

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
HIGHWAY 401 UNDERPASS AT NORWICH AVENUE  
CITY OF WOODSTOCK, ONTARIO  
SITE 23-170, G.W.P. 3054-13-00**

**GEOCRES No.: 40P2-78**

**Report to  
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## TABLE OF CONTENTS

### **PART 1        FACTUAL INFORMATION**

<b>1</b>	<b>INTRODUCTION .....</b>	<b>1</b>
<b>2</b>	<b>SITE DESCRIPTION .....</b>	<b>1</b>
<b>3</b>	<b>SITE INVESTIGATION AND FIELD TESTING.....</b>	<b>2</b>
<b>4</b>	<b>LABORATORY TESTING.....</b>	<b>3</b>
<b>5</b>	<b>DESCRIPTION OF SUBSURFACE CONDITIONS .....</b>	<b>3</b>
5.1	Pavement Structure .....	4
5.2	Topsoil .....	5
5.3	Embankment Fill .....	5
5.4	Sandy Silt/Silt to Sand .....	6
5.5	Silty Clay to Clayey Silt .....	7
5.6	Sandy Silt to Silty Sand Till .....	8
5.7	Silty Clay Till .....	9
5.8	Groundwater Levels.....	10
5.9	Analytical Testing.....	11
<b>6</b>	<b>MISCELLANEOUS.....</b>	<b>12</b>
<b>7</b>	<b>INTRODUCTION .....</b>	<b>13</b>

### **PART 2        ENGINEERING DISCUSSION AND RECOMMENDATIONS**

<b>8</b>	<b>STRUCTURE FOUNDATIONS.....</b>	<b>14</b>
8.1	Spread Footings Bearing on Native Soil.....	14
8.2	Spread Footings Bearing on Engineered Fill .....	15
8.3	Caissons .....	16
8.4	Steel H-Pile Foundations .....	17
8.4.1	Axial Resistance .....	17
8.4.2	Downdrag .....	18
8.4.3	Pile Driving .....	18
8.4.4	Pile Tips.....	18
8.4.5	Abutment Type.....	19
8.4.6	Pile Lateral Resistance .....	19
8.5	Frost Cover .....	21
8.6	Recommended Foundation .....	22
<b>9</b>	<b>BACKFILL TO ABUTMENTS.....</b>	<b>22</b>
<b>10</b>	<b>EARTH PRESSURE .....</b>	<b>22</b>
<b>11</b>	<b>SEISMIC CONSIDERATIONS.....</b>	<b>23</b>
11.1	Seismic Design Parameters.....	23
11.2	Dynamic Earth Pressures .....	23
11.3	Liquefaction Potential.....	24
<b>12</b>	<b>REALIGNMENT OF EMBANKMENTS .....</b>	<b>24</b>

12.1	Norwich Avenue Realignment.....	24
12.1.1	Slope Stability .....	25
12.1.2	Embankment Settlements .....	26
12.2	Re-grading of Pattullo Avenue West .....	27
12.3	Subgrade Preparation and Embankment Construction .....	28
<b>13</b>	<b>EXCAVATION AND GROUNDWATER CONTROL .....</b>	<b>28</b>
<b>14</b>	<b>PROTECTION SYSTEM.....</b>	<b>29</b>
<b>15</b>	<b>CEMENT TYPE.....</b>	<b>29</b>
<b>16</b>	<b>CONSTRUCTION CONCERNS .....</b>	<b>29</b>
<b>17</b>	<b>CLOSURE.....</b>	<b>31</b>

## APPENDICES

Appendix A	Record of Borehole Sheets
Appendix B	Laboratory Test Results
Appendix C	Analytical Test Results
Appendix D	Site Photographs
Appendix E	Borehole Location and Soil Strata Drawings
Appendix F	Previous Investigation, Borehole Locations and Soil Strata Drawing and Record of Borehole Sheets, Geocres No.: 40P2-45
Appendix G	Comparison of Foundation Alternatives
Appendix H	List of Specifications and Suggested Text for NSSP and Monitoring Plan
Appendix I	Slope Stability Analyses Results
Appendix J	Figure 1, Abutment on Compacted Fill

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**GEOCRES No.: 40P2-78**

**PART 1: FACTUAL INFORMATION**

**1 INTRODUCTION**

This report presents the results of a foundation investigation completed at the location of a proposed replacement of the Highway 401 Underpass at Norwich Avenue (Highway 59) near Woodstock, Ontario. The replacement of the Norwich Avenue structure constitutes part of the Highway 401 improvement project.

The purpose of this investigation was to explore the subsurface conditions at the project site and, based on the data obtained and available archive data, to provide a borehole location plan, records of boreholes, stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions presented in the report was developed from the compilation of data obtained in the course of the current and previous investigations.

A previous foundation investigation was carried out at this site in 1990 for the then proposed widening of Highway 401. The results of the investigation were documented in the MTO report titled "Foundation Investigation and Design Report for Highway 59 Underpass and Athlone Avenue (N/S-W Ramp), W.P. 481-89-03, Site 23-170, Highway 401, District 2, London, GEOCRES 40P2-45", dated September, 1990. The information presented in the above noted report was reviewed and incorporated in this report. Relevant Record of Borehole sheets and the Borehole Location and Soil Strata drawing are enclosed in Appendix F, for reference.

Thurber Engineering Ltd. (Thurber) carried out the investigation as a sub-consultant to MMM Group Limited (MMM) under the Ministry of Transportation (MTO) Agreement Number 3013-E-0027.

**2 SITE DESCRIPTION**

The site of the underpass is located at the intersection of Highway 401 and Norwich Avenue (Highway 59), south of the City of Woodstock. At the project site, Norwich Avenue runs generally in the north-south direction and Highway 401 runs in the west-east direction. The existing bridge is a single span structure approximately 33 m in length and accommodates two lanes of traffic in each

direction; with the middle lane used for left-turn traffic immediately north and south of the structure. The existing interchange ramps are in a diamond configuration.

The surrounding land use generally consists of a mixture of commercial properties to the west, north and east of the project site with agricultural land and a golf course located to the south.

Photographs of the bridge and surrounding area are presented in Appendix D.

The topography of the site is generally undulating with drumlins to the south and southeast. The site is situated in the Physiographic Region known as the Oxford Till Plain characterized by drumlinized till deposits. The surficial deposits contain mainly silt with variable amounts of clay, sand and gravel particles.

### **3 SITE INVESTIGATION AND FIELD TESTING**

The site investigation and field testing for this project was carried out between November 10 and 17, 2014 and between December 14 and 16, 2015, and consisted of drilling and sampling a total of thirteen (13) boreholes, identified as NW-01 to NW-10 and PA-01 to PA-03. During the 2014 field investigation, two boreholes (NW-02 and NW-03) were drilled at the location of the north bridge abutment, one borehole (NW-04) at the south abutment and the remainder of boreholes, namely Boreholes NW-05 to NW-10, were advanced along the proposed realignment of the Norwich Avenue embankment to the north and south of the bridge. During the 2015 investigation, additional three boreholes denoted as PA-01 to PA-03 were drilled along Pattullo Avenue West located to the south of the Underpass Structure. Boreholes were extended to depths ranging from 6.4 to 15.8 m below the existing ground surface. The approximate borehole locations are shown on the Borehole Locations and Soil Strata Drawings included in Appendix E.

Prior to commencement of drilling, utility clearances were obtained for all borehole locations. In 2014, drilling was carried out using a track mounted CME 55 drill rig with solid stem augers; during the 2015 investigation, drilling was conducted using Diedrich D-120 with hollow stem augers. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT).

The drilling and sampling operations were supervised on a full time basis by a member of Thurber's technical staff. The supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory in Oakville, Ontario for further examination and testing.

Groundwater conditions were observed in the open boreholes during and upon completion of the drilling operations. Three standpipe piezometers were installed in the boreholes. Two piezometers consisted of 25 mm Schedule 40 PVC pipe with a 1.5 m long slotted screen were installed at alternate corners of the structure within boreholes NW-02 and 04, and a piezometer consisting of 19 mm Schedule 40 PVC pipe with a 3 m long slotted screen was installed in Borehole PA-01 on Pattullo Avenue West. The piezometers screens were enclosed in filter sand to permit groundwater level monitoring. Following the final water level reading, the piezometers were decommissioned and

boreholes backfilled in general accordance with MOE Regulation 903. Details of the borehole depths, base elevations and completion details are summarized in Table 3.1 below.

**Table 3-1. Borehole Installation and Backfilling Details**

<b>Borehole</b>	<b>Borehole Depth/ Base Elevation (m)</b>	<b>Borehole Backfilling Details</b>
NW-01	10.2 / 285.5	Backfilled with bentonite holeplug and cuttings to surface.
NW-02	14.0 / 289.9	Piezometer with 1.5 m slotted screen installed with tip at 12.2 m/Elev. 291.8. Filter to 10.4 m, bentonite holeplug to 9.8 m, bentonite holeplug and cuttings to 600 mm then concrete to surface.
NW-03	11.0 / 284.5	Backfilled with bentonite holeplug and cuttings to surface.
NW-04	10.8 / 282.4	Piezometer with 1.5 m slotted screen installed with tip at 9.1 m /Elev. 284.1. Sand filter to 7.3 m, bentonite holeplug to 6.7 m, bentonite holeplug and cuttings to surface.
NW-05	10.1 / 282.3	Backfilled with bentonite holeplug and cuttings to surface.
NW-06	6.4 / 292.3	Backfilled with bentonite holeplug and cuttings to surface.
NW-07	6.7 / 285.4	Backfilled with bentonite holeplug and cuttings to surface.
NW-08	6.7 / 287.6	Backfilled with bentonite holeplug and cuttings to surface.
NW-09	6.7 / 285.3	Backfilled with bentonite holeplug and cuttings to surface.
NW-10	6.7 / 284.9	Backfilled with bentonite holeplug and cuttings to surface.
PA-01	15.8 / 274.4	Piezometer with 3.0 m slotted screen installed with tip at 11.9 m/Elev. 278.3. Filter to 8.5 m, bentonite holeplug to surface.
PA-02	15.8 / 276.3	Backfilled with bentonite holeplug and cuttings to surface.
PA-03	15.8 / 279.5	Backfilled with bentonite holeplug and cuttings to surface.

#### **4 LABORATORY TESTING**

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to gradation analysis (hydrometer and/or sieve) and Atterberg Limits testing, where appropriate. The results of these tests are summarized on the Record of Borehole sheets included in Appendix A, and are presented on the figures included in Appendix B.

#### **5 DESCRIPTION OF SUBSURFACE CONDITIONS**

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix A and on the "Borehole Locations and Soil Strata" drawings included in Appendix E.

A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description for interpretation of the site conditions. It should be recognised that soil conditions may vary between and beyond borehole locations.

The subsurface information documented in the 1990 MTO report (Geocres 40P2-45) was reviewed and relevant borehole information utilized in preparation of this report to supplement the soil stratigraphy at the pier and abutments. The Record of Boreholes 1 to 7, and the Borehole Location and Soil Strata drawing from the above report are enclosed in Appendix F.

In summary, the soil stratigraphy below the fill materials and topsoil generally consists of a native deposit of sandy silt and silty clay to clayey silt believed to be of the glaciolacustrine origin, underlain by a very dense cohesionless till and very stiff to hard silty clay till. The water levels in the piezometers installed in Borehole NW04 and PA-01 were measured at 3.5 m depth (Elev. 289.7) and 5.5 m depth (Elev. 284.7), respectively. In Borehole NW-02, the piezometer was dry.

Descriptions of the individual strata are presented below.

### 5.1 Pavement Structure

Borehole NW-02 was drilled through the existing Norwich Avenue north approach and encountered a pavement structure consisting of approximately 125 mm of asphalt overlying 1.4 m of granular road base extending to a 1.5 m depth (Elev. 302.4). In Boreholes PA-01 to PA-03 drilled through the shoulder of Pattullo Avenue, the road base was encountered extending to a depth between 2.1 m and 2.3 m or to Elev. 288.1 and Elev. 283.0, respectively. The granular road base was predominantly sand and gravel with trace to some silt. A silty sand layer with some clay was noted in Borehole PA-01 at 0.8 m depth. SPT tests performed in this material gave N-values ranging from 9 to 34 blows per 0.3 m of penetration, indicating a loose to dense relative density. Moisture contents within this fill varied from 2 to 10%.

Grain size analysis was completed on a sample of the road base material. The results are summarized on the Record of Borehole sheet in Appendix A, and the grain size distribution curve for the sample is included in Figure B1 of Appendix B. The results of the tests are summarized as follows:

Soil Particles	Percentage (%)
Gravel	16 to 44
Sand	42 to 56
Silt	31
Clay	11
Silt and Clay	7 to 13

## **5.2 Topsoil**

A surficial layer of topsoil was encountered in the remaining boreholes (NW-01 and NW-03 through NW-10) drilled adjacent to the west side of Norwich Avenue. The thickness of the topsoil layer varied from 125 to 150 mm.

Boreholes 3 to 5 from the 1990 investigation encountered 200 mm to 700 mm of topsoil/organic soil.

## **5.3 Embankment Fill**

Boreholes NW-02 and 7 (1990 investigation) were advanced from the top of the existing Norwich Avenue approaches to the bridge and encountered an embankment fill. The fill was classified as sandy clayey silt in Borehole NW-02 drilled on the north side of the bridge. In Borehole 7, drilled on the south site, the fill was described as sand with some silt and some gravel. The fill extended to a depth of 6.1 m (Elev. 297.8) in Borehole NW-02, and to 5.9 m depth (Elev. 295.6) in Borehole 7. SPT tests performed in the sandy clayey silt fill gave N-values between 8 and 31 blows per 0.3 m of penetration, indicating a stiff to hard consistency of the material. The sand fill (on the north side) was compact to dense.

Moisture contents within the cohesive fill varied from 10 % to 16%; no moisture content measurements were available for Borehole 7 completed in 1990. The Atterberg Limits testing was performed on a sample of this fill and a Liquid Limit of 25% and Plasticity Index of 9 % was obtained (Figure B6 in Appendix B) indicating low plasticity of this material.

Boreholes NW-06 to NW-10 were drilled along the west toe of the Norwich Avenue embankment and encountered as much as 2.8 m of fill. The fill in Borehole NW-06 located on the north side of the bridge consisted of approximately 1.4 m of sand and silt with some clay and occasional cobbles. The base of this fill was encountered at 1.5 m depth (Elev. 297.2).

The fill in Boreholes NW-07 to NW-010 located on the south side of the bridge consisted of predominantly granular material ranging in composition from silt to sand and silt with trace to some gravel and clay. The granular fill thickness ranged from 1.3 m to 2.8 m, with the base of fill encountered between Elev. 290.5 and Elev. 291.3. SPT tests performed in the granular fill gave N-values between 7 and 18 blows per 0.3 m of penetration, indicating a loose to compact relative density. Moisture contents within the granular fill varied from 15 to 22 %.

In Borehole NW-10, a 0.6 m thick layer of clayey silt fill was encountered below the topsoil with the base at Elev. 290.8. One SPT test performed in this fill gave N-value of 18 blows per 0.3 m of penetration, indicating a very stiff consistency. Moisture content of 20 % was measured in this fill.

The fill in Boreholes PA-01 to PA-03 located along Pattullo Avenue West consisted of predominantly silty sand to sand silt with trace to some gravel, some clay and occasional cobble. Frequent silty clay lenses were noted within this fill material. The fill thickness



ranged from 3.8 m to 5.0 m. The base of the fill was encountered between Elev. 284.1 in Borehole PA-01 and Elev. 289.2 in Borehole PA-03.

SPT tests performed in the fill gave N-values between 1 and 30 blows per 0.3 m of penetration, indicating a very loose to compact relative density. A very loose fill zone in Boreholes PA-01 and PA-02 between 2.1 m and 3.8 m depth may indicate presence of soft silty clay lenses in the fill, as no water was observed during drilling. Borehole PA-02 was dry on completion of drilling operations, and the water level in Borehole PA-01 was encountered at 9.2 m depth, below the soft zones.

In Borehole PA-01, a 900 mm layer of sand and gravel fill was encountered underlying the silty sand fill. The base of the sand and gravel fill was encountered at 7.0 m depth or at Elev. 283.2.

Moisture contents within the granular fill varied from 8 to 22 %.

Grain size analysis were completed on selected samples of the fill material. The results are summarized on the Record of Borehole sheets in Appendix A, and the grain size distribution curves for these samples are included in Figures B2a and B2b of Appendix B. The results of the tests are summarized as follows:

Soil Particles	Percentage (%)
Gravel	0 to 41
Sand	28 to 47
Silt	28 to 54
Clay	10 to 18
Silt and Clay	13

Atterberg Limits tests were completed on a sample of the sandy clayey silt collected from Borehole NW-02. The results are summarized on the Record of Borehole sheet in Appendix A and the Atterberg Limits plot is presented on Figure B7 of Appendix B. The results of the laboratory tests indicate on a low plasticity of the deposit.

#### **5.4 Sandy Silt/Silt to Sand**

A deposit ranging in composition from sandy silt to silt to sand with trace to some clay and trace of gravel was encountered underlying the fill or topsoil in Boreholes NW-02, NW-03, NW-07, NW-10 and in Borehole 5 (1990). In Borehole NW-09, approximately 1.8 m of this deposit was encountered embedded in the silty clay/clayey silt. Occasional clay seams were noted in this deposit. The thickness of this layer ranged from 0.8 to 3.0 m with an underside depth of 1.4 m to 9.1 m (Elev. 294.8 to Elev. 287.9).

SPT tests performed in this layer gave N-values from 9 to 109 blows per 0.3 m of penetration indicating a loose to very dense relative density, predominantly being compact. The moisture content of this cohesionless layer ranged between 8% and 22%.

Grain size analyses were completed on two samples of this layer. The results are summarized on the Record of Borehole sheets in Appendix A and the grain size distribution curves for these samples are included in Figure B3 of Appendix B. The results of the laboratory tests are summarized as follows:

Soil Particles	Percentage (%)
Gravel	0
Sand	21 to 22
Silt	60
Clay	18 to 19

Atterberg Limits analysis was also completed on samples of the sandy silt with some clay consisting of clayey silt seam collected from Boreholes NW-03 and NW-09. The Liquid Limits of 17% and 22% and the Plasticity Indices of 6% and 9% were obtained, indicating a low plasticity seams within the transition of the sandy silt to silty clay/clayey silt. The results of the Atterberg Limits testing are presented on Figure B8 in Appendix B, and on the Record of Borehole sheets.

### 5.5 Silty Clay to Clayey Silt

A deposit of silty clay to clayey silt with trace to some sand and trace gravel was encountered in all boreholes either below the fill or native cohesionless deposit or below the topsoil. Where fully penetrated in the boreholes drilled in the northern part of the site, namely in Boreholes NW-01 to NW-06 and Boreholes 3 to 5 and 7, the thickness of this layer ranged from 1.3 m to 7.0 m with an underside depth of 1.5 to 12.9 m (Elev. 294.2 to 286.3 m). Boreholes NW-07 to 10 were terminated within this layer at a depth of 6.7 m below the ground surface (Elev. 287.6 to 284.9).

SPT tests performed in this deposit gave N-values ranging from 4 to in excess of 100 blows per 0.3 m of penetration indicating a firm to hard consistency. Typically, the N-values ranged from 9 to 40 blows per 0.3 m of penetration indicating a stiff to hard consistency of the deposit. Moisture contents within this layer varied from 11 to 32%.

Grain size analyses were completed on selected samples of the silty clay/clayey silt. The results are summarized on the Record of Borehole sheets in Appendix A and the grain size distribution curves for these samples are included in Figures B4a and B4b of Appendix B. The results of the laboratory tests are summarized as follows:

Soil Particles	Percentage (%)
Gravel	0
Sand	5 to 21
Silt	37 to 70
Clay	14 to 51

Atterberg Limits tests were also completed on selected samples of the silty clay/clayey silt. The results are summarized on the Record of Borehole sheets in Appendix A and the Atterberg Limits plots for these samples are included in Figure B9 of Appendix B. The results of the laboratory tests indicate on a low to intermediate plasticity of the deposit.

Parameter	Value
Plastic Limit	15 to 19
Liquid Limit	25 to 38
Plasticity Index	9 to 19

## 5.6 Sandy Silt to Silty Sand Till

A till deposit grading from sandy silt to silty sand with trace to some clay and trace gravel was encountered in Boreholes NW-01 to NW-06, PA-01, PA-02 and Boreholes 3 to 5 and 7 underlying the silty clay to clayey silt or extending below the fill. Occasional layers of gravelly sand and occasional cobbles were also encountered within the till during drilling. Boreholes NW-01 to 05 and Boreholes 3 to 5 and 7 were terminated within this layer at a depth varying from 6.4 to 25.9 m below ground surface (Elev. 292.3 to 271.2). In Boreholes PA-01 and PA-02, the silty sand to sandy silt till was 6.6 m and 4.2 m in thickness and extended to depths of 13.6 m (Elev. 276.6) and 11.3 m (Elev.280.8).

In Boreholes 3 and 5 from the 1990 investigation, the content of gravel was noted to increase to as much as 18 % below a depth of 10.6 (Elev. 284.6) and at 21.8 m (Elev. 272.5), respectively. This deposit was classified in the 1990 investigation as “Heterogeneous mixture of clayey silt, sand and gravel (Glacial Till)”, which would be comparable to the silty sand/sandy silt till with some clay and gravel described in this section. Boreholes 3 and 5 were terminated in this till at a depth of 18.7 m and 23.1 m (Elev. 276.5 and 271.2).

SPT tests performed in this layer gave N-values from 21 to in excess of 100 blows per 0.3 m of penetration indicating a compact to very dense relative density. The majority of the recorded N-values were higher than 100 blows per 0.3 m of penetration, indicating a very dense relative density of the till. The moisture content of the till layers ranged between 9% and 25%.

Grain size analyses were completed on selected samples of this deposit. The results are summarized on the Record of Borehole sheets in Appendix A and the grain size distribution curves for these samples are included in Figures B5a and B5b of Appendix B. The results of the laboratory tests are summarized as follows:

Soil Particles	Percentage (%)
Gravel	3 to 32
Sand	18 to 61
Silt	25 to 71
Clay	7 to 14
Silt and Clay	7

Glacial till inherently contain cobbles and boulders.

### 5.7 Silty Clay Till

Underlying the cohesionless till in Boreholes PA-01 and PA-02, and fill in Borehole PA-03 was a cohesive till consisting of silty clay with trace to some sand and trace gravel. Occasional coarser layers were encountered in the cohesive till. In Borehole PA-03, the upper 0.9 m layer of the deposit consisted of significant proportion of sand and was classified as sandy silty clay till, and a layer of gravelly silty sand was encountered at the base of this borehole. Boreholes PA-01 to PA-03 were terminated in the silty clay till at a depth of 15.8 m below the ground surface with the base of the boreholes between Elev. 274.4 and Elev. 279.5.

SPT tests performed in this deposit gave N-values ranging from 10 to in excess of 100 blows per 0.3 m of penetration indicating a stiff to hard consistency. Typically, the consistency of the silty clay till was hard with a stiff zones encountered in Borehole PA-03 to approximately 10 m depth. Moisture contents within the silty clay till varied from 8 to 35%.

Grain size analyses were completed on selected samples of the silty clay till. The results are summarized on the Record of Borehole sheets in Appendix A and the grain size distribution curves for these samples are included in Figure B6 of Appendix B. The results of the laboratory tests are summarized as follows:

Soil Particles	Percentage (%)
Gravel	0 to 4
Sand	5 to 48
Silt	29 to 37
Clay	19 to 63

Atterberg Limits tests were also completed on selected samples of the silty clay till. The results are summarized on the Record of Borehole sheets in Appendix A and the Atterberg Limits plots for these samples are included in Figure B10 of Appendix B. The results of the laboratory tests indicate on an intermediate plasticity of the deposit.

Parameter	Value
Plastic Limit	19 to 22
Liquid Limit	39 to 44
Plasticity Index	20 to 24

Glacial till inherently contain cobbles and boulders.

## 5.8 Groundwater Levels

Water levels were observed during drilling operations and in the open boreholes upon completion of the drilling. As outlined in Table 3-1, standpipe piezometers were installed in Boreholes NW-02, NW-04 and PA-01 to monitor groundwater levels after drilling. The measured groundwater levels are summarized in Table 5-1, below.

The values shown are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant or prolonged precipitation events.

**Table 5-1. Measured Groundwater Levels**

Borehole	Date	Groundwater Level		Comment
		Depth (m)	Elevation (m)	
NW-01	Nov. 12, 2014	9.4	286.4	Open Borehole
NW-02	Nov. 17, 2014	Dry	-	Open Borehole
	Nov. 28, 2014	Dry	-	Piezometer
	Jul. 15, 2015	Dry	-	
NW-03	Nov. 12, 2014	7.3	288.1	Open Borehole
NW-04	Nov. 14, 2014	1.6	291.6	Open Borehole
	Nov. 19, 2014	3.9	289.3	Piezometer
	Nov. 28, 2014	3.7	289.5	
	Jul. 15, 2015	3.5	289.7	
NW-05	Nov. 13, 2014	4.3	288.1	Open Borehole
NW-06	Nov. 11, 2014	Dry	-	Open Borehole

Borehole	Date	Groundwater Level		Comment
		Depth (m)	Elevation (m)	
NW-07	Nov. 13, 2014	4.6	287.5	Open Borehole
NW-08	Nov. 13, 2014	4.3	290.0	Open Borehole
NW-09	Nov. 10, 2014	4.1	287.9	Open Borehole
NW-10	Nov. 10, 2014	Dry	-	Open Borehole
PA-01	Dec. 15, 2015	9.2	281.0	Piezometer
	Jan. 06, 2016	5.5	284.7	
PA-02	Dec. 15, 2016	Dry to 8.8	Dry to 283.3	Open Borehole
PA-03	Dec. 16, 2016	12.2	283.1	Open Borehole
3 <sup>*)</sup>	Apr. 20, 1990	3.2	292.0	Open Borehole
4 <sup>*)</sup>	Apr. 23, 1990	4.8	290.3	Open Borehole
5 <sup>*)</sup>	Apr. 19, 1990	2.3	292.0	Open Borehole
7 <sup>*)</sup>	Apr. 26, 1990	12.0	289.5	Open Borehole

Note: <sup>\*)</sup> Geocres No. 40P2-45

## 5.9 Analytical Testing

Two representative soil samples retrieved from the site were submitted to AGAT Laboratories in Mississauga, Ontario for analysis of pH and soluble sulphates. The analysis results are presented below in Table 5-2.

