

FOUNDATION INVESTIGATION AND DESIGN REPORT
FOR
CULVERT EXTENSIONS
W.P. 72-00-00
HIGHWAY 401, DISTRICT 31
TOWNSHIPS OF NORTH DUMFRIES AND BLANDFORD-BLENHEIM
OXFORD COUNTY
ONTARIO

Distribution:

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PML Ref: 02KF137D
Geocres No. 40P8-128

July 2003

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	– Drawing 2
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FOUNDATION INVESTIGATION REPORT
For
Culvert Extensions
W.P. 72-00-00
Highway 401, District 31
Townships of North Dumfries and Blandford-Blenheim
Oxford County
Ontario

INTRODUCTION

This report summarizes the results of the foundation investigation carried out for the proposed extension and/or replacement of three culverts along the Highway 401 alignment from 4.1 km east of Drumbo Road (County Road 29) easterly to 2.0 km west of Cedar Creek Road (Regional Road 97) in the Townships of North Dumfries and Blandford-Blenheim, Ontario. The investigation was conducted for Delcan Corporation on behalf of the Ontario Ministry of Transportation.

For the purposes of this report, the culverts have been designated by numbers 1 to 3 follows:

CULVERT No.	SITE No.	TOWNSHIP	PROPOSED CENTRELINE HIGHWAY 401 CHAINAGE (m)
1	33-374	North Dumfries	Station 10+500
2	Not assigned	Blandford-Blenheim	Station 21+950
3	Not assigned	Blandford-Blenheim	Station 26+715

This report pertains to the proposed culvert extensions and associated bedding/backfill zones.

SITE DESCRIPTION

The sites are located in the Townships of North Dumfries and Blandford-Blenheim in the County of Oxford (Southwestern Ontario), in the Highway 401 corridor approximately 7.7 to 13.5 km east of the Drumbo Road (County Road 29) interchange. The surrounding area is primarily rural in nature, with active agricultural operations or vacant lands adjacent to Highway 401.

The study area is part of the Waterloo Hills (Waterloo Moraine) physiographic region. The surface is composed of sandy hills and moraines with sandy outwash soils occupying the hollows, the topography gently sloping to the southwest. In general, the surficial geology in the region is fairly uniform with predominant sand and silt deposits. Bedrock consists of dolostone of the Salina Formation and is expected to exist at a depth of about 35 m.

INVESTIGATION PROCEDURES

The field work for this study was carried out in the period of November 7 to December 17, 2002 and consisted of eight boreholes (two for Culvert 1, two for Culvert 2 and four for Culvert 3) drilled to depths of 1.5 to 14.0 m below grade at the locations shown on Drawings 1 to 3, appended. For ease of reference and distinction among the culverts, the following number series was employed to identify the boreholes put down at each culvert: Culvert 1 – 100 series; Culvert 2 – 200 series; Culvert 3 – 300 series.

The locations of and ground surface elevations at the boreholes were established in the field by Peto MacCallum Ltd. The following five benchmarks provided by Delcan Corporation were used for vertical reference:

BM: Top of southeast corner of culvert,
south side of Highway 401, 30.1 m
right at Station 10+505.4
Elevation 291.856 (geodetic)

BM 222: Plate on north side of Highway 401
at Station 21+690
Elevation 301.337 (geodetic)

BM 223: Top of southwest corner of culvert,
south side of Highway 401,
Station 21+942
Elevation 293.152 (geodetic)

BM 215-67: Plate on west pier of Dereham Road
(Trussler Road) underpass structure
Elevation 292.499 (geodetic)

BM 237: RIB on south side of Highway 401 at
Station 26+590
Elevation 291.388 (geodetic)

With the exception of borehole 304, the boreholes were advanced using continuous flight solid and hollow stem augers, powered by truck and track-mounted CME-75 drill rigs, supplied and operated by specialist drilling contractors, working under the full-time supervision of a member of our engineering staff. The programmed location of a borehole at the south end of Culvert 3 was not accessible to the drilling equipment. Therefore, the borehole was repositioned to the highway shoulder (borehole 303) and an additional confirmatory testhole (borehole 304) was advanced by hand-augering at the programmed location.

Representative samples of the overburden were recovered at frequent depth intervals using a conventional split spoon sampler during drilling. Standard penetration tests were conducted simultaneously with the sampling operation to assess the strength characteristics of the substrata. At the locations of five boreholes, dynamic cone penetration tests were also performed to further assess the strength characteristics of the soils.

The groundwater conditions in the boreholes were closely monitored during the course of the field work. Upon completion of drilling, the boreholes were backfilled with auger cuttings to the ground surface.

All of the recovered samples were returned to our laboratory for detailed visual examination, classification and routine moisture content determinations. Atterberg Limits tests and grain size distribution analyses were carried out on selected samples, their results being presented in Figures 1 to 4 (Appendix A) and on the Record of Borehole sheets (Appendix B).

SUMMARIZED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole sheets for details of the subsurface conditions including soil classifications, inferred stratigraphy, boundary elevations, standard and dynamic cone penetration test results, groundwater observations and moisture content determinations. The results of laboratory grain size distribution analyses and Atterberg Limits testing are also shown on the borehole logs.

The locations of boreholes are presented on Drawings 1 to 3.

