

REPORT ON

**FOUNDATION INVESTIGATION AND DESIGN
STORM SEWER OUTLET
HIGHWAY 401 WIDENING AND REHABILITATION
GWP 288-99-00
FROM 2.0 KM WEST OF REGIONAL ROAD 97
EAST TO 1.3 KM WEST OF
HOMER WATSON BOULEVARD
REGIONAL MUNICIPALITY OF WATERLOO**

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TABLE OF CONTENTS

<u>SECTION</u>	<u>PAGE</u>
PART A - FOUNDATION INVESTIGATION	
1.0 INTRODUCTION.....	1
2.0 SITE DESCRIPTION.....	2
3.0 INVESTIGATION PROCEDURES.....	3
4.0 GENERAL SITE GEOLOGY AND STRATIGRAPHY.....	4
4.1 Site Geology	4
4.2 Site Stratigraphy	4
4.2.1 Westerly Site – Station 16+905	5
4.2.2 Easterly Site – Station 17+040	5
4.3 Groundwater Conditions.....	6
PART B - FOUNDATION DESIGN	
5.0 ENGINEERING RECOMMENDATIONS	10
5.1 General.....	10
5.2 Design Recommendations	11
5.3 Construction Considerations	12

In Order
Following
Page 12

LIST OF ABBREVIATIONS

LIST OF SYMBOLS

RECORD OF BOREHOLE SHEETS

FIGURE 1 – Key Plan

DRAWING 1 - Borehole Locations

DRAWING 2 - Soil Strata

APPENDIX A – Laboratory Test Data

PART A - FOUNDATION INVESTIGATION

**STORM SEWER OUTLET
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) has been retained by Dillon Consulting Limited (Dillon) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out a foundation investigation for the detailed design work as part of GWP 288-99-00. The project involves design work for the upgrading of about 7.8 kilometres of Highway 401 from 2.0 kilometres west of Cedar Creek Road (Regional Road 97) east to 1.3 kilometres west of Homer Watson Boulevard in the Regional Municipality of Waterloo. The work includes highway upgrades, widening and realignment. This component of the project consists of a new 30 metre long, 600 millimetre diameter storm outlet under the eastbound lanes at Station 16+905 or Station 17+040.

The purpose of the foundation investigation was to determine the subsurface conditions at the site by means of a limited number of boreholes, in-situ tests and laboratory tests on selected samples. Based on our interpretation of the data obtained, recommendations on the foundation aspects of the design of the proposed works are provided. Comments are also provided on anticipated construction problems where they may affect the location and design of the proposed outlet.

The terms of reference for the scope of work are outlined in our proposal dated May 27, 2002. The work was carried out in accordance with our Quality Control Plan for Foundation Investigation and Design Services, dated September 2001.

2.0 SITE DESCRIPTION

GWP 288-99-00 comprises about 7.8 kilometres of Highway 401 extending from 2.0 kilometres west of Regional Road 97 to about 1.3 kilometres west of Homer Watson Boulevard in the Regional Municipality of Waterloo. The location of the project is shown on the Key Plan, Figure 1. The project chainages extend from Station 12+825 to Station 20+131, Township of North Dumfries and from Station 10+000 to Station 10+500, City of Kitchener/City of Cambridge.

This portion of Highway 401 is a Class I divided four lane highway. The existing pavement cross-section is four 3.75 metre wide lanes typically with 3.0 metre wide partially paved outside shoulders and 1.0 metre wide inside shoulders. Fully paved outside shoulders are present in the horizontal curve immediately west of Regional Road 46 from Station 17+200 to Station 18+100. The median width throughout this section of Highway 401 is typically 15 metres.

This report addresses the subsurface conditions for the proposed storm outlet to be constructed at Station 16+905 or Station 17+040. The outlet is to be constructed under the eastbound lanes using tunneling or other trenchless technology to drain the proposed median storm sewer. The proposed 600 millimetre diameter outlet will have an invert elevation of about 298.7 metres at the south ditch. The ground surface elevations at the borehole locations for this investigation ranged between about 300.4 and 300.7 metres. The top of pavement elevation is approximately 301.3 metres. Vegetation cover on both sides of the existing highway consists of grass, shrubs and a narrow band of large, mature trees. An existing culvert for Cedar Creek is located at about Station 16+960.