**Table 5-2. Results of Analytical Testing**

Location	Borehole	Sample	Depth (m)	pH	Sulphate (µg/g)
North Abutment	NW-02	SS 11	12.5	7.9	42
South Abutment	NW-04	SS1	0.3	7.6	18

The results of the analyses are enclosed in Appendix C.

## 6 MISCELLANEOUS

Borehole locations were selected and marked in the field by an experienced Thurber staff member and were established with a Trimble Pathfinder ProXRT differential GPS unit. The co-ordinates and ground surface elevations at the boreholes were surveyed by MMM Group Limited upon completion of drilling.

Determination Drilling and Soil Investigations Holdings Inc. from Hamilton, Ontario supplied and operated the drill rig, sampling and in-situ testing equipment for the field program carried out in 2014. Altech Drilling and Investigative Services Ltd. of Elmira, Ontario, supplied and operated the drilling, sampling and in-situ testing equipment for the field program conducted in 2015. The field investigation was supervised on a full time basis by Mr. George Azzopardi of Thurber in 2014 and Mr. Tim Craplewe in 2015, both of Thurber. Overall supervision of the investigation program was conducted by Mr. Stephane Loranger, C.E.T and Weiss Mehdawi, P.Eng.

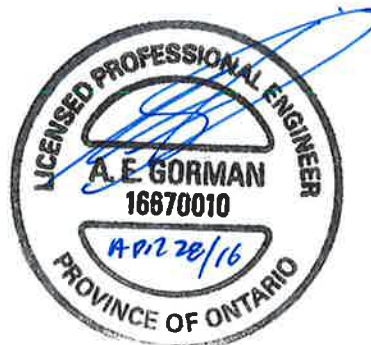
Routine laboratory testing was carried out by Thurber's geotechnical laboratory in Oakville, Ontario. Interpretation of the data and preparation of this report were carried out by Ms. Anna Piascik, P.Eng. The report was reviewed by Mr. Alastair Gorman, P.Eng. and by Dr. P.K. Chatterji, P.Eng., who is a Designated Principal Contact for MTO Foundations Projects.

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**FOUNDATION INVESTIGATION AND DESIGN REPORT**  
**HIGHWAY 401 UNDERPASS AT NORWICH AVENUE**  
**CITY OF WOODSTOCK, ONTARIO**  
**SITE 23-170, G.W.P. 3054-13-00**  
**GEOCRES No.: 40P2-78**

**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**7 INTRODUCTION**

This section of the report provides an interpretation of the geotechnical data presented in the factual report and provides geotechnical recommendations to assist the design team in selecting and designing a suitable foundation system for the proposed replacement of the Highway 401 Underpass at Norwich Avenue (Highway 59) along a new alignment near Woodstock, Ontario.

The existing underpass is a rigid frame structure with a span of 33 m. As shown on the General Arrangement (GA) drawing dated December 2014, the realigned underpass is to be located approximately 25 m west (centreline to centreline distance) of the existing structure alignment with a skew of 19 degrees to the centreline of Highway 401. The proposed underpass is a two span structure with a total span length of 71.4 m and deck width of 25.7 m. Future widening of the deck by 3.5 m is indicated on the drawing. The new underpass will carry two lanes of traffic in each direction of travel, and the middle lane transitioning into the left turn lane in both direction of the traffic.

The proposed foundations indicated on the General Arrangement drawing include H-piles to be driven through the embankment fill to facilitate the integral abutments, and caissons to support the pier. The undersides of the abutments are shown at elevation 299.10 and 298.15 m at the north and south abutment, respectively. To elevate the structure over Highway 401, the height of the approach embankments along the centreline of the alignment will be approximately 8.5 to 7.6 m above the Highway 401 grade at the north and south approaches, i.e., at Elev. 303.9 and Elev. 302.9, respectively.

To accommodate shifting of the Norwich Avenue Underpass approximately 25 m west, realignment of the Norwich Avenue embankments and grade raise of Pattullo Avenue are required. The new Norwich Avenue alignment will meet the existing embankment at approximately Station 9+750, some 210 m north of the structure. To the south of the structure, the realigned Norwich Avenue will intersect Pattullo Avenue at Sta. 10+231, and then will meet the existing embankment at approximately Station 10+400. The embankment height will vary from 8.5 m at the structure to 7 m at Pattullo Avenue. The final grade of the new road will be nominally higher than the existing road grade. The footprints of the realigned Norwich Avenue will overlap the footprints of the existing embankments.



The discussion and recommendations presented in this report are based on information provided by MMM Group Limited (MMM) and on the factual data obtained in the course of this investigation, in combination with the subsurface information presented in the MTO Report, Geocres 40P2-45.

## **8 STRUCTURE FOUNDATIONS**

In summary, the soil stratigraphy below the fill materials and topsoil consists of deposit of sandy silt/sand and silty clay/clayey silt believed to be of the glaciolacustrine origin. This deposit was encountered with its base sloping down from Elev. 294.2 in the vicinity of the proposed north bridge approach to Elev. 286.3 in the vicinity of the south approach. The glaciolacustrine deposits are underlain by a very dense cohesionless till comprising various proportions of sand, silt, clay and gravel and occasional cobbles; cobbles and boulders are inherent in glacial tills.

The groundwater levels in the open boreholes upon completion of drilling were measured from 1.6 m depth to being lower than 12.8 m depth (borehole open and dry). The piezometer sealed into the cohesionless till on the north side of the bridge with the screen tip at 12.2 m depth (Elev. 291.6 m) was dry. The water level in the piezometer sealed into the same till on the south side of the bridge with the screen tip at 9.1 m depth (Elev. 283.9) was at 3.5 m depth (Elev. 289.7).

Based on the conditions encountered at this site, consideration was given to the following foundation types:

- Spread footings:
  - bearing on native soil
  - bearing on engineered fill
- Augered caissons (drilled shafts)
- Driven steel H-Piles.

A comparison of the foundation alternatives, with advantages and disadvantages of each, are included in Appendix G.

### **8.1 Spread Footings Bearing on Native Soil**

The existing fill and the native firm silty clay to clayey silt soils are not considered to be suitable for the support of spread footings. The spread footings, if selected, could be placed on the underlying hard silty clay/clayey silt and/or very dense cohesionless till. For design of spread footings bearing on the undisturbed native soils, the founding elevations, factored geotechnical resistance at Ultimate Limit States ( $ULS_f$ ) and geotechnical reaction at Serviceability Limit States (SLS) provided in Table 8-1 may be used for an assumed minimum footing width of 3 m.

**Table 8-1. Founding Elevation and Bearing Capacities for Spread Footings**

Foundation Unit	Referenced Borehole	Highest Founding Elevation (m)	Factored Resistance at ULS (kPa)	Geotechnical Reaction at SLS (kPa)
North Abutment	NW-02 NW-03	294.0	400	280
Pier	4 <sup>*)</sup>	292.5	375	250
South Abutment	NW-04 7 <sup>*)</sup>	291.0	400	280

<sup>\*)</sup> From Geocres 40P2-45

The values of geotechnical resistances at SLS quoted above correspond to 25 mm of settlement of an individual footing and are for concentric, vertical loads only. In the case of eccentric or inclined loading, the geotechnical resistance should be calculated as illustrated in the CHBDC 2006 Clause 6.7.3 and Clause 6.7.4.

Resistance to lateral forces / sliding resistance between the footing concrete and the sandy silty and silty clay to clayey silt at the founding level should be evaluated in accordance with the CHBDC, 2006 assuming an ultimate (unfactored) coefficient of friction of 0.35.

The exposed soils at the founding level should be protected from disturbance due to construction traffic and weathering/run off. For protection, a 100 mm concrete working slab should be placed at the footing subgrade as soon as the subgrade is inspected and approved. A note to this effect should be added to the appropriate contract drawings.

The water levels in the open boreholes during the field investigation (Table 5-1) were observed to be at or below the founding levels. A perched groundwater may also be encountered during excavations and local groundwater control may be required to construct the spread footings in the dry and to prevent disturbance of the founding stratum.

Excavation and backfilling for the footings should be in accordance with OPSS 902.

## **8.2 Spread Footings Bearing on Engineered Fill**

Foundations consisting of spread footings founded on engineered fill pads can be considered at the abutments at this site. The highest permitted base elevation, at which engineered fill pads may be founded, are giving in Table 8-1.

If an engineered fill pads are used to obtain higher founding elevations, all organics or other deleterious materials should be stripped from the footprint of the foundation to expose competent native subgrade material.

The engineered fill should consist of OPSS Granular “A” or Granular B Type II placed in 150 mm lifts and compacted to 100% of its SPMDD at  $\pm 2\%$  of optimum moisture content. The top of the founding pad should be at least 1 m wider than the footprint of the spread footing. The side slopes of the engineered fill pad should be inclined not steeper than 1H: 1V. The engineered fill arrangement is shown in Figure 1 enclosed in Appendix J.

A 3 m wide footing bearing on a minimum 1 m thick pad of engineered fill may be designed for the following capacities:

Factored Geotechnical Resistance at ULS	- 900 kPa
Geotechnical Resistance at SLS	- 350 kPa

The geotechnical SLS resistance values given above are based on an estimated total settlement not exceeding 25 mm and are for concentric vertical loading. This settlement is expected to be substantially completed by the end of construction. Differential settlement is not expected to exceed 15 mm across the width of the structure or the span from pier to abutment. In the case of eccentric or inclined loading, the geotechnical resistance should be calculated as illustrated in the CHBDC 2006 Clause 6.7.3 and Clause 6.7.4.

The horizontal resistance against sliding between cast-in-place concrete founded on engineered fill can be computed using an ultimate friction factor of 0.60.

### 8.3 Caissons

Augered caissons, founded into the hard silty clay/clayey silt and/or very dense cohesionless till at or below elevations shown in Table 8-2, are considered a feasible foundation alternative for the abutments, and particularly for the pier.

**Table 8-2. Founding Elevation and Axial Resistance for Design of Caissons**

Location (Relevant Borehole)	Highest Caisson Founding Elevation (m)	Factored Geotechnical Resistance at ULS (kN)		Geotechnical Reaction at SLS (kN)	
		1.2 m dia.	1.5 m dia.	1.2 m dia.	1.5 m dia.
North Abutment (NW-02 and 03)	287.0	4,800	7,500	4,000	5,500
Pier 4*)	285.0				
South Abutment (NW-04, 5* and 7*)	283.0				

\*) Boreholes 4, 5 and 7 – Geocres No. 40P2-45

The values of geotechnical resistances at SLS quoted above refer to 25 mm of settlement.

The geotechnical lateral resistance may be calculated using design parameters values provided in Sec. 8.4.6.

The base of the caissons will be below the groundwater level and dewatering, base cleaning and base inspection will be required. The values in Table 8-2 include the base component of the bearing capacity.

Construction of the caissons will require the use of a sealed liner and/or slurry methods to control groundwater and to support the sidewalls of the shaft. Each caisson should be concreted and completed within the shift that it was started.

The presence of cobbles and boulders within the glacial till deposit is to be expected, and the caisson drilling equipment should be able to remove/penetrate these obstructions. The suggested text for NSSP to address these obstructions is included in Appendix H.

## 8.4 Steel H-Pile Foundations

### 8.4.1 Axial Resistance

The ground conditions at the site are considered to be suitable for the use of driven steel H-pile foundations at the bridge abutments. To develop required capacity, the piles should be driven into very dense cohesionless till.

The recommended geotechnical resistances and reactions for steel H-piles (HP 310x110 or HP 360x132) driven into the very dense cohesionless till are presented in Table 8-3.

**Table 8-3. Recommended Axial Resistance for Steel H-Piles**

Foundation Element	Reference Borehole	Approximate Pile Tip Elevation (m)	Factored Geotechnical Resistance at ULS (kN) per pile	Geotechnical Reaction at SLS (kN) per pile
North Abutment	NW-02 NW-03, 3*)	282.0	1800 (HP 310x110)	1600 (HP 310x110)
Pier	4 *)	280.0		
South Abutment	NW-04 5, 7*)	282.0	2000 (HP360x132)	1800 (HP360x132)

*Note \*): Boreholes 3 to 5 and 7 from Geocres 40P2-45*

The values of geotechnical resistances at SLS quoted above refer to 25 mm of settlement.

The above pile tip elevations assume that piles are driven to effective refusal and penetrate a minimum 3 m into the very dense cohesionless till. If practical refusal is met in the very dense till at shallower depth than required for structural pile performance (flexibility), pre-augering to approximately 2 m above the design pile tip elevation may be needed prior to driving piles.

Oversize materials (e.g. greater than 75 mm nominal diameter) should not be used for any new fill through which the piles will be driven.

Piles should be installed in accordance with OPSS 903.

#### **8.4.2 Downdrag**

Driven H-piles could encounter practical refusal in the very dense till deposit. The weight of the new approach embankment fill to be placed for the realignment of Norwich Avenue will induce consolidation settlements of the underlying silty clay/clayey silt layer. As a result, downdrag forces will develop along the length of abutment piles embedded in this deposit.

For design purposes, an unfactored downdrag load of 200 kN per pile should be used to evaluate the impact of downdrag load on the bearing capacities of the abutment piles.

This downdrag load should be multiplied by a load factor of 1.25 as per CHBDC Commentary Clause C6.8.4 to obtain a factored downdrag load. In accordance with Section 6.8.4 of the CHBDC and Clause C6.8.4 of the Commentary, in the structural design of a pile, the factored downdrag load should be added to the factored permanent loads to assess the effects of downdrag. The factored dead and downdrag load should not exceed the factored structural resistance of a pile at the neutral plane. The location of the neutral plane for a pile or group of piles should be determined by using unfactored loads and unfactored geotechnical parameters.

In geotechnical analysis of downdrag load, the effect of live load should not be considered.

#### **8.4.3 Pile Driving**

Pile installation should be in accordance with OPSS 903.

Pile driving should be controlled in accordance with Standard Drawing SS103-11 (Hiley Formula) and an ultimate pile resistance should be specified by the designer. The Hiley formula need not be used until the piles are within 2.0 m of the design pile tip elevation. The appropriate pile driving note is “Piles to be driven in accordance with Standard SS 103-11 using an ultimate resistance of “R” kN per pile. “R” should have a minimum value of twice the design load at ULS as calculated by the Structural Engineer.

If the proposed bridge design requires that the deviation at the top of the pile be limited to tight tolerance, a driving template or other means may be required to achieve the specified maximum deviation.

It is anticipated that new abutment piles will be installed from the prepared grade, which would require placement of new fill to the underside of the abutment stems.

#### **8.4.4 Pile Tips**

To prevent pile damage when setting the piles in the very dense till or if cobbles or boulders are encountered, piles should be equipped with tip protections.

All driven H-piles should be fitted with pile tip protection from an approved manufacturer such as Titus Steel (Standard H-point), Skyline Steel or approved equivalent.

#### 8.4.5 Abutment Type

The subsurface conditions at this site are considered suitable for integral, semi-integral or conventional abutment design. The use of H-piles at the abutments allows for the design of integral abutments, as indicated on the preliminary General Arrangement Drawing.

The integral abutment design requires that the piles possess flexibility in the upper 3 m of the pile length. It is anticipated that new abutment piles will be installed from the prepared grade corresponding to the underside of the abutment stems. This would involve excavating the existing embankment fill along the Norwich Avenue and placement of a new fill. The fill should be properly placed in layers not exceeding 300 mm in thickness and compacted to 95 percent of Standard Proctor maximum density.

To provide the required flexibility for piles to be installed through the compacted fill, the upper 3 m of the piles should be surrounded by a 600 mm diameter CSP as specified by the integral abutment design procedures. After the pile is installed, the space between the pile and the CSP should be filled with loose uniform sand. An NSSP should be included in the contract documents specifying the grain size distribution of the sand as listed in Table 8-4.

**Table 8-4. Integral Abutment Sand Backfill Grading**

MTO Sieve Designation		Percentage Passing
2 mm	#10	100%
600 µm	#30	80%-100%
425 µm	#40	40%-80%
250 µm	#60	5%-25%
150 µm	#100	0%-6%

For an integral abutment installation, the following procedure is suggested:

1. At each pile centre, auger a hole of sufficient diameter to accept a 600 mm CSP to a depth of 3.0 m below the underside of the abutment stem.
2. Install the CSP.
3. Drive the pile; care should be taken to prevent soil or debris from entering the CSP.
4. After completion of pile driving, fill the CSP using sand as specified in Table 8-4.

#### 8.4.6 Pile Lateral Resistance

The geotechnical lateral resistance of an H-pile embedded in dense to very dense soil may be calculated using a value for the coefficient of horizontal subgrade reaction ( $k_s$ ) and ultimate lateral resistance ( $p_{ult}$ ) as follows:

$$k_s = n_h z / D \quad (\text{kN/m}^3)$$

$$p_{ult} = 3 \gamma' z K_p \quad (\text{kPa})$$

where  $z$  = depth of embedment of pile (m)

$D$  = pile width or diameter (m)

$n_h$	=	coefficient related to soil relative density ( $\text{kN/m}^3$ )
$\gamma'$	=	effective unit weight ( $\text{kN/m}^3$ )
$K_p$	=	passive earth pressure coefficient

The geotechnical lateral resistance acting on a pile in cohesive soil may be calculated using a value for the coefficient of horizontal subgrade reaction ( $k_s$ ) and ultimate lateral resistance ( $p_{ult}$ ) as follows:

$$k_s = 67 \, s_u / D \quad (\text{kN/m}^3)$$

$$p_{ult} = 9 \, s_u \quad (\text{kPa})$$

where  $s_u$  = undrained shear strength (kPa)

$D$  = pile width or diameter (m)

The above equations and recommended parameters in Table 8-5, below, may be used to analyse the interaction between a pile and the surrounding soil. The lateral pressures obtained from the analysis should not exceed the ultimate lateral resistance.

**Table 8-5. Lateral Earth Pressure Coefficients**

Elevations (m)	$\gamma$ ( $\text{kN/m}^3$ )	$K_p$ (-)	$S_u$ (kPa)	$n_h$ ( $\text{kN/m}^3$ )	Soil Conditions
<b>North Abutment</b>					
Surface to 297.8	20	3.0	-	4,000	Fill
297.8 – 294.8	20	3.2	-	6,000	Silty Clay/Sandy Silt
294.8 – 292.0	18	-	150	-	Silty Clay/Sandy Silt
292.0 – 284.5	10 <sup>(*)</sup>	4.2	-	12,000	Silty Sand/Sandy Silt Till
<b>South Abutment</b>					
Surface to 293.0	20	-	-	3,000	Fill
293.0 – 289.5	18	-	100	-	Silty Clay
289.5 – 287.7	8 <sup>(*)</sup>	-	100	-	Silty Clay
287.7 – 282.4	10 <sup>(*)</sup>	4.2	-	12,000	Sand and Silt Till

Note: (\*) submerged unit weight below the water table

The subgrade reaction modulus of loose sand against the CSP for an integral abutment arrangement is in the order of 1300 kPa/m.

The spring constant,  $K_s$ , for analysis may be obtained by the expression,  $K_s = k_s \times L \times D$  ( $\text{kN/m}$ ), where  $L$  is the length (m) of the pile segment or element used in the analysis and remaining variables are as defined earlier. The ultimate lateral resistance,  $P_{ult}$ , may be obtained from the expression,  $P_{ult} = p_{ult} \times L \times D$ . This represents the ultimate load at which the pile fails and will not support any additional load at greater displacements.

Lateral resistance may be assessed from the given above equations and using parameters in Table 8-5. Alternatively, the values given in the CHBDC Clause 6.8.7.1, Table C 6.4, may be utilized. As an example, in the Table C 6.4, the lateral resistance of an HP310x110 pile driven in the “noncohesive material” is to be limited to 120 kN at ULS, and 35 kN at SLS for the lateral movement of 10 mm.

The modulus of subgrade reaction may have to be reduced due to pile interaction, based on the center-to-center pile spacing. The reduction factors to be used for a pile group oriented perpendicular and/or parallel to the direction of loading are provided in Table 8-6 with intermediate values to be obtained by linear interpolation.

**Table 8-6. Subgrade Reaction Reduction Factors for Pile Spacing**

Condition	Pile Spacing, Centre to Centre	Reduction Factor
Pile group oriented <i>perpendicular</i> to direction of loading	4D	1.0
	1D	0.5
Pile group oriented <i>parallel</i> to direction of loading	8D	1.0
	6D	0.7
	4D	0.4
	3D	0.25

Horizontal loads may be resisted by means of battered piles (i.e. for H-pile case) if load requirements exceed the available lateral pile resistances.

Where downward sloping ground exists in front of a pile, reduction of lateral passive resistance should be taken into account during design. For foundation design at the piles, it can be assumed that full lateral resistance can only be mobilized where the width of the soil in front of the pile or caisson is equal to or greater than approximately 4 times the diameter of the pile or caisson. The mobilized passive resistance for sloping ground in front of a pile can be estimated using the following reduction factors:

**Table 8-7. Passive Resistance Reduction Factors**

Slope Inclination	Passive Resistance Reduction Factor
2H:1V	0.60
2.5H:1V	0.65
3H:1V	0.70
4H:1V	0.75

## 8.5 Frost Cover

The depth of frost penetration at this site is 1.3 m. The base of all pile caps, caissons caps or footings, should be provided with a minimum of 1.3 m of earth cover as protection against frost action.



## 8.6 Recommended Foundation

From a geotechnical perspective, and based on current information, the preferred abutment foundation consists of steel H-piles driven into the dense to very dense till deposit, which will allow for the integral abutment design. Caissons or spread footings can be considered for support of the pier. The caisson foundation would be more advantageous from the constructability perspective, as they would allow for minimizing the construction impact on operation of Highway 401, i.e. less excavation and shorter construction time.

## 9 BACKFILL TO ABUTMENTS

The backfill to the abutment walls should be Granular A or Granular B Type II material meeting the requirements of OPS. PROV 1010. The backfill should be in accordance with OPSS 902 and placed to the extent shown in OPSD 3101.150.

Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS 501. The design of the abutment should incorporate a subdrain as shown in OPSD 3101.150.

## 10 EARTH PRESSURE

Earth pressures acting on the structure may be assumed to be triangular and to be governed by the characteristics of the abutment backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are given by the following expression:

$$p_h = K(\gamma h + q) \quad (\text{kN/m}^3)$$

where	$p_h$	=	horizontal pressure on the wall at depth h (kPa)
	K	=	earth pressure coefficient (see table below)
	$\gamma$	=	unit weight of retained soil (see table below)
	h	=	depth below top of fill where pressure is computed (m)
	q	=	value of any surcharge (kPa)

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of the fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I or 1.7 m for Granular A or Granular B Type II.

Earth pressure coefficients for backfill to the embankment wall are dependent on the material used as backfill. Typical values are shown in Table 10-1.

**Table 10-1. Earth Pressure Coefficients**

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		Existing Sand Fill or OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active	0.27	0.40	0.31	0.48
Passive	3.7	N/A	3.3	N/A
At Rest	0.43	N/A	0.47	N/A

The factors in Table 10-1 are “ultimate” values and require certain movements for the respective conditions to be mobilized. The values to be used in design can be estimated from Figure C6.16 in the Commentary to the CHBDC.

## 11 SEISMIC CONSIDERATIONS

### 11.1 Seismic Design Parameters

The following seismic parameters should be used for design:

- Velocity Related Seismic Zone                      0
- Zonal Velocity Ratio                                      0.05
- Acceleration Related Seismic Zone                1
- Zonal Acceleration Ratio                              0.05
- Peak Horizontal Ground Acceleration            0.08

The soil profile type at this site has been classified as Type I. Therefore, according to Table 4.4 of the CHBDC, a Site Coefficient “S” (ground motion amplification factor) of 1.0 should be used in seismic design.

### 11.2 Dynamic Earth Pressures

In accordance with Clause 4.6.4 of the CHBDC, retaining structures should be designed using active ( $K_{AE}$ ) and passive ( $K_{PE}$ ) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 11-1 may be used:

**Table 11-1. Earth Pressure Coefficients for Earthquake Loading**

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		Existing Sand Fill or OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active ( $K_{AE}$ )*	0.3	0.47	0.34	0.58
Passive ( $K_{PE}$ )	3.6	N/A	3.2	N/A
At Rest ( $K_{OE}$ )**	0.53	N/A	0.58	N/A

\* After Mononobe and Okabe, passive case assumes a horizontal surface in front of the wall.

\*\* After Woods.

### 11.3 Liquefaction Potential

It is expected that under the existing conditions the foundation soils will not be prone to liquefaction. The existing embankments are above the groundwater level and are not considered to be in danger of undergoing liquefaction.

## 12 REALIGNEMENT OF EMBANKMENTS

### 12.1 Norwich Avenue Realignment

Based on the preliminary GA drawing, the proposed Norwich Avenue will be shifted approximately 25 m west at the structure location (centerline to centerline distance). The final grade of the new road will be at approximately Elev. 303.9 at the north approach embankment and at Elev. 302.9 at the south approach embankment. The alignment is on vertical curve with the existing embankment at Station 9+750, which is some 210 m north of the north bridge abutment, and at Station 10+400, some 350 m south of the south abutment. The new embankment grade slopes down to the south being at approximately Elev. 296.6 at Pattullo Avenue at approximate Station 10+231.

The embankments will be approximately 8.5 m and 7.6 m in height at the centerline of the structure, immediately at the north and south abutments, respectively, with the footprints overlapping the footprints of the existing embankments. As the adjacent ground slopes down to the west in the vicinity of the bridge, the proposed embankment geometry will result in fill as much as 10 m in height on the west side of the existing south approach embankment.

No evidence of the existing embankment slope instability was observed during the field investigation. The existing embankment inclinations are relatively flat and covered by vegetation (grass and occasional shrubs).

Based on the subsurface information, the embankments will be constructed on firm to hard silty clay/clayey silt and compact to very dense sandy silt/silt, which are underlain by the very dense cohesionless till.

The new embankment may be constructed with inorganic earth fill meeting the gradation and specification of SSM.

The slope stability analyses and estimate of the settlements were conducted for the realigned embankment. The proximity of the existing bridge and approach embankments has been considered in analyses, as the existing bridge will continue to be used for traffic flow during construction of the new bridge.

At all areas of the new embankment fill placement, the stability and settlement analyses assume that prior to construction of the new embankments, all organic matter/topsoil and soft, disturbed soils will be removed below the embankment footprint, and the existing embankment fill will be left in place in the transition zone between embankments.

#### **12.1.1 Slope Stability**

Slope Stability analyses were performed on the critical (i.e. highest fill and/or thickest foundation clay) sections of the proposed new approach embankments to assess the stability of the embankments for the proposed heights and geometries.

The critical section refers to the new south approach embankment and represents both front slope and side slope of the approach. The geometry of the new/existing embankment considered in the analyses were based on the preliminary information provided by MMM.

Limit equilibrium slope stability analyses were performed using the commercially available program GeoStudio 2004 produced by Geo-Studio International Ltd, employing the Morgenstern-Price method of analysis. For all analyses, the Factor of Safety of numerous potential failure surfaces was computed in order to establish the minimum Factor of Safety. The Factor of Safety is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause the failure. A target minimum Factor of Safety of 1.3 is normally adopted for the design of embankment slopes under static conditions.

The stability analyses were performed to check that the target minimum Factor of Safety was achieved for the design embankment height and geometry.

The parameters employed in the analyses were estimated from empirical correlations based on the results of the SPT N-values, and both total stress and effective stress analyses were carried out for the south approach embankment. The simplified stratigraphy, parameters used in the analyses and output of the computations are presented on the attached Figures 1 and 2 in Appendix I.

Limit equilibrium analysis indicates a Factor of Safety of more than 1.3 during construction, and for the long-term conditions for the above noted geometry and embankment height. Provided proper construction methods are used, no global stability concerns are anticipated for embankments, including approaches built at this site.

### **12.1.2 Embankment Settlements**

Settlements of the underlying silty clay/clayey silt can be expected as a result of the loading from the new fill, in addition to a compression of the new fill, itself. To estimate the magnitude of the expected settlements, analyses were carried out on the critical sections of the proposed embankments. For the settlement analyses, the critical section was considered to be at the south approach embankment where embankment is the highest, and considering consistency/compressibility of the underlying foundation soils.

The MTO Guideline “Embankment Settlement Criteria for Design” defining acceptable post construction settlement criteria, dated July 2, 2010, was applied in the design of the embankment. The criteria in the Guideline refer to the settlements for the 20-year post-paving period for the bridge approach embankments.

The consolidation settlement parameters were determined from empirical correlations proposed in literature using the results of the in-situ SPT and laboratory testing.

For the 10 m high embankment, the primary consolidation settlements of the foundation soils were estimated to be in the range of 100 mm to 200 mm. Significant percentage of the estimated settlements will occur during construction and within six months following the completion of the embankment construction to full height. These settlements will occur along the new roadway both longitudinally and laterally. The new fill will be placed against the existing embankment fill. Since the consolidation of the silty clay/clayey silt beneath the existing embankment has already been completed, the remaining settlements will occur as the differential settlements between the west crest of the existing embankment and west crest of the new embankment.

In light of the above, delaying paving operations to accommodate the settlements is recommended. If the new embankments are constructed to full height by October during the first season of construction, and paving is delayed to the following spring (May), this will allow an adequate period of preloading to mitigate the differential settlements.

Monitoring the embankment settlements by utilizing appropriately placed/distributed settlement pins along the west crests of the new embankment and within the existing embankment roadway is recommended to record the rate of settlements. This would indicate the appropriate time for paving the roadway.

Suggested wording for the NSSP to address the preloading and monitoring requirements, and the Monitoring Plan drawing have been included in Appendix H.

The embankment should be overbuilt to accommodate the anticipated consolidation settlements of as much as 200 mm.

The settlement/compression of the embankment fill was estimated to be in order of 50 mm, which corresponds to 0.5% strain under its own weight. This settlement is anticipated to be completed by the end of embankment construction.

The existing Norwich Avenue will be used for traffic operations during construction of the new underpass and realigned embankments. Deformation of the existing embankment during construction should be expected and regular maintenance of the pavement structure will be required to ensure safe operation of the existing Norwich Avenue.

## **12.2 Re-grading of Pattullo Avenue West**

Realigned Norwich Avenue will intersect Pattullo Avenue West, located to the south of the Underpass Structure. The roads will intersect at Station 10+230.95 of Norwich Avenue and Station 10+000 of Pattullo Avenue. At that location the proposed grade of Norwich Avenue indicated on the drawings at Elev. 296.6 (approximately) will be only nominally higher than the existing grade of Pattullo Avenue West. However, as part of the general improvements, the grade of the existing Pattullo Avenue West will be raised. The grade raise will be as much as 1.5 m in a short distance from the intersection and will gradually diminish to the west to meet the existing Pattullo Avenue West grade at Station 9+840. The height of the existing embankment varies from 6.7 m at the intersection to 3.0 m at Station 9+840.

The three boreholes advanced along the Pattullo Avenue West encountered a fill deposit underlain by native cohesionless and cohesive tills. Pavement/road structure overlay an embankment fill consisting of a sandy silt to silty sand with some clay. Frequent silty clay seams were encountered in this fill. The fill was very loose to compact. Underlying the embankment fill are cohesionless and cohesive tills. The cohesionless till consisted of compact to very dense silty sand/sandy silt, and the cohesive deposit consisted of stiff to hard silty clay. A piezometer installed in Borehole PA-01 indicated water level at 5.5 m depth (Elev. 284.7).

Considering subsurface conditions encountered below the embankment fill in the boreholes, namely compact to very dense silty sand/sandy silt till and stiff to hard silty clay till, the proposed grade raise of as much as 1.5 m, if constructed as indicated in Sec. 12.3, should not cause embankment instability.

The embankment fill was found to consist of silty sand to sandy silt containing some clay and frequent silty clay lenses. The load imposed by the additional fill placed to raise the grade will induce some settlements of the existing embankment fill. Due to heterogeneous nature of the fill, the amount of the settlement is difficult to predict accurately, and the amount of settlement will vary along the embankment. However, it was estimated that the settlement under the grade raise of 1.5 m will not exceed 50 mm. The settlement within the native deposits due to grade raise will be nominal.

In light of the above, it is recommended that:

- the fill for the grade raise be placed as soon as practical in the contract schedule,
- the placement of final asphalt and construction of curbs and gutters (if required) be delayed for at least three months after the completion of the final fill placement.

### **12.3 Subgrade Preparation and Embankment Construction**

Prior to embankment construction, all organic soils/topsoil/vegetation should be removed from below the footprint of the proposed embankments. For the grade raise the existing asphalt layer should be removed and salvaged, if practical. The existing embankment fill in the transition zone/footprint area of the new or widened embankment may remain in place.

The new embankment fill should be placed in lifts with loose thickness not exceeding 300 mm and compacted in accordance with OPSS501. Side slopes of the embankment fill should be no steeper than 2H:1V. Inspection and testing should be carried out by qualified personnel during placement operation to ensure that appropriate materials are used and that adequate levels of compaction have been achieved.

In order to improve interaction between the existing and newly placed embankment fill, the new fill must be benched into the existing embankment side slope in accordance with the requirements of OPSD 208.010.

Mid-height berm are required for the earth embankments 8 m or more in height.

Erosion protection of the new embankment slopes in form of topsoil placement and seeding should be implemented as soon as possible. Spring run-off should not be allow to discharge on the embankment slopes in an uncontrolled manner. Asphalt barrier curb or curb with gutter as per OPSD 601.010 should be considered to protect the embankment slopes before erosion protection is established.

## **13 EXCAVATION AND GROUNDWATER CONTROL**

All excavation should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the fill forming the existing Norwich Avenue embankment may be classified as Type 3 soils. The near surface native soils and above the water level may also be classed as Type 3 soils. The underlying hard silty clay and dense sand and silt layers may be classified as Type 2 soil.

The sides of temporary excavations should be sloped in accordance with the requirements of the OHSA. Where space does not permit the sides to be sloped, roadway protection should be used.

Based on the preliminary GA, some excavation below the groundwater or perched water level to construct the foundation may be required. Excavation below the groundwater level without prior dewatering is not recommended since the inflow of groundwater will cause boiling and sloughing of the soil below the water table making it difficult to maintain a dry, sound base on which to work.

The design of the dewatering system, that may be required, is the responsibility of the Contractor and the Contract Documents should alert him to this responsibility and the need to engage a dewatering specialist. The Contractor should also be prepared to pump from sumps to remove any remaining seepage water or surface water collecting in an excavation. Placement of concrete should be done in the dry. Unwatering should remain operational and effective until the foundation is installed and

backfilled. Unwatering operations may result in the removal of volume of water that will trigger a requirements for a permit to take water (PTTW). Accordingly, it is recommended that an application for a PTTW be commenced.

Furthermore, the excavation and backfilling for foundations should be carried out in accordance with OPSS 902.

#### 14 PROTECTION SYSTEM

If roadway protection is required, it should be implemented in accordance with OPSS 539 and designed for Performance Level 2 (maximum 25 mm horizontal deflection).

Conventional steel soldier piles and timber lagging walls is one option to provide temporary support to the soils during excavation. Timber lagging boards should be installed as soon as the soil face is exposed and properly prepared.

The following parameters apply for design of the temporary shoring system with horizontal backfill.

$\gamma$	=	20 kN/m <sup>3</sup>	(bulk unit weight)
$\gamma_w$	=	10 kN/m <sup>3</sup>	(submerged unit weight under groundwater table)
$K_a$	=	0.33	(Active pressure coefficient for road embankment fill)
	=	0.31	(Active pressure coefficient for native soils)
$K_p$	=	3.0	(Passive pressure coefficient for road embankment fill)
	=	3.2	(Passive pressure coefficient for native soils)
$h_w$	=	289.5 m	(approximate elevation for hydrostatic pressure build-up behind temporary shoring)

The design of roadway protection is the responsibility of the Contractor. The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors should be considered when designing the shoring system. All shoring systems should be designed by a Professional Engineer experienced in such designs, who will determine an appropriate support system.

Temporary groundwater and surface water control measures will be required to remain operational during construction.

#### 15 CEMENT TYPE

The water soluble sulphate tests on two samples indicate sulphate concentrations of 42 and 18 µg/g. Soluble sulphate concentrations less than 1000 µg/g indicate a moderate degree of exposure to sulphate attack for concrete in contact with soil and groundwater.

#### 16 CONSTRUCTION CONCERNS

Potential construction concerns include, but are not necessarily limited to:



- Potential variability of pile lengths due to the presence of probable cobbles/boulders and driving into very dense glacial till. It is possible that piles will achieve refusal at higher levels than specified in the design. If design requires longer piles, pre-augering will be required.
- Excavation below the water level, if required, will involve lowering of the groundwater level below the excavation base to maintain a reasonably dry excavation and stable side slopes.
- Roadway protection will be required to maintain traffic during construction. Temporary protection systems should be properly designed by a Professional Engineer experienced in such designs.
- Deformation of the existing Norwich Avenue embankment during construction should be expected during construction of the realigned embankments, and regular maintenance of the pavement structure will be required to ensure safe traffic operation of the existing Norwich Avenue.

The successful performance of the underpass and embankments will depend largely upon workmanship and quality control during construction. Pile driving supervision, subgrade examination and field density testing should be carried out by qualified geotechnical personnel during construction to confirm that foundation recommendations are correctly implemented and material specifications are met.

## 17 CLOSURE

Engineering analysis and preparation of the report was carried out by Ms. Anna Piascik, P.Eng. The report was reviewed by Mr Alastair Gorman, P.Eng and by Dr. P.K. Chatterji, P.Eng., who is a Designated Principal Contact for MTO Foundations Projects.

**Thurber Engineering Ltd.**

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Senior Geotechnical Engineer



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Senior Foundation Engineer/Senior Associate



P. K. Chatterji, Ph.D, P.Eng.  
Review Principal



## **Appendix A**

### **Record of Borehole Sheets**

## SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

### 1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

### 2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

### 3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT <sup>(1)</sup> 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer



### 4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

### 5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$

 Water Level  
 Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value      Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT      Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

## EXPLANATION OF ROCK LOGGING TERMS


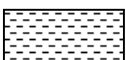

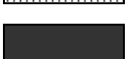

### ROCK WEATHERING CLASSIFICATION

<b>Fresh (FR)</b>	No visible signs of weathering.
<b>Fresh Jointed (FJ)</b>	Weathering limited to the surface of major discontinuities.
<b>Slightly Weathered (SW)</b>	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.
<b>Moderately Weathered (MW)</b>	Weathering extends throughout the rock mass, but the rock material is not friable.
<b>Highly Weathered (HW)</b>	Weathering extends throughout the rock mass and the rock is partly friable.
<b>Completely Weathered (CW)</b>	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.

### DISCONTINUITY SPACING

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

### SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

### STRENGTH CLASSIFICATION

<b>Rock Strength</b>	<b>Approximate Uniaxial Compressive Strength</b>		<b>Field Estimation of Hardness*</b>
	<b>(MPa)</b>	<b>(psi)</b>	
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

### TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length
Solid Core Recovery:(SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run
Rock Quality Designation:(RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a % of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index:(FI)	Frequency of natural fractures per 0.3m of core run.

# UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS W <sub>L</sub> < 50%	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. (W <sub>L</sub> < 30%).
		CI	Inorganic clays of medium plasticity, silty clays. (30% < W <sub>L</sub> < 50%).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS W <sub>L</sub> > 50%	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

# RECORD OF BOREHOLE No NW-01

1 OF 2

METRIC

GWP# 3054-13-00 LOCATION Norwich Ave. Underpass N 4 775 259.9 E 204 177.4 ORIGINATED BY GA  
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2014.11.12 - 2014.11.12 CHECKED BY SBP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W <sub>P</sub>	W	W <sub>L</sub>		
295.8	GROUND SURFACE							20	40	60	80	100				
0.0	TOPSOIL: (150mm)							20	40	60	80	100				
0.2	Silty <b>CLAY</b> to Clayey <b>SILT</b> , some sand, trace gravel, occasional rootlets Firm to Stiff Brown Moist		1	SS	8		295									0 15 61 24
			2	SS	13											
294.2																
1.5	<b>SILT</b> , some sand grading to <b>SAND</b> and <b>SILT</b> , trace clay, trace gravel, occasional cobbles Very Dense Brown Moist (TILL)		3	SS	54		294									
			4	SS	103											
			5	SS	100/ 0.150		293									
			6	SS	103/ 0.150		292									
			7	SS	122		291									0 40 53 7
			8	SS	111		288									
			9	SS	106		287									
							286									

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15 10 5 0  
 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No NW-01

2 OF 2

METRIC

GWP# 3054-13-00 LOCATION Norwich Ave. Underpass N 4 775 259.9 E 204 177.4 ORIGINATED BY GA  
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2014.11.12 - 2014.11.12 CHECKED BY SBP

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									
	Continued From Previous Page		10	SS	111												
285.5																	
10.2	END OF BOREHOLE AT 10.2m. BOREHOLE OPEN TO 10.2m AND WATER LEVEL AT 9.4m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																



# RECORD OF BOREHOLE No NW-02

1 OF 2

METRIC

GWP# 3054-13-00 LOCATION Norwich Ave. Underpass N 4 775 252.1 E 204 206.5 ORIGINATED BY GA  
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2014.11.17 - 2014.11.17 CHECKED BY SBP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE				WATER CONTENT (%) w <sub>P</sub> w      w <sub>L</sub>				GR	SA	SI	CL
303.9	GROUND SURFACE							20	40	60	80	100							
0.0	ASPHALT:(125mm)							20	40	60	80	100							
0.1	SAND and GRAVEL, trace silt Dense Brown Moist (FILL)		1	SS	34		303							○					41   52   7 (SI+CL)
			2	SS	32									○					
302.4																			
1.5	Clayey SILT, sandy Stiff to Hard Brown/Grey Moist (FILL)		3	SS	16		302							○					
			4	SS	17									○					
			5	SS	31		301							○	H				0   28   54   18
			6	SS	8		300												
							299							○					
							298												
297.8																			
6.1	Sandy SILT, trace gravel Very Dense Brown Moist		7	SS	70		297							○					
			8	SS	109		296							○					
							295												
294.8																			
9.1	Silty CLAY, some sand Hard Grey Moist		9	SS	36		294							○					0   12   42   46

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity 20  
15 10 5 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No NW-02

2 OF 2

METRIC

GWP# 3054-13-00 LOCATION Norwich Ave. Underpass N 4 775 252.1 E 204 206.5 ORIGINATED BY GA  
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2014.11.17 - 2014.11.17 CHECKED BY SBP

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									
	Continued From Previous Page																
291.8			10	SS	104/ 0.150		293										
12.2	Sandy <b>SILT</b> , trace gravel Very Dense Brown Moist (TILL)		11	SS	106/ 0.150		292										
289.9			12	SS	62/ 0.150		291										
14.0	END OF BOREHOLE AT 12.8m. BOREHOLE OPEN TO 12.8m AND DRY. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.  WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m)  2014.11.28 Dry 2015.07.15 Dry						290										

# RECORD OF BOREHOLE No NW-03

1 OF 2

METRIC

GWP# 3054-13-00 LOCATION Norwich Ave. Underpass N 4 775 238.5 E 204 184.8 ORIGINATED BY GA  
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2014.11.12 - 2014.11.12 CHECKED BY SBP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL LIMIT      MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)					
								○ UNCONFINED      + FIELD VANE				W <sub>P</sub> W      W <sub>L</sub>					
								● QUICK TRIAXIAL      × LAB VANE									
295.4	GROUND SURFACE						20	40	60	80	100						
0.0	TOPSOIL: (125mm)						20	40	60	80	100						
0.1	Sandy <b>SILT</b> , some clay, trace gravel Compact Brown Moist		1	SS	16								○				
	Clayey silt seams		2	SS	28								⊕				0 21 60 19
293.9																	
1.5	Silty <b>CLAY</b> , trace to some sand, trace gravel Hard Brown Moist		3	SS	36								○				
			4	SS	57								○				
292.4																	
3.0	Silty <b>SAND</b> to <b>SILT</b> , some sand, some clay, trace gravel Very Dense Brown Moist (TILL)		5	SS	107								○				7 60 25 8
			6	SS	103/ 0.150								○				
											</						

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No NW-03

2 OF 2

METRIC

GWP# 3054-13-00 LOCATION Norwich Ave. Underpass N 4 775 238.5 E 204 184.8 ORIGINATED BY GA  
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2014.11.12 - 2014.11.12 CHECKED BY SBP

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					W <sub>p</sub>	W	W <sub>L</sub>		
	Continued From Previous Page							20	40	60	80	100					
284.5			10	SS	114		285										
11.0	END OF BOREHOLE AT 11.0m. BOREHOLE OPEN TO 11.0m AND WATER LEVEL AT 7.3m BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																

# RECORD OF BOREHOLE No NW-04

1 OF 2

METRIC

GWP# 3054-13-00 LOCATION Norwich Ave. Underpass N 4 775 160.3 E 204 200.0 ORIGINATED BY GA  
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2014.11.14 - 2014.11.04 CHECKED BY SBP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT				UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)					GR	SA	SI	CL
								○ UNCONFINED      + FIELD VANE	● QUICK TRIAXIAL      × LAB VANE											
293.2	GROUND SURFACE							20	40	60	80	100								
0.0	TOPSOIL: (150mm)							20	40	60	80	100								
0.2	Silty <b>CLAY</b> , trace to some sand Firm to Hard Grey Moist		1	SS	4									○						
			2	SS	4									○						
			3	SS	7									○	—			0	9	
			4	SS	38									○						
			5	SS	37									○						
			6	SS	43									○	—			0	21	
287.7																				
5.5	<b>SAND</b> and <b>SILT</b> , trace clay, trace to some gravel Very Dense Grey Wet (TILL)		7	SS	105									○						
			8	SS	110									○				0	43	
			9	SS	104/ 0.150									○						

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15 10 5 10  
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No NW-04

2 OF 2

METRIC

GWP# 3054-13-00 LOCATION Norwich Ave. Underpass N 4 775 160.3 E 204 200.0 ORIGINATED BY GA  
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2014.11.14 - 2014.11.04 CHECKED BY SBP

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									
	Continued From Previous Page																
282.4			10	SS	114/		283										
10.8	END OF BOREHOLE AT 10.8m. BOREHOLE OPEN TO 10.8m AND WATER LEVEL AT 1.6m. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.  WATER LEVEL READINGS: DATE      DEPTH (m)      ELEV. (m) 2014.11.19      3.9      289.3 2014.11.28      3.7      289.5 2015.07.15      3.5      289.7				0.150												

## METRIC

SOIL PROFILE			SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		NATURAL MOISTURE CONTENT	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa	PLASTIC LIMIT		
292.4	GROUND SURFACE						○ UNCONFINED + FIELD VANE	w <sub>p</sub>	w	kN/m <sup>3</sup>	
0.0	TOPSOIL: (125mm)						● QUICK TRIAXIAL × LAB VANE	w <sub>L</sub>			
0.1	Silty CLAY, trace sand, occasional rootlets in the upper 1.0m zone Firm to Hard Dark Brown Moist		1	SS	8	292					
			2	SS	9	291					
			3	SS	6	290					
			4	SS	28	289					
			5	SS	31	288					
			6	SS	30	287					
286.3						286					
6.1	Sandy SILT to Silty SAND, some gravel, trace clay Very Dense Grey Wet (TILL)		7	SS	102	285					
			8	SS	104	284					
			9	SS	112	283					

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

ONTMT4S 1224.GPJ 2015TEMPLATE(MTO).GDT 4/27/16

# RECORD OF BOREHOLE No NW-05

2 OF 2

METRIC

GWP# 3054-13-00 LOCATION Norwich Ave. Underpass N 4 775 135.8 E 204 205.9 ORIGINATED BY GA  
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2014.11.13 - 2014.11.13 CHECKED BY SBP

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					WATER CONTENT (%)						
						20	40	60	80	100	20	40	60				
282.3	Continued From Previous Page		10	SS	108												
10.1	END OF BOREHOLE AT 10.1m. BOREHOLE OPEN TO 10.1m AND WATER LEVEL AT 4.3m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.				0.150												



# RECORD OF BOREHOLE No NW-06

1 OF 1

METRIC

GWP# 3054-13-00 LOCATION Norwich Ave. Underpass N 4 775 283.2 E 204 178.9 ORIGINATED BY GA  
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2014.11.11 - 2014.11.11 CHECKED BY SBP

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									
298.7	GROUND SURFACE							20	40	60	80	100					
0.0	TOPSOIL: (125mm)							20	40	60	80	100					
0.1	SAND and SILT, some clay Compact Brown Moist (FILL)		1	SS	11		298							○			0 39 43 18
			2	SS	15									○			
297.2																	
1.5	Clayey SILT, trace to some sand, trace gravel Hard Brown Moist		3	SS	43		297							○			
			4	SS	59		296							○			
			5	SS	70		295							○			
294.2																	
4.6	SILT, some sand, some clay, trace gravel Very Dense Brown Moist (TILL)		6	SS	80		294							○			0 18 68 14
							293										
292.3			7	SS	104									○			
6.4	END OF BOREHOLE AT 6.4m. BOREHOLE OPEN TO 6.4m AND DRY. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																

ONTMT4S 1224.GPJ 2015TEMPLATE(MTO).GDT 4/27/16

# RECORD OF BOREHOLE No NW-07

1 OF 1

METRIC

GWP# 3054-13-00 LOCATION Norwich Ave. Underpass N 4 775 112.9 E 204 215.1 ORIGINATED BY GA  
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2014.11.13 - 2014.11.13 CHECKED BY SBP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					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 (%)	
								20 40 60 80 100								
292.1	GROUND SURFACE															
0.0	TOPSOIL: (150mm)															
0.2	SAND and SILT, some clay, occasional rootlets Compact Brown Moist (FILL)		1	SS	10											
			2	SS	18									0 40 43 17		
290.6																
1.5	SAND, some gravel, trace silt Compact Brown/Dark Brown Moist		3	SS	19											
289.9																
2.3	Silty CLAY, trace sand, trace gravel Very Stiff Grey Moist		4	SS	29											
					5	SS	22									
			6	SS	17											
			7	SS	22									0 9 40 51		
285.4																
6.7	END OF BOREHOLE AT 6.7m. BOREHOLE OPEN TO 6.7m AND WATER LEVEL AT 4.6m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.															



ONTMT4S 1224.GPJ 2015TEMPLATE(MTO).GDT 4/27/16

# RECORD OF BOREHOLE No NW-08

1 OF 1

METRIC

GWP# 3054-13-00 LOCATION Norwich Ave. Underpass N 4 775 097.2 E 204 222.0 ORIGINATED BY GA  
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2014.11.13 - 2014.11.13 CHECKED BY SBP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)								
294.3	GROUND SURFACE							20	40	60	80	100	W <sub>P</sub>	W	W <sub>L</sub>	GR	SA	SI	CL	
0.0	TOPSOIL: (150mm)							20	40	60	80	100								
0.2	Silty <b>SAND</b> , some gravel, some clay Loose to Very Dense Brown Moist (FILL)  Occasional cobbles		1	SS	12		294							○						
			2	SS	50/ 0.150									○						
			3	SS	10		293								○					12 47 31 10
			4	SS	6		292									○				
291.3																				
3.0	Clayey <b>SILT</b> to Silty <b>CLAY</b> , some sand, trace gravel Stiff to Hard Brown Moist		5	SS	8		291							○						
						290														
6			SS	30		289									▬ ○ ▬				0 12 41 47	
						288									○					
287.6																				
6.7	END OF BOREHOLE AT 6.7m. BOREHOLE OPEN TO 6.7m AND WATER LEVEL AT 4.3m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																			

ONTMT4S 1224.GPJ 2015TEMPLATE(MTO).GDT 4/27/16

# RECORD OF BOREHOLE No NW-09

1 OF 1

METRIC

GWP# 3054-13-00 LOCATION Norwich Ave. Underpass N 4 775 041.3 E 204 235.2 ORIGINATED BY GA  
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2014.11.10 - 2014.11.10 CHECKED BY SBP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					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						
292.0	GROUND SURFACE													
0.0	TOPSOIL: (125mm)													
0.1	SAND and SILT, some clay, occasional rootlets Loose Brown Moist (FILL)		1	SS	8									
			2	SS	7		291							0 41 42 17
290.5														
1.5	ClayeySILT, trace sand, trace gravel Very Stiff Brown Moist		3	SS	16		290							
289.7														
2.3	SandySILT to SiltySAND, some gravel, trace to some clay Loose to Compact Brown Moist		4	SS	9		289							
			5	SS	27									
287.9							288							
4.1	ClayeySILT to SiltyCLAY, trace sand  Hard Grey Moist		6	SS	32		287							0 16 70 14
			7	SS	51		286							
285.3														
6.7	END OF BOREHOLE AT 6.7m. BOREHOLE OPEN TO 6.7m AND WATER LEVEL AT 4.1m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.													

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No NW-10

1 OF 1

METRIC

GWP# 3054-13-00 LOCATION Norwich Ave. Underpass N 4 775 012.3 E 204 248.7 ORIGINATED BY GA  
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2014.11.10 - 2014.11.10 CHECKED BY SBP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  <b>γ</b>  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						
291.6	GROUND SURFACE							20 40 60 80 100						
0.0	TOPSOIL: (150mm)							20 40 60 80 100						
0.2	Clayey <b>SILT</b> , trace sand, occasional rootlets Very Stiff Brown Moist (FILL)		1	SS	18		291							
290.8														
0.8	Sandy <b>SILT</b> , some clay, occasional clay seams Compact to Dense Brown Moist		2	SS	33		290							
			3	SS	20		289							
			4	SS	27		288							
288.6														
3.0	Silty <b>CLAY</b> , trace sand Stiff to Very Stiff Brown Moist		5	SS	24		287							
			6	SS	15		286							
			7	SS	26		285							
284.9														
6.7	END OF BOREHOLE AT 6.7m. BOREHOLE OPEN TO 6.7m AND DRY. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.													

ONTMT4S 1224.GPJ 2015TEMPLATE(MTO).GDT 4/27/16

# RECORD OF BOREHOLE No PA-01

1 OF 2

METRIC

GWP# 3054-13-00 LOCATION N 4 774 966.2 E 204 187.9 ORIGINATED BY TIM  
 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2015.12.14 - 2015.12.15 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
290.2	GROUND SURFACE							20 40 60 80 100						
0.0	<b>SAND</b> and <b>GRAVEL</b> , some silt Loose to Compact Grey Moist (FILL)  Layer of silty sand with some clay and gravel between 0.8 and 1.2m depth		1	SS	20		290							44 46 10 (SH+CL)
			2	SS	16		289							16 42 31 11
			3	SS	9									
288.1							288							
2.1	Silty <b>SAND</b> , some gravel, some clay, occasional cobbles, frequent silty clay lenses Very Loose to Compact Grey Moist (FILL)		4	SS	6									
			5	SS	3		287							
			6	SS	12		286							
							285							
284.1														
6.1	<b>SAND</b> and <b>GRAVEL</b> , some silt Dense Brown Wet (FILL)		7	SS	38		284							41 46 13 (SH+CL)
283.2														
7.0	Silty <b>SAND</b> to Sandy <b>SILT</b> , trace to some gravel, trace clay, occasional cobbles Compact to Very Dense Brown Wet (TILL)		8	SS	21		283							
							282							
			9	SS	50/ 0.100		281							

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15 5  
10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No PA-01

2 OF 2

METRIC

GWP# 3054-13-00 LOCATION N 4 774 966.2 E 204 187.9 ORIGINATED BY TIM  
 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2015.12.14 - 2015.12.15 CHECKED BY AMP

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									
	Continued From Previous Page																
			10	SS	50/ 0.163		280										
							279										
			11	SS	200/ 0.100		278										
							277										
276.6																	
13.6	Silty <b>CLAY</b> , trace to some sand, trace gravel Hard Brown Moist (TILL)		12	SS	42		276									0 6 37 57	
							275										
274.4			13	SS	39												
15.8	END OF BOREHOLE AT 15.8m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.  WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2015.12.15 9.2 281.0 2016.01.06 5.5 284.7																






ONTMT4S 1224.GPJ 2015TEMPLATE(MTO).GDT 4/27/16

# RECORD OF BOREHOLE No PA-02

1 OF 2

METRIC

GWP# 3054-13-00 LOCATION N 4 774 971.2 E 204 210.3 ORIGINATED BY TIM  
 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2015.12.15 - 2015.12.15 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa											
								20 40 60 80 100							PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT w <sub>p</sub> w w <sub>L</sub> WATER CONTENT (%)				
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
292.1	GROUND SURFACE						292												
0.0	<b>SAND</b> and <b>GRAVEL</b> , some silt Compact Brown Moist (FILL)		1	SS	12		292												
			2	SS	16		291												
			3	SS	17		290												
290.0							290												
2.1	Silty <b>SAND</b> , some gravel, some clay, occasional cobbles, frequent silty clay lenses Very Loose to Compact Brown Moist (FILL)		4	SS	3		289												
			5	SS	1		288												
			6	SS	26		287												
	Slight organic odour						286												
			7	SS	11		285												
285.0							285												
7.1	Silty <b>SAND</b> to Sandy <b>SILT</b> , trace to some gravel, trace clay, occasional cobbles Very Dense Brown Moist (TILL) 0.5m layer of gravelly sand at 7.5m depth		8	SS	28		284												
							283												
			9	SS	62														

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE



# RECORD OF BOREHOLE No PA-02

2 OF 2

METRIC

GWP# 3054-13-00 LOCATION N 4 774 971.2 E 204 210.3 ORIGINATED BY TIM  
 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2015.12.15 - 2015.12.15 CHECKED BY AMP

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    × LAB VANE											
	Continued From Previous Page							20 40 60 80 100											
280.8			10	SS	50/ 0.150		282												
11.3	Silty <b>CLAY</b> , trace to some sand, trace gravel, occasional cobbles Very Stiff to Hard Brown Moist (TILL)						281												
			11	SS	80		280					○	16	34	50				
							279												
			12	SS	46		278					○							
							277												
276.3			13	SS	18								5	32	63				
15.8	END OF BOREHOLE AT 15.8m. BOREHOLE OPEN TO 8.8m DEPTH AFTER AUGER REMOVAL AND DRY BOREHOLE BACKFILLED WITH CUTTINGS AND BENTONITE HOLEPLUG TO SURFACE.																		



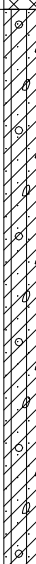
+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15  
 10  
 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No PA-03

1 OF 2

METRIC

GWP# 3054-13-00 LOCATION N 4 774 978.5 E 204 249.5 ORIGINATED BY TIM  
 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2015.12.16 - 2015.12.16 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
295.3	GROUND SURFACE							20 40 60 80 100							
0.0	<b>SAND</b> and <b>GRAVEL</b> , some silt Compact to Dense Brown Moist (FILL)		1	SS	13		295								
			2	SS	33		294								31 56 13 (SI+CL)
			3	SS	31										
293.0															
2.3	Sandy <b>SILT</b> , some clay, trace to some gavel, occasional cobbles, frequent silty clay lenses Compact Brown Moist (FILL)		4	SS	30		293								8 38 42 12
			5	SS	11		292								
							291								
			6	SS	23		290								
289.2															
6.1	Silty <b>CLAY</b> , trace to some sand, trace gravel, becoming sandy to 7.0m depth, occasional cobbles, slight organic odour Stiff to Hard Brown Moist (TILL)		7	SS	10		289								4 48 29 19
							288								
			8	SS	37		287								
			9	SS	10		286								0 6 33 61

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No PA-03

2 OF 2

METRIC

GWP# 3054-13-00 LOCATION N 4 774 978.5 E 204 249.5 ORIGINATED BY TIM  
 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2015.12.16 - 2015.12.16 CHECKED BY AMP

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    × LAB VANE														
	Continued From Previous Page							20	40	60	80	100										
279.5   <																						

ONTMT4S 1224.GPJ 2015TEMPLATE(MTO).GDT 4/27/16

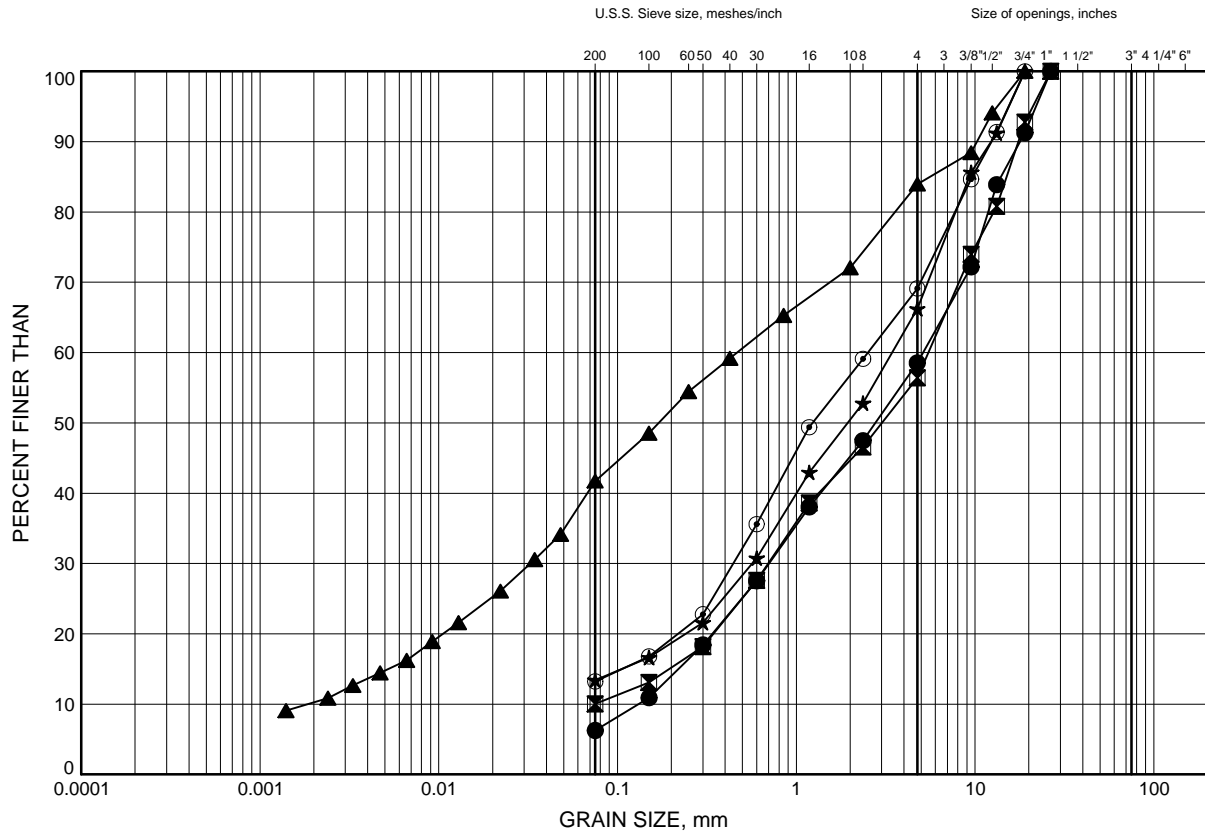
## **Appendix B**

### **Laboratory Test Results**

# GRAIN SIZE DISTRIBUTION

FIGURE B1

## SAND & GRAVEL FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	NW-02	1.07	302.88
⊠	PA-01	0.30	289.90
▲	PA-01	1.07	289.13
★	PA-02	0.30	291.80
⊙	PA-03	1.07	294.23

Date April 2016

GWP# 3054-13-00



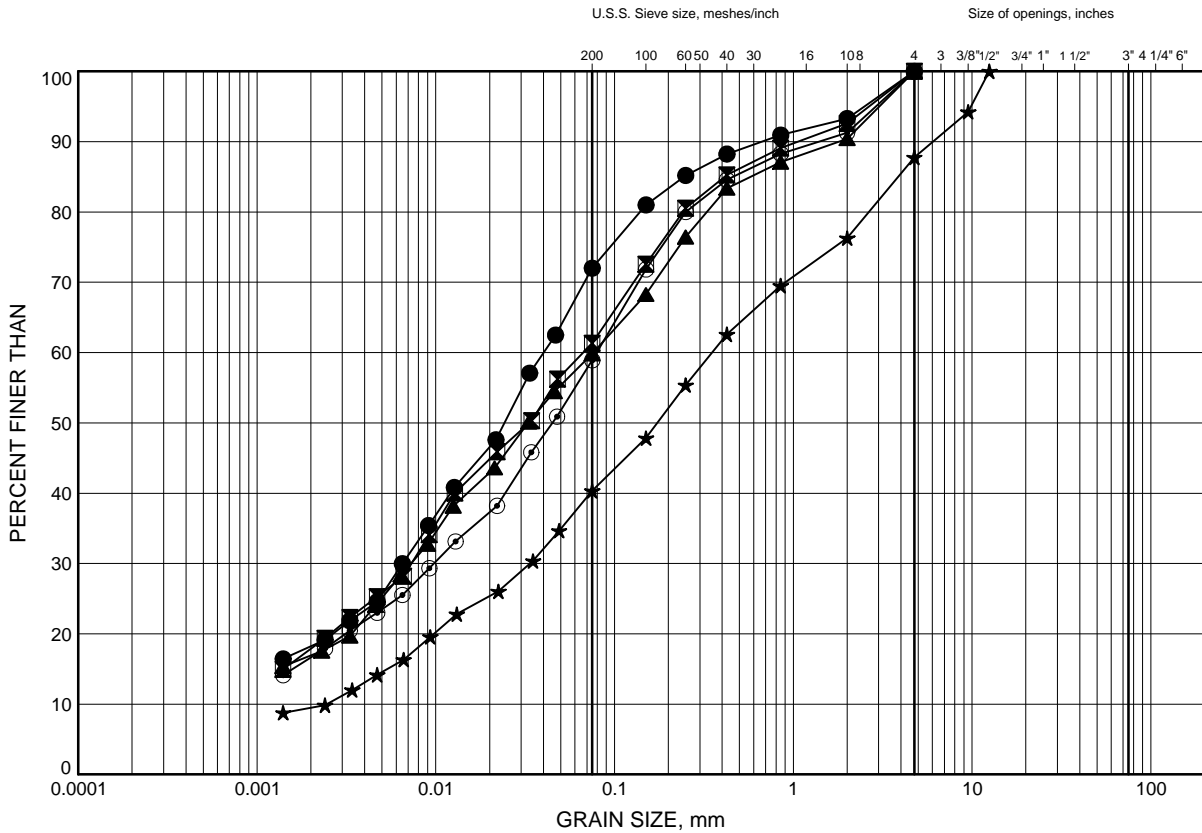
Prep'd AN

Chkd. AMP

# GRAIN SIZE DISTRIBUTION

FIGURE B2a

## EMBANKMENT FILL MATERIALS



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	NW-02	3.35	300.59
⊠	NW-06	1.07	297.68
▲	NW-07	1.07	291.07
★	NW-08	1.83	292.47
⊙	NW-09	1.07	290.95

Date April 2016

GWP# 3054-13-00



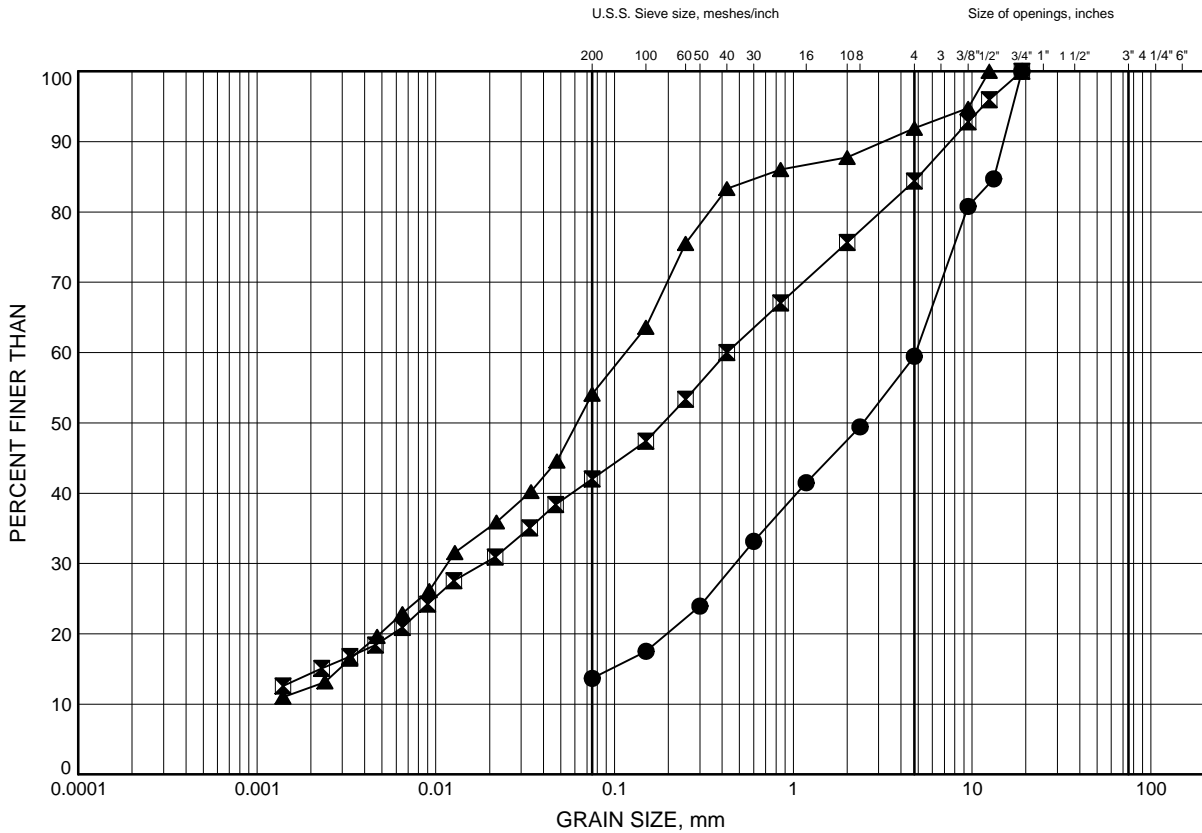
Prep'd AN

Chkd. AMP

# GRAIN SIZE DISTRIBUTION

FIGURE B2b

## EMBANKMENT FILL MATERIALS



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PA-01	6.40	283.80
⊠	PA-02	4.88	287.22
▲	PA-03	2.59	292.71

Date April 2016

GWP# 3054-13-00



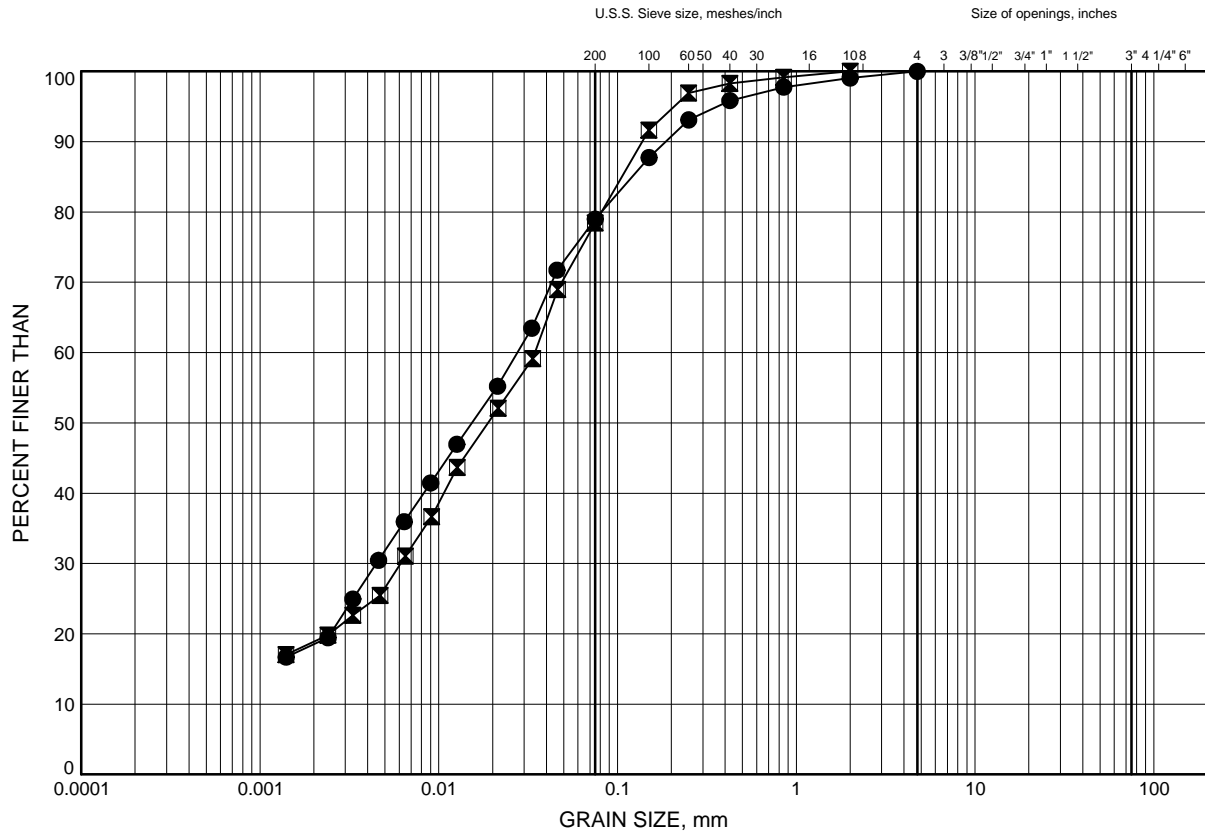
Prep'd AN

Chkd. AMP

# GRAIN SIZE DISTRIBUTION

FIGURE B3

## SANDY SILT



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	NW-03	1.07	294.38
⊠	NW-10	2.59	289.03

Date April 2016  
GWP# 3054-13-00



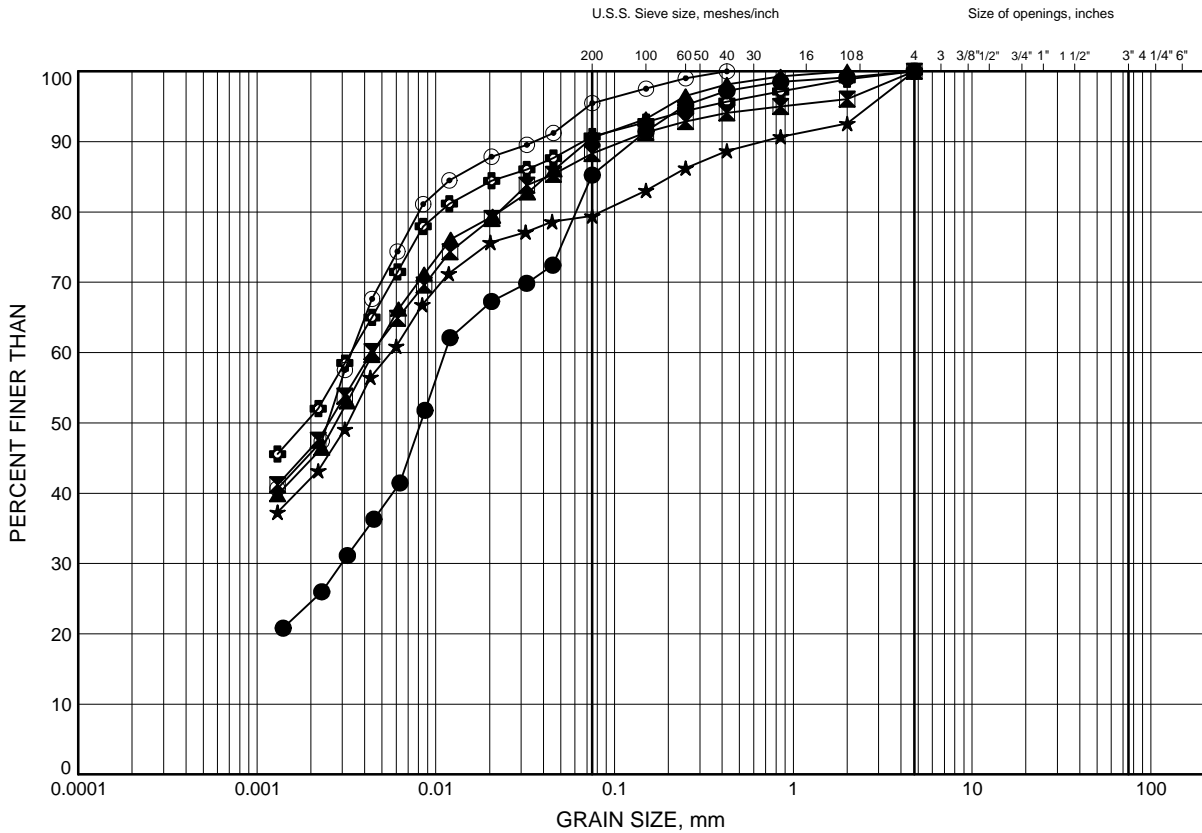
Prep'd AN  
Chkd. AMP



# GRAIN SIZE DISTRIBUTION

FIGURE B4a

## SILTY CLAY to CLAYEY SILT



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	NW-01	1.07	294.69
⊠	NW-02	9.45	294.49
▲	NW-04	1.83	291.40
★	NW-04	4.88	288.36
⊙	NW-05	2.59	289.78
⊕	NW-07	6.40	285.74

Date April 2016

GWP# 3054-13-00



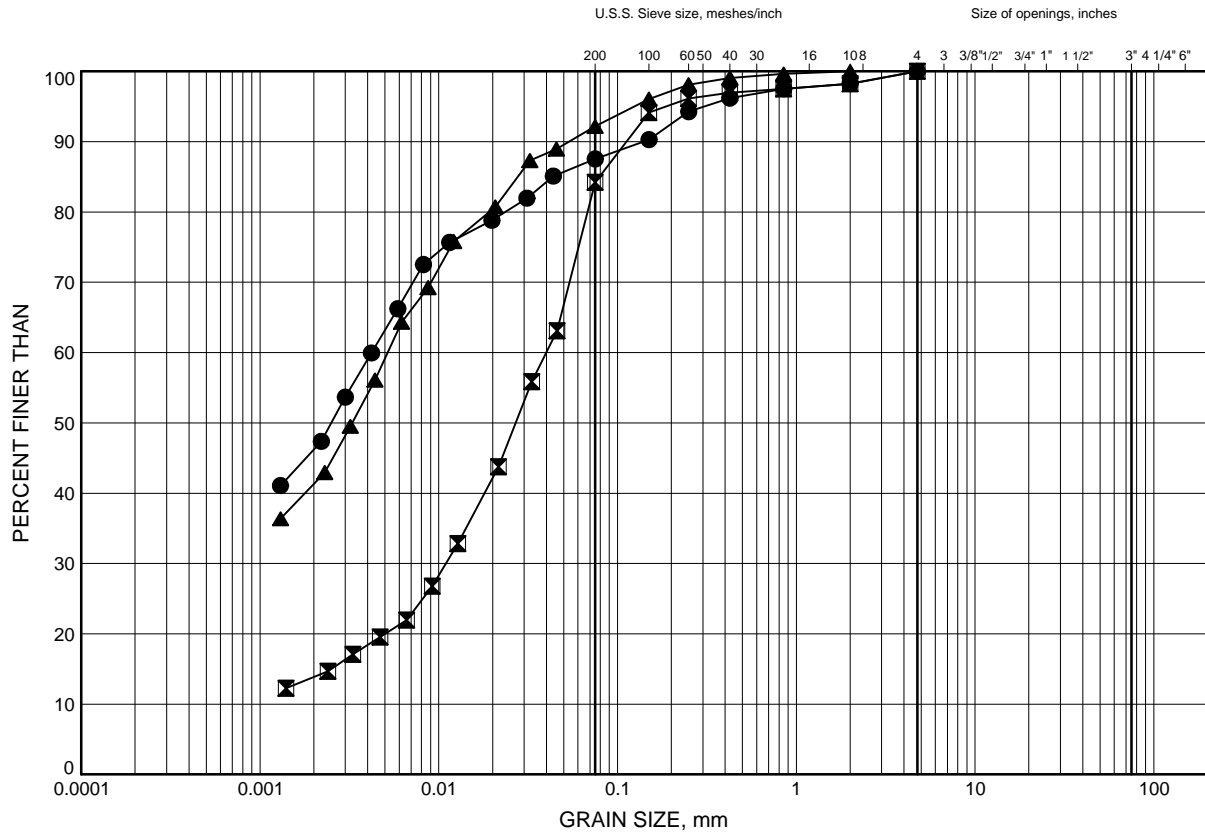
Prep'd AN

Chkd. AMP

# GRAIN SIZE DISTRIBUTION

FIGURE B4b

## SILTY CLAY to CLAYEY SILT



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	NW-08	4.88	289.42
⊠	NW-09	4.88	287.14
▲	NW-10	6.40	285.22

Date April 2016

GWP# 3054-13-00



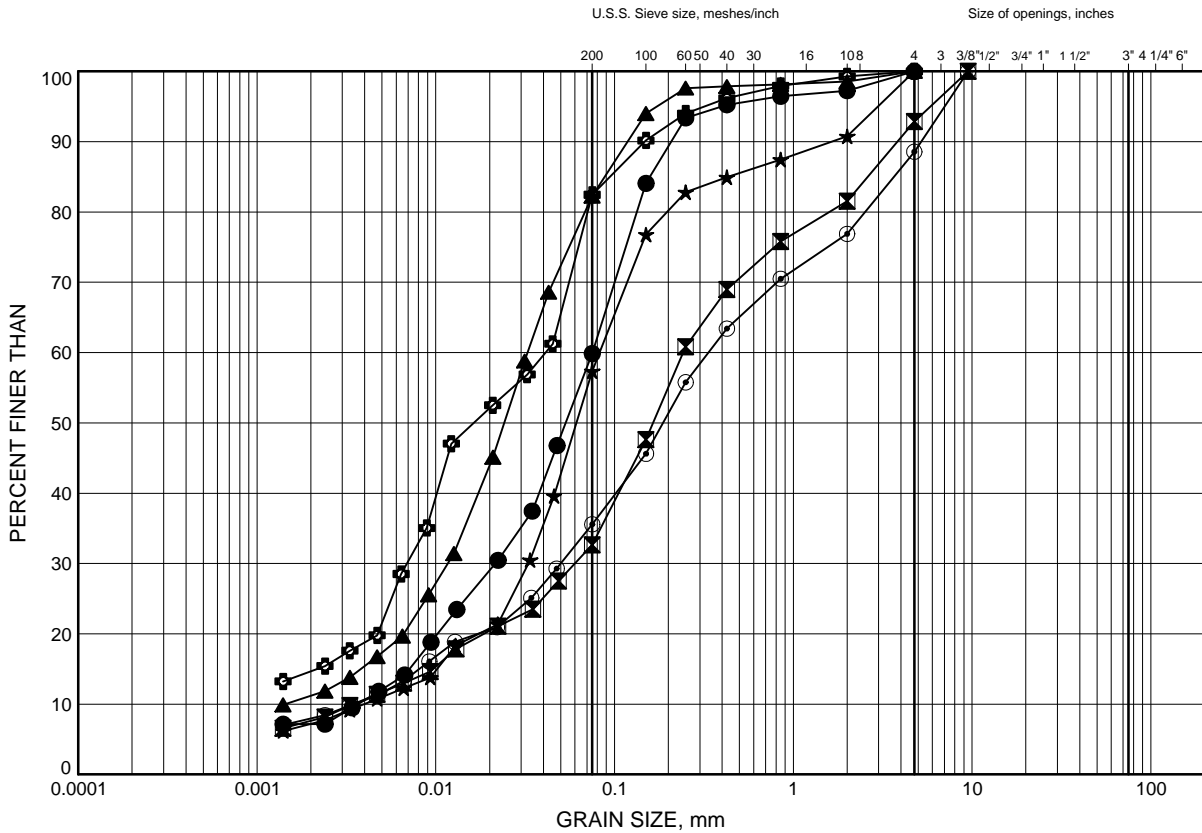
Prep'd AN

Chkd. AMP

# Norwich Ave. Underpass GRAIN SIZE DISTRIBUTION

FIGURE B5a

## SILTY SAND to SANDY SILT TILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	NW-01	6.40	289.36
⊠	NW-03	3.35	292.09
▲	NW-03	7.92	287.52
★	NW-04	7.92	285.31
⊙	NW-05	9.45	282.92
⊕	NW-06	4.88	293.87

Date April 2016

GWP# 3054-13-00



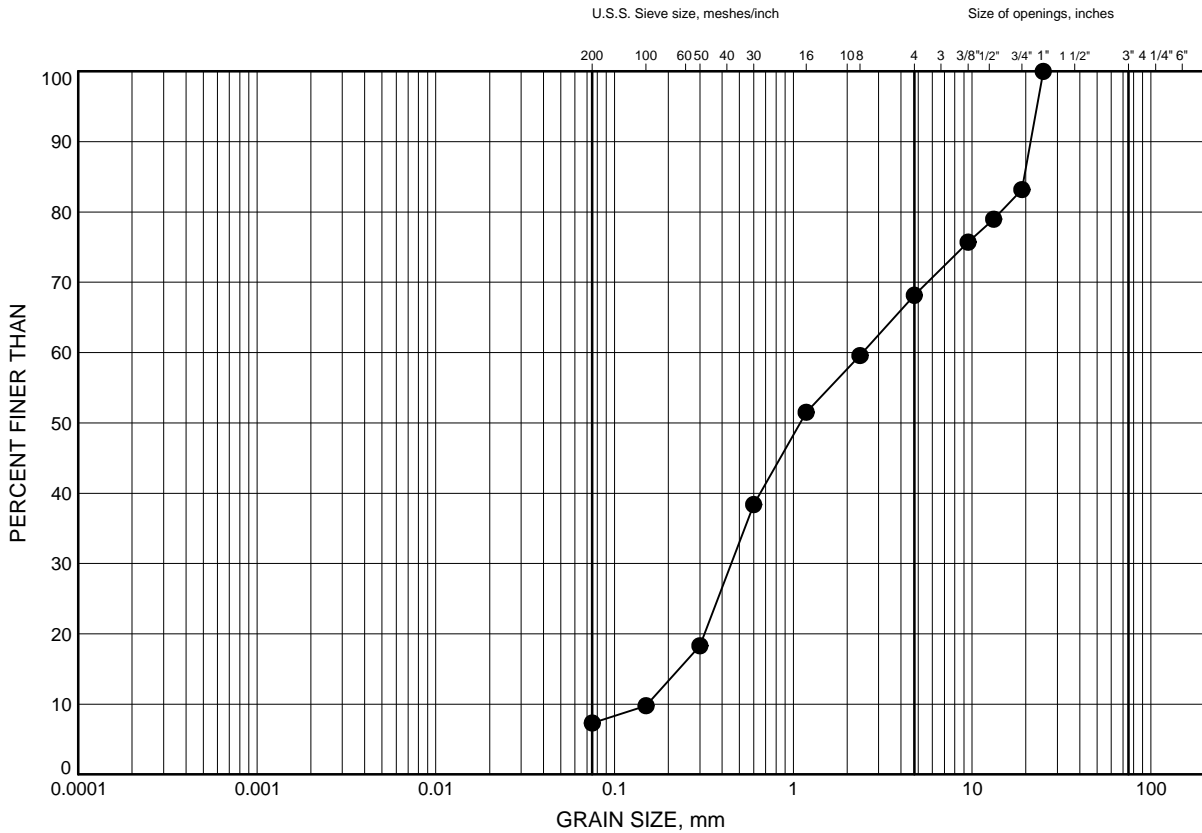
Prep'd AN

Chkd. AMP

# GRAIN SIZE DISTRIBUTION

FIGURE B5b

## SILTY SAND TILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PA-02	7.92	284.18

Date April 2016  
GWP# 3054-13-00

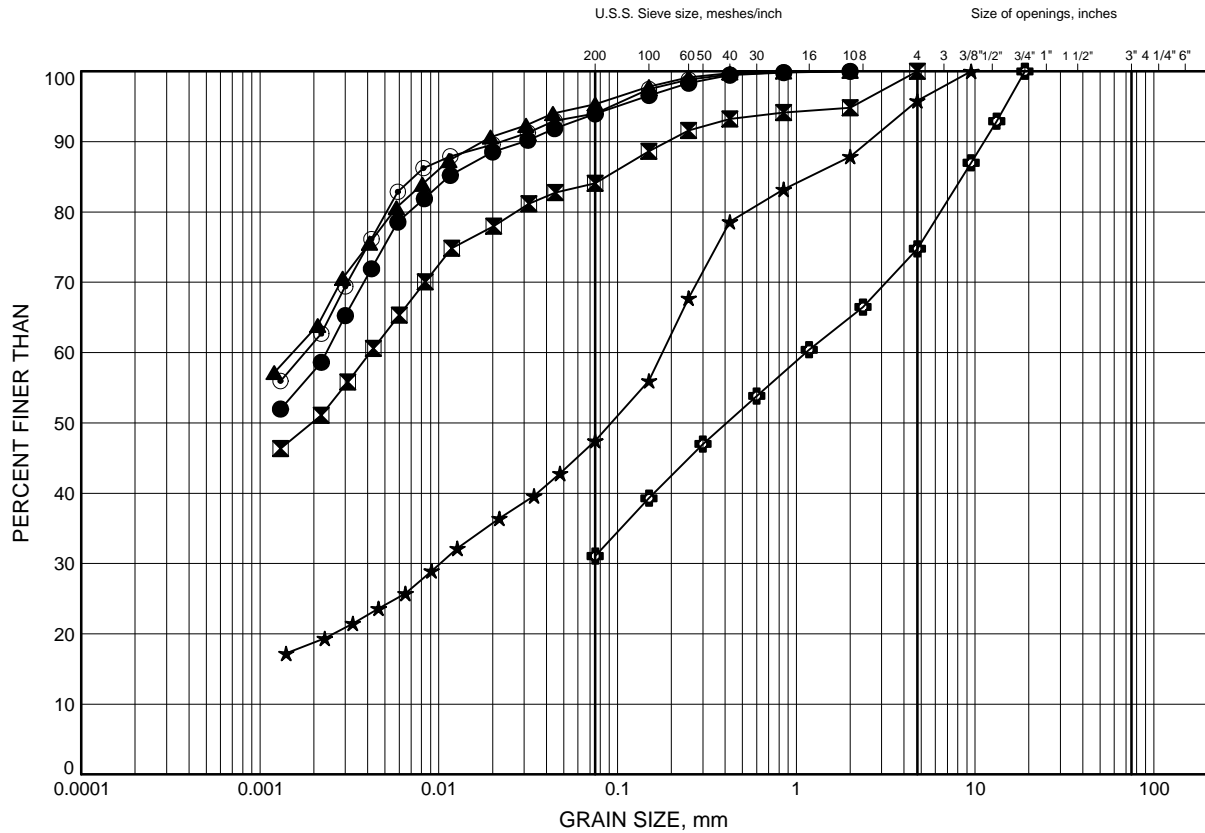


Prep'd AN  
Chkd. AMP

# GRAIN SIZE DISTRIBUTION

FIGURE B6

## SILTY CLAY TILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PA-01	14.02	276.18
⊠	PA-02	12.50	279.60
▲	PA-02	15.54	276.56
★	PA-03	6.40	288.90
⊙	PA-03	9.45	285.85
⊕	PA-03	15.54	279.76

Date April 2016

GWP# 3054-13-00



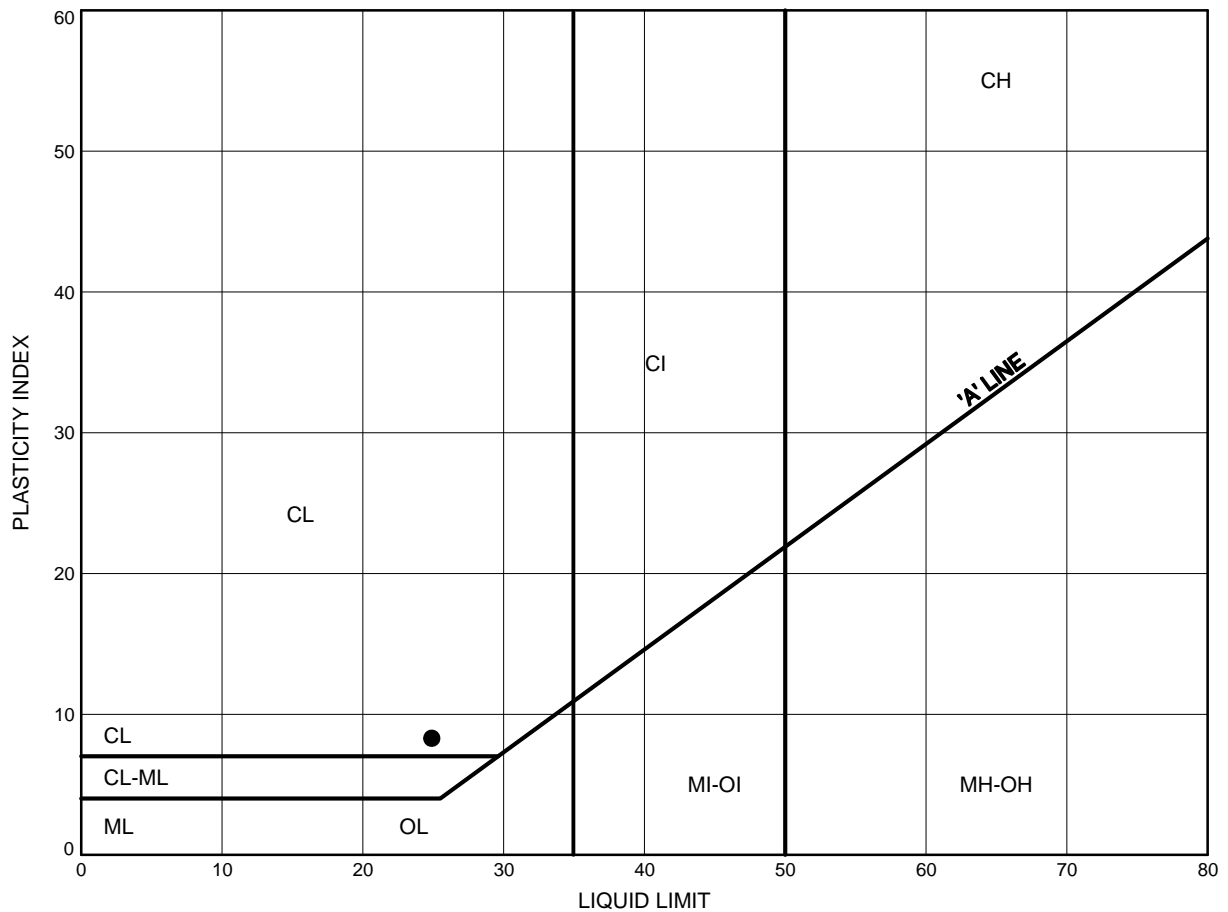
Prep'd AN

Chkd. AMP

# ATTERBERG LIMITS TEST RESULTS

FIGURE B7

## EMBANKMENT FILL MATERIALS



### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	NW-02	3.35	300.59

Date April 2016  
GWP# 3054-13-00

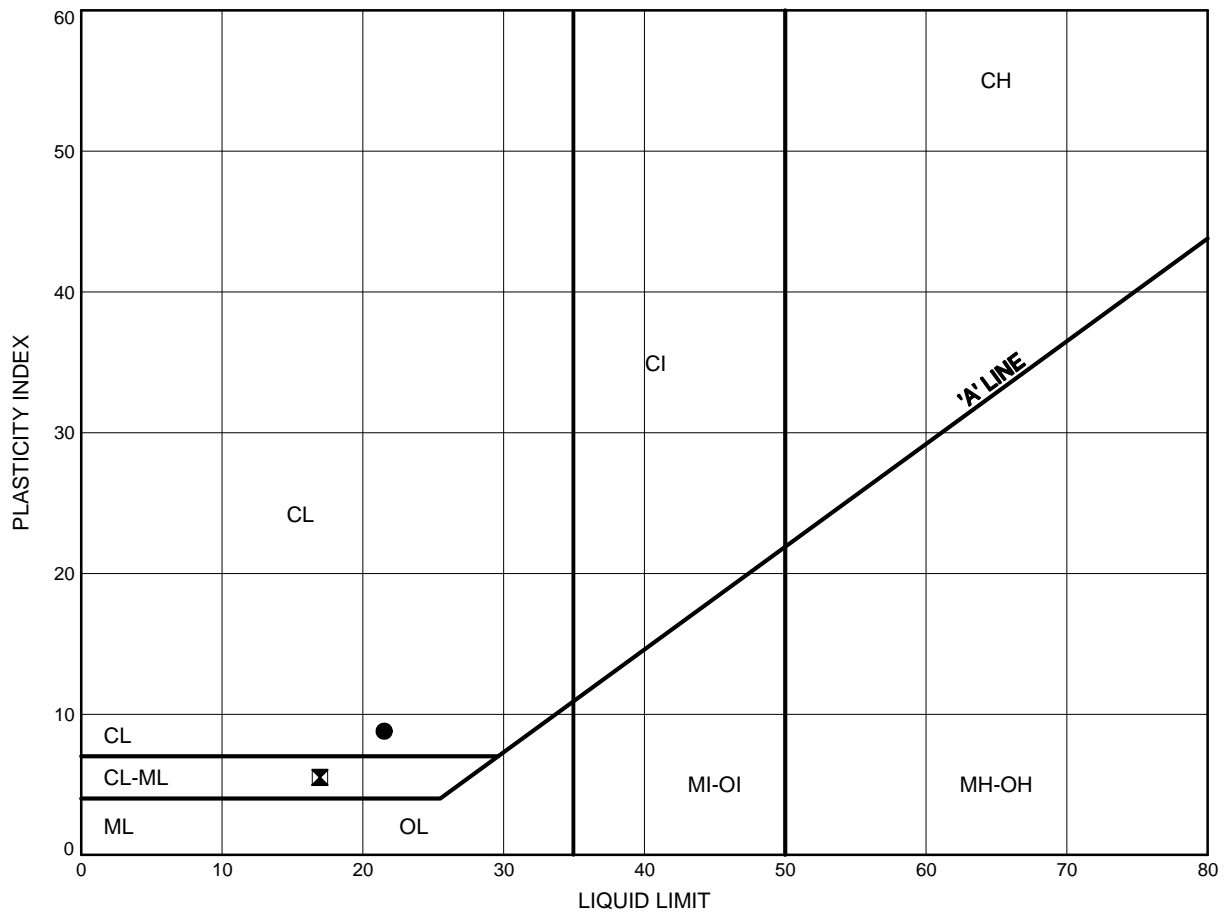


Prep'd AN  
Chkd. AMP

# ATTERBERG LIMITS TEST RESULTS

FIGURE B8

## CLAYEY SILT



### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	NW-03	1.07	294.38
⊠	NW-09	2.59	289.42

Date April 2016

GWP# 3054-13-00



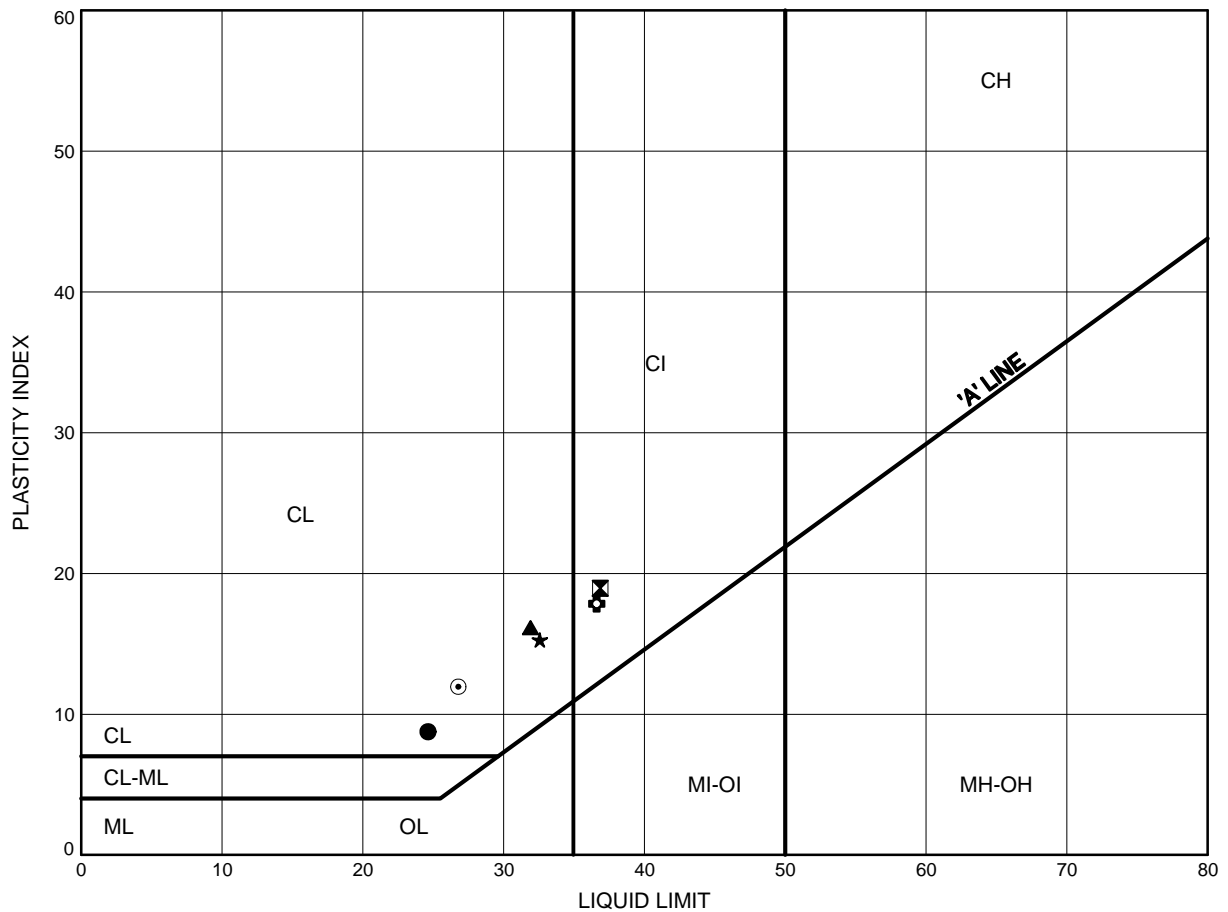
Prep'd AN

Chkd. AMP

# ATTERBERG LIMITS TEST RESULTS

FIGURE B9

## SILTY CLAY to CLAYEY SILT



### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	NW-01	1.07	294.69
⊠	NW-04	1.83	291.40
▲	NW-04	4.88	288.36
★	NW-05	2.59	289.78
⊙	NW-07	6.40	285.74
⊕	NW-08	4.88	289.42