The subsurface stratigraphy revealed in the boreholes drilled at the culvert locations generally comprised a surficial fill and/or topsoil underlain by native deposits of sand and silt. Groundwater was measured to be at depths of 0.7 to 7.9 m (elevation 283.4 and 290.6).

A culvert-specific description of the geotechnical characteristics of the major types of soil encountered is presented below.

Culvert 1

Fill

Fill was present in both boreholes drilled at the site. In borehole 101, it consisted of cobbles and boulders mixed with organic topsoil and was 200 mm thick. Borehole 102 was drilled through the shoulder of the roadway embankment. The embankment fill was made up of three layers – 200 mm of sand and gravel over 150 mm of sandy silty topsoil underlain by 5.3 m of sand. The fill was typically loose to very loose in relative density and had a moisture content of 5 to 8%.

Sand

Directly beneath the fill at elevation 289.9 (borehole 101) and 288.7 (borehole 102) was fine to coarse sand. The relative density of this major cohesionless deposit was typically compact (SPT-“N” values of 12 to 32), very loose (SPT-“N” values of 0 to 1) to elevation 286.5 in borehole 101. The moisture content of the sand varied between 13 and 22%, typically being in a range of 15 to 17%.

The results of grain size distribution analyses conducted on the sand are presented in Figure 2 (Appendix A). The deposit was not penetrated in borehole 102 terminated at a depth of 11.3 m (elevation 283.1).

Silt

In borehole 101, non-plastic silt was encountered below the sand at 10.2 m depth (elevation 279.9). Being dense, this unit had a thickness of 1.6 m and a moisture content of 22%.

Silty Sand

Underlying the silt was fine silty sand. This layer was 600 mm thick and dense.

Silt Till

Non- to slightly plastic silt till was identified at a depth of 12.4 m (elevation 277.7). The silt till was very dense. Borehole 101 was terminated in this unit at 14.0 m depth (elevation 276.1).

Groundwater

Water was introduced into borehole 101 during the wash-boring process and therefore the groundwater level in the borehole was not established. It was noted, however, that the sand retrieved in the samples commencing at 0.8 m depth (elevation 289.3) was saturated. In borehole 102, water was detected at an approximate depth of 6.0 m (elevation 288.4) during drilling. Observed water levels are subject to seasonal fluctuations and rainfall patterns.

Culvert 2

Topsoil

A surficial sandy silt topsoil was present in both boreholes drilled at the site. The topsoil was up to 100 mm thick.

Fill

Fill was encountered directly beneath the topsoil in borehole 201. Composed of silty sand, the fill was 1.3 m thick and loose to very loose in relative density.

Peat

Fibrous peat was revealed in borehole 201 at 1.4 m depth (elevation 287.5). The peat had a thickness of 400 mm and a moisture content of 207%.

Silty Sand/Silty Sand and Gravel

Cohesionless deposits of silty sand were encountered below the topsoil in borehole 202 and below 5.6 m depth (elevation 283.3 and 286.6) in both boreholes. Silty sand and gravel was contacted between depths of 2.0 to 4.1 m in both boreholes as well. The deposits were typically compact in borehole 201 (SPT-"N" values of 13 to 25), loose in borehole 202 (SPT-"N" values of 6 and 7, locally 15), and very dense (SPT-"N" value of 60) in the lower sand layer in borehole 202.

The sandy deposits had moisture contents in a typical range of 17 to 20% and were not penetrated upon termination of the boreholes at 6.6 m depth (elevation 282.3 and 285.6).

Clayey Silt

The sandy deposits were overlain or interlayered with cohesive clayey silts encountered at depths of 1.8 and 2.5 m (elevation 287.1 and 289.7) in boreholes 201 and 202 respectively. Having a moisture content of 14 to 17%, these layers were 300 to 400 mm thick and firm to very stiff in consistency.

Silt Till

Identified within the sandy deposits at depths of 4.0 and 4.1 m (elevation 284.9 and 288.1) were very stiff (SPT-“N” value of 22) clayey silt till in borehole 201 and very dense (SPT-“N” value of 58) silt till in borehole 202. The silt till had a moisture content of 12% and was penetrated at 5.6 m depth (elevation 283.3 and 286.6). The results of the Atterberg Limits test performed on the clayey silt till are presented in Figure 1 (Appendix A). The liquid and plastic limits of a selected sample were 22 and 13 respectively. The results of grain size distribution analyses conducted on the till are presented in Figure 3 (Appendix A).

Groundwater

Water was observed in both boreholes in the course of the field work. Upon completion of drilling, it was measured to be at depths of 0.7 and 1.6 m (elevation 288.2 and 290.6) in boreholes 201 and 202 respectively. The surface water level at the north end of the culvert at the time of drilling was elevation 288.8. Observed water levels are subject to seasonal fluctuations and rainfall patterns.

Culvert 3

Fill

Fill was present in all boreholes. The fill was relatively shallow in boreholes 301 and 304, comprising 400 mm of cobbles and sandy silt in the former borehole and 300 mm of silty sand in the latter. In borehole 302 drilled within the highway median, the fill was 2.2 m thick and consisted of 200 mm of topsoil over loose to very loose sand. In borehole 303, the fill was 3.5 m thick and consisted of 300 mm of shoulder granular material over dense silty sand. Moisture contents of 10 and 11% were measured in the fill.

Topsoil / Alