

Golder Associates Ltd.

500 Nottinghill Road
London, Ontario, Canada N6K 3P1
Telephone: (519) 471-9600
Fax: (519) 471-4707



REPORT ON

**FOUNDATION INVESTIGATION
AND DESIGN REPORT
OVERHEAD SIGNS
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**

Submitted to:

Dillon Consulting Limited
P.O. Box 426, Terminal B
495 Richmond Street
London, Ontario
N6A 4W7

DISTRIBUTION:

- 6 Copies - Dillon Consulting Limited
- 2 Copies - Golder Associates Ltd.

April 22, 2002

001-3230-4
Geocres No. 40P8-124



Golder Associates Ltd.

500 Nottingham Road
London, Ontario, Canada N6K 3P1
Telephone: (519) 471-9600
Fax: (519) 471-4707



April 22, 2002

001-3230-4

Dillon Consulting Limited
P.O. Box 426, Terminal B
495 Richmond Street
London, Ontario
N6A 4W7

Attention: Mr. B.G. Huston, P. Eng., Partner

**RE: FOUNDATION INVESTIGATION AND DESIGN REPORT
OVERHEAD SIGNS, 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**

Dear Sirs:

Please find enclosed six (6) copies of the Foundation Investigation and Design report for the proposed overhead signs together with two digital copies of the report on compact disks. The number of printed reports and digital copies is as per the subconsultant agreement for this project.

We have received the April 10, 2002 memorandum from the Ministry of Transportation, Ontario (MTO) Foundations Section with respect to the draft report prepared for the proposed structures. The MTO had no comments on the draft report.

We trust that this letter and our finalized report are satisfactory. Please do not hesitate to contact our office if you have any questions or require further information.

Yours truly,

GOLDER ASSOCIATES LTD.

Philip R. Bedell, P. Eng.

Mr. F.J. Heffernan, P. Eng.
Designated MTO Contact

cc: Mr. G. Mahabir, P. Eng., MTO Southwestern Region
Ms. A. Piascik, P. Eng., MTO Foundations Section



PRB/WMK/cb
c:\projects\temp_pdf\lrr-hd\reports\001-3230-4\0422-cover letter for rpt.doc



TABLE OF CONTENTS

<u>SECTION</u>	<u>PAGE</u>
1.0 INTRODUCTION.....	1
2.0 INVESTIGATION PROCEDURES.....	2
3.0 SITE GEOLOGY AND STRATIGRAPHY	3
3.1 Regional Geological Conditions	3
3.2 Site Stratigraphy	3
3.2.1 OS 1 – Station 13+550 (Eastbound).....	3
3.2.2 OS 2 – Station 14+165 (Eastbound).....	4
3.2.3 OS 3 – Station 14+360 (Westbound).....	4
3.2.4 OS 4 – Station 14+975 (Westbound).....	5
3.2.5 Previous Boreholes.....	6
4.0 DESIGN AND CONSTRUCTION CONSIDERATIONS.....	7
4.1 Design Parameters	7
4.1.1 Vertical Loads	8
4.1.2 Lateral Loads	9
4.2 Construction Considerations	9

LIST OF DRAWINGS

Drawing 1 Overhead Sign Locations, Borehole Locations

LIST OF FIGURES

Figure 1 Grain Size Distribution Curve, Silt some Sand
 Figure 2 Grain Size Distribution Curve, Sand
 Figure 3 Grain Size Distribution Curve, Sand and Gravel

LIST OF APPENDICES

Appendix A Records of Boreholes, Pavement Investigation, GWP 288-99-00, March 2001

1.0 INTRODUCTION

Golder Associates Ltd. has been retained by Dillon Consulting Limited on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the proposed overhead signs on Highway 401 within GWP 288-99-00. The overhead signs are to be constructed at the following locations:

<u>DESIGNATION</u>	<u>LOCATION</u>
OS 1	Station 13+550 (Eastbound)
OS 2	Station 14+165 (Eastbound)
OS 3	Station 14+360 (Westbound)
OS 4	Station 14+975 (Westbound)

Drawing 1 shows all of the overhead sign locations in plan.

2.0 INVESTIGATION PROCEDURES

The subsurface investigation for the four overhead signs was carried out on March 4 and 5, 2002, at which time four boreholes were drilled at the proposed sign locations. The boreholes were located as follows:

<u>BOREHOLE</u>	<u>LOCATION</u>	<u>OFFSET(from centreline median)</u> (m)
OS 1	Station 13+550	20.5 Right
OS 2	Station 14+165	22.5 Right
OS 3	Station 14+360	25.2 Left
OS 4	Station 14+975	20.5 Left

The boreholes were advanced using a rubber tire mounted CME 750 drilling machine supplied and operated by a specialist drilling contractor. The boreholes were advanced using hollow stem augers. Samples were obtained at regular intervals of depth using 50 millimetre outside diameter split spoon sampling equipment in accordance with the Standard Penetration Test procedure. The water levels in the boreholes were observed and recorded throughout the drilling operations.

The field work was supervised on a full-time basis by a member of our engineering staff who arranged for underground service locates, designated the borehole locations in the field, directed the drilling, sampling and in situ testing operations, logged the boreholes and cared for the samples obtained. The soil samples were identified in the field, placed in labelled containers and transported to Golder Associates Ltd.'s London laboratory for further examination and routine testing. Index and classification tests consisting of water content determinations and grain size distribution analyses were carried out on selected samples.

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 Archibald, Gray & McKay Engineering & Surveying Ltd. Ground surface elevations at the borehole locations are understood to be referenced to geodetic datum.

To supplement the information obtained from the current investigation, Records of Boreholes 1 through 4, drilled in the median as part of the geotechnical investigation and pavement design component of the project, were reviewed during the preparation of this report. These Records of Boreholes have been attached to this report in Appendix A.

