposit. Based on the borehole results, a maximum founding level of about Elevation 143 m may be taken for design of the footing in the immediate vicinity of the culvert (i.e. at the “low point”); this founding level must be checked to ensure that there is a minimum of 1.2 m of soil cover above the footing level, to provide adequate protection against frost penetration. Consideration could be given to stepping the footing upward toward the

north and south ends of the wall, where the existing ground surface is at about Elevation 146 m to 147 m, provided that the minimum frost depth requirement is met and that the clayey silt till deposit is present at founding level.

The factored geotechnical resistances at ULS and the geotechnical resistances at SLS (for 25 mm of settlement, due to the loading of the retaining wall footing and the N-EW Ramp embankment) given in the following table may be used for design of the spread footings placed on the properly prepared clayey silt till. Based on the expected wall height, a range of likely footing widths has been provided for assessment of the geotechnical resistance; these geotechnical resistances should be revisited if the foundation geometry differs from that provided in the table.

<i>Assumed Footing Width</i>	<i>Factored Geotechnical Resistance at ULS</i>	<i>Geotechnical Resistance at SLS *</i>
1 m	350 kPa	300 kPa
2 m	400 kPa	300 kPa
3 m	450 kPa	300 kPa

\* Under the loading of the retaining wall footing and N-EW Ramp embankment.

For the anticipated embankment and retaining wall loading (i.e., wall height of 2 m to 4.5 m), a maximum differential settlement of approximately 5 mm to 10 mm is predicted.

The geotechnical resistances provided above are given under the assumption that the loads will be applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the surface of the footing, inclination of the load should be taken into account in accordance with the *Canadian Highway Bridge Design Code (CHBDC)*.

Resistance to lateral forces / sliding resistance between the concrete footings and subsoils should be calculated in accordance with Section 6.7.5 of the *CHBDC*. The coefficient of friction,  $\tan \delta$ , may be taken as 0.45 for cast-in-place concrete footings constructed on the undisturbed, very stiff to hard clayey silt till. This represents an unfactored value; in accordance with the *CHBDC*, a factor of 0.8 is to be applied in calculating the horizontal resistance.

Slope stability analyses have been performed to assess the global stability of the N-EW embankment and retaining wall at this location. A factor of safety of greater than 1.3 is obtained for the proposed wall and embankment configuration.

#### **6.4 Retaining Wall Adjacent to Plains Road / York Road**

A new retaining wall is required along the east side of the future Plains Road embankment, extending along the crest of the Grindstone Creek valley from about Station 10+640 to 10+740 immediately south of York Road, and along the new York Road embankment to immediately east of the new culvert outlet, in order to prevent the new embankment fills from encroaching on the

Grindstone Creek channel and floodplain. This wall will be up to about 8 m high along Plains Road, and will vary from about 8 m to 9 m high at the west end of the wall along York Road, to about 2 m high at the east end of the retaining wall/headwall; these wall heights are relative to the existing ground surface along the wall alignments.

The subsoils along the proposed wall alignment generally consist of very stiff to hard clayey silt till, although the upper 0.5 m of the till has a less stiff consistency based on the measured SPT “N” values. However, as noted previously in Section 6.2 with respect to the outfall of the culvert at this site, there is up to about 1.5 m of very soft to soft surficial silty clay present immediately adjacent to the Grindstone Creek channel, as encountered in Borehole C-2003-04. Subexcavation of this very soft to soft material will be required to minimize settlement due to the embankment/wall loading and promote global stability of the embankment/wall in this area, and further discussion in this regard is provided in Sections 6.4.1 and 6.4.2.

Consideration has been given to two feasible wall types: a retained soil system (RSS) wall, or a concrete gravity wall founded on shallow spread footings; recommendations for both of these wall types are provided in the subsections that follow. Based on the subsoil conditions at the site (assuming subexcavation of the very soft to soft silty clay) and the wall heights of less than about 8 m, the most feasible wall type from a foundations perspective is an RSS wall. The base of the wall will be maintained above the normal creek water level and will generally be above the design flood level (Elevation 140 m) for this culvert outfall; it is anticipated that erosion protection can be provided in front of the wall where necessary to allow the use of an RSS wall at this site.

The loading due to the new Plains Road and York Road embankment, which will be about 4.5 m to 12 m high relative to the natural ground surface along the wall alignment, will induce some settlement in the very stiff to hard clayey silt till soils. The magnitude of the settlement is expected to vary from about 10 mm to 25 mm, with the lower magnitude of settlement near the south and east ends of the wall where the embankment and/or wall heights are lower, and the higher magnitude of settlement near the central/north end where the embankment and wall heights are higher; the maximum differential settlement will be about 15 mm, but this will occur gradually over a distance of more than several metres. It should be noted that these predicted settlements assume subexcavation of the upper 0.5 m of “stiff” clayey silt till or, where present, the very soft to soft surficial silty clay deposit; further comments on subexcavation are provided in both Sections 6.4.1 and 6.4.2.

#### **6.4.1 Retained Soil System (RSS) Wall**

Since the long-term settlements due to the embankment loading are estimated to be less than 25 mm (provided that the very soft to soft surficial silty clay immediately adjacent to the creek is subexcavated), the construction of a mechanically-reinforced soil retaining system (RSS wall) is

considered suitable for this site. The RSS wall consists of granular fill placed and compacted in layers and reinforced with metal or fabric strips or grids. A facing material, typically pre-cast concrete panels mechanically fastened to the reinforcing strips or grids, is used to form the face of the reinforced soil structure and to prevent the loss of fill material; these facing panels are supported on a strip footing.

Slope stability analyses have been carried out using the commercially available program SLOPE/W, produced by Geo-Slope International Ltd., employing the Morgenstern-Price method of analysis. The results of this analysis indicate that a factor of safety of 1.3 or greater is achieved during normal flow and the design flood for the highest wall section of about 8 m to 9 m, provided that the reinforced soil mass is at least 70 per cent of the height of the wall, and that the upper 0.5 m of stiff clayey silt till soil is subexcavated along the Plains Road wall alignment (i.e. that the reinforced soil mass is embedded 0.5 m depth relative to the current ground surface); as an alternative to this embedment, the width of the reinforced soil mass can be increased to 75 per cent of the wall height to ensure that a factor of safety of 1.3 against global instability is achieved. It is noted that the internal factor of safety must be checked by the designer/supplier of the RSS wall system.

As noted above, in order to minimize settlement and promote global stability of the RSS walls, the upper 0.5 m of topsoil and disturbed and/or stiff clayey silt till should be stripped from beneath the reinforced earth mass and the facing footing. In the immediate vicinity of the Grindstone Creek channel, the very soft to soft surficial silty clay should be removed from beneath the reinforced earth mass and the facing footing, down to Elevation 136.3 m; the area to be subexcavated should extend 5 m laterally on either side of the existing creek channel, and should be defined by lines extending from the outside edges of the reinforced earth mass outward and downward at 1 horizontal to 1 vertical. This subgrade should be inspected following subexcavation to ensure that all soft clayey materials have been removed, then the subexcavated area should be replaced with Granular "A" or Granular "B" backfill that is placed and compacted in accordance with the requirements of MTO's Special Provision SP105S10.