3.0 INVESTIGATION PROCEDURES

The field work for this investigation was carried out on June 6, 2002. At this time, two boreholes were put down at the proposed outlet locations. Also, two median boreholes (boreholes 101 and 102) from the pavement investigation have been included for the new outlet crossing. The table below summarizes the borehole locations, ground surface elevations and depths.

BOREHOLE	CHAINAGE	GROUND SURFACE ELEVATION	BOREHOLE DEPTH
	(m)	(m)	(m)
1	16+905, 3.4 m RT	300.60	7.32
2	17+040, 4.4 m RT	300.60	7.32
101	16+900, CL	300.42	3.05
102	17+000, CL	300.70	3.05

NOTES: RT right of the right edge of Highway 401 eastbound lanes pavement
CL centreline of Highway 401 median

The investigation was carried out using an all-terrain vehicle mounted CME 750 drill rig supplied and operated by Lantech Drilling Services Inc. In the boreholes, samples of the overburden were obtained at suitable intervals of depth using 50 millimetre outside diameter split-spoon samplers in accordance with the Standard Penetration Test (SPT) procedures and dynamic cone penetration testing was carried out adjacent to boreholes 1 and 2. Groundwater conditions in the boreholes were observed throughout the drilling operations. Standpipes were installed in the boreholes to permit monitoring of the groundwater levels at the site. The boreholes were backfilled using MTO recommended procedures.

The field work was supervised on a full-time basis by a member of our engineering staff who located the boreholes in the field, directed the drilling, sampling and in-situ testing operations and logged the boreholes. The samples were identified in the field, placed in labeled containers and transported back to our laboratory in London for further examination. Index and classification tests were carried out on selected samples. The results of the testing are shown on the Record of Borehole sheets and in Appendix A.

Temporary traffic control was provided by a specialist contractor in accordance with the Ontario Traffic Manual, Temporary Conditions, Book 7, dated March 2001.

Survey control was provided by Golder Associates. Ground surface elevations at the borehole locations are understood to be referenced to geodetic datum. The locations of the boreholes are shown on the Record of Borehole sheets and on Drawing 1, attached. Stratigraphic profiles along the proposed outlet crossings are shown on Drawing 2.

4.0 GENERAL SITE GEOLOGY AND STRATIGRAPHY

4.1 Site Geology

Highway 401 in the area of the project crosses the Waterloo Hills geographic region, which is identified in the Physiography of Southern Ontario by Chapman and Putnam (1984). This region is predominantly characterized by hilly terrain, which is the result of the convergence of three lobes of the Laurentian Ice Sheet, in the vicinity of the Cities of Kitchener and Waterloo. The Ontario Lobe advanced from the east, the Georgian Bay Lobe from the north and the Huron Lobe from the north-northwest during an approximate 1,000 year period some 13,000 to 14,000 years ago. This glacial activity resulted in ice contact deposits, such as kames, which occasionally appear as high conical hills, hummocky kame moraines and a few eskers, made up mainly of sand and gravel. There are also lateral and end moraine ridges consisting of sandy silt tills. During the melting of the ice lobes, major outwash deposits and spillways were formed in the low areas between the hills which contain a significant amount of sand and gravel. In some of the lower areas, especially in areas of till deposits, peat and muck were deposited.

This foundation investigation is located in a portion of the project where sand and gravel spillways are present. The lower levels of this moraine contain some organic deposits. The bedrock beneath this portion of the project is of the Middle Silurian Guelph Formation, consisting of buff to brown, fine to medium fossiliferous limestone. Bedrock formations are too far below the surface to have any effect on the foundation design for the proposed outlet.

4.2 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole sheets, Drawing 2 and in Appendix A, following the text of this report. The stratigraphic boundaries shown on the borehole sheets are inferred from non-continuous sampling and, therefore, may represent transitions between soil types rather than exact planes of geological change. Subsoil conditions will vary between and beyond the borehole locations.

Relevant information on subsurface conditions was obtained from boreholes 1 and 101 at the proposed westerly outlet crossing location and from boreholes 2 and 102 at the proposed easterly outlet crossing location. In summary, the topsoil and/or fill materials overlie a complex sequence of layers of sands, sand and gravel, and silts. Detailed descriptions of the subsurface conditions encountered in the boreholes for the two proposed outlet crossing sites are provided in the following sections.

4.2.1 Westerly Site – Station 16+905

Topsoil and Fill Materials

At ground surface, a 0.2 metre thick layer of granular fill was encountered in borehole 1 and a silty black topsoil layer 0.1 metres thick was encountered in borehole 101. Sand and gravel fill with an SPT 'N' value of 23 blows per 0.3 metres associated with the existing pavement extended to elevation 299.5 metres in borehole 1. The measured water content of a sample of the sand and gravel fill was about 11 per cent

Sands

Layers of sand and silty sand were encountered beneath the sand and gravel fill in borehole 1 and beneath the topsoil in borehole 101. The surface of the sand layers ranged from elevation 299.5 to 300.3 metres. Where fully penetrated, the sand layers were between 0.9 and 3.8 metres thick. SPT 'N' values measured within the sand deposits range from 11 to 35 blows per 0.3 metres, indicating compact to dense materials, with an average 'N' value of about 17 blows per 0.3 metres penetration. Dynamic cone penetration testing within the sand materials adjacent to borehole 1 indicated driving resistances between 10 and 32 blows per 0.3 metres penetration with an average of about 19 blows per 0.3 metres penetration. Samples of the sand deposits had measured water contents of from about 21 to 25 per cent. A grain size distribution curve for a sample of the silty sand from borehole 1 is shown on Figure A-1.

Sand and Gravel

A brown sand and gravel layer was encountered at depth in borehole 1. The borehole was terminated in this sand and gravel layer at elevation 293.3 metres after penetrating it for some 0.6 metres. An SPT 'N' value of 20 blows per 0.3 metres of penetration was measured within the sand and gravel indicating a generally compact state.

4.2.2 Easterly Site – Station 17+040

Topsoil and Fill Materials

Borehole 102 encountered a 0.3 metre thick topsoil layer at ground surface. Borehole 2 encountered surficial sand and gravel fill layers 0.5 and 0.8 metres thick with a 0.1 metre thick layer of topsoil between them. The fill layers are compact with SPT 'N' value of 12 blows per 0.3 metres penetration measured in the lower layer. The fill sample retrieved from the SPT testing had a water content of about 12 per cent.

Silty Sand

A layer of silty sand was encountered beneath the fill in borehole 2. The sand layer had a surface elevation of 299.2 metres and was 2.3 metres thick. SPT 'N' values measured within the silty sand deposit ranged from 6 to 7 blows per 0.3 metres of penetration, indicating loose materials. Dynamic cone penetration testing within the silty sand materials indicated driving resistances between 5 and 8 blows per 0.3 metres penetration with an average of about 6 blows per 0.3 metres penetration. Samples of the silty sand had measured water contents of from about 12 to 17 per cent with an average water content of about 14 per cent. A grain size distribution curve for a sample of the silty sand is shown on Figure A-2.

Sand and Gravel

Brown sand and gravel layers were encountered beneath the sand layer in borehole 2 and below the topsoil in borehole 102. The sand and gravel layers are 0.9 metres to 1.5 metres thick with surface elevation ranging between 296.9 and 300.5 metres. SPT 'N' values ranging from 4 blows per 0.3 metres of penetration to 40 blows for 75 millimetres of penetration were measured within the sand and gravel layers, indicating a very loose to very dense state as well as the potential presence of cobbles and boulders in borehole 2.

Silty Sand and Sandy Silt

Layers of silty fine sand and sandy silt were encountered beneath the sand and gravel in borehole 2. The surface of these layers is at elevation 295.4 metres. The silty fine sand layer was 1.5 metres thick. Borehole 2 was terminated in the sandy silt deposit after penetrating it for some 0.6 metres. The silty sand and sandy silt deposits had SPT 'N' values 9 and 17 blows per 0.3 metres penetration, respectively.

Clayey Silt

Borehole 102 encountered and was terminated in a clayey silt deposit below the sand and gravel layers. The surface elevation of the clayey silt layer is at elevation 298.4 metres and it was penetrated for 0.8 metres before terminating the borehole. The clayey silt deposit had an SPT 'N' value of 12 blows per 0.3 metres penetration.

4.3 Groundwater Conditions

Groundwater conditions were observed during and upon completion of drilling operations. Standpipes were installed in boreholes 1 and 2 to monitor the groundwater conditions at the site. Details of the standpipe installations are provided on the attached Record of Borehole sheets. The

table below summarizes the groundwater conditions in the boreholes. Groundwater levels are expected to fluctuate seasonally and are expected to be higher during wet periods.

Groundwater was encountered in the four boreholes drilled at the site at elevations between 298.2 and 299.2 metres. The water levels measured in the standpipes generally ranged between elevation 298.8 metres in borehole 1 at the proposed westerly crossing and elevation 299.0 metres in borehole 2 at the proposed easterly crossing. The corresponding water level in Cedar Creek was at elevation 297.85 metres. Readings should also be taken prior to construction.

A summary of the observed and subsequently measured groundwater levels in the boreholes is provided below.

BOREHOLE NUMBER	GROUND SURFACE ELEVATION	GROUNDWATER LEVEL IN OPEN BOREHOLE ON COMPLETION OF DRILLING		GROUNDWATER LEVEL IN STANDPIPE ON June 7, 2002	
		Depth Below Existing Ground Surface	Elevation	Depth Below Existing Ground Surface	Elevation
	(m)	(m)	(m)	(m)	(m)
1	300.60	1.37	299.23	1.77	298.83
2	300.60	2.44	298.16	1.58	299.02
101	300.42	1.22	299.20	-	-
102	300.70	1.62	299.08	-	-

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PART B - FOUNDATION DESIGN

**STORM SEWER OUTLET
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GWP 288-99-00
FROM 2.0 KM WEST OF REGIONAL ROAD 97
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REGIONAL MUNICIPALITY OF WATERLOO**

5.0 ENGINEERING RECOMMENDATIONS

5.1 General

This section of the report provides our recommendations on the foundation aspects of design for the construction of the proposed storm sewer outlet which forms part of the Highway 401 upgrades, widening and realignment. Our recommendations are based on our interpretation of the factual information obtained during the investigation. It should be noted that the interpretation and recommendations are intended for use only by the design engineer. Where comments are made on construction they are provided only in order to highlight those aspects which could affect the design of the project.

The works described in this report are associated with the foundation component of the project, which includes the construction of a new 30 metre long, 600 millimetre diameter outlet under the eastbound lanes from the proposed median storm sewer.

It is understood that an outlet for the median storm sewer is required beneath the eastbound lanes of Highway 401 adjacent to Cedar Creek. The proposed storm outlet is to be constructed under the eastbound lanes at Station 16+905 or at Station 17+040 by tunneling or another trenchless technology. The proposed outlet will have an invert elevation of about 298.7 metres at the south ditch. The ground surface elevations at the borehole locations for this investigation ranged between about 300.4 and 300.7 metres and the pavement surface is at about elevation 301.3 metres.

The subsurface conditions at the proposed outlet locations are detailed on Records of Boreholes 1 and 101 for the westerly crossing and boreholes 2 and 102 for the easterly crossing. The following table provides a summary of the proposed inverts and anticipated subsurface conditions at each of the proposed outlet locations:

PROPOSED OUTLET LOCATION	EXISTING GROUND SURFACE ELEVATION	PROPOSED INVERT ELEVATION	ANTICIPATED SUBSURFACE CONDITIONS	
			Material	Groundwater Elevation
	(m)	(m)		(m)
STATION 16+905				
Median	300.42	298.97	Compact sand	299.20
South Shoulder	300.60	298.75	Compact silty sand	299.23
STATION 17+040				
Median	300.70	298.81	Compact sand and gravel	298.08
South Shoulder	300.60	298.65	Loose silty sand	299.02

Based on the above, the proposed westerly outlet location will be completed in compact native sands about 0.5 metres below the ground water level and the easterly outlet location will be completed in loose sand and compact sand and gravel materials about 0.4 metres below the groundwater level.

5.2 Design Recommendations

The following options have been considered for the new outlet crossing under the eastbound lanes. It is understood that general groundwater lowering is not acceptable from environmental considerations and substantial dewatering will not be permitted:

- i) Tunneling: This alternative would be difficult to carry out without adequately dewatering the anticipated granular materials and/or using a small diameter earth pressure balancing tunneling machine. Further, some ground loss and/or settlements may take place.
- ii) Jack and Bore: This option is more suitable for cohesive soils and extensive loss of granular soils at the face of the bore would occur without lowering of the groundwater levels at the crossing. This would impact the highway pavement.
- iii) Horizontal directional drilling: This alternative would require more ground cover than the nominal 2 metres available at the crossing sites. Also, more space will be required to accommodate the bends in the entry and exit of the drill string.
- iv) Pipe ramming: This option, utilizing a heavy wall steel pipe, can be constructed with minimal temporary dewatering of the granular soils at the entry and exit pits. Also, this option is more suited for the loose to compact granular soils at the proposed crossing sites.

Option iv) is considered a feasible and preferred option. The following paragraphs provide design details for Option iv).

Based on the results of the investigation, both locations present essentially the same challenges for successfully installing the outlet crossing. While the sands at the westerly crossing are somewhat more dense than the sands and sand and gravel at the easterly location, the latter layers contain more gravel sized particles. Groundwater conditions are very similar at both locations.

Based on an anticipated excavation extending to elevation 298.0 metres at the westerly location, the sheeting should be driven to elevation 296.5 metres. At the easterly location, the sheeting for the pits should be driven to about elevation 295 metres to fully penetrate the sand and gravel layer. At least 0.3 metres of crushed stone should be placed as a working base in the pit and to facilitate dewatering from within the pit. The spoils may be mined out of the casing when the crossing is completed.

Backfill around the completed outlet connection in the median should be carried out as per Ontario Provincial Standard Drawing (OPSD) 802.02.

5.3 Construction Considerations

Excavations for the pits will be required at the proposed new outlet crossing location. The excavations should be carried out in accordance with the guidelines outlined in the current edition of the Occupational Health and Safety Act and Regulations for Construction Projects. The fills and the granular soils below the groundwater level at this site would be classified as Type 3 soils. All native granular soils above the groundwater level would be classified as Type 2 soils. Generally, temporary open-cut slopes should be maintained no steeper than 1 horizontal to 1 vertical (1H:1V). Where space restrictions dictate or excavations extend below the groundwater level, the excavation should be carried out within vertical cuts within a braced steel sheet pile excavation.

The design of braced sheeting should be based on a rectangular earth pressure distribution using the following coefficients of lateral earth pressure:

'active', K_a	0.31
'at rest', K_o	0.47
'passive', K_p	3.1

and a soil unit weight 20 kN/m^3 .

Ramming of the open ended heavy wall 600 millimetre diameter steel pipe below the travelled eastbound lanes has the potential to create heave in the pavement surface. Should this occur, the contractor should be reminded to immediately mill off any such deformation of the pavement.

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APPENDIX A
LABORATORY DATA

RECORD OF BOREHOLE No 1

1 OF 1

METRIC

G.W.P. 288-99-00 LOCATION STA. 16+905, o/s 18.1m Right of CL MEDIAN ORIGINATED BY DJM
 DIST HWY 401 BOREHOLE TYPE POWER AUGER (HOLLOW STEM) COMPILED BY W.F.
 DATUM GEODETIC DATE 2002.06.06 CHECKED BY M.E.B

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	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						
300.6	GROUND SURFACE													
300.4	FILL, granular A													
0.2	FILL, sand and gravel, Compact Brown													
299.5			1	SS	23									
1.1	SILTY SAND, fine, Compact to dense Brown													
			2	SS	35									
			3	SS	18									
297.7														
2.9	SAND, fine to coarse, trace gravel Compact Brown													
			4	SS	14									
			5	SS	15									
			6	SS	26									
			7	SS	17									
293.9														
6.7	SAND AND GRAVEL, Compact Brown													
293.3			8	SS	20									
7.3	End of Borehole													
	Note: Water level encountered in borehole at elev. 299.23m during drilling June 6, 2002. Water level in Standpipe at elev. 298.83m June 7, 2002.													

RECORD OF BOREHOLE No 2

1 OF 1

METRIC

G.W.P. 288-99-00 LOCATION STA. 17+040, o/s 19.0m Right of CL MEDIAN ORIGINATED BY DJM
 DIST HWY 401 BOREHOLE TYPE POWER AUGER (HOLLOW STEM) COMPILED BY W.F.
 DATUM GEODETIC DATE 2002.06.06 CHECKED BY M.E.B

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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	W _p W W _L	WATER CONTENT (%)	GR SA SI CL			
300.6	GROUND SURFACE													
0.0	FILL, sand and gravel Brown													
300.1	TOPSOIL, silty Black													
300.5	FILL, silty sand and gravel Compact Brown		1	SS	12									
299.2	SILTY SAND, fine to medium, trace to some silt, clayey silt and peat layers Loose Brown		2	SS	6									
1.4			3	SS	6									
			4	SS	7									
296.9														
3.7	SAND AND GRAVEL, with cobbles & boulders Very dense Brown		5	SS	40/ 75mm									
			6	SS	100									
295.4														
5.2	SILTY FINE SAND, Loose Brown													
			7	SS	9									
293.9														
6.7	SANDY SILT, Compact Brown		8	SS	17									
293.3														
7.3	End of Borehole													
	Note: Water level encountered in borehole at elev. 298.16m during drilling June 6, 2002. Water level in Standpipe at elev. 299.02m June 7, 2002.													

RECORD OF BOREHOLE No 101

1 OF 1

METRIC

G.W.P. 288-99-00 LOCATION STA. 16+900 CL MEDIAN ORIGINATED BY M.R.
 DIST HWY 401 BOREHOLE TYPE POWER AUGER (SOLID STEM) COMPILED BY W.F.
 DATUM GEODETIC DATE 2001.03.12 CHECKED BY M.E.B

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)			
300.4	GROUND SURFACE					▽	300													
300.0	TOPSOIL, silty Black																			
	SAND, fine, with some silt, Compact Brown		1	SS	16															
299.1																				
	SAND, fine to medium, trace silt, trace gravel Compact Brown		2	SS	14															
298.1							299													
	SAND, fine to medium, trace gravel, Compact Brown																			
297.4			3	SS	11		298													
3.1	End of Borehole																			
	Note: Water level in open borehole at elev. 299.20m following drilling March 12, 2001.																			

RECORD OF BOREHOLE No 102

1 OF 1

METRIC

G.W.P. 288-99-00 LOCATION STA. 17+000 CL MEDIAN ORIGINATED BY M.R.
 DIST HWY 401 BOREHOLE TYPE POWER AUGER (SOLID STEM) COMPILED BY W.F.
 DATUM GEODETIC DATE 2001.03.12 CHECKED BY M.E.B

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20 40 60 80 100									
300.7	GROUND SURFACE					▽	300	20 40 60 80 100					10 20 30				
300.9	TOPSOIL, sandy Black																
0.3	SAND AND GRAVEL, trace silt Very loose Brown		1	SS	4												
299.3	SAND AND GRAVEL, occasional clay lumps Compact Brown		2	SS	12												
298.4	CLAYEY SILT, trace sand and gravel, trace topsoil, Stiff Brown		3	SS	12												
297.7	End of Borehole																
3.1	Note: Water level in open borehole at elev. 299.08m following drilling March 12, 2001.																

LIST OF ABBREVIATIONS

The abbreviations commonly employed on each "Record of Borehole", on the figures and in the text of the report, are as follows:

I. SAMPLE TYPES

<i>AS</i>	auger sample
<i>CS</i>	chunk sample
<i>DO</i>	drive open
<i>DS</i>	Denison type sample
<i>FS</i>	foil sample
<i>RC</i>	rock core
<i>ST</i>	slotted tube
<i>TO</i>	thin-walled, open
<i>TP</i>	thin-walled, piston
<i>WS</i>	wash sample
<i>SS</i>	split spoon

II. PENETRATION RESISTANCES

Dynamic Penetration Resistance:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 0.3 m (12 in.).

Standard Penetration Resistance, N:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 0.3 m (12 in.).

<i>WH</i>	sampler advanced by static weight-weight, hammer
<i>PH</i>	sampler advanced by hydraulic force
<i>PM</i>	sampler advanced by manual force

III. SOIL DESCRIPTION

(a) Cohesionless Soils

	"N" Blows/0.3 m or <u>Blow/ft.</u>
Relative Density	
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils

	"Cu" = "Su" <u>kPa</u>	<u>psf.</u>
Consistency		
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1000
Stiff	50 to 100	1000 to 2000
Very stiff	100 to 200	2000 to 4000
Hard	over 200	over 4000

IV. SOIL TESTS

<i>C</i>	consolidation test
<i>H</i>	hydrometer analysis
<i>M</i>	sieve analysis
<i>MH</i>	combined analysis, sieve and hydrometer ¹
<i>Q</i>	undrained triaxial ²
<i>R</i>	consolidated undrained triaxial ²
<i>S</i>	drained triaxial
<i>U</i>	unconfined compression
<i>V</i>	field vane test
<i>Chem</i>	chemical analysis

NOTES:

1. Combined analyses when 5 to 95 per cent of the material passes the No. 200 sieve.
2. Undrained triaxial tests in which pore pressures are measured are shown as Q or R.

LIST OF SYMBOLS

I. GENERAL

π	3.1416
e	base of natural logarithms 2.7183
$\log_e a$ or $\ln a$	natural logarithm of a
$\log_{10} a$ or $\log a$	logarithm of a to base 10
t	time
g	acceleration due to gravity
V	volume
W	weight
m	mass
M	moment
F	factor of safety

II. STRESS AND STRAIN

u	pore pressure
σ	normal stress
σ'	normal effective stress (σ is also used)
τ	shear stress
ϵ	linear strain
ϵ_{sy}	shear strain
ν	Poisson's ration (μ is also used)
E	modulus of linear deformation (Young's modulus)
G	modulus of shear deformation
K	modulus of compressibility
η	coefficient of viscosity

III. SOIL PROPERTIES

(a) Unit weight

γ	unit weight of soil (bulk density)
γ_s	unit weight of solid particles
γ_w	unit weight of water
γ_d	unit dry weight of soil (dry density)
γ'	unit weight of submerged soil
G_s	specific gravity of solid particles $G_s = \gamma_s/\gamma_w$
e	void ratio
n	porosity
w	water content
S_r	degree of saturation

(b) Consistency

w_L	liquid limit
w_P	plastic limit
I_P	plasticity index
w_S	shrinkage limit
I_L	liquidity index $= (w - w_P)/I_P$
I_C	consistency index $= (w_L - w)/I_P$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
D_r	relative density $= (e_{max} - e)/(e_{max} - e_{min})$

(c) Permeability

h	hydraulic head or potential
q	rate of discharge
v	velocity of flow
i	hydraulic gradient
κ	coefficient of permeability
j	seepage force per unit volume

(d) Consolidation (one-dimensional)

m_v	coefficient of volume change $= -\Delta e/(1+e)\Delta\sigma'$
C_c	compression index $= -\Delta e/\Delta\log_{10}\sigma'$
c_v	coefficient of consolidation
T_F	time factor $= c_v t/d^2$ (d , drainage path)
U	degree of consolidation

(e) Shear strength

τ_f	shear strength	in terms of effective stress $\tau_f = c' + \sigma' \tan \phi$
c'	effective cohesion intercept	
ϕ'	effective angle of shearing resistance, or friction	
S_u	apparent cohesion*	in terms of total stress $\tau_f = cu + \sigma \tan \phi_u$
ϕ_u	apparent angle of shearing resistance, or friction	
μ	coefficient of friction	
S_t	sensitivity	

*For the case of a saturated cohesive soil, $\phi_u = 0$ and the undrained shear strength $\tau_f = S_u$ is taken as half the undrained compressive strength.



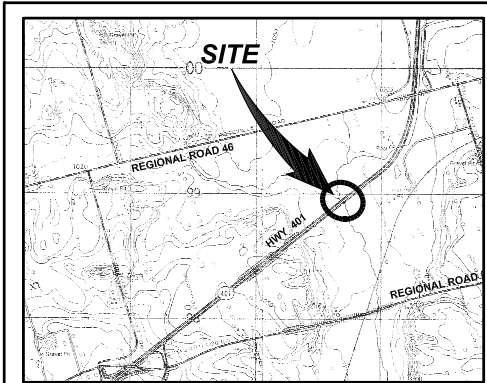
PROPOSED
STORM SEWER OUTLET
BOREHOLE LOCATIONS

SHEET



Golder Associates Ltd.
LONDON, ONTARIO, CANADA

REFERENCE
DRAWING SUPPLIED BY
DILLON CONSULTING



KEY PLAN

LEGEND

Borehole

No.	ELEVATION (metres)	STATION	CENTRELINE MEDIAN OFFSET
1	300.60	16+905	18.1m RT
2	300.60	17+040	19.0m RT
101	300.42	16+900	ON CL
102	300.70	17+000	ON CL

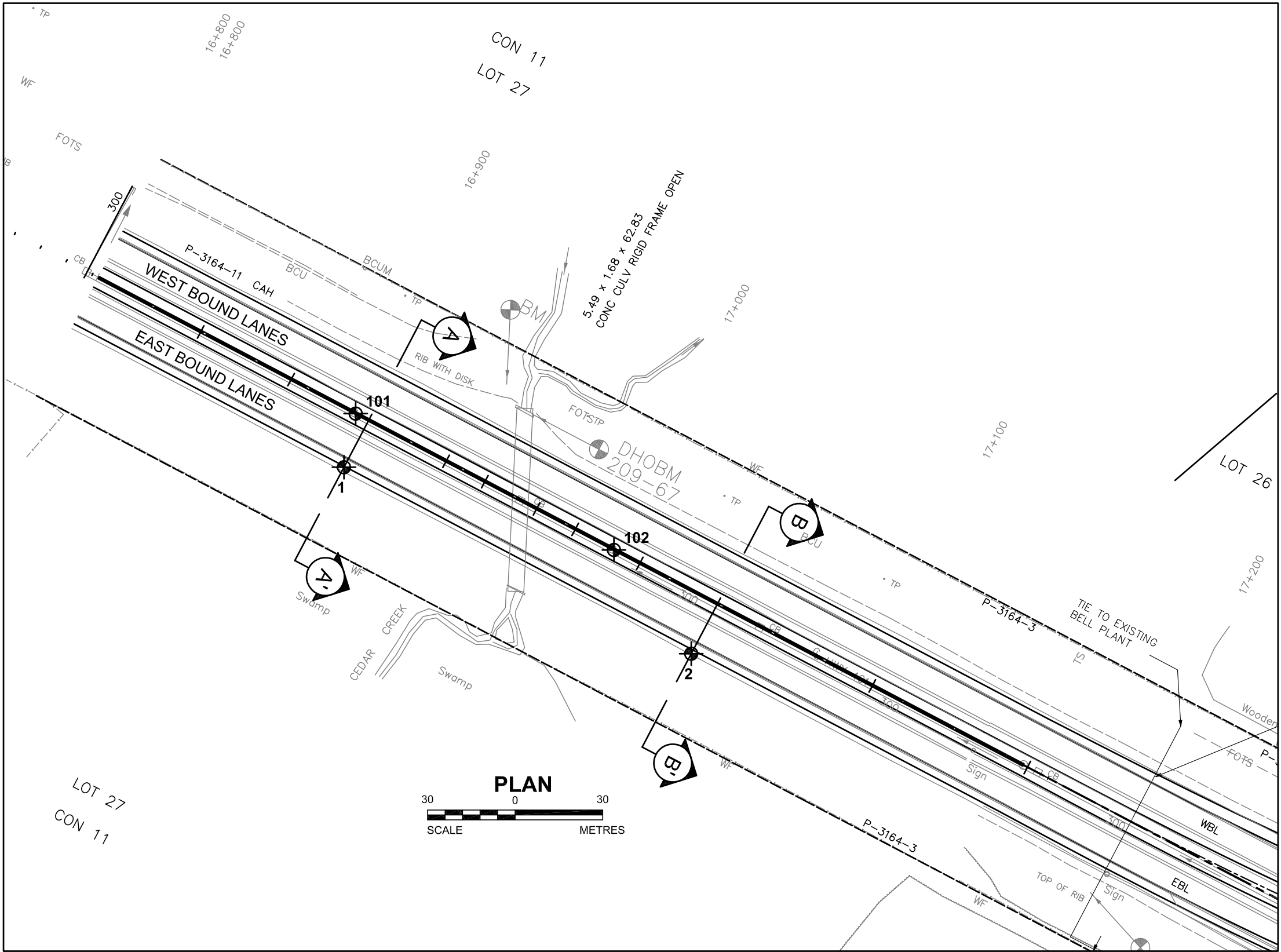
NOTES

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

NO.	DATE	BY	REVISION

Geocres No. 40P8-125

HWY. No.	401	PROJECT NO.:	001-3230-5	
SUBM'D.	—	CHKD:	AMH	DATE: JUNE. 2002
DRAWN:	WDF	CHKD:	AMH	APPD. PRB
				DWG. 1



PLAN

30 0 30
SCALE METRES

REFERENCE
FOR SOIL STRATA REFER TO DRAWING 2