3.0 SITE GEOLOGY AND STRATIGRAPHY

3.1 Regional Geological Conditions

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.

This portion of the project is located in outwash and kame moraine deposits and the underlying soils consist predominantly of sands and gravels. The underlying bedrock is the Late Silurian Salina Formation, consisting of shales, shaley limestones, some gypsum and anhydrite deposits.

3.2 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of the in situ and laboratory testing are given on the attached Record of Borehole sheets. The stratigraphic boundaries shown on the Record of Boreholes are inferred from non-continuous sampling and represent transitions between soil types rather than exact planes of geological change. Subsurface conditions may vary significantly between and beyond the locations.

A description of the subsurface conditions encountered in the boreholes at each sign location is provided in the following sections.

3.2.1 OS 1 – Station 13+550 (Eastbound)

A compact layer of silty sand and gravel fill some 1.1 metres thick was encountered at ground surface in borehole OS 1. The fill was underlain by 0.3 metres of silty topsoil. The topsoil, in turn, was underlain by silty sand fill and by clayey silt fill 0.8 metres in thickness.

Beneath the lower fill, a stratum of loose to dense sand about 6.1 metres thick was encountered at elevation 317.3 metres. The sand had N values, as measured in the standard penetration testing, of from 6 blows per 0.3 metres near the surface to 40 blows per 0.3 metres at depth. Natural water

contents were measured from 6 to 24 per cent with an average water content of about 9 per cent above the water level and about 21 per cent below the water level.

Beneath the sand, the borehole was terminated in, a layer of compact sandy silt which was encountered at elevation 311.2 metres. Occasional silt layers were noted in the sandy silt. The sandy silt had N values of from 20 to 23 blows per 0.3 metres and natural water contents of from 24 to 36 per cent.

A typical grain size distribution curve for a sample of the silt some sand recovered from the standard penetration testing is provided on Figure 1.

The water level was encountered at a depth of 6.9 metres, or elevation 312.6 metres, during drilling on March 4, 2002.

3.2.2 OS 2 – Station 14+165 (Eastbound)

Borehole OS 2 encountered 0.5 metres of sandy topsoil at ground surface. Beneath the topsoil, a layer of compact sand some 3.2 metres thick was encountered. The sand had measured N values of from 12 to 25 blows per 0.3 metres and had natural water contents of from 5 to 16 per cent with an average natural water content of about 8 per cent.

The sand was underlain by 1.5 metres of compact to very dense sand and gravel which was encountered at elevation 328 metres and was, in turn, underlain by compact to very dense sands. The sand and gravel had measured N values of 38 and 76 blows per 0.3 metres and natural water contents of 5 and 8 per cent.

The lower sands were encountered at elevation 324.4 metres and had N values of from 24 to 84 blows per 0.3 metres and natural water contents of from 2 to 23 per cent with an average water content of 7 per cent. Borehole OS 2 explored the lower sands for some 5.2 metres prior to termination at a depth of 10.4 metres.

A typical grain size distribution curve for a sample of the sand recovered from the standard penetration testing in borehole OS 2 is provided on Figure 2.

Groundwater was encountered at a depth of 9.5 metres, or elevation 320.2 metres, during drilling on March 4, 2002.

3.2.3 OS 3 – Station 14+360 (Westbound)

Borehole OS 3 was advanced through the pavement shoulder. Some 1.4 metres of very dense sand and gravel fill materials associated with the shoulder construction were encountered at

ground surface. Beneath the shoulder fill materials, about 0.6 metres of stiff clayey silt fill was encountered.

A layer of compact silt with a trace of organic material was encountered beneath the fill at elevation 332.9 metres. The silt layer was some 0.6 metres thick. The silt had a single measured N value of 20 blows per 0.3 metres and a natural water content of 21 per cent.

Beneath the silt, alternating layers of compact to very dense sands and sand and gravel were encountered at elevation 332.1 and extended to the depth explored. The sands and sand and gravel had measured N values of from 27 to 53 blows per 0.3 metres and had natural water contents of from 1 to 3 per cent. The borehole was terminated at a depth of 11.1 metres in a layer of dense sand and gravel.

A typical grain size distribution curve for a sample of the sand recovered from the standard penetration testing in borehole OS 3 is provided on Figure 3.

Borehole OS 3 remained dry during drilling on March 5, 2002.

3.2.4 OS 4 – Station 14+975 (Westbound)

Some 0.6 metres of sandy topsoil was encountered at ground surface in borehole OS 4. Beneath the topsoil, a layer of compact to very dense silty sand and gravel fill material some 1.5 metres thick was encountered.

Beneath the fill materials, alternating layers of compact to very dense sands and sand and gravel were encountered at elevation 327.2 metres. The sand layers were about 0.8 to 1.5 metres thick while the sand and gravel layers were about 2.3 to greater than 4.3 metres thick. The sands had measured N values of from 10 to 47 blows per 0.3 metres and had natural water contents of from about 4 to 19 per cent. The sand and gravel had measured N values of from 34 blows per 0.3 metres to 100 blows per 0.15 metres. The sand and gravel layers had natural water contents of from 3 to 10 per cent. Borehole OS 4 was terminated in very dense sand and gravel at a depth of 11.0 metres.

A typical grain size distribution curve for a sample of sand and gravel recovered from the standard penetration testing is provided on Figure 4.

Borehole OS 4 remained dry during drilling on March 5, 2002.

3.2.5 Previous Boreholes

The Records of Boreholes for boreholes 1 through 4 drilled through the median during the pavement investigation for this project are included in Appendix A. The results of these boreholes generally support the results of the current boreholes.

4.0 DESIGN AND CONSTRUCTION CONSIDERATIONS

This section of the report provides recommendations on the geotechnical aspects of the proposed overhead signs based on our interpretation of the factual information obtained. 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 designs. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods, scheduling and the like.

The following table summarizes the subsurface information compiled at the overhead sign locations. The depths are referenced to ground surface at the borehole locations.

<u>LOCATION</u>	<u>GENERAL SOIL AND GROUNDWATER CONDITIONS.</u>
OS 1	<ul style="list-style-type: none"> - fill materials to 2.1 metres depth (elevation 317.3 metres) - loose to dense sands to 8.2 metres depth (elevation 311.2 metres) - compact sandy silt to 11.1 metres depth (elevation 308.3 metres) - groundwater at 6.9 metres depth (elevation 312.6 metres)
OS 2	<ul style="list-style-type: none"> - compact sands to 3.7 metres depth (elevation 326.0 metres) - compact to very dense sand and gravel to 5.2 metres depth (elevation 324.4 metres) - compact to very dense sands to 10.4 metres depth (elevation 319.3 metres) - groundwater at 9.5 metres depth (elevation 320.2 metres)
OS 3	<ul style="list-style-type: none"> - fill materials to 2.1 metres depth (elevation 332.9 metres) - compact silt to 2.9 metres depth (elevation 332.1 metres) - alternating layers of compact to very dense sands and sand and gravel to 11.1 metres depth (elevation 323.9 metres) - borehole remained dry during drilling
OS 4	<ul style="list-style-type: none"> - fill materials to 2.1 metres depth (elevation 327.2 metres) - alternating layers of compact to very dense sands and sand and gravel to 11.0 metres depth (elevation 318.3 metres) - borehole remained dry during drilling.

4.1 Design Parameters

The following unfactored parameters may be used for the design of the overhead sign foundations. It is assumed that the foundations will consist of drilled, cast-in-place concrete caissons.

LOCATION	SOIL TYPE	ANGLE OF FRICTION, ϕ (°)	EFFECTIVE COHESION, c' (kPa)	UNIT WEIGHT γ' (Mg/m ³)	COEFFICIENT OF LATERAL EARTH PRESSURE (K_p)	SHAFT RESISTANCE FACTOR B	BEARING CAPACITY FACTOR N_t
OS 1	Fill	N/A	N/A	2.0	N/A	N/A	N/A
	Sand	32	0	2.0	3.3	0.4	40
	Sandy silt	29	0	1.9	2.9	0.2	15
OS 2	Upper sand	32	0	2.0	3.3	0.4	40
	Sand and gravel	34	0	2.1	3.5	0.6	70
	Lower sand	32	0	2.0	3.3	0.5	50
OS 3	Fill	N/A	N/A	2.0	N/A	N/A	N/A
	Silt	28	0	1.9	2.8	0.2	15
	Sand	32	0	2.0	3.3	0.4	40
	Sand and gravel	34	0	2.1	3.5	0.5	70
OS 4	Fill	N/A	N/A	2.0	N/A	N/A	N/A
	Sand	32	0	2.0	3.3	0.4	40
	Sand and gravel	34	0	2.1	3.5	0.5	70

4.1.1 Vertical Loads

Based on the subsurface conditions encountered in the boreholes, the unit shaft resistance that may be used in the assessment of the vertical load carrying capacity of the caissons may be calculated using the following equation:

$$f_s = B\gamma'dC\Delta L$$

where d is the depth along the caisson, B is a shaft resistance factor, C is the circumference of the caisson, and ΔL is the individual layer thicknesses.

The upper 1.2 metres below the ground surface should be neglected to account for frost action. The portion of the caisson within fill materials should also be neglected.

The component of vertical load carrying capacity that may be derived from end bearing may be calculated using the following equation:

$$q_b = (N_t\gamma'd)A$$

where d is the depth to the base of the caisson, N_t is a bearing capacity factor, and A is the cross-sectional area of the caisson.

A resistance factor of 0.4 should be applied to obtain the factored axial resistance at ultimate limit states (ULS). The axial resistance at serviceability limit states (SLS) is greater than at ULS and ULS values will govern design.

4.1.2 Lateral Loads

The unfactored passive lateral earth pressure, P_p , distributed along the caisson with depth, d , in metres, may be calculated using the following expression and the parameters given above:

$$P_p = K_p \gamma' d$$

The unfactored lateral resistance should be calculated assuming an equivalent pile width equal to 3 times the caisson diameter. A resistance factor of 0.5 should be applied to the lateral resistance as calculated to obtain the factored lateral geotechnical resistance. The contribution to the lateral resistance from the fill materials should be ignored.

The passive resistance in front of the caisson within the upper 1.2 metres below the ground surface should also be neglected in the design of the foundations to account for frost action. The design frost depth for this site should be 1.2 metres.

4.2 Construction Considerations

Based on the results of the boreholes and the anticipated founding elevations, excavations for the caissons are not expected to extend below the groundwater level.

A temporary liner will be required to support the sides of the excavation and prevent caving. Cleaning of the base of the caisson should be carried out prior to placement of concrete to remove all loosened or disturbed material. Surface water run off should be directed away from the excavations.

Although not specifically encountered in the boreholes drilled at the overhead sign locations, cobbles and boulders are inherent in the local geology and should therefore be expected during caisson excavation at the site.

GOLDER ASSOCIATES LTD.

Michael E. Beadle, P. Eng.

Philip R. Bedell, P. Eng.
Principal


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

MEB/PRB/cb
n:\active\3200\001-3200\001-3230-4 dillon - overhead signs - hwy 401\reports\0313-foundation report.doc


DIST
CONT. No.
GWP No.