Date April 2016

GWP# 3054-13-00



Prep'd AN

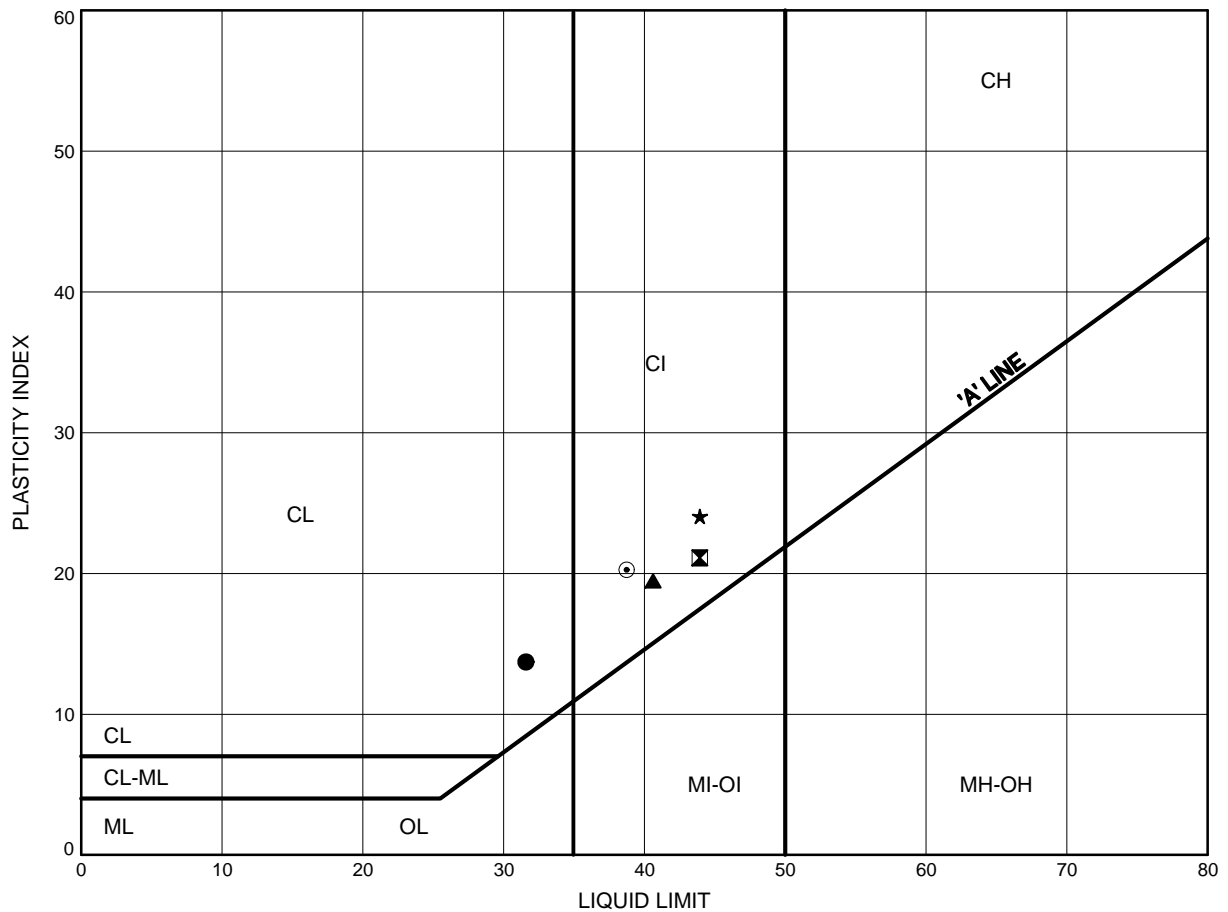
Chkd. AMP



# ATTERBERG LIMITS TEST RESULTS

FIGURE B10

## SILTY CLAY TILL



### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	NW-10	6.40	285.22
⊠	PA-01	14.02	276.18
▲	PA-02	12.50	279.60
★	PA-02	15.54	276.56
⊙	PA-03	9.45	285.85

Date April 2016

GWP# 3054-13-00



Prep'd AN

Chkd. AMP

## **Appendix C**

### **Analytical Test Results**



# AGAT Laboratories

## Certificate of Analysis

AGAT WORK ORDER: 14T925116

PROJECT: 19-5161-224

5835 COOPERS AVENUE  
MISSISSAUGA, ONTARIO  
CANADA L4Z 1Y2  
TEL (905) 712-5100  
FAX (905) 712-5122  
<http://www.agatlabs.com>

CLIENT NAME: THURBER ENGINEERING LTD

SAMPLING SITE:

ATTENTION TO: Stephen Peters

SAMPLED BY:

pH, Sulphate (Soil)						
DATE RECEIVED: 2014-12-05			DATE REPORTED: 2014-12-15			
		SAMPLE DESCRIPTION:		14-04 SS11 (40'-42')	14-02 SS1 (6'-2')	NW-02 SS11 (40'-42')
		SAMPLE TYPE:		Soil	Soil	Soil
		DATE SAMPLED:		12/4/2014	12/4/2014	12/4/2014
		G / S	RDL	6157014	6157025	6157026
Parameter	Unit			8.13	8.12	7.91
pH, 2:1 CaCl2 Extraction	pH Units			33	25	42
Sulphate (2:1)	µg/g	2				18

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard



**Certified By:**

## Method Summary

CLIENT NAME: THURBER ENGINEERING LTD

AGAT WORK ORDER: 14T925116

PROJECT: 19-5161-224

ATTENTION TO: Stephen Peters

SAMPLING SITE:

SAMPLED BY:

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
<b>Soil Analysis</b>			
pH, 2:1 CaCl <sub>2</sub> Extraction	INOR-93-6031	MSA part 3 & SM 4500-H+ B	PH METER
Sulphate (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH



**AGAT** Laboratories

5835 COOPERS AVENUE  
MISSISSAUGA, ONTARIO  
CANADA L4Z 1Y2  
TEL (905)712-5100  
FAX (905)712-5122  
<http://www.agatlabs.com>

## Quality Assurance

CLIENT NAME: THURBER ENGINEERING LTD

PROJECT: 19-5161-224

SAMPLING SITE:

AGAT WORK ORDER: 14T925116

ATTENTION TO: Stephen Peters

SAMPLED BY:

### Soil Analysis

RPT Date: Dec 15, 2014			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper
pH, Sulphate (Soil)															
pH, 2:1 CaCl2 Extraction	6157135		7.90	7.91	0.1%	NA	100%	80%	120%	NA			NA		
Sulphate (2:1)	6156506		17	17	3.8%	< 2	99%	80%	120%	103%	80%	120%	102%	70%	130%

Comments: NA signifies Not Applicable.

**Certified By:**



**AGAT QUALITY ASSURANCE REPORT (V1)**

Page 3 of 4

AGAT Laboratories is accredited to ISO/IEC 17025 by the Canadian Association for Laboratory Accreditation Inc. (CALA) and/or Standards Council of Canada (SCC) for specific tests listed on the scope of accreditation. AGAT Laboratories (Mississauga) is also accredited by the Canadian Association for Laboratory Accreditation Inc. (CALA) for specific drinking water tests. Accreditations are location and parameter specific. A complete listing of parameters for each location is available from [www.cala.ca](http://www.cala.ca) and/or [www.scc.ca](http://www.scc.ca). The tests in this report may not necessarily be included in the scope of accreditation.

Results relate only to the items tested and to all the items tested

## **Appendix D**

### **Site Photographs**



**Photograph 1 – Looking north along the Norwich Avenue bridge deck**



**Photograph 2 – Looking south along the Norwich Avenue bridge deck**



**Photograph 3 – Looking east onto Highway 401 from the bridge deck**



**Photograph 4 – Looking west onto Highway 401 from the bridge deck**





**Photograph 5 – Looking north-west towards bridge.**



**Photograph 6 – Looking south-east towards bridge**

**Appendix E**  
**Borehole Locations and Soil Strata Drawings**



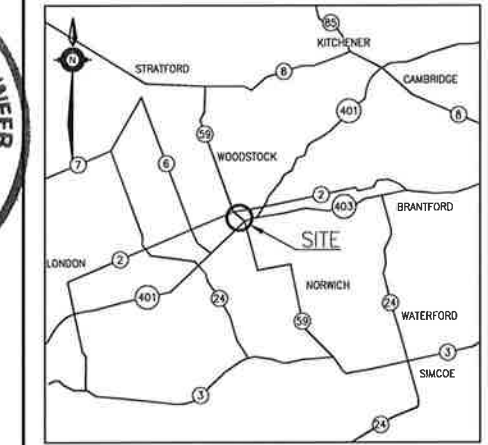


SHEET  
ST-2

METRIC







**THURBER ENGINEERING LTD.**



## KEYPLAN

## LEGEND

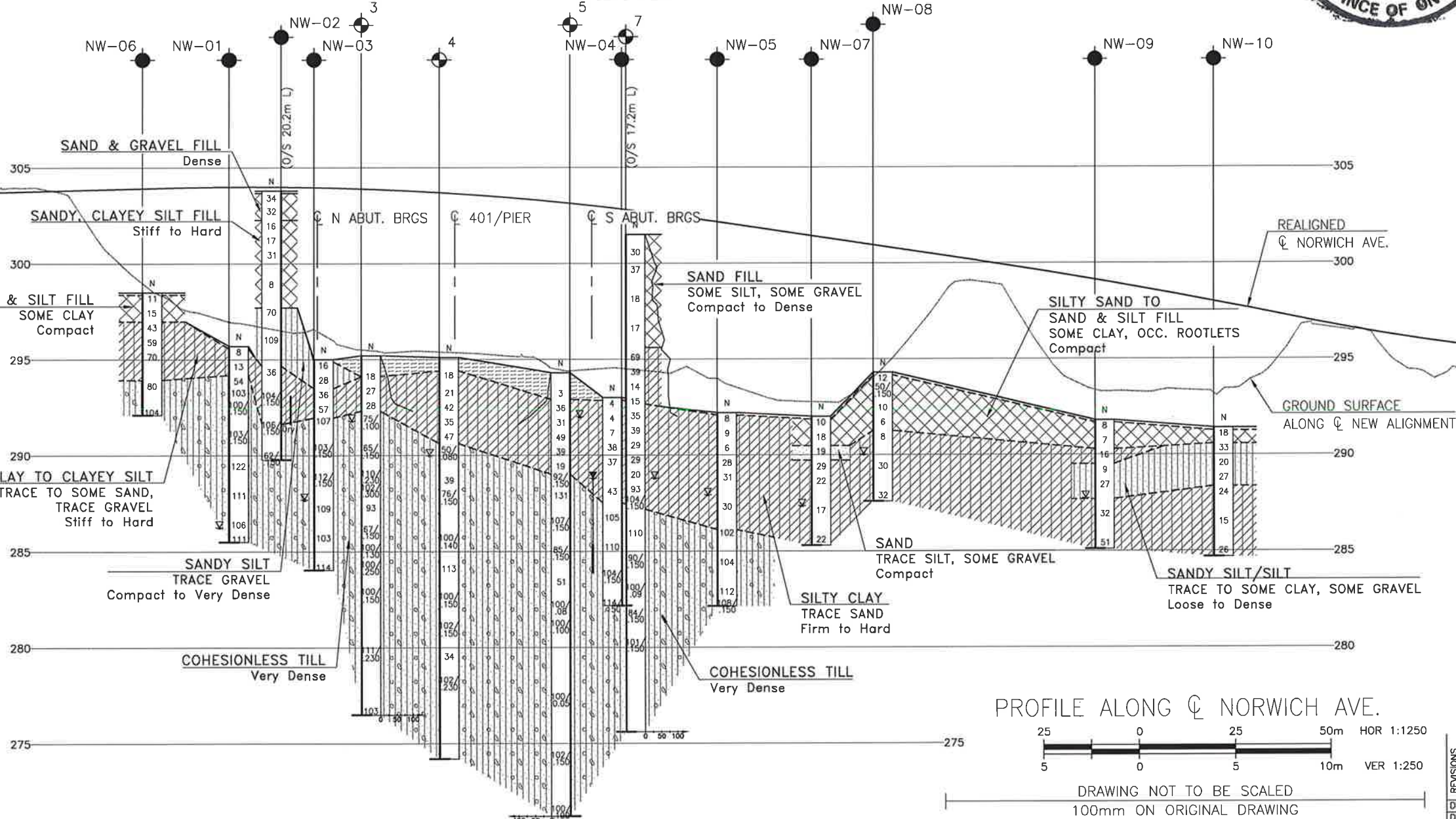
- |   |                                       |
|---|---------------------------------------|
|  | Borehole (Current Investigation)      |
|  | Borehole (Previous Investigation)     |
| N   | Blows /0.3m (Std Pen Test, 475J/blow) |
| CONE  | Blows /0.3m (60° Cone, 475J/blow)     |
| PH  | Pressure, Hydraulic                   |
|  | Water Level                           |
|  | Water Level In Piezometer             |
| 90%   | Rock Quality Designation (RQD)        |
| A/R   | Auger Refusal                         |

NO	ELEVATION	NORTHING	EASTING
NW-01	295.7	4 775 259.9	204 177.4
NW-02	303.8	4 775 252.1	204 206.5
NW-03	295.4	4 775 238.5	204 184.8
NW-04	293.0	4 775 160.3	204 200.0
NW-05	292.2	4 775 135.8	204 205.9
NW-06	298.5	4 775 283.2	204 178.9
NW-07	292.0	4 775 112.9	204 215.1
NW-08	294.3	4 775 097.2	204 222.0
NW-09	291.8	4 775 041.3	204 235.2
NW-10	291.4	4 775 012.3	204 248.7
3	295.2	4 775 227.2	204 191.8
4	295.1	4 775 209.7	204 206.8
5	294.3	4 775 175.4	204 201.7
7	301.5	4 775 163.2	204 222.3

-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

**GEOCRES No. 40P2-78**



PROFILE ALONG C NORWICH AVE.

Figure 10.1 illustrates the horizontal and vertical alignment of a road. The horizontal alignment (HOR) is shown at the top with a scale of 1:1250, featuring a 25m segment. The vertical alignment (VER) is shown below with a scale of 1:250, featuring a 10m segment. Both alignments show a transition from a lower level to a higher level.

DRAWING NOT TO BE SCALED  
100mm ON ORIGINAL DRAWING

REVISIONS										
	DATE	BY	DESCRIPTION							
	DESIGN	SBP	CHK	SBP	CODE	LOAD	DATE APR 2016			
	DRAWN	AN	CHK		SITE 23-170	ISTRUCT	ISCHM	IDWG: 2		



HWY 401 CONT No 2015-3021 GWP No 3054-13-00	
HIGHWAY 401/ NORWICH AVENUE UNDERPASS BOREHOLE LOCATIONS AND SOIL STRATA	SHEET ST-3
	METRIC

**KEYPLAN**

**LEGEND**

- Borehole (Current Investigation)
- ⊕ Borehole (Previous Investigation)
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60° Cone, 475J/blow)
- PH Pressure, Hydraulic
- ▽ Water Level
- ⊕ Water Level in Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

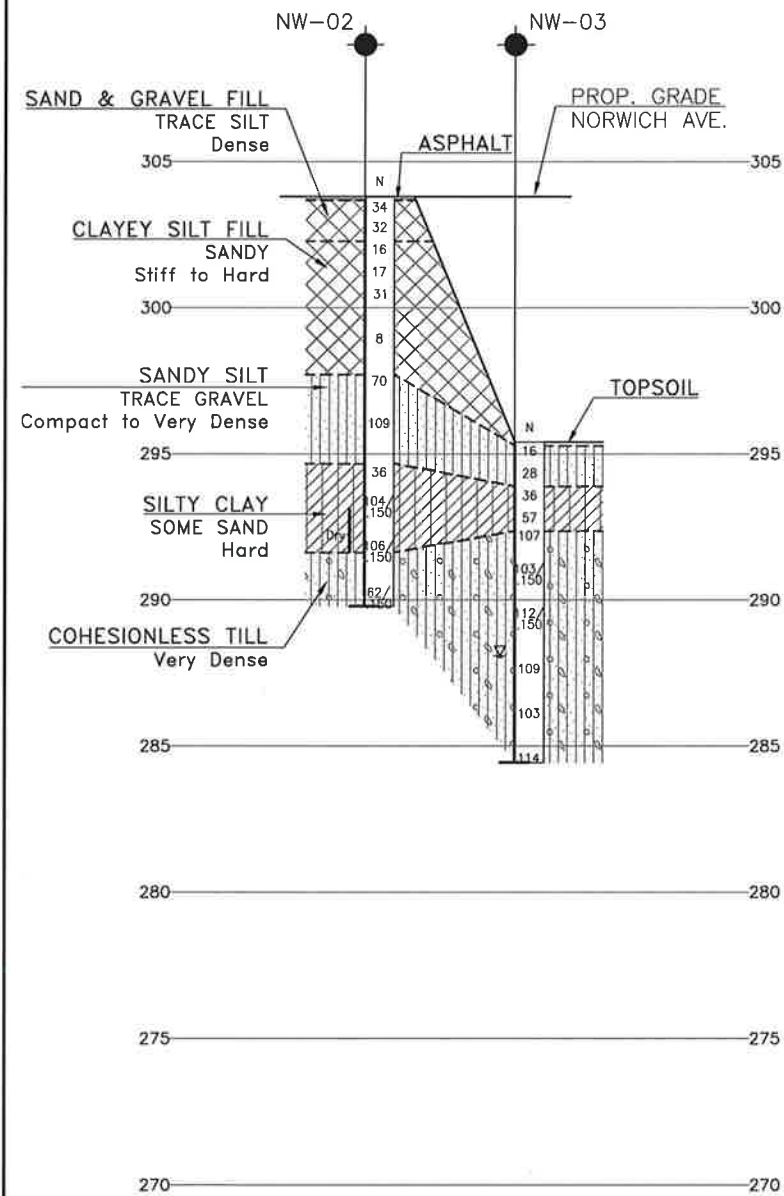
NO	ELEVATION	NORTHING	EASTING
NW-01	295.7	4 775 259.9	204 177.4
NW-02	303.8	4 775 252.1	204 206.5
NW-03	295.4	4 775 238.5	204 184.8
NW-04	293.0	4 775 160.3	204 200.0
NW-05	292.2	4 775 135.8	204 205.9
NW-06	298.5	4 775 283.2	204 178.9
NW-07	292.0	4 775 112.9	204 215.1
NW-08	294.3	4 775 097.2	204 222.0
NW-09	291.8	4 775 041.3	204 235.2
NW-10	291.4	4 775 012.3	204 248.7
3	295.2	4 775 227.2	204 191.8
4	295.1	4 775 209.7	204 206.8
5	294.3	4 775 175.4	204 201.7
7	301.5	4 775 163.2	204 222.3

**NOTES-**

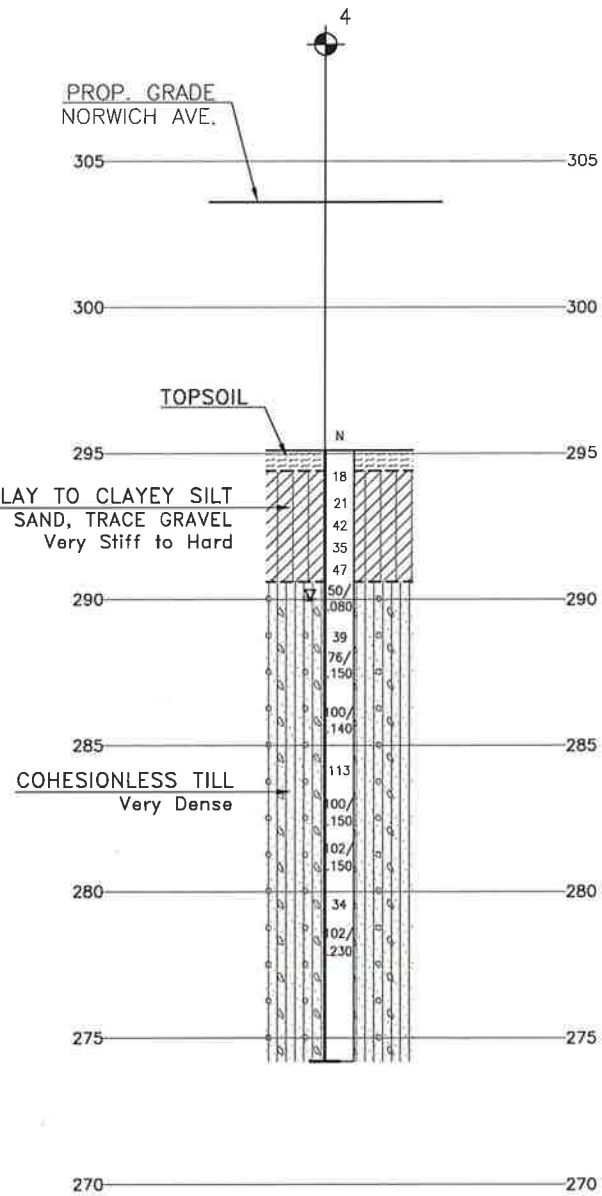
1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

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

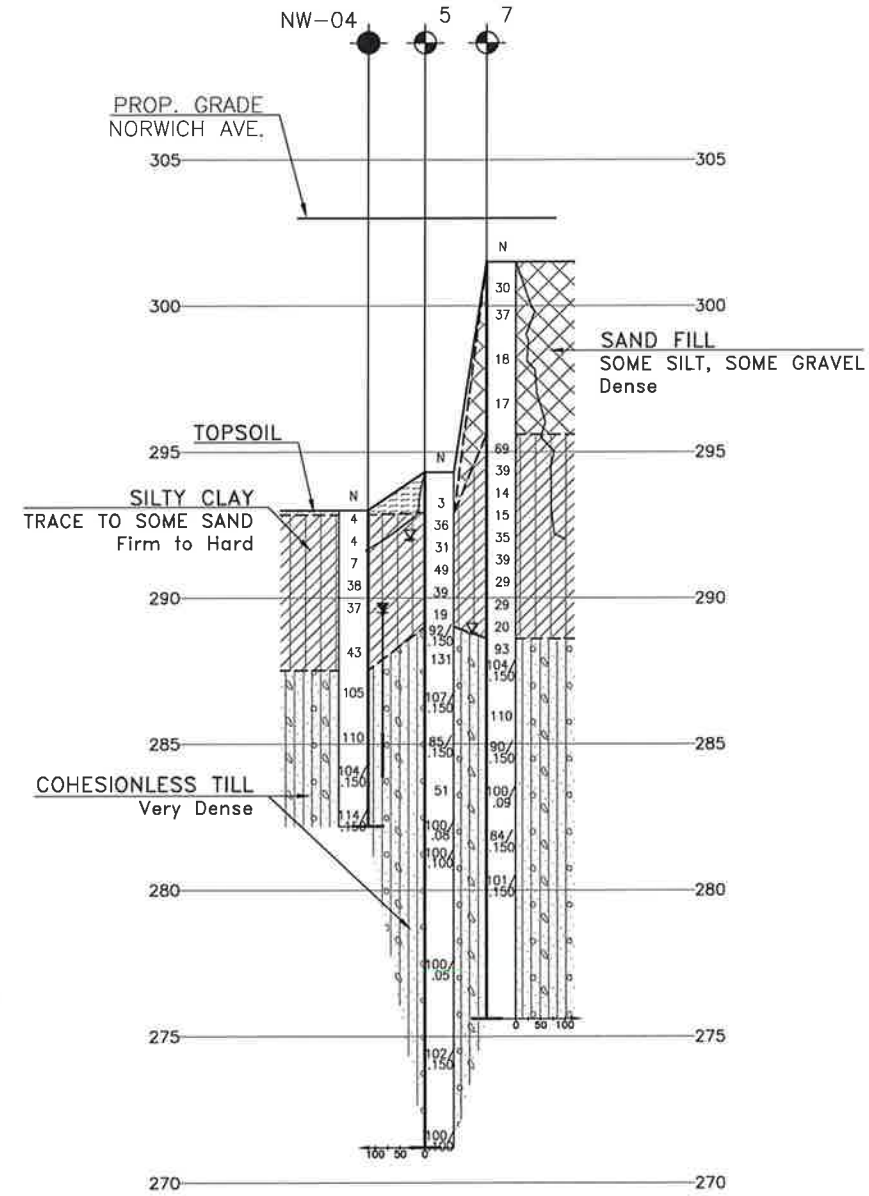
**GEOCREs No. 40P2-78**



SECTION A-A



SECTION B-B



SECTION C-C



DRAWING NOT TO BE SCALED  
100mm ON ORIGINAL DRAWING

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	SBP	CHK	SBP
DRAWN	AN	CHK	SITE
			23-170
			STRUCT
			SCHEME
			LDWG
			3





## **Appendix F**

### **Previous Investigation Borehole Locations and Soil Strata Drawing and Record of Borehole Sheets Geocres No.: 40P2-45**

## EXPLANATION OF TERMS USED IN REPORT

**N VALUE:** THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS  $\bar{N}$ .

**DYNAMIC CONE PENETRATION TEST:** CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

**CONSISTENCY:** COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH ( $c_u$ ) AS FOLLOWS:

$c_u$ (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

**DENSENESS:** COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

**RECOVERY:** SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

**MODIFIED RECOVERY:** SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY, IS:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

**JOINTING AND BEDDING:**

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	> 3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

## ABBREVIATIONS AND SYMBOLS

### FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE

### MECHANICAL PROPERTIES OF SOIL

$m_v$	$kPa^{-1}$	COEFFICIENT OF VOLUME CHANGE
$C_c$	1	COMPRESSION INDEX
$C_s$	1	SWELLING INDEX
$C_\alpha$	1	RATE OF SECONDARY CONSOLIDATION
$c_v$	$m^2/s$	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
$T_v$	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
$\sigma'_{vo}$	kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$	kPa	PRECONSOLIDATION PRESSURE
$\tau_f$	kPa	SHEAR STRENGTH
$c'$	kPa	EFFECTIVE COHESION INTERCEPT
$\phi'$	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$	kPa	APPARENT COHESION INTERCEPT
$\phi_u$	-°	APPARENT ANGLE OF INTERNAL FRICTION
$\tau_R$	kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$	kPa	REMOULDED SHEAR STRENGTH
$S_t$	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

### STRESS AND STRAIN

$u_w$	kPa	PORE WATER PRESSURE
$r_u$	1	PORE PRESSURE RATIO
$\sigma$	kPa	TOTAL NORMAL STRESS
$\sigma'$	kPa	EFFECTIVE NORMAL STRESS
$\tau$	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
$\epsilon$	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
$\mu$	1	COEFFICIENT OF FRICTION

### PHYSICAL PROPERTIES OF SOIL

$\rho_s$	$kg/m^3$	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	$e_{min}$	1, %	VOID RATIO IN DENSEST STATE
$\gamma_s$	$kN/m^3$	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	$I_D$	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
$\rho_w$	$kg/m^3$	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
$\gamma_w$	$kN/m^3$	UNIT WEIGHT OF WATER	$s_r$	%	DEGREE OF SATURATION	$D_n$	mm	n PERCENT - DIAMETER
$\rho$	$kg/m^3$	DENSITY OF SOIL	$w_L$	%	LIQUID LIMIT	$C_u$	1	UNIFORMITY COEFFICIENT
$\gamma$	$kN/m^3$	UNIT WEIGHT OF SOIL	$w_p$	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
$\rho_d$	$kg/m^3$	DENSITY OF DRY SOIL	$w_s$	%	SHRINKAGE LIMIT	q	$m^3/s$	RATE OF DISCHARGE
$\gamma_d$	$kN/m^3$	UNIT WEIGHT OF DRY SOIL	$I_p$	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
$\rho_{sat}$	$kg/m^3$	DENSITY OF SATURATED SOIL	$I_L$	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
$\gamma_{sat}$	$kN/m^3$	UNIT WEIGHT OF SATURATED SOIL	$I_C$	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
$\rho'$	$kg/m^3$	DENSITY OF SUBMERGED SOIL	$e_{max}$	1, %	VOID RATIO IN LOOSEST STATE	j	$kN/m^2$	SEEPAGE FORCE
$\gamma'$	$kN/m^3$	UNIT WEIGHT OF SUBMERGED SOIL						

# RECORD OF BOREHOLE No 1

1 OF 1

METRIC

W.P. 481 - 89 - 03 LOCATION CO-ORDS. N 4 775 051.1; E 204 202.2 ORIGINATED BY M.V.  
DIST 2 HWY 401 BOREHOLE TYPE CONE TEST & HOLLOW STEM AUGER COMPILED BY M.V.  
DATUM GEODETIC DATE 90 04 24 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	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100					
304.0	Hwy. 59 Shoulder													
0.0			1	SS	96	/15cm								
			2	SS	17									
			3	SS	15									
			4	SS	14									
298.3	Sand, Some Silt, Some Gravel, Compact ( Fill )													
5.7	Silty Sand, Trace of Gravel, Very Dense		5	SS	102									
296.5			6	SS	107									
7.5			7	SS	83									
	Silty Clay, Trace of Sand, Trace of Gravel, Hard		8	SS	67									
			9	SS	67									
			10	SS	88									
293.0			11	SS	56									
11.0			12	SS	50	/5cm								
			13	SS	75	/8cm								
			14	SS	100	/8cm								
			15	SS	75	/15cm								
	Sandy Silt, Trace of Gravel, Very Dense		16	SS	91	/15cm								
			17	SS	100	/10cm								
282.4			18	SS	81	/15cm								
21.6	End of Borehole													
	* Water Level Not Stabilized													



RECORD OF BOREHOLE No 2

1 OF 1

METRIC

W.P. 481 - 89 - 03 LOCATION CO-ORDS. N 4 775 030.4; E 204 171.0 ORIGINATED BY M.V.  
DIST 2 HWY 401 BOREHOLE TYPE CONE TEST COMPILED BY M.V.  
DATUM GEODETIC DATE 90 04 20 CHECKED BY

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE									
296.3	Ground Surface												
0.0													
293.9													
2.4	End of Cone Test										120/25cm		

# RECORD OF BOREHOLE No 3

1 OF 1

METRIC

W.P. 481 - 89 - 03 LOCATION CO-ORDS. N 4 775 007.0; E 204 176.8 ORIGINATED BY M V  
DIST 2 HWY 401 BOREHOLE TYPE CONE TEST & HOLLOW STEM AUGER COMPILED BY M V  
DATUM GEODETTIC DATE 90 04 20 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 7 kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100					
295.2	Ground Surface													
0.0	Topsoil													
294.1	Sand, Some Silt, Compact		1	SS	18									
1.1	Clayey Silt, Trace of Sand, Trace of Gravel, Very Stiff		2	SS	27									
292.3			3	SS	28									
2.9			4	SS	75	10cm								
			5	SS	65	15cm								
	Sandy Gravel, Some Silt		6	SS	110	23cm								
			7	SS	102	3cm								
			8	SS	93									
	Silty Sand, Trace of Gravel, Very Dense		9	SS	67	15cm								
			10	SS	100	13cm								
284.6			11	SS	100	25cm								
10.6			12	SS	100	15cm								
			13	SS	111	23cm								
	Heterogeneous Mixture of Clayey Silt, Sand & Gravel, Hard ( Glacial Till )													
276.5			14	SS	103									
18.7	End of Borehole													

# RECORD OF BOREHOLE No 4

1 OF 1 METRIC

W.P. 481 - 89 - 03 LOCATION CO-ORDS. N 4 774 989.5; E 204 191.8 ORIGINATED BY M V  
 DIST 2 HWY 401 BOREHOLE TYPE HOLLOW STEM AUGER COMPILED BY M V  
 DATUM GEODETIC DATE 90 04 23 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	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100					
295.1	Hwy. 401 Median													
294.8	Sand And Organic Silt		1	SS	18		294							1 8 43 48
0.7	Silty Clay to Clayey Silt, Trace of Sand, Trace of Gravel, Very Stiff to Hard		2	SS	21									
			3	SS	42		292							
			4	SS	35									
290.6			5	SS	47									
4.5			6	SS	50	8cm	290							7 22 38 33
			7	SS	39									
			8	SS	76	/15cm								3 44 (53)
			9	SS	100	/14cm	288							
			10	SS	113		286							
			11	SS	100	/15cm	284							
			12	SS	102	/15cm								
	Sandy Silt, Trace of Gravel, Dense to Very Dense		13	SS	34		282							
			14	SS	102	/23cm	280							5 17 (78)
274.2							278							
20.9	End of Borehole						276							
	Water Level Not Stabilized													

# RECORD OF BOREHOLE No 5

1 OF 1

METRIC

W.P. 481 - 89 - 03 LOCATION CO-ORDS. N 4 774 955.2; E 204 186.7 ORIGINATED BY M V  
 DIST 2 HWY 401 BOREHOLE TYPE CONE TEST, HOLLOW STEM AUGER & BW CASING COMPILED BY M V  
 DATUM GEODETIC DATE 90 04 17 TO 90 04 19 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT 7 kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	W <sub>p</sub>	W	W <sub>L</sub>		
284.3	Ground Surface						294	SHEAR STRENGTH kPa		WATER CONTENT (%)				
0.0	Topsoil							○ UNCONFINED + FIELD VANE		10 20 30				
292.9	Sand And Silt, Trace of Gravel, Loose		1	SS	3			● QUICK TRIAXIAL × LAB VANE						
1.4	Silty Clay, Trace of Sand, Trace of Gravel, Very Stiff to Hard		2	SS	36		292	120/28cm						
			3	SS	31		290							
			4	SS	49		288							
			5	SS	39		286							
			6	SS	19		284							
289.0			7	SS	92	/15cm	282							
5.3	Sand And Gravel          Sandy Silt, Some Gravel, Occasional Gravel Seams, Very Dense		8	SS	131	/15cm	280							0 1 46 53
			9	SS	107	/15cm	278							45 47 (8)
			10	SS	85	/15cm	276							
			11	SS	51		274							0 38 (62)
			12	SS	100	/8cm	272							
			13	SS	100	/10cm								
			14	SS	100	/5cm								
			15	SS	102	/15cm								
			16	SS	100	/10cm								16 45 (39)
272.5														
21.8	Heterogeneous Mixture of Clayey Silt, Sand and Gravel, Hard													
271.2	( Glacial Till )													
23.1	End of Borehole													

# RECORD OF BOREHOLE No 6

1 OF 1

METRIC

W.P. 481 - 89 - 03 LOCATION CO-ORDS. N 4 774 932.0; E 204 191.6 ORIGINATED BY M V  
DIST 2 HWY 401 BOREHOLE TYPE CONE TEST COMPILED BY M V  
DATUM GEODETIC DATE 90 04 19 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	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	20					
293.7	Ground Surface												
0.0													
290.1													
3.6	End of Cone Test												

# RECORD OF BOREHOLE No 7

1 of 1 METRIC

W.P. 481 - 89 - 03 LOCATION CO-ORDS. N 4 774 943.0; E 204 207.3 ORIGINATED BY M V  
 DIST 2 HWY 401 BOREHOLE TYPE CONE TEST & HOLLOW STEM AUGER COMPILED BY M V  
 DATUM GEODETIC DATE 90 04 25 & 90 04 25 CHECKED BY

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			20 40 60 80 100	20 40 60 80 100	W <sub>p</sub> W W <sub>L</sub>	WATER CONTENT (%)				
301.5	Hwy. 59 Shoulder														
0.0	Sand, Some Silt, Some Gravel, Compact to Dense ( Fill )		1	SS	30										
			2	SS	37										
			3	SS	18										
			4	SS	17										
295.6			5	SS	69										
5.9	Sand, Some Silt, Some Gravel		6	SS	39										
			7	SS	14										
			8	SS	15										
			9	SS	35										
	Clayey Silt, Trace of Sand, Trace of Gravel, Very Stiff to Hard		10	SS	39										
			11	SS	29										
			12	SS	29										
			13	SS	20										
288.5			14	SS	93										
12.9	Silty Sand, Some Gravel, Occasional Gravel Seams, Very Dense		15	SS	104	/15cm									
			16	SS	110										
			17	SS	90	/15cm									
			18	SS	100	/8cm									
			19	SS	84	/15cm									
	Sand And Gravel		20	SS	101	/15cm									
275.6															
25.9	End of Borehole														
	* Water Level Not Stabilized														

# RECORD OF BOREHOLE No R1

1 OF 1

METRIC

W.P. 481 - 89 - 03 LOCATION CO-ORDS. N 4 775 135.0; E 204 146.0 ORIGINATED BY M.V.  
 DIST 2 HWY 401 BOREHOLE TYPE CONE TEST & HOLLOW STEM AUGER COMPILED BY M.V.  
 DATUM GEODETIC DATE 90 04 26 & 90 04 27 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100	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								
288.7	Unpaved Parking Area												
0.0	Gravel Fill		1	SS	23		298						
			2	SS	19								3 31 50 16
			3	SS	51		296						6 34 45 15
			4	SS	44								
			5	SS	51								
			6	SS	106		294						2 27 60 11
			7	SS	102	/23cm	292						
			8	SS	120		290						
289.1	Sand, Some Silt, Very Dense		9	SS	76	/13cm							
9.6	End of Borehole												
	Note: Borehole was Terminated Due to Presence of Very Hard Strata												

# RECORD OF BOREHOLE No R2

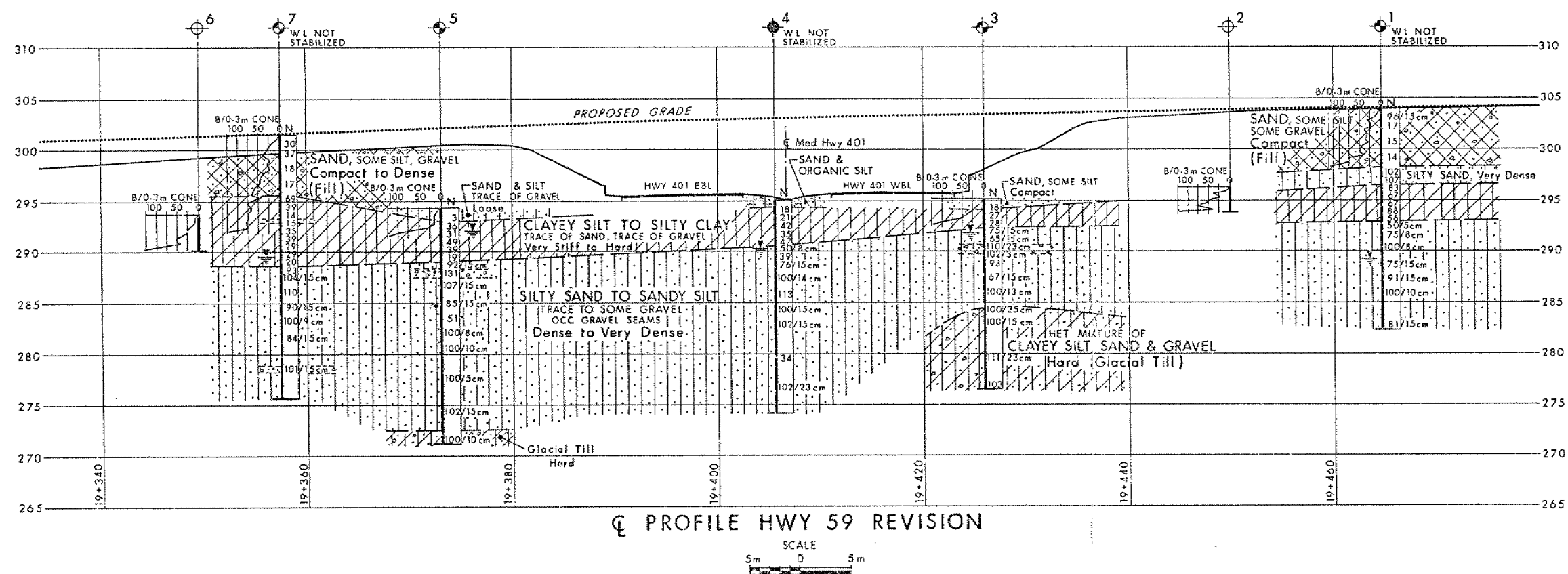
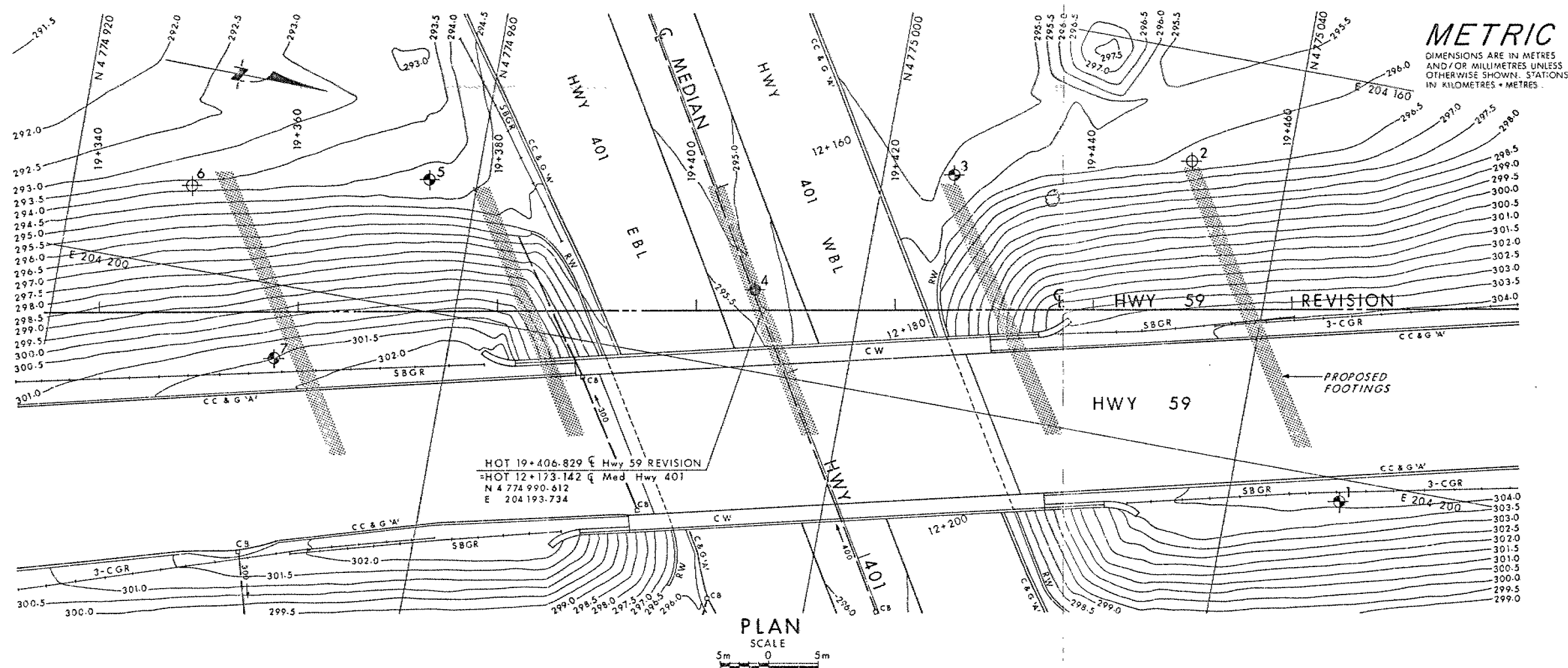
1 OF 1

METRIC

W.P. 481 - 89 - 03 LOCATION CO-ORDS. N 4 775 107.0; E 204 094.0 ORIGINATED BY M.V.  
DIST 2 HWY 401 BOREHOLE TYPE CONE TEST & HOLLOW STEM AUGER COMPILED BY M.V.  
DATUM GEODETIC DATE 90 04 27 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100	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								
296.9	Unpaved Parking Area												
0.0	Gravel Fill		1	SS	36								
			2	SS	46								
	Gravelly Sand, Some Silt, Very Dense		3	SS	60								
			4	SS	70								
			5	SS	122								
	Clayey Silt to Silt, Some Sand, Trace of Gravel, Occasional Sand Seams, Hard ( Glacial Till )		6	SS	76	/15cm							
			7	SS	125								
289.1			8	SS	55	/3cm							
7.8	End of Borehole												
	Note: Borehole Was Terminated Due to Presence of Very Hard Strata												
	* Water Level Not Stabilized												

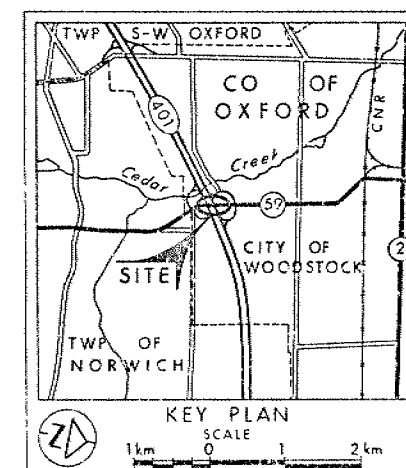








CONT No  
WP No 481-89-03

HWY 59 UNDERPASS

BORE HOLE LOCATIONS &amp; SOIL STRATA



LEGEND

- |   |                                       |
|---|---------------------------------------|
|  | Bore Hole                             |
|  | Dynamic Cone Penetration Test (Cone)  |
|  | Bore Hole & Cone                      |
| N   | Blows/0.3m {Std Pen Test, 475 J/blow} |
| CONE  | Blows/0.3m {60° Cone, 475 J/blow}     |
|  | WL at time of investigation 1990.04   |

No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
1	304.0	4775051.1	204202.2
2	296.3	4775030.4	204171.0
3	295.2	4775007.0	204176.8
4	295.1	4774989.5	204191.8
5	294.3	4774955.2	204186.7
6	293.7	4774932.0	204191.6
7	301.5	4774943.0	204207.3

= NOTE =

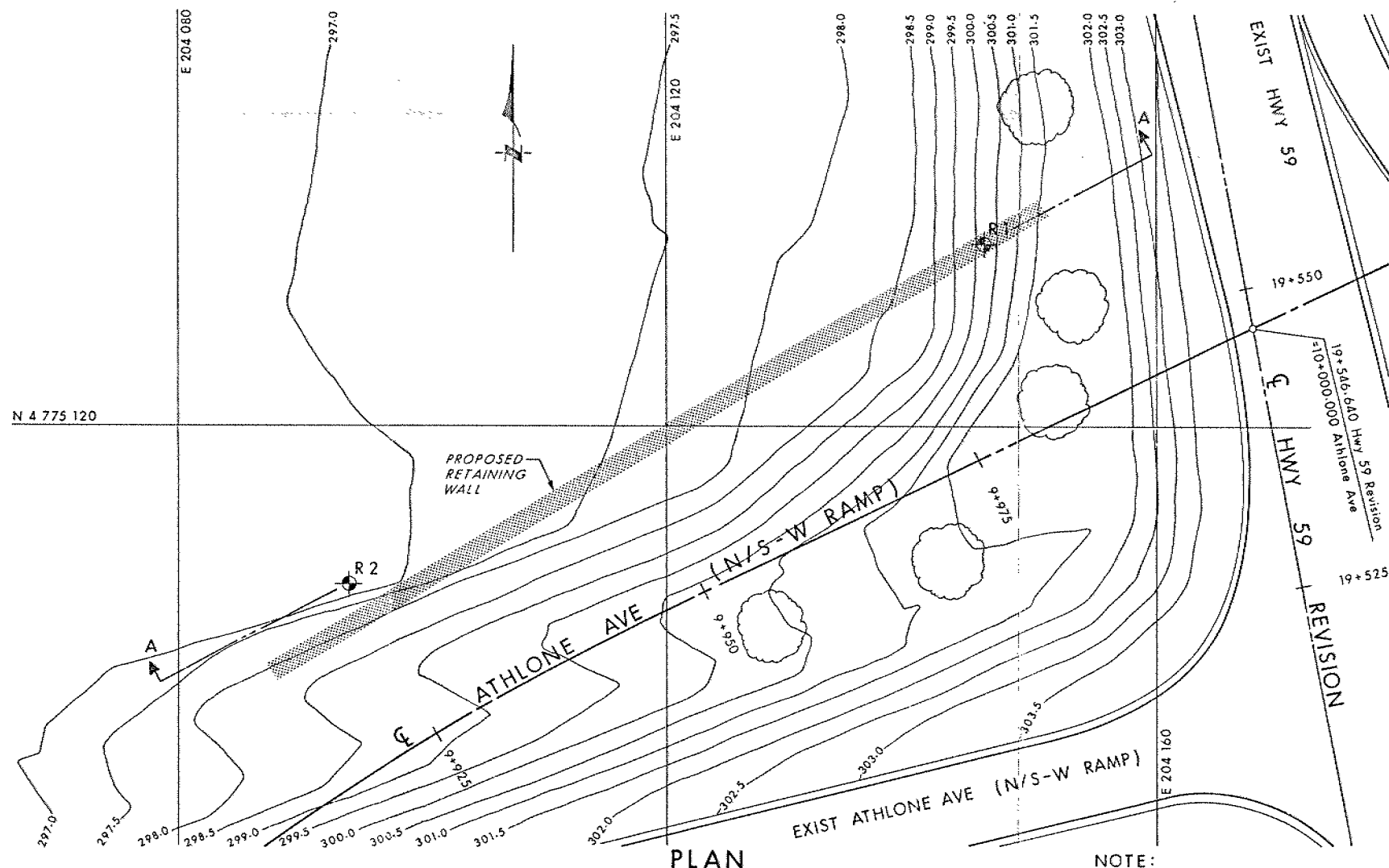
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

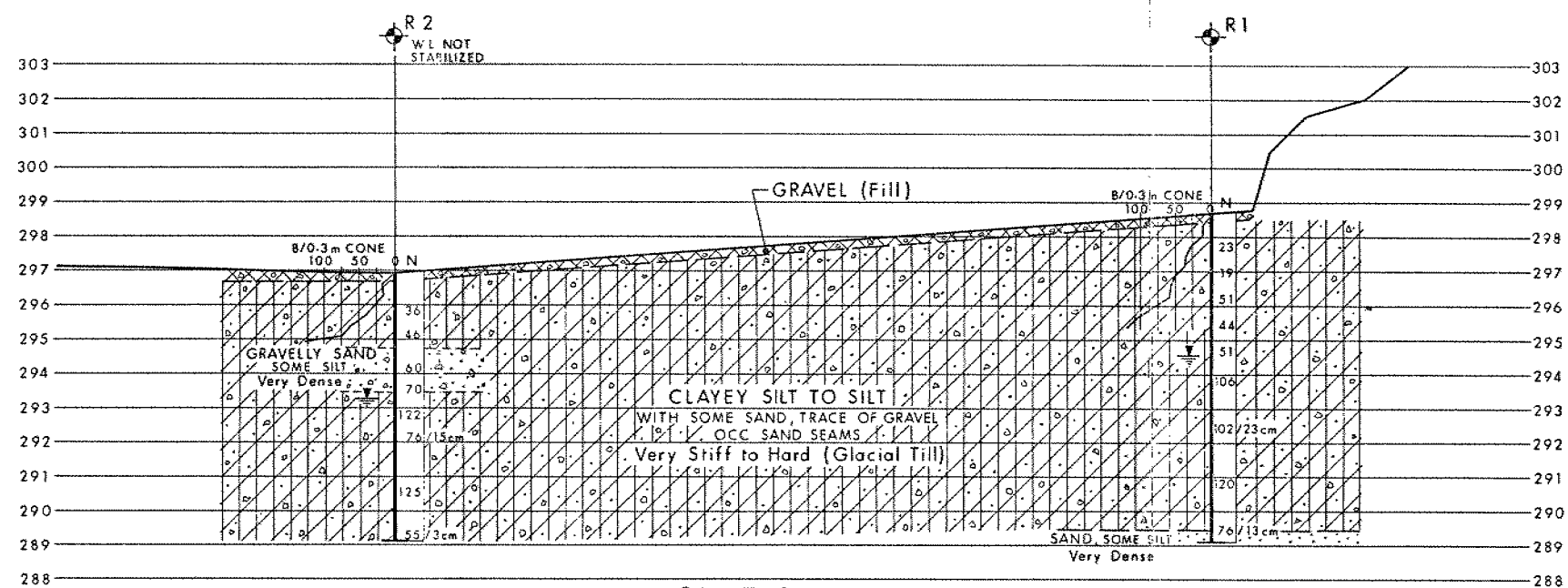
REV.	DATE	BY	DESCRIPTION
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Geocres No 40P2-45

HWY No 401		DIST 2	
SUBMDM V	CHECKED <input checked="" type="checkbox"/>	DATE 1990 09 12	SITE 23-170
DRAWN <input checked="" type="checkbox"/>	CHECKED <input checked="" type="checkbox"/>	APPROVED	DWG 4818903-A



NOTE:  
Contours in the area of retaining wall location do not reflect actual conditions encountered at time of field investigation.



**METRIC**

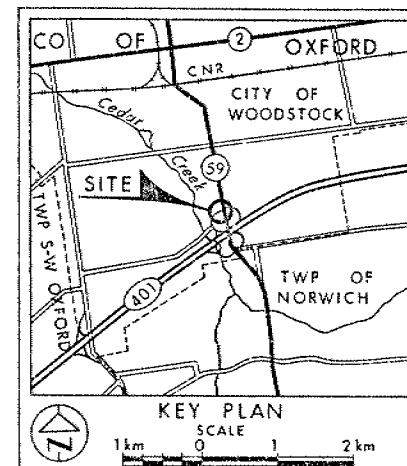
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES UNLESS  
OTHERWISE SHOWN. STATIONS  
IN KILOMETRES + METRES.

CONT No  
WP No 481-89-03

ATHLONE AVE (N/S-W RAMP)  
RETAINING WALL  
BORE HOLE LOCATIONS & SOIL STRATA



SHEET



LEGEND

- Bore Hole
- ⊕ Dynamic Cone Penetration Test (Cone)
- ⊕ Bore Hole & Cone
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- W.L. at time of investigation 1990 04

No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
R1	298.7	4 775 135.0	204 146.0
R2	296.9	4 775 107.0	204 094.0

NOTE

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

REV	DATE	BY	DESCRIPTION

Geocres No 42 P2-45

HWY No 401/59 DIST 2  
SUBMIT: M.V. CHECKED: DATE 1990 09 14 15 TE  
DRAWN: CHECKED: APPROVED: DWS 4818903-B

## **Appendix G**

### **Comparison of Foundation Alternatives**

### COMPARISON OF FOUNDATION ALTERNATIVES

Spread Footings on Native Soils	Spread Footings on Engineered Fill Pad	Driven H-piles	Caissons / Drilled Shafts
<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Relative ease of construction.</li> <li>ii. More cost effective than deep foundations.</li> </ul>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Relative ease of construction.</li> <li>ii. More cost effective than deep foundations.</li> <li>iii. Higher geotechnical resistances and reaction values than for the spread footing placed on native soils.</li> </ul>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Higher geotechnical resistance if driven to refusal compared to spread footings</li> <li>ii. Installation less influenced by weather and groundwater compared to spread footing</li> <li>iii. Facilitate the integral abutment design.</li> <li>iv. Requires less excavation than spread footings</li> </ul>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Higher geotechnical resistance is available for caissons</li> <li>ii. Construction of caissons could continue in freezing weather.</li> <li>iii. Limited extent of excavation and less impact on operation of Highway 401.</li> </ul>
<p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Potentially deep excavation at abutments</li> <li>ii. May require groundwater control.</li> <li>iii. Not feasible for integral abutment design.</li> </ul>	<p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Potentially deep excavation at abutments</li> <li>ii. May require groundwater control.</li> <li>iii. Not feasible for integral abutment design.</li> </ul>	<p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Piles may encounter refusal at varying depth</li> <li>ii. Higher unit costs than spread footings.</li> <li>iii. Piles may require predrilling to achieve design length, complicating installation.</li> <li>iv. Potential difficulties penetrating hard till</li> </ul>	<p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Higher unit cost than for spread footings or H-piles.</li> <li>ii. Temporary liners will be required to install caissons through cohesionless soils.</li> <li>iii. Difficulty in sealing liners at base.</li> <li>iv. Potential difficulties penetrating very dense/hard till layers during augering.</li> <li>v. Difficulties in cleaning and inspecting bases.</li> </ul>
Low risk of encountering problems during construction.	Low risk of encountering problems during construction.	High risk of encountering harder layers and cobbles and boulders that would require additional procedures to advance the piles to the desired elevation.	High risk of encountering harder layers, as well as cobbles and boulders that would require additional procedures to advance the augers to the desired elevation.
<b>FEASIBLE</b>	<b>FEASIBLE</b>	<b>RECOMMENDED</b>	<b>RECOMMENDED</b>

**Appendix H**  
**List of Specifications and Suggested Text for NSSP**  
**and**  
**Monitoring Plan**

The following Standard Specifications and Standard Drawings are referenced in this report:

OPSS 501

OPSS 539

OPSS 804

OPSS 902

OPSS 903

OPSS.PROV 1010

OPSS.PROV 206

OPSD 3090.101

OPSD 601.010

**Suggested wording for “NSSP – Presence of Cobbles and Boulders”**

Cobbles and boulders should be expected within the existing embankment fill and native deposits underlying the site. The cobbles and boulders may interfere with H-pile and caissons installation. The Contractor should be prepared to remove, dislodge or otherwise penetrate these obstructions to advance the piles/caissons to the specified tip elevation/resistance while meeting the specified deflection tolerances.

**Suggested wording for “NSSP – Drilling of Caisson Sockets”**

Excavation for the caissons installation through the glacial till may encounter cobbles and boulders, and the installation equipment should be capable of dislodging and removing such obstructions.

The Contractor is responsible for constructing the caissons excavations without disturbing the sides or base of the excavations, and for cleaning of the socket bases.

Water seepage and /or soil sloughing into the caissons excavation will occur from the fill and cohesionless soils at some locations. The cohesionless soils will be susceptible to disturbance under conditions of unbalanced hydrostatic head. Temporary liners shall be available on site to support the caissons sidewalls and provide the seepage cut-off, where required.

**Suggested wording for “NSSP – Preload Requirements and Embankment Monitoring”**

**Stage 2:**

By the end of October of 2016 the Contractor shall complete the construction of the fill embankments of Norwich Avenue, including the north and south approaches to the underpass, using the Select Subgrade Material (SSM) specified under this contract.

The Contractor shall not place granular sub-base or base material on the road embankment from Station 9+920 to Station 10+200. Within this station range the Contractor shall place a layer of 200 mm compacted Select Subgrade Material in excess of the cross-section template subgrade.

The Contractor shall also install evenly distributed settlement pins at 20 m intervals along the west crest of the new embankment to record the rate of settlements.

The Contractor shall survey the settlement pins on a weekly basis from the completion of fill placement until winter shut down and shall record the elevation of the top of the pin to an accuracy of 2mm. Survey shall recommence at least one month prior to paving and a minimum of four sets of readings shall be taken, with at least one week between readings.

The preloaded embankment within the above-listed stations shall be left in place for a minimum period of 6 months.

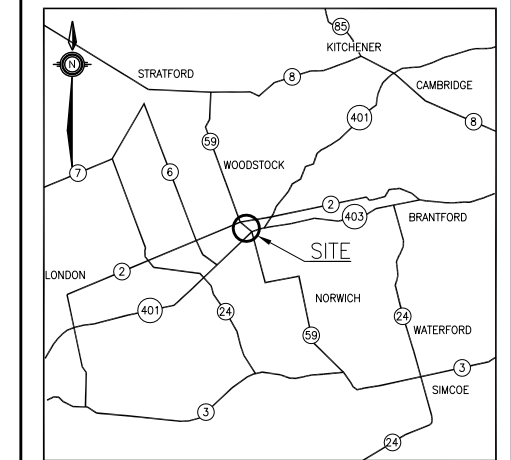
**Stage 3:**

In the spring of 2017 the Contractor shall review with the CA the results of settlement monitoring of the settlement pins to determine the appropriate time for paving the roadway. Paving may commence provided the fill has been in place for 6 months and provided that the rate of settlement is no greater than 5mm over a four week period.

At the appropriate paving time, the Contractor shall re-grade the granular fill to the template subgrade elevations, and construct the full pavement structure, including granular sub-base and base material, as specified under this contract.



SHEET

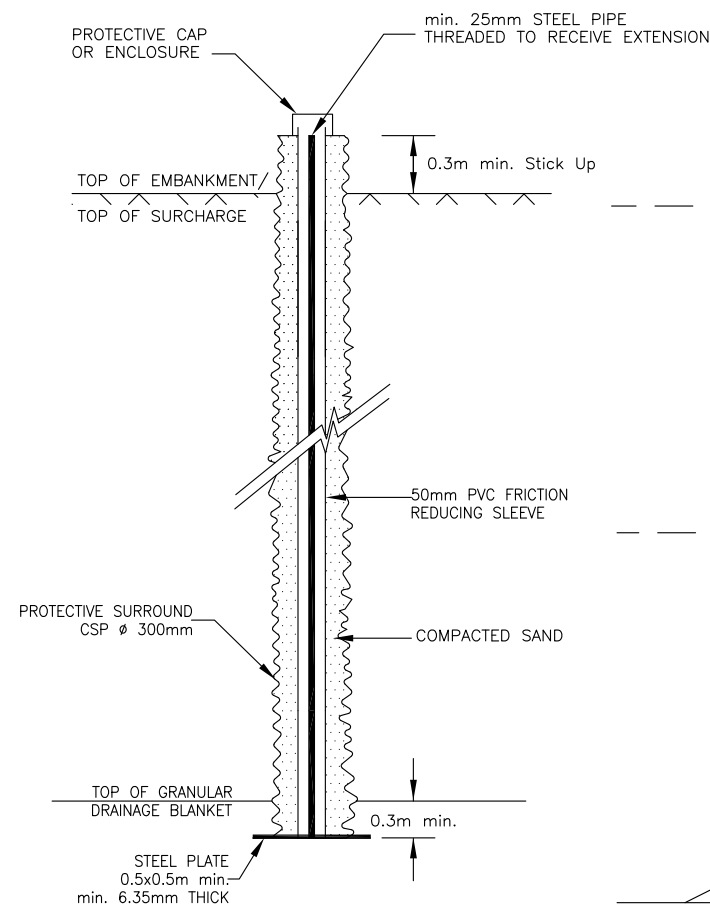


### LEGEND

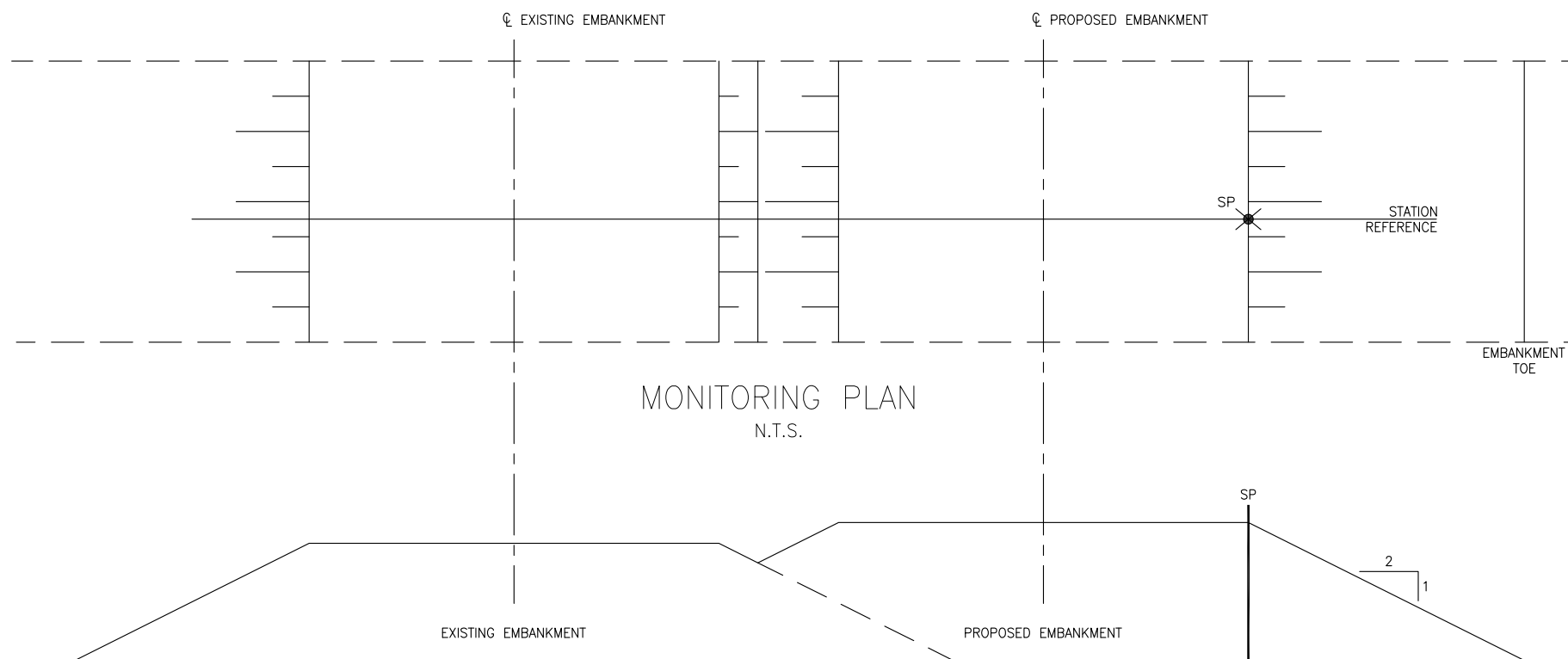
Settlement Plate (SP)

SETTLEMENT PLATE No	STATION	℄ OFFSET
SP1	9+930	10.65m
SP2	9+955	10.65m
SP3	10+050	10.65m
SP4	10+075	10.65m
SP5	10+100	10.65m
SP6	10+125	10.65m
SP7	10+150	10.65m
SP8	10+175	10.65m
SP9	10+200	10.65m

**GEOCRES No. 40P2-78**

[illegible]

SETTLEMENT PLATE (SP)  
N.T.S.



CROSS SECTION A-A  
N.T.S.

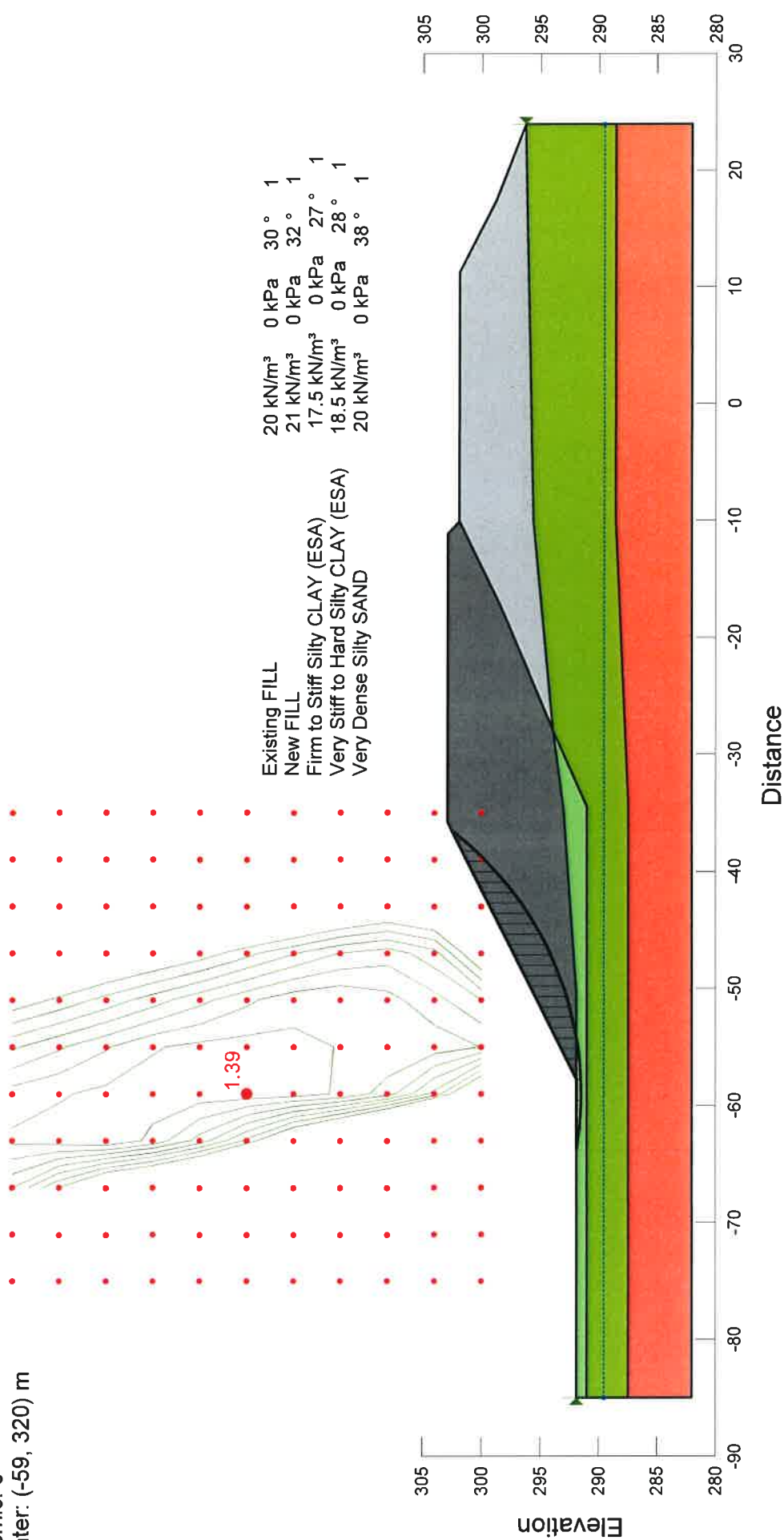
DRAWING NOT TO BE SCALED  
100mm ON ORIGINAL DRAWING



**Appendix I**  
**Slope Stability Analyses Results**

Title: Norwich Avenue (Woodstock, Ontario)  
Comments: New Approach Embankment Stability Assessment  
Name: South Abutment (ESA)

Method: GLE, Half-Sine  
Minimum Slip Surface Depth: 2 m  
Seismic: 0  
Center: (-59, 320) m

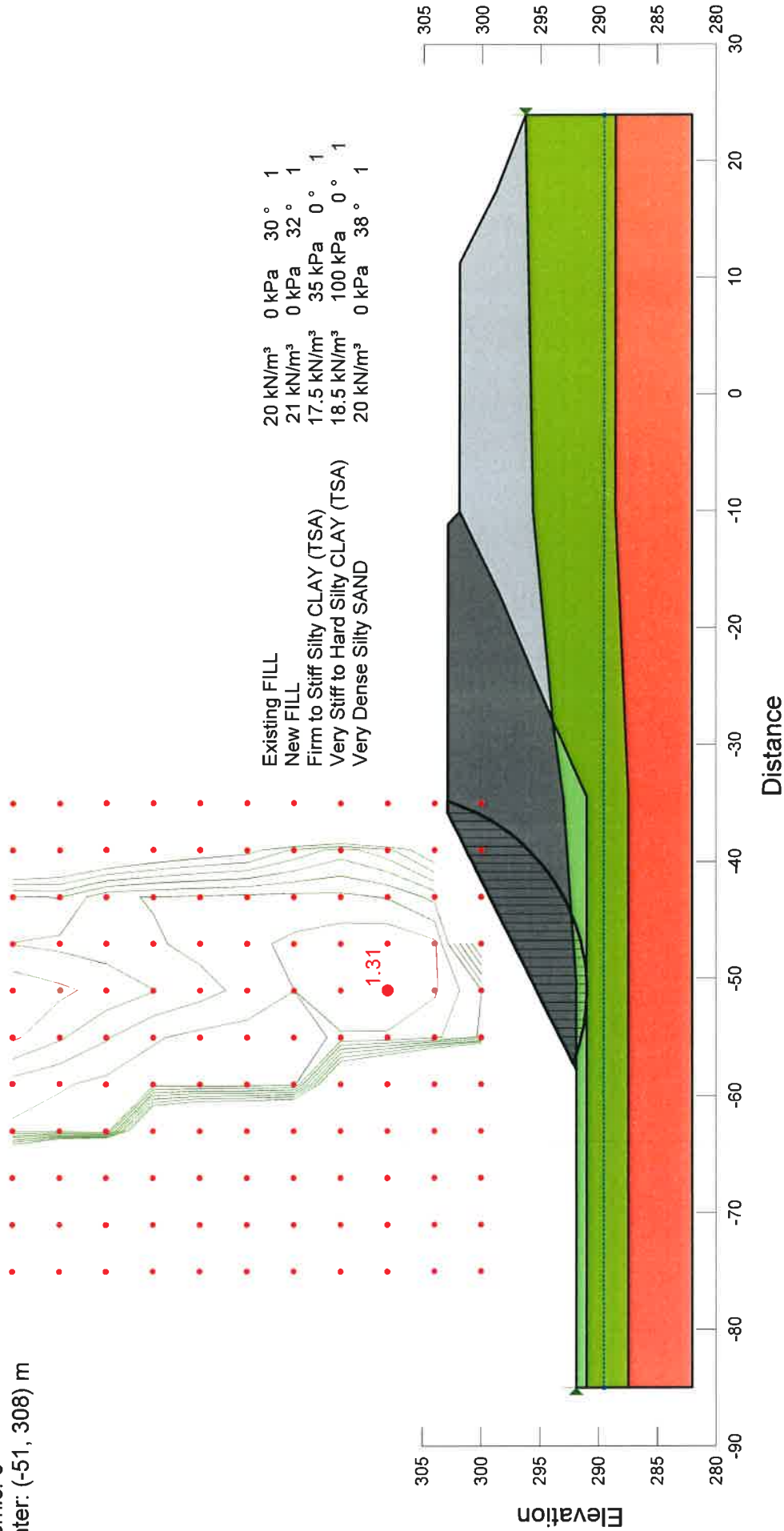


Reviewed By: \_\_\_\_\_  
Last Edited By: Stephen Peters  
Last Solved Date: 2014-12-10, 10:09:06 AM  
Directory: H:\1915161\224 Hwy 401 Ingersoll 3013-E-0027 Foundations\Analysis\Norwich\Norwich\_001.gsz

FIGURE 1

Title: Norwich Avenue (Woodstock, Ontario)  
Comments: New Approach Embankment Stability Assessment  
Name: South Abutment (TSA)

Method: GLE, Half-Sine  
Minimum Slip Surface Depth: 2 m  
Seismic: 0  
Center: (-51, 308) m

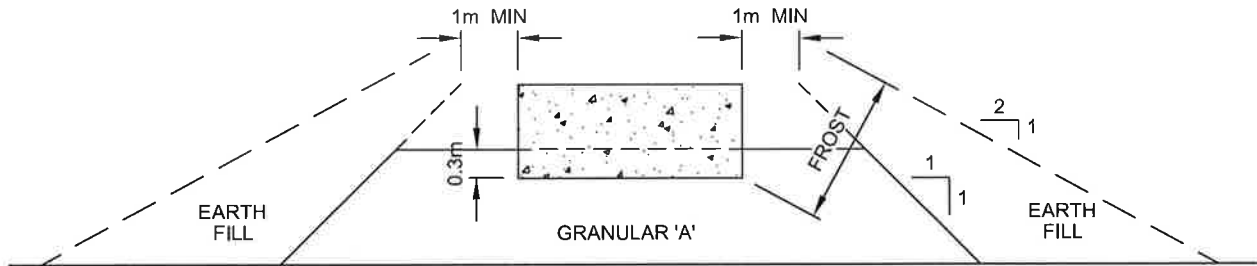


Reviewed By: \_\_\_\_\_  
Last Edited By: Stephen Peters  
Last Solved Date: 2014-12-10, 10:09:15 AM  
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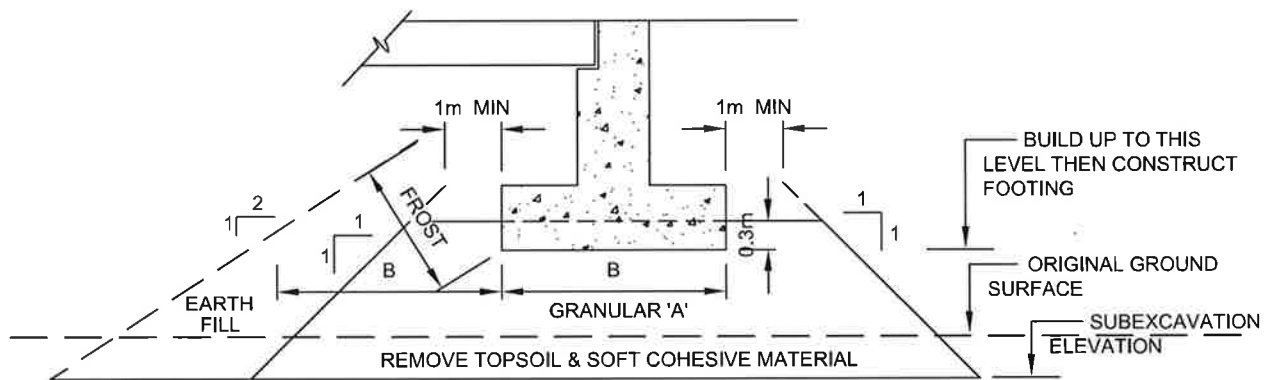
FIGURE 2

## **Appendix J**

### **Figure 1 – Abutment on Compacted Fill**



## CROSS-SECTION



## LONGITUDINAL SECTION

### NOTES:

1. REMOVE TOPSOIL AND OR SOFT SUBSOIL UNDER AREA OF COMPACTED GRANULAR 'A' AND EARTH FILL.
2. PLACE GRANULAR 'A' AND EARTH FILL TO BOTTOM OF FOOTING LEVEL, COMPACTED ACCORDING TO O.P.S.S. 501.
3. CONSTRUCT CONCRETE FOOTING.
4. PLACE REMAINDER OF GRANULAR 'A' AND EARTH FILL AS REQUIRED.
5. SOURCE M.T.C. 1982.

ABUTMENT ON COMPACTED FILL  
SHOWING GRANULAR 'A' CORE



**THURBER ENGINEERING LTD.**

ENGINEER :	MRA	DRAWN :	MFA	APPROVED :	-
DATE :	MARCH 2015	SCALE :	N.T.S.	DRAWING No.	FIGURE 1