The facing footing should be supported on a levelling pad consisting of Granular "A" fill, with a thickness of at least 150 mm. It should be noted, however, that there is some potential for encountering softened/loosened soil below this depth along the facing footing, and provision should be made in the contract for subexcavation of such soils under the levelling pad and replacement with compacted Granular "A" fill.

Assuming that the RSS wall acts as a unit and utilizes the full width of the reinforced soil mass, which is taken as 70 per cent of the height of the wall, the following factored geotechnical resistances at ULS may be used for design of RSS walls founded on the properly prepared till deposit:

<b><i>RSS Wall Height</i></b>	<b><i>Assumed Reinforced Width</i></b>	<b><i>Factored Geotechnical Resistance at ULS</i></b>	<b><i>Geotechnical Resistance at SLS</i></b>
8 m	5.6 m	450 kPa	300 kPa
2 m	1.4 m	250 kPa	200 kPa

The resistance to lateral forces / sliding resistance between the compacted Granular “A” and the till subgrade should be calculated in accordance with Section 6.7.5 of the *CHBDC*. The coefficient of friction,  $\tan \delta$ , between the compacted Granular “A” of the RSS wall and the very stiff to hard clayey silt till may be taken as 0.55. This coefficient of friction represents an unfactored value; in accordance with the *CHBDC*, a factor of 0.8 is to be applied in calculating the horizontal resistance.

#### **6.4.2 Spread Footings for Support of Concrete Wall**

Spread footings for a concrete retaining wall at this location should be placed on the properly prepared, very stiff to hard clayey silt till deposit, a minimum of 1.2 m below the existing ground surface in order to extend below the upper stiff and/or disturbed till material that has been encountered in the boreholes. For the portion of the retaining wall along the York Road embankment in the immediate vicinity of the existing Grindstone Creek channel, the spread footings should extend below the very soft to soft surficial silty clay to be founded at a maximum elevation of 136.3 m. Since the ground surface elevation along the length of the proposed retaining wall varies, the spread footings could be stepped to minimize the depth of excavation required below existing ground surface, provided that the minimum cover of 1.2 m is maintained for frost protection purposes and that the subexcavation requirements noted above are met.

Slope stability analyses have been carried out using the commercially available program SLOPE/W, produced by Geo-Slope International Ltd., employing the Morgenstern-Price method of analysis. The results of this analysis indicate that a factor of safety against global instability of 1.4 is obtained for the highest wall section of about 8 m to 9 m height, based on a minimum 4 m wide wall footing founded at least 1.2 m below the lowest surrounding grade. This factor of safety is considered to be acceptable for the long-term stability of this embankment and wall configuration.

The following factored geotechnical resistances at ULS and geotechnical resistances at SLS may be used for design of spread footings founded on the properly prepared till deposit, taking into account the slope in front of the wall along the Plains Road alignment.

<b><i>Footing Width</i></b>	<b><i>Factored Geotechnical Resistance at ULS</i></b>	<b><i>Geotechnical Resistance at SLS</i></b>
3 m	300 kPa	250 kPa
4 m	350 kPa	250 kPa

These geotechnical resistances are given under the assumption that the loads will be applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the surface of the footing, inclination of the load should be taken into account in accordance with the *Canadian Highway Bridge Design Code (CHBDC)*.

Resistance to lateral forces / sliding resistance between the concrete footings and subsoils should be calculated in accordance with Section 6.7.5 of the *CHBDC*. The coefficient of friction,  $\tan \delta$ , may be taken as 0.45 for cast-in-place concrete footings constructed on the undisturbed, very stiff to hard clayey silt till. This represents an unfactored value; in accordance with the *CHBDC*, a factor of 0.8 is to be applied in calculating the horizontal resistance.

## **6.5 Retaining Wall Adjacent to EW-S Ramp**

A new retaining wall is required along the west side of the EW-S Ramp embankment immediately south of York Road, due to property constraints at this location. The existing ground surface along the proposed retaining wall alignment varies from about Elevation 146 m to 148 m, rising from the south to the north. The wall will be about 200 m in length (extending from approximately Station 9+840 to 10+143), and approximately 2 m to 3.5 m high relative to the existing ground surface.

### **6.5.1 Retained Soil System (RSS) Wall**

It is understood that a retained soil system (RSS) wall is planned at this location as part of the new EW-S Ramp construction, and this is considered to be the most practicable and cost-effective wall option at this location from a foundations perspective. The loading due to the new EW-S Ramps embankment/RSS wall, which will be up to about 3.5 m high, will result in up to about 40 mm of settlement within the clayey silt portion of the fill and the firm to stiff surficial silty clay deposit (where present), that extend to approximately 2 m to 3 m below the existing ground surface along the proposed wall alignment.

In order to minimize settlement and promote global stability of the RSS wall, the upper 3 m of the fill and surficial silty clay deposit should be subexcavated from beneath the reinforced earth mass and the facing footing. The subgrade should be inspected following subexcavation to ensure that all soft clayey materials have been removed, then the subexcavated area should be replaced with Granular "A" or "B" backfill that is placed and compacted in accordance with the requirements of MTO's Special Provision SP105S10. The facing footing should be supported on a levelling pad consisting of Granular "A" fill, with a thickness of at least 150 mm.

Assuming that the RSS wall acts as a unit and utilizes the full width of the reinforced soil mass, which is taken as 70 per cent of the height of the wall, the following factored geotechnical



resistances at ULS may be used for design of RSS walls founded on compacted Granular “A” or “B” fill following subexcavation of the existing fill and surficial silty clay:

<i><b>RSS Wall Height</b></i>	<i><b>Assumed Reinforced Width</b></i>	<i><b>Factored Geotechnical Resistance at ULS</b></i>	<i><b>Geotechnical Resistance at SLS</b></i>
3.5 m	2.5 m	250 kPa	200 kPa

The geotechnical resistance at SLS given in the table above is for 25 mm of settlement. For the proposed wall height of 2 m to 3.5 m, it is expected that the total settlement will be on the order of 10 mm to 15 mm, and the differential settlement along the length of the wall will be approximately 5 mm to 10 mm.

The resistance to lateral forces / sliding resistance between the compacted Granular “A” and the subgrade should be calculated in accordance with Section 6.7.5 of the *CHBDC*. The coefficient of friction,  $\tan \delta$ , between the compacted Granular “A” of the RSS wall and the compacted granular fill used following subexcavation may be taken as 0.65. This coefficient of friction represents an unfactored value; in accordance with the *CHBDC*, a factor of 0.8 is to be applied in calculating the horizontal resistance.

The internal stability of the mechanically-reinforced soil walls should be checked by the RSS supplier / designer. The Factor of Safety related to global stability for properly designed and constructed RSS walls at this site will be greater than 1.3, provided that the existing fill and the surficial silty clay to clayey silt deposit are subexcavated prior to construction of the wall.

## **6.6 Lateral Earth Pressures for Design**

The lateral earth pressures acting on concrete retaining walls, where adopted, will depend on the type and method of placement of the backfill materials, on the nature of the soils 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. 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 Ontario Provincial Standard Specifications (OPSS) Granular ‘A’ or Granular ‘B’ but with less than 5 per cent passing the 200 sieve should be used as backfill behind the walls. This fill should be placed and compacted in accordance with MTO’s Special Provision SP105S10. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements

with respect to sub-drains and frost taper should be in accordance with OPSD 3501.00 and 3504.00.

- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the wall stem, in accordance with *CHBDC* Section 6.9.3 and Figure 6.9.3. Compaction equipment should be used in accordance with MTO's Special Provision SP105S10. Other surcharge loadings should be accounted for in the design, as required.
- The granular fill may be placed either in a zone with width equal to at least 1.2 m behind the back of the wall stem (Case I in Figure C6.9.1(l) of the *Commentary to the CHBDC*) or within the wedge-shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing (Case II in Figure C6.9.1(l) of the *Commentary to the CHBDC*).
- For Case I, the pressures are based on the existing and proposed fill materials and the following parameters (unfactored) may be assumed:

Soil unit weight:	20 kN/m <sup>3</sup>
Coefficients of lateral earth pressure:	
Active, $K_a$	0.35
At rest, $K_o$	0.50

- For Case II, the pressures are based on the granular fill as placed and the following parameters (unfactored) may be assumed:

	<b>Granular 'A'</b>	<b>Granular 'B'</b>
		<b>Type II</b>
Soil unit weight:	22 kN/m <sup>3</sup>	21 kN/m <sup>3</sup>
Coefficients of lateral earth pressure:		
Active, $K_a$	0.27	0.27
At rest, $K_o$	0.43	0.43

- If the wall support allows lateral yielding of the stem, active earth pressures may be used in the geotechnical design of the structure. If the wall support does not allow lateral yielding, at-rest earth pressures should be assumed for geotechnical design.

## 6.7 Construction Considerations

### 6.7.1 Surface Water Control

Excavations for the new culverts and portions of the retaining wall foundations will extend below the Grindstone Creek level. The creek flow should be channelled using a temporary culvert, in conjunction with upstream/downstream cut-offs, to reduce the flow of water from the creek into the excavations and permit construction in dry conditions. Assuming that these measures are effective, any seepage into the excavation during normal creek flow conditions should be adequately controlled by pumping from properly filtered sumps.

Surface water should be directed away from the excavation area, to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade; further discussion on this aspect is provided in Section 6.7.3.

### **6.7.2 Excavations and Temporary Roadway Protection**

Temporary excavations for the culvert and retaining wall construction will extend through the existing Highway 6 and York Road embankment fill, the soft to firm surficial clayey silt to silty clay, and into the stiff to hard clayey silt till.

Excavations must be carried out in accordance with the guidelines outlined in the latest edition of the Occupational Health and Safety Act and Regulations for Construction Projects. The site soils are classified as Type 3 soil according to the OHSA. Where space permits, temporary open-cut excavations through these materials should be made with side slopes not steeper than 1 horizontal to 1 vertical (1H:1V).

Where temporary roadway protection is required, the temporary excavation support system should be designed and constructed in accordance with MTO's Special Provision SP105S19. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in SP105S19, provided that any utilities that may be present along Highway 6 or York Road adjacent to the excavation areas can tolerate 25 mm of deformation.

### **6.7.3 Subgrade Protection**

The clayey silt till that is exposed at the founding level will be susceptible to disturbance due to construction traffic and/or ponded water. An Operational Constraint (OC) or Non-Standard Special Provision (NSP) should be included in the Contract Documents to warn the contractor of this effect and limit detrimental conditions; in this regard, a working mat of lean concrete should be placed immediately after preparation and inspection of the footing subgrade.

## **7.0 CLOSURE**

This Foundation Design Report was prepared by Ms. Lisa Coyne, P.Eng., an Associate and Senior Engineer with Golder. Mr. Fintan J. Heffernan, P.Eng., a Designated MTO Contact for Golder, conducted an independent review of the report.

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## 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.) drive open sampler for a distance of 300 mm (12 in.)

#### (b) Cohesive Soils

Consistency	$c_{us}$	$s_u$
	<b>kPa</b>	<b>psf</b>
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

#### 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
in 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
*	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 (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

PROJECT 001-1141F		RECORD OF BOREHOLE No C-2003-01				1 OF 1		METRIC										
W.P. 19-95-00		LOCATION N 4795862.2 ; E 271801.5				ORIGINATED BY PKS												
DIST Central HWY 6		BOREHOLE TYPE Continuous Split-Spoon Sampling				COMPILED BY LCC												
DATUM Geodetic		DATE May 7, 2003				CHECKED BY LCC												
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	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)
149.2	Ground Surface							20	40	60	80	100						
0.0	Clayey Silt, trace to some sand, trace organics Soft to firm Brown Moist to wet		1	SS	2	149												
148.3			2	SS	6													
0.9	Clayey Silt, trace sand and gravel (TILL) Stiff to Hard Brown Moist		3	SS	40													
147.4						148												
1.8	End of Borehole																	
Notes: 1. Water level in open borehole at 0.1 m depth (Elev. 149.1 m) on completion of drilling. 2. Borehole advanced using portable drilling equipment with a half-weight hammer. The SPT "N" values have been adjusted on this log to reflect the value that would be obtained using a standard-weight hammer.																		

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PROJECT <u>001-1141F</u>		<b>RECORD OF BOREHOLE No C-2003-02</b>		1 OF 1	<b>METRIC</b>
W.P. <u>19-95-00</u>		LOCATION <u>N 4795761.2 ; E 271973.8</u>		ORIGINATED BY <u>PKS</u>	
DIST <u>Central</u> HWY <u>6</u>		BOREHOLE TYPE <u>Continuous Split-Spoon Sampling</u>		COMPILED BY <u>LCC</u>	
DATUM <u>Geodetic</u>		DATE <u>May 6, 2003</u>		CHECKED BY <u>LCC</u>	

SOIL PROFILE				SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT  γ  kN/m³	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 × REMOULDED			WATER CONTENT (%) w <sub>p</sub> w w <sub>L</sub>							
141.7	Ground Surface															
0.0	Silty Clay, trace sand and gravel, trace organics and rootlets Firm Brown Moist		1	SS	5		141									
140.5			2	SS	5											
1.2	Clayey Silt, trace sand and gravel (TILL) Stiff Brown to grey-brown Moist		3	SS	13											
139.9	Brown to grey-brown Moist						140									
1.8	End of Borehole															
<div>Notes:</div> <div>1. Water level in open borehole at about 0.3 m depth (Elev. 141.4 m) on completion of drilling.</div> <div>2. Borehole advanced using portable drilling equipment with a half-weight hammer. The SPT "N" values have been adjusted on this log to reflect the value that would be obtained using a standard-weight hammer.</div>																