HWY. 401
288-99-00

OVERHEAD SIGN LOCATIONS
BOREHOLE LOCATIONS

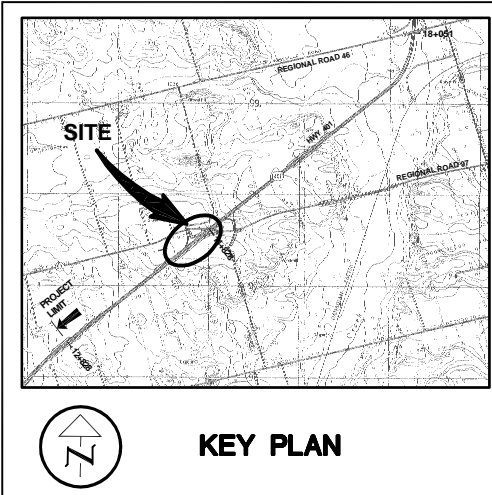
Golder Associates






Golder Associates Ltd.
LONDON, ONTARIO, CANADA



SHEET

REFERENCE
DRAWING SUPPLIED BY DILLON CONSULTING
ENTITLED HWY 401, GENERAL ARRANGEMENT

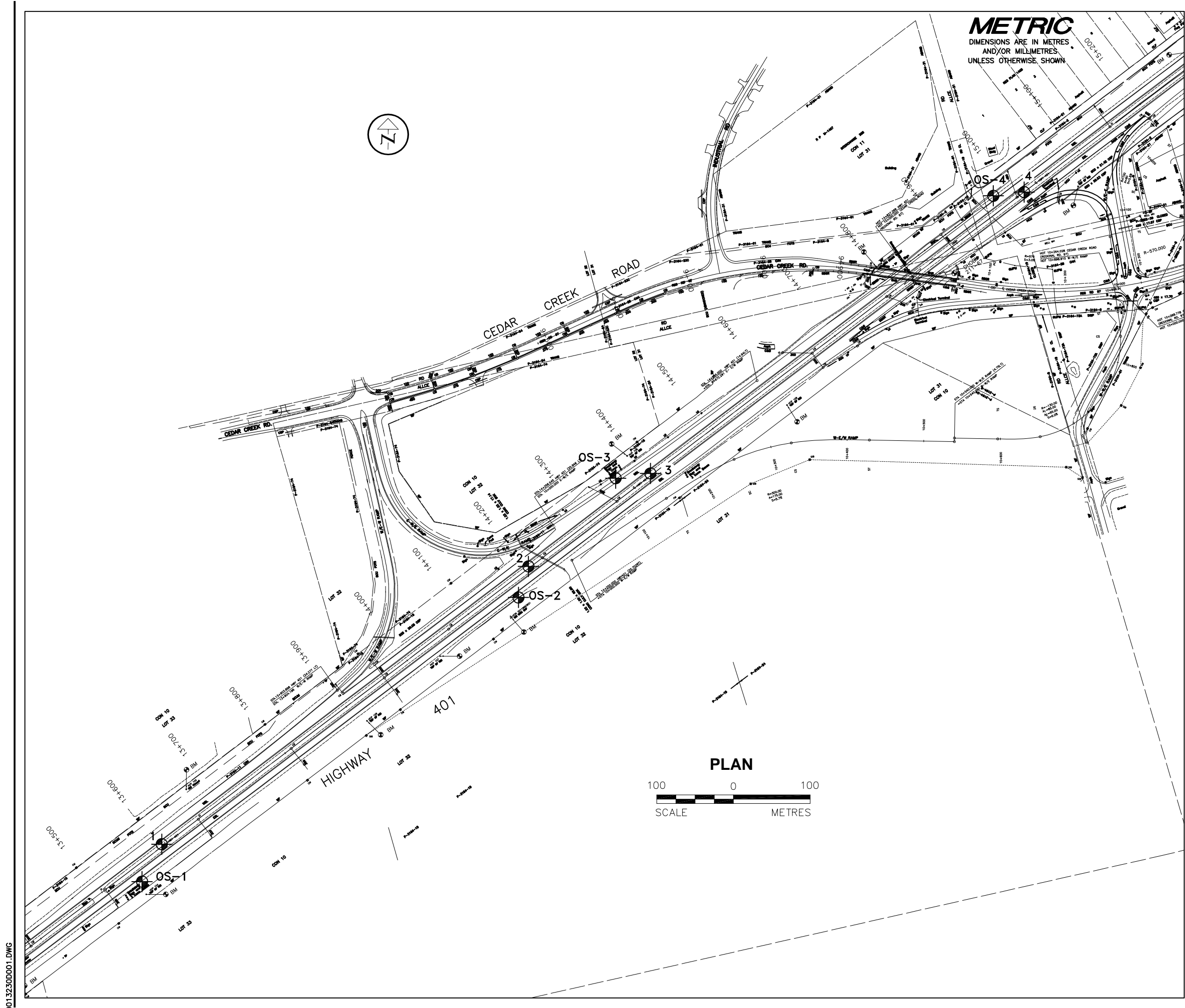


LEGEND		
	Borehole	
	Seal	
	Piezometer	
N	Blows/0.3m (Std. Pen. Test, 475 j/blow)	
	WL in piezometer	
	WL during drilling	
No.	ELEVATION (metres)	LOCATION STATION & o/s Q OF MEDIAN
1	318.10	13+600 o/s 2.5m LEFT
2	330.50	14+200 o/s 2.2m LEFT
3	335.00	14+400 o/s 2.5m LEFT
4	326.00	15+010 o/s 2.0m RIGHT
OS1	319.42	13+550 o/s 20.5m RIGHT
OS2	329.62	14+165 o/s 22.5m RIGHT
OS3	335.01	14+360 o/s 25.2m LEFT
OS4	329.30	14+975 o/s 20.5m LEFT

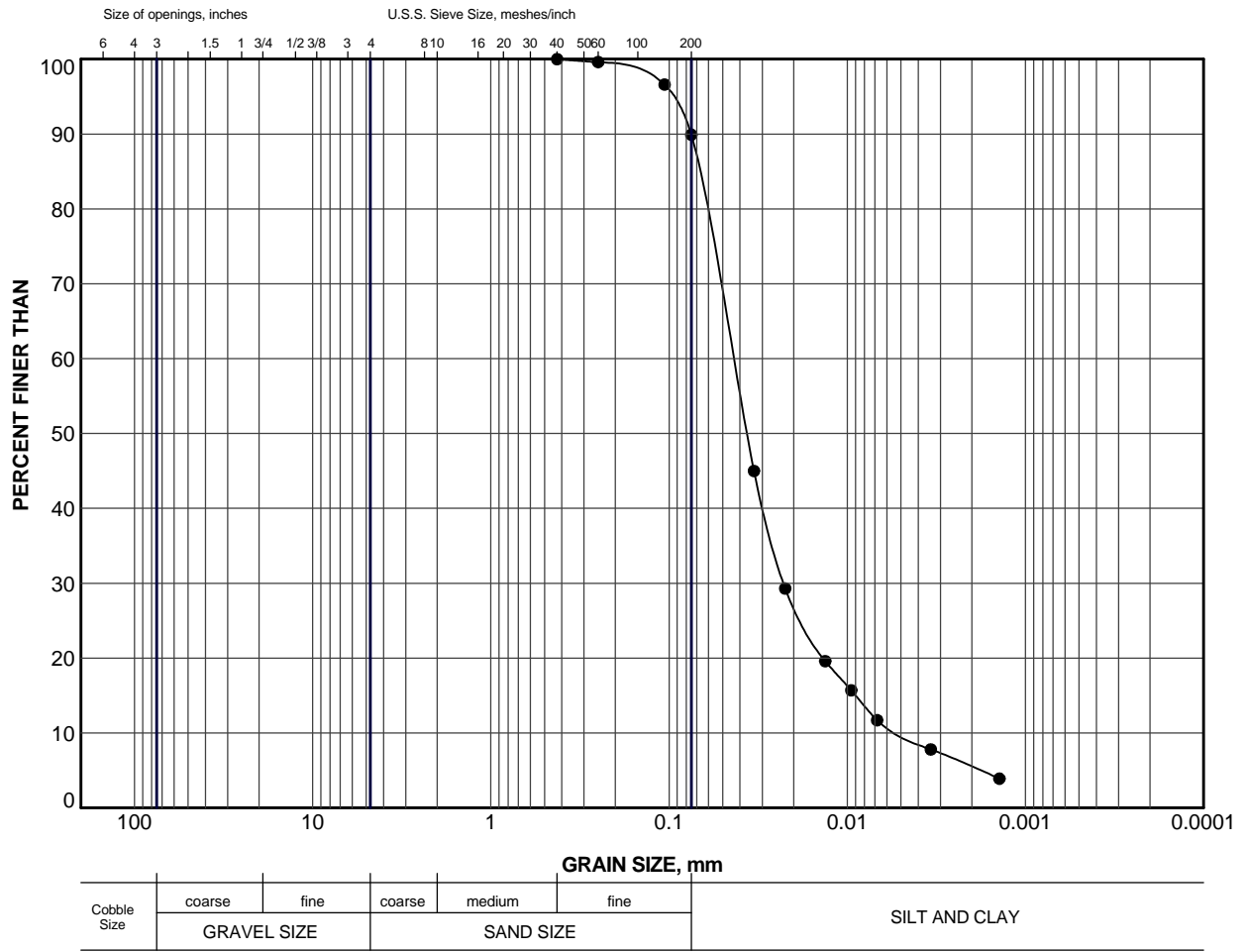
NOTES
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

NO.	DATE	BY	REVISION


Geocres No. 40P8-124			
HWY. No.	401	PROJECT NO.:	001-3230-4
SUBM'D.	-	CHKD:	-
DATE:	MAR. 2002	APPD.	-
DRAWN:	WDF/BG	CHKD.	MEB
DWG.	1		

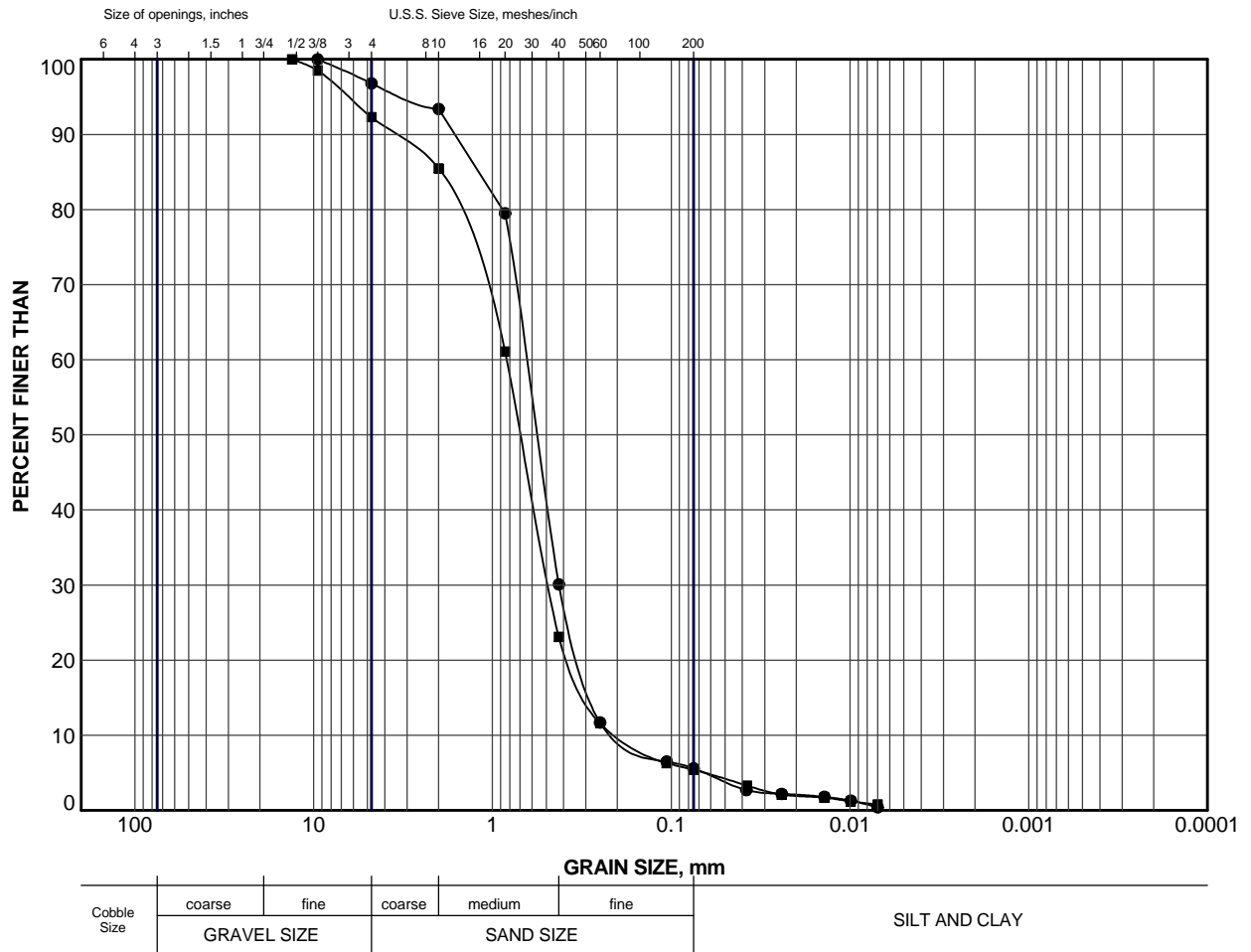


I013230D001.DWG




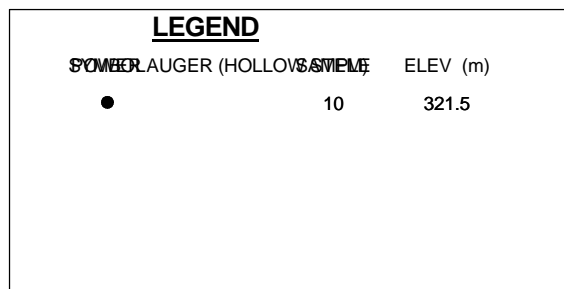
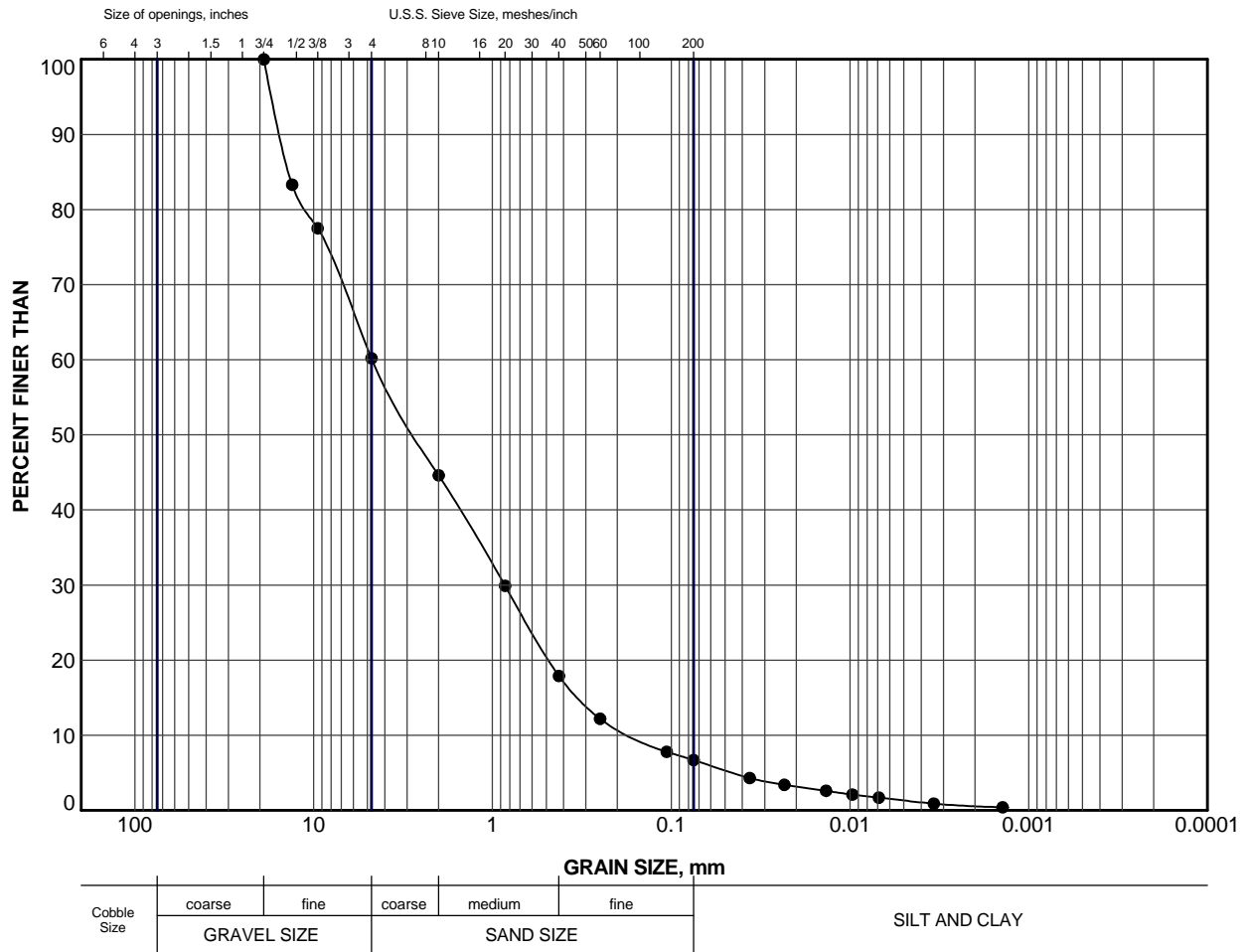
LEGEND		
POWER LAUGER (HOLLOW STEM)	SAMPLE NO.	ELEV. (m)
●	11	310.8