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<b>PROJECT</b> 001-1141F		<b>RECORD OF BOREHOLE No C-2003-03</b>		1 OF 1	<b>METRIC</b>
<b>W.P.</b> 19-95-00		<b>LOCATION</b> N 4795771.7 :E 272029.4		<b>ORIGINATED BY</b> PKS	
<b>DIST</b> Central HWY 6		<b>BOREHOLE TYPE</b> 108 mm Diameter Solid Stem Augers		<b>COMPILED BY</b> LCC	
<b>DATUM</b> Geodetic		<b>DATE</b> June 16, 2003		<b>CHECKED BY</b> LCC	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								20 40 60 80 100		20 40 60 80 100	10 20 30			
145.8	Ground Surface													
0.0	Asphalt													
0.2	Sand and gravel (FILL)													
145.2														
0.6	Silty clay, trace to some sand and gravel (FILL) Firm to very stiff Brown Moist		1	SS	16									
			2	SS	7									
143.2			3	SS	5									
2.6	Silty Clay, some sand, trace gravel, trace organics													
142.8	Firm													
3.1	Dark brown / black Moist		4	SS	25									
	Clayey Silt, trace sand and gravel, containing shale pieces (TILL) Very stiff to hard Red-brown Moist		5	SS	34									
			6	SS	53									
			7	SS	25									
138.8														
7.0	Clayey Silt, trace sand and gravel, containing shale and limestone pieces (TILL/RESIDUAL SOIL) Hard Red Dry to moist		8	SS	49									
			9	SS	50/05									
134.8														
11.0	End of Borehole		10	SS	90/15									
	Notes:  1. Borehole dry on completion of drilling.													

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PROJECT <u>001-1141F</u>		<b>RECORD OF BOREHOLE No C-2003-04</b>		1 OF 1	<b>METRIC</b>
W.P. <u>19-95-00</u>		LOCATION <u>N 4795733.6 ; E 272053.6</u>		ORIGINATED BY <u>PKS</u>	
DIST <u>Central</u> HWY <u>6</u>		BOREHOLE TYPE <u>Continuous Split-Spoon Sampling</u>		COMPILED BY <u>LCC</u>	
DATUM <u>Geodetic</u>		DATE <u>May 6, 2003</u>		CHECKED BY <u>LCC</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m³	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 × REMOULDED		WATER CONTENT (%) W <sub>P</sub> W W <sub>L</sub>						
137.8	Ground Surface						137									
0.0	Silty Clay, trace to some sand and gravel, containing organics, wood pieces, and pockets of sand Very soft to firm Brown Wet		1	SS	1											
			2	SS	3											
136.4		3	SS	25/15												
1.5	Clayey Silt, trace sand and gravel, containing shale and limestone pieces (TILL) Hard Red Moist End of Borehole  Notes:  1. Water level in open borehole at 0.6 m depth (Elev. 137.2 m) on completion of drilling.  2. Borehole advanced using portable drilling equipment with a half-weight hammer. The SPT "N" values have been adjusted on this log to reflect the value that would be obtained using a standard-weight hammer.															

PROJECT <u>001-1141F</u>		<b>RECORD OF BOREHOLE No C-2004-01</b>		1 OF 1	<b>METRIC</b>
W.P. <u>19-95-00</u>		LOCATION <u>N 4795738.0; E 271894.0</u>		ORIGINATED BY <u>PKS</u>	
DIST <u>Central</u> HWY <u>6</u>		BOREHOLE TYPE <u>108mm Diameter Solid Stem Augers</u>		COMPILED BY <u>KG</u>	
DATUM <u>Geodetic</u>		DATE <u>November 9, 2004</u>		CHECKED BY <u>LCC</u>	

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 + FIELD VANE ● QUICK TRIAXIAL × REMOULDED												
144.8	Ground Surface																			
0.0	Clayey Silt, some sand, trace gravel, organics, topsoil and wood (FILL) Stiff Brown Moist		1	SS	11		144													
			2	SS	9															
143.3	Clayey Silt, some sand, trace gravel, shale and limestone fragments (TILL) Brown to red-brown Very stiff to hard Moist		3	SS	36			143												
1.5			4	SS	38															
			5	SS	29															
			6	SS	33															
			7	SS	120															
139.6	End of Borehole																			
5.2	Notes:  1. Open hole dry upon completion of drilling.																			

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<b>PROJECT</b> 001-1141F		<b>RECORD OF BOREHOLE No C-3</b>		1 OF 1	<b>METRIC</b>
<b>W.P.</b> 19-95-00		<b>LOCATION</b> N 4795753.1; E 271931.1		<b>ORIGINATED BY</b> PKS	
<b>DIST</b> Central HWY 6		<b>BOREHOLE TYPE</b> 108mm Diameter Solid Stem Augers		<b>COMPILED BY</b> LCC	
<b>DATUM</b> Geodetic		<b>DATE</b> November 19, 2002		<b>CHECKED BY</b> LCC	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)					
								20 40 60 80 100					w <sub>p</sub> w w <sub>L</sub>					
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED												
148.0	Ground Surface																	
0.0	Asphalt																	
0.2	Sand and gravel (FILL)																	
147.4	Compact																	
0.6	Brown																	
	Moist																	
	Clayey silt, some sand and gravel (FILL)						147											
	Soft to firm																	
	Brown to grey-brown																	
	Moist		1	SS	3													
							146											
			2	SS	5		145											
							144											
			3	SS	6		143											
142.7																		
5.3	Clayey Silt, trace sand and gravel (TILL)		4	SS	6		142											
	Firm to hard																	
	Grey to red-brown		5	SS	29													
	Moist						141											
			6	SS	21													
							140											
			7	SS	22		139											
							138											
			8	SS	29													
136.9	End of Borehole		9	SS	46		137											
11.1	End of Borehole																	
	Note:																	
	Borehole dry on completion of drilling.																	

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PROJECT 001-8059		RECORD OF BOREHOLE No NW-7		1 OF 1		METRIC							
W.P. 19-95-00		LOCATION N 4795513.3; E 272096.8		ORIGINATED BY GD									
DIST Central HWY 6		BOREHOLE TYPE 108 mm Diameter Solid Stem Augers		COMPILED BY KG									
DATUM Geodetic		DATE Sept. 22, 2003		CHECKED BY LCC									
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					
145.4	GROUND SURFACE						20 40 60 80 100						
0.0	Topsoil		1	SS	11								
0.2	Sand and gravel, trace silt (FILL)												
144.8	Compact Brown Moist												
0.6	Clayey silt, trace to some sand, trace gravel, trace organics (FILL)		2	SS	12								
	Firm to stiff Brown Moist		3	SS	5								
			4	SS	9								
142.4	Clayey Silt to Silty Clay, trace sand and gravel, containing shale fragments (TILL)		5	SS	17								
3.1	Very stiff to hard Brown Moist		6	SS	29								
			7	SS	41								
			8	SS	36								
	Becoming grey-brown below 6.1 m depth		9	SS	26								
			10	SS	25								
			11	SS	24								
	Becoming red-brown below 12.2 m depth		12	SS	50								
132.6	End of Borehole												
12.8	Notes:  1. Open hole dry upon completion of drilling operations.  2. Water level in piezometer at 1.4 m depth (Elev. 144.0 m) on November 1, 2003.												