PROJECT					WP 288-99-00 HWY 401					
TITLE										
GRAIN SIZE DISTRIBUTION SILT, SOME SAND										
 Golder Associates LONDON, ONTARIO					PROJECT No.		FILE No. 001-3230-4.GPJ			
					SCALE		N/A			
					DRAWN		WDF		14/3/02	
					CHECK				14/3/02	
<div>FIGURE 1</div>										



LEGEND		
Power Auger (Hollow Stem)	8	ELEV (m)
●	8	323.3
■	10	327.2

PROJECT					WP 288-99-00 HWY 401				
TITLE					GRAIN SIZE DISTRIBUTION SAND				
 Golder Associates LONDON, ONTARIO					PROJECT No.			FILE No. 001-3230-4.GPJ	
					DRAWN WDF 14/3/02			SCALE N/A	
					CHECK 14/3/02			REV.	
					FIGURE 2				



PROJECT					WP 288-99-00 HWY 401									
TITLE										GRAIN SIZE DISTRIBUTION SAND AND GRAVEL				
PROJECT No.					FILE No.					001-3230-4.GPJ				
DRAWN					WDF					14/3/02				
CHECK										14/3/02				
 Golder Associates LONDON, ONTARIO										FIGURE 3				

APPENDIX A

RECORDS OF BOREHOLES
PAVEMENT INVESTIGATION
GWP 288-99-00
MARCH 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 Blow/ft.
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"	
Consistency	kPa	psf
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	$\left. \begin{array}{l} \text{in terms} \\ \text{of effective} \\ \text{stress} \end{array} \right\} \tau_f = c' + \sigma' \tan \phi$
c'	effective cohesion intercept	
ϕ'	effective angle of shearing resistance, or friction	
S_u	apparent cohesion*	
ϕ_u	apparent angle of shearing resistance, or friction	$\left. \begin{array}{l} \text{in terms of} \\ \text{total stress} \end{array} \right\} \tau_f = cu + \sigma \tan \phi_u$
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.

RECORD OF BOREHOLE No 1

1 OF 1

METRIC

PROJECT 001-3230-4
G.W.P. 288-99-00 LOCATION STA. 13+600 O/S 2.5m LEFT ORIGINATED BY M.A.
DIST HWY 401 BOREHOLE TYPE POWER AUGER (SOLID STEM) COMPILED BY W.F.
DATUM GEODETIC DATE 19.3.01 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							WATER CONTENT (%)
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE						
318.10	GROUND SURFACE							20 40 60 80 100	10 20 30						
0.00	TOPSOIL, sandy						318								
317.82	Dark brown														
0.28	FILL, sand, fine to medium, trace gravel														
317.19	Brown						317								
0.91	FILL, sandy silt, with clay and topsoil		1	SS	39										
	Dense														
316.45	Black						316								
1.65	SANDY SILT, Compact		2	SS	12										
	Brown														
315.66															
2.44	SAND, fine to medium														
	Brown														
315.05															
3.05	End of Borehole														
	Note: Borehole dry during drilling 19.3.01														

N_MOT 001-3230-4.GPJ ON_MOT.GDT 14/3/02 DATA INPUT:

RECORD OF BOREHOLE No 2

1 OF 1

METRIC

PROJECT 001-3230-4

G.W.P. 288-99-00

LOCATION STA. 14+200 O/S 2.2m LEFT

ORIGINATED BY M.R.

DIST HWY 401

BOREHOLE TYPE POWER AUGER (SOLID STEM)

COMPILED BY W.F.

DATUM GEODETIC

DATE 19.3.01

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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100					
330.50	GROUND SURFACE													
0.00	TOPSOIL, silty													
0.18	Black SAND, fine to medium, trace silt, trace gravel													
329.43	Dense Brown		1	SS	31		330							
1.07	SILT, trace fine sand													
328.52	Compact to dense Brown						329							
1.98	CLAYEY SILT, trace sand		2	SS	23									
328.06	Very stiff Brown													
2.44	SAND, fine to medium, with silt						328							
327.45														
3.05	End of Borehole													
	Note: Borehole dry during drilling 19.3.01													

+ 3. X 3. Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 3

1 OF 1

METRIC

PROJECT 001-3230-4
G.W.P. 288-99-00 LOCATION STA. 14+400 O/S 2.5m LEFT ORIGINATED BY M.R.
DIST HWY 401 BOREHOLE TYPE POWER AUGER (SOLID STEM) COMPILED BY W.F.
DATUM GEODETIC DATE 19.3.01 CHECKED BY M.E.B.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100						
								SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE						
							PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT w _p w w _L WATER CONTENT (%)							
335.00	GROUND SURFACE													
0.00	TOPSOIL, silty					334								
0.18	Black													
334.39	SILTY FINE SAND, with clay													
0.61	SILTY FINE SAND, Loose to compact Brown		1	SS	16	333								
333.02			2	SS	9									
1.98	SAND, fine to medium, trace gravel Loose Brown					332								
331.95														
3.05	End of Borehole													
	Note: Borehole dry during drilling 19.3.01													

+³, x³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 4

1 OF 1

METRIC

PROJECT 001-3230-4
G.W.P. 288-99-00 LOCATION STA. 15+010 O/S 2.0m RIGHT ORIGINATED BY M.A.
DIST HWY 401 BOREHOLE TYPE POWER AUGER (SOLID STEM) COMPILED BY W.F.
DATUM GEODETIC DATE 15.3.01 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									
326.00	GROUND SURFACE							20	40	60	80	100					
0.00	TOPSOIL, sandy Dark brown																
0.23	FILL, crushed granular material																
325.39																	
0.61	FILL, silty sand and gravel, trace clay, trace clay seams Compact Brown		1	SS	17		325										
			2	SS	15												
324.02							324										
1.98	SAND AND GRAVEL, with cobbles and boulders Very dense Brown																
323.08			3	SS	65/175mm												
2.92	End of Borehole																
	Note: Borehole dry during drilling 15.3.01																

RECORD OF BOREHOLE No OS1

1 OF 1

METRIC

PROJECT 001-3230-4
G.W.P. 288-99-00 LOCATION STA. 13+550. o/s 20.5m Rt. of Median Centreline ORIGINATED BY M.E.B.
DIST HWY 401 BOREHOLE TYPE POWER AUGER (HOLLOW STEM) COMPILED BY W.F.
DATUM GEODETIC DATE 4.3.02 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	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
319.42	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	10 20 30			GR SA SI CL	
0.00	FILL, silty sand and gravel, some topsoil Compact Brown						319							
318.35			1	SS	14									
1.07	TOPSOIL, silty						318							
318.05	Black													
1.37	FILL, silty sand													
317.64	Compact		2	SS	16									
1.78	Brown													
317.29	FILL, clayey silt, some sand, topsoil						317							
2.13	Very stiff													
	Brown		3	SS	9									
	SAND, trace gravel						316							
	Loose		4	SS	6									
	Brown													
315.61														
3.81	SILTY SAND						315							
3.96	Compact		5	SS	10									
	Brown													
	SAND		6	SS	22									
	Compact to dense						314							
	Brown		7	SS	27									
			8	SS	19		313							
			9	SS	40		312							
			10	SS	18									
311.19							311							
8.23	SILT, some sand													
	Compact		11	SS	23		310							
	Brown													
			12	SS	20									
							309							
			13	SS	22									
			14	SS	22									
308.29														
11.13	End of Borehole													
	Note: Water level encountered in borehole at elev. 312.56m during drilling 4.3.02													

PROJECT <u>001-3230-4</u>		RECORD OF BOREHOLE No OS2		1 OF 1	METRIC
G.W.P. <u>288-99-00</u>	LOCATION <u>STA. 14+165, o/s 22.5m Rt. of Median Centreline</u>	ORIGINATED BY <u>M.E.B.</u>			
DIST <u> </u> HWY <u>401</u>	BOREHOLE TYPE <u>POWER AUGER (HOLLOW STEM)</u>	COMPILED BY <u>W.F.</u>			
DATUM <u>GEODETIC</u>	DATE <u>4.3.02</u>	CHECKED BY <u>M.E.B.</u>			

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						
							20 40 60 80 100							
329.62	GROUND SURFACE													
0.00	TOPSOIL, sandy Black													
329.11														
0.51	SAND, trace to some gravel Compact Brown		1	SS	13									
			2	SS	12									
			3	SS	17									
			4	SS	25									
325.96														
3.66	SAND AND GRAVEL, Compact to very dense Brown		5	SS	38									
			6	SS	76									
324.44														
5.18	SAND, trace gravel, Compact to dense Brown		7	SS	24									
			8	SS	29									
			9	SS	38									
			10	SS	45									
321.39														
8.23	SAND, fine Dense to very dense Brown		11	SS	84									
			12	SS	42									
319.87														
9.75	SAND, Very dense Brown		13	SS	64									
319.26														
10.36	End of Borehole													
	Note: Water level encountered in borehole at elev. 320.17m during drilling 4.3.02													

ON_MOT 001-3230-4.GPJ ON_MOT.GDT 14/3/02 DATA INPUT:

PROJECT 001-3230-4

G.W.P. 288-99-00

LOCATION STA. 14+360, o/s 25.2m Lt. of Median Centreline

ORIGINATED BY M.E.B.

DIST HWY 401

BOREHOLE TYPE POWER AUGER (HOLLOW STEM)

COMPILED BY W.F.

DATUM GEODETIC

DATE 5.3.02

CHECKED BY M.E.B.

[illegible]

+³, ×³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE

RECORD OF BOREHOLE No OS4

1 OF 1

METRIC

PROJECT 001-3230-4
G.W.P. 288-99-00 LOCATION STA. 14+975, o/s 20.5m Lt. of Median Centreline ORIGINATED BY M.E.B.
DIST HWY 401 BOREHOLE TYPE POWER AUGER (HOLLOW STEM) COMPILED BY W.F.
DATUM GEODETIC DATE 5.3.02 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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100					
329.30	GROUND SURFACE													
0.00	TOPSOIL, sandy Black						329							
328.69														
0.61	FILL, silty sand and gravel, trace organic material Compact to very dense Brown		1	SS	30		328							
			2	SS	64									
327.17														
2.13	SAND, Compact Brown		3	SS	10		327							
326.40														
2.90	SAND AND GRAVEL, Dense to very dense Brown		4	SS	54		326							
			5	SS	48									
			6	SS	34		325							
324.12														
5.18	SAND, some gravel, with fine sand layers Dense to very dense Brown		7	SS	47		324							
			8	SS	38		323							
322.59														
6.71	SAND AND GRAVEL, Very dense Brown		9	SS 100/150mm			322							
			10	SS	60									
			11	SS 70/125mm			321							
			12	SS 60/150mm			320							
			13	SS	74		319							
			14	SS 85/150mm										
318.33														
10.97	End of Borehole													
	Note: Borehole dry during drilling 5.3.02													

+³, ×³. Numbers refer to Sensitivity ○³% STRAIN AT FAILURE