MISS\_MTO 001-8059 HWY6 NOISE BARRIER WALL.GPJ ON MOT.GDT 24/1/05

PROJECT 001-8059			<b>RECORD OF BOREHOLE No NW-8</b>			1 OF 1		<b>METRIC</b>							
W.P. 19-95-00			LOCATION N 4795536.1 ; E 272025.1			ORIGINATED BY GD									
DIST Central HWY 6			BOREHOLE TYPE 108 mm Diameter Solid Stem Augers			COMPILED BY KG									
DATUM Geodetic			DATE Sept. 23, 2003			CHECKED BY LCC									
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 × REMOULDED							
146.3	GROUND SURFACE														
0.0	Crushed limestone (FILL)		1	SS	12										
145.9	Compact Brown Moist														
0.4	Clayey silt, some sand, trace gravel, trace organics (FILL)		2	SS	6										
145.2	Stiff to firm Brown and grey Moist														
1.1	Silty Clay, trace sand and gravel, trace organics		3	SS	3										
144.2	Soft to firm Mottled grey-brown Moist														
2.1	Clayey Silt to Silty Clay, some sand, trace gravel, containing shale fragments (TILL)		4	SS	26										
	Very stiff to hard Grey-brown to grey Moist		5	SS	35										
			6	SS	34										
			7	SS	35										
			8	SS	33										
139.8	End of Borehole														
6.6	Notes:  1. Water level at 5.8 m depth (Elev. 140.5 m) upon completion of drilling operations.														

**RECORD OF BOREHOLE No RW-1**

1 OF 2

**METRIC**

PROJECT 001-1141F

W.P. 19-95-00

LOCATION N 4795657.1 : E 272113.9

ORIGINATED BY GPD

DIST Central HWY 6

BOREHOLE TYPE 108mm Diameter Solid Stem Augers

COMPILED BY LCC

DATUM Geodetic

DATE September 18-22, 2003

CHECKED BY LCC

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						
145.7	Ground Surface							20 40 60 80 100						
8.9	Topsoil							○ UNCONFINED + FIELD VANE						
	Clayey Silt, trace to some sand, trace gravel (TILL)		1	SS	11			● QUICK TRIAXIAL × REMOULDED						
	Stiff to hard		2	SS	27									
	Brown		3	SS	29									
	Dry to moist		4	SS	29									
	Becoming grey-brown at 3.8 m depth		5	SS	19									5 8 51 36
			6	SS	27									
			7	SS	17									1 9 53 37
			8	SS	32									
			9	SS	50									
	Becoming reddish-grey at 9.1 m depth		10	SS	46									
135.5	Clayey Silt, some sand, trace to some gravel, shale and limestone fragments (TILL / RESIDUAL SOIL)		11	SS	67/15									
10.2	Hard Grey to red-brown Dry to moist		12	SS	66									
			13	SS	103									13 21 56 10

Continued Next Page

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


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PROJECT <u>001-1141F</u>		RECORD OF BOREHOLE <b>No RW-1</b>		2 OF 2		<b>METRIC</b>													
W.P. <u>19-95-00</u>		LOCATION <u>N 4795657.1 , E 272113.9</u>		ORIGINATED BY <u>GPD</u>															
DIST <u>Central</u> HWY <u>6</u>		BOREHOLE TYPE <u>108mm Diameter Solid Stem Augers</u>		COMPILED BY <u>LCC</u>															
DATUM <u>Geodetic</u>		DATE <u>September 18-22, 2003</u>		CHECKED BY <u>LCC</u>															
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED			WATER CONTENT (%) W <sub>p</sub> — W — W <sub>L</sub>			γ kN/m <sup>3</sup>			GR SA SI CL		
130.3	--- CONTINUED FROM PREVIOUS PAGE ---							20 40 60 80 100											
15.4	End of Borehole  Notes: 1. Borehole dry on completion of drilling operations. 2. Water level in piezometer measured at 9.7m depth (Elevation 136.0m) on November 1, 2003.		14	SS	57/15		130												

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PROJECT <u>001-1141F</u>		<b>RECORD OF BOREHOLE No RW-2</b>		1 OF 1	<b>METRIC</b>
W.P. <u>19-95-00</u>		LOCATION <u>N 4795698.2 ; E 272086.6</u>		ORIGINATED BY <u>GPD</u>	
DIST <u>Central</u> HWY <u>6</u>		BOREHOLE TYPE <u>Continuous Split-Spoon Sampling</u>		COMPILED BY <u>LCC</u>	
DATUM <u>Geodetic</u>		DATE <u>September 5, 2003</u>		CHECKED BY <u>LCC</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	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 × REMOULDED		WATER CONTENT (%) w <sub>p</sub> w w <sub>L</sub>				
143.5	Ground Surface													
0.0	Clayey Silt, trace sand and gravel (TILL) Stiff to hard Brown Dry to moist		1	SS	13									
			2	SS	35									
			3	SS	72									
141.5														
2.0	End of Borehole													
	Notes:  1. Borehole dry on completion of drilling operations.  2. Borehole advanced using portable drilling equipment with a half-weight hammer. The SPT "N" values have been adjusted on this log to reflect the value that would be obtained using a standard-weight hammer.													

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PROJECT <u>001-1141F</u>		<b>RECORD OF BOREHOLE</b>		<b>No RW-2A</b>	1 OF 1	<b>METRIC</b>
W.P. <u>19-95-00</u>	LOCATION <u>N 4795692.4 ; E 272073.9</u>	ORIGINATED BY <u>GPD</u>				
DIST <u>Central</u> HWY <u>6</u>	BOREHOLE TYPE <u>108mm Diameter Solid Stem Augers</u>	COMPILED BY <u>LCC</u>				
DATUM <u>Geodetic</u>	DATE <u>September 22, 2003</u>	CHECKED BY <u>LCC</u>				

[illegible]

MISS\_MTO 0011141FAAMTO.GPJ ON\_MOT.GDT 14/3/05

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

<b>PROJECT</b> 001-1141F		<b>RECORD OF BOREHOLE No RW-3</b>		1 OF 1	<b>METRIC</b>
<b>W.P.</b> 19-95-00		<b>LOCATION</b> N 4795728.7 ; E 272049.3		<b>ORIGINATED BY</b> GPD	
<b>DIST</b> Central <b>HWY</b> 6		<b>BOREHOLE TYPE</b> Continuous Split-Spoon Sampling		<b>COMPILED BY</b> LCC	
<b>DATUM</b> Geodetic		<b>DATE</b> September 5, 2003		<b>CHECKED BY</b> LCC	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
140.3	Ground Surface													
0.0	Clayey Silt, trace sand and gravel (TILL) Stiff to very stiff Brown Dry to moist		1	SS	8									
			2	SS	23									
138.5			3	SS	31/15									
1.8	End of Borehole													
	Notes:  1. Borehole dry on completion of drilling operations.  2. Borehole advanced using portable drilling equipment with a half-weight hammer. The SPT "N" values have been adjusted on this log to reflect the value that would be obtained using a standard-weight hammer.													

MISS\_MTO\_0011141FAAMTO.GPJ ON MOT.GDT 14/3/05

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

CONT No.  
WP No. 19-95-01

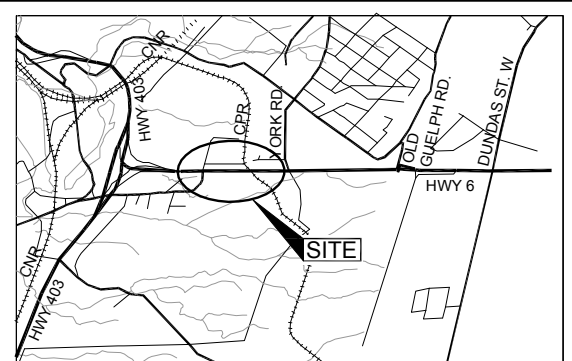


HIGHWAY 6  
CULVERTS AND RETAINING WALLS  
BOREHOLE LOCATION PLAN

SHEET



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



KEY PLAN  
SCALE  
500 0 500 1000m  
APPROX.

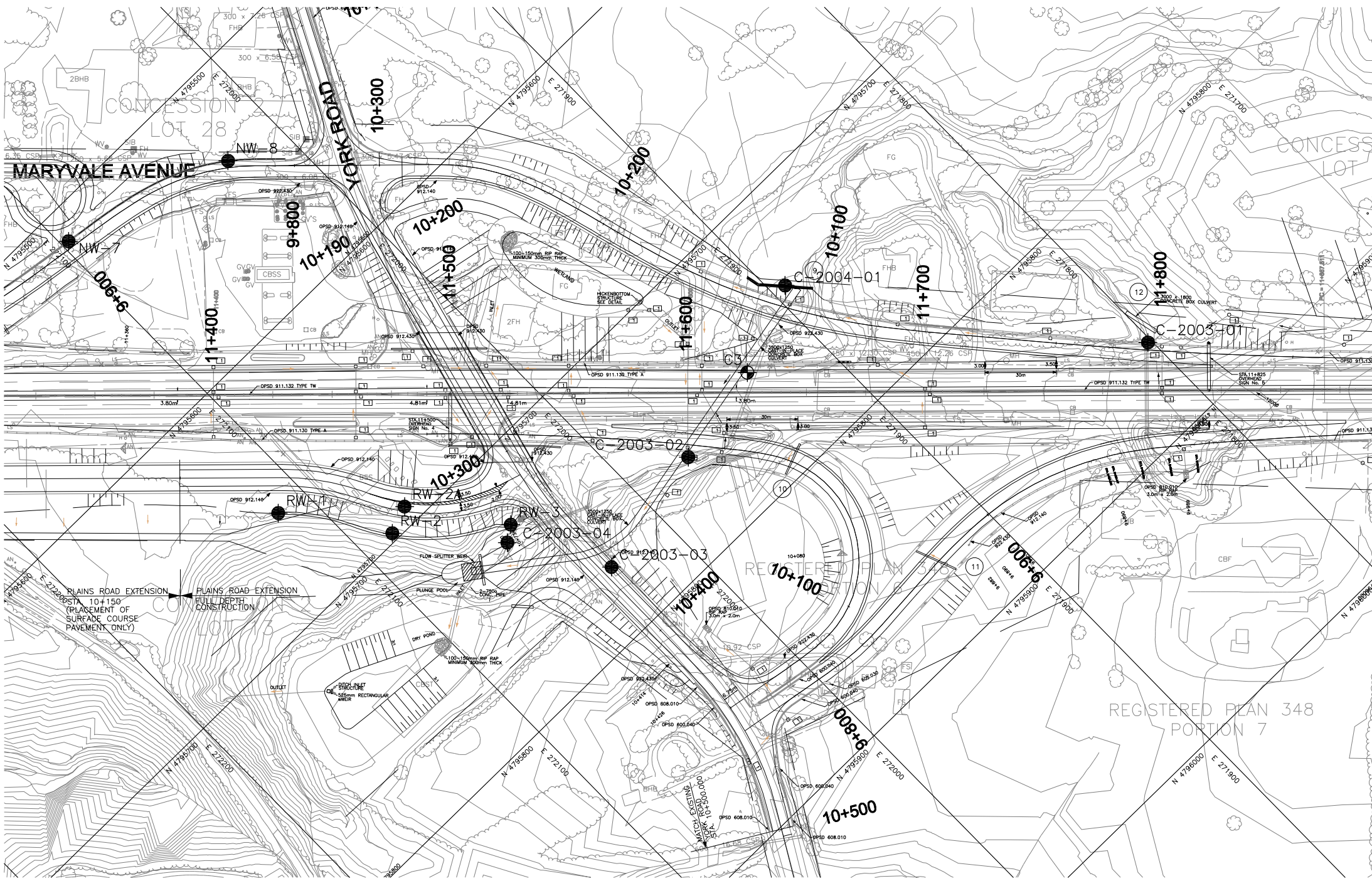
LEGEND

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
C-2003-01	149.2	4795862.2	271801.5
C-2003-02	141.7	4795761.2	271973.8
C-2003-03	145.8	4795771.7	272029.4
C-2003-04	137.8	4795733.6	272053.6
C-2004-01	144.8	4795738.0	271894.0
C3	148.0	4795753.1	271931.1
NW-7	145.4	4795513.3	272096.9
NW-8	146.3	4795536.1	272025.1
RW-1	145.7	4795657.1	272113.9
RW-2	143.5	4795698.2	272086.6
RW-2A	147.1	4795692.4	272073.9
RW-3	140.3	4795728.7	272049.3

REFERENCE

Base plans provided in digital format by URS Canada Inc., drawing received on September 30, 2004.

NO.	DATE	BY	REVISION
Geocres No.			
HWY. 6		PROJECT NO. 001-1141F(6)	DIST.
SUBM'D. KG	CHKD. LCC	DATE: JUNE 2005	SITE:
DRAWN: MSM	CHKD. PKS	APPD. LCC	DWG. 1



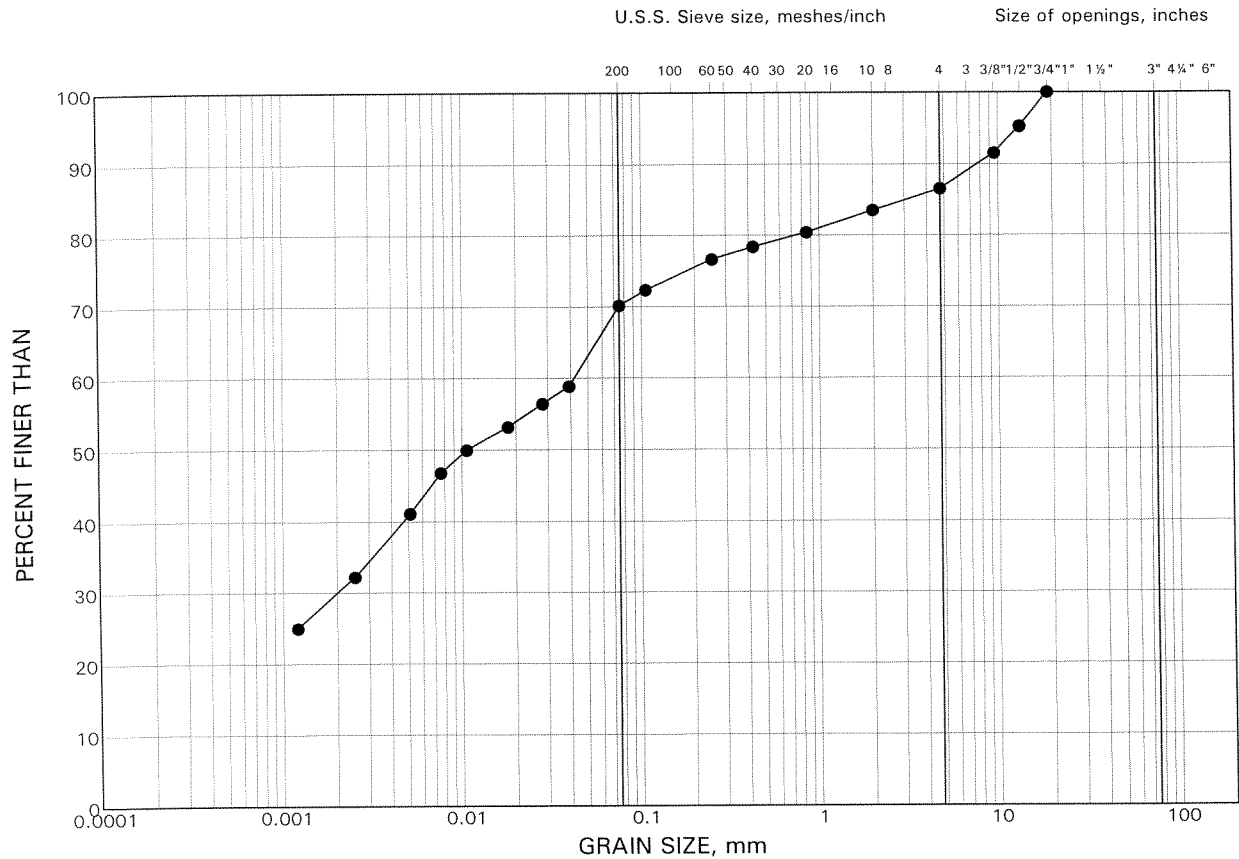
PLAN

SCALE  
20 0 20 40 m

# GRAIN SIZE DISTRIBUTION TEST RESULT

Surficial Clayey Silt to Silty Clay

FIGURE 1

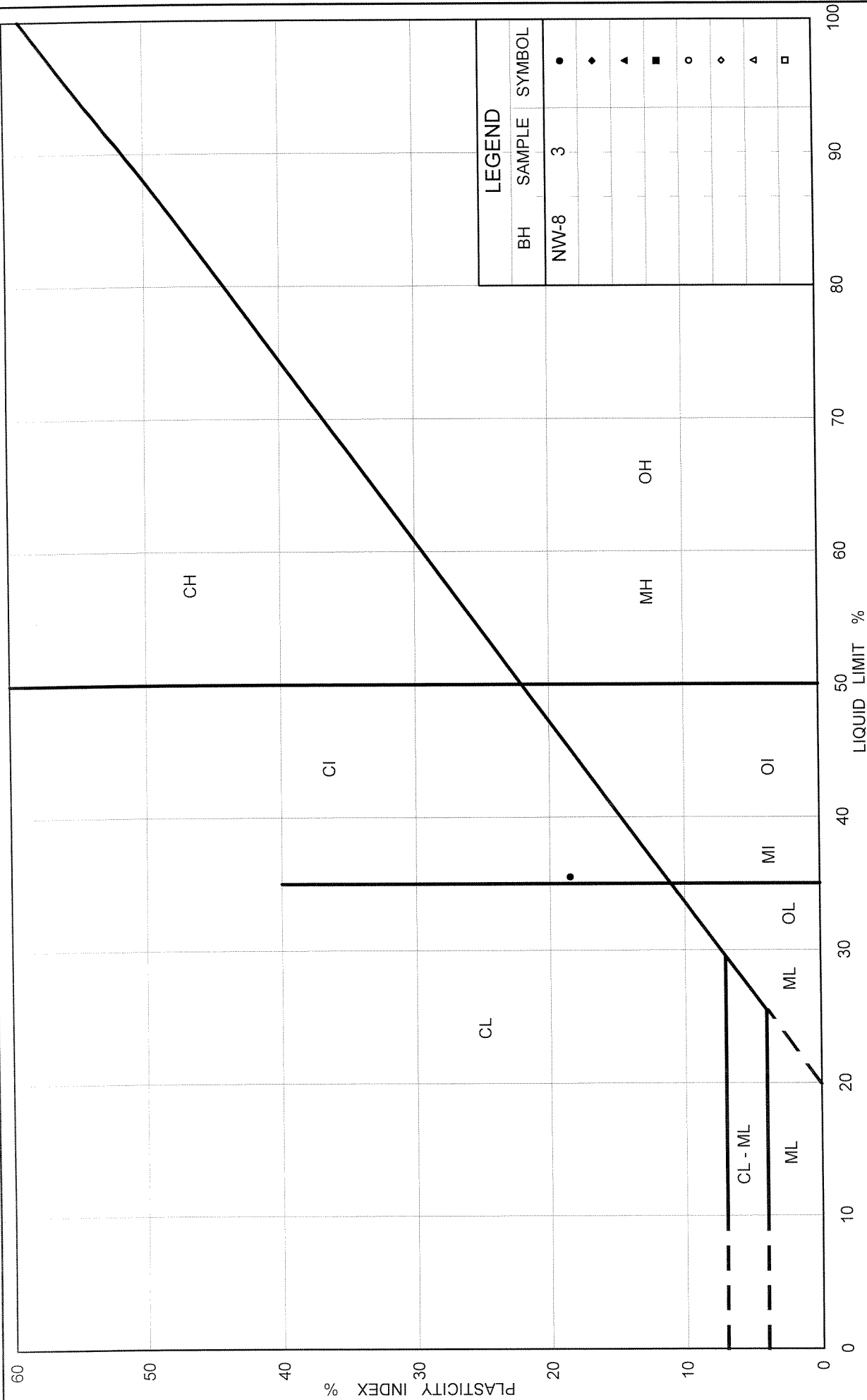


SILT AND CLAY SIZES		FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED		SAND SIZE			GRAVEL SIZE		SIZE

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	NW-8	3	144.5





LEGEND		
BH	SAMPLE	SYMBOL
NW-8	3	•
		◆
		▲
		■
		○
		◇
		△
		□

Ministry of Transportation  
Ontario

**FIG No. 2**

**PLASTICITY CHART**

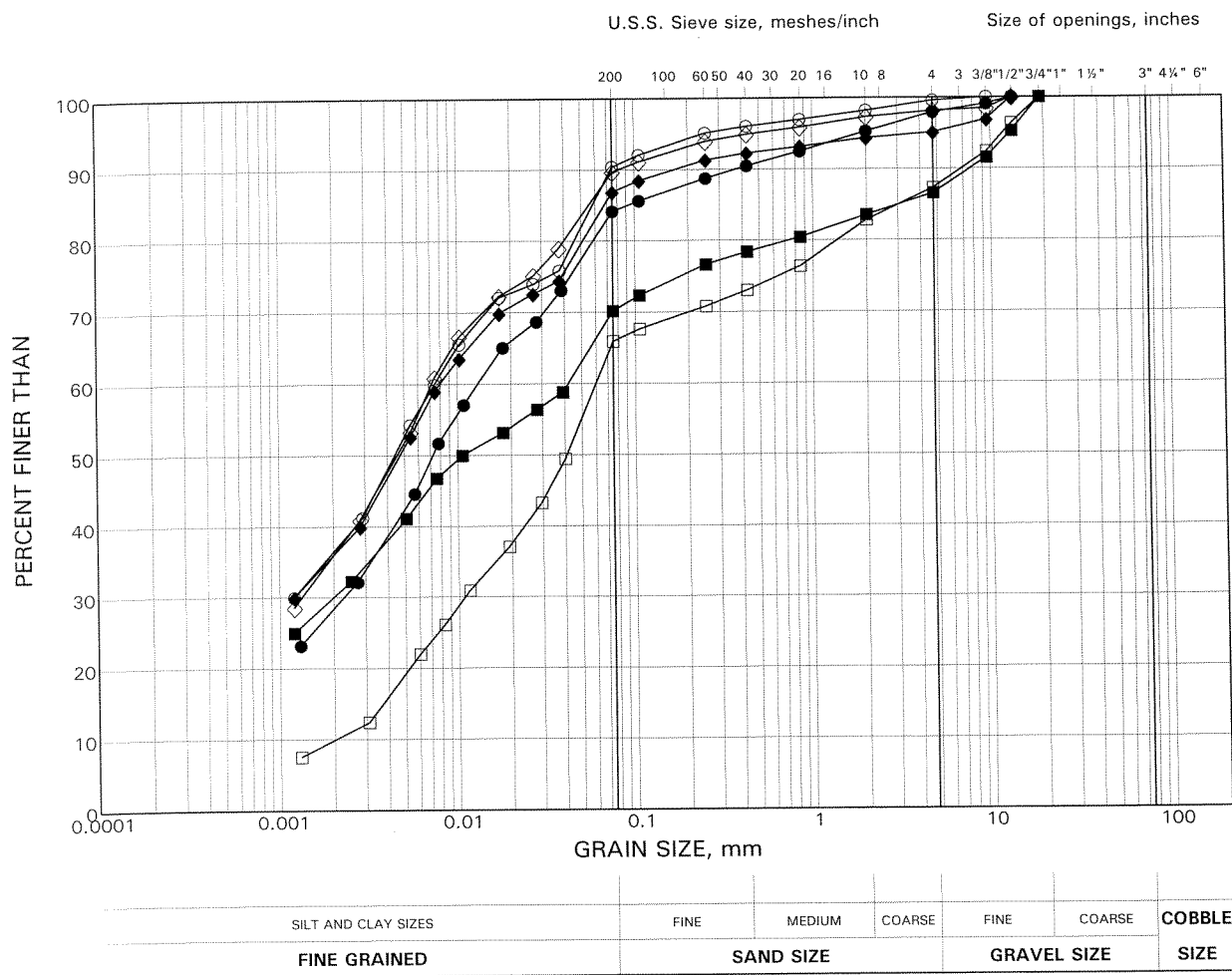
**Surficial Clayey Silt to Silty Clay**

Project No. 001-1141F

# GRAIN SIZE DISTRIBUTION TEST RESULTS

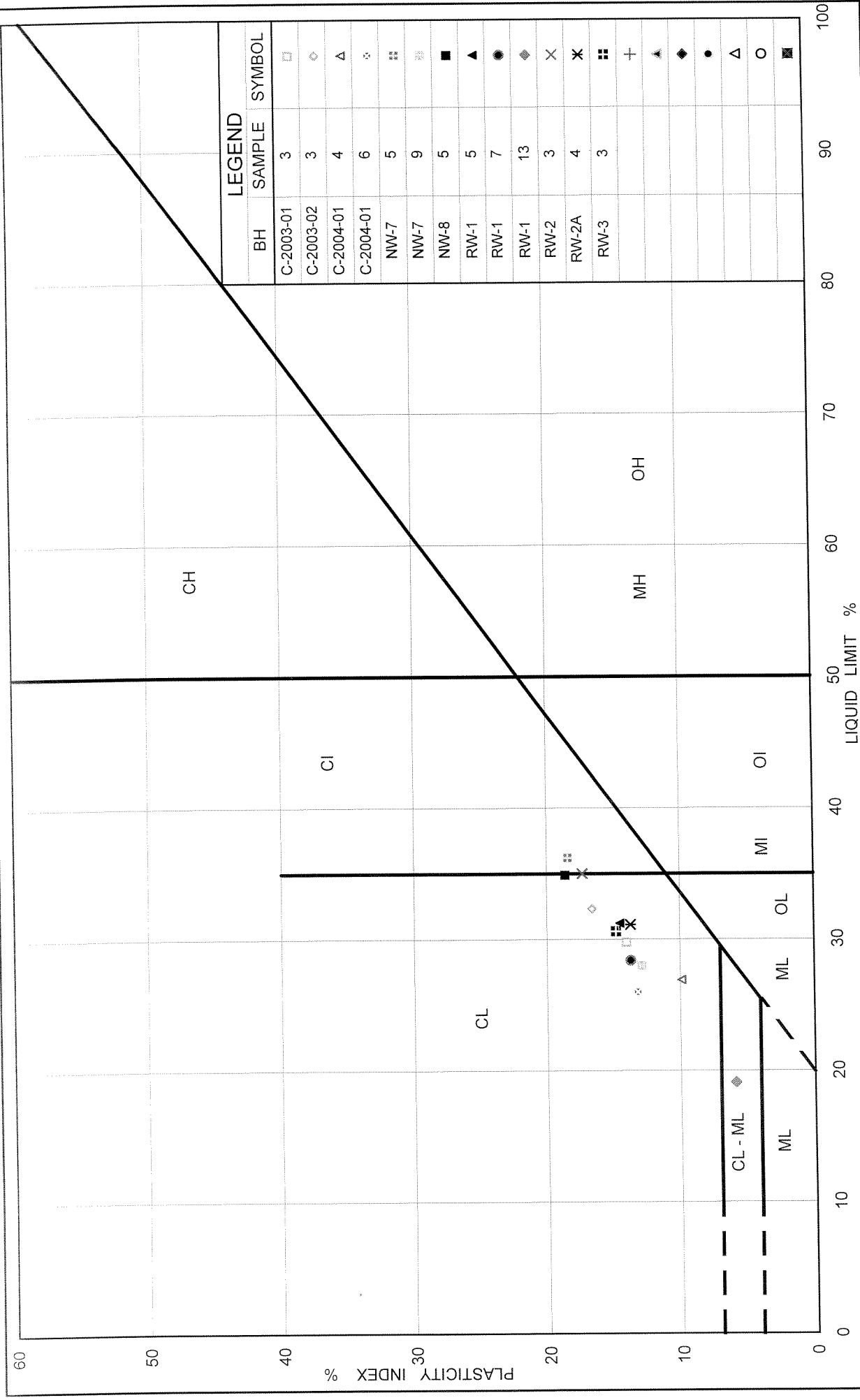
Clayey Silt Till and Till / Residual Soil

FIGURE 3



## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	C-2004-1	4	142.2
■	NW-8	3	144.5
◆	RW-1	5	142.4
○	RW-1	7	140.8
□	RW-1	13	131.7
◇	RW-2A	4	144.5



Ministry of Transportation

Ontario

**PLASTICITY CHART**

Clayey Silt Till and Till / Residual Soil

FIG No. 4

Project No. 001-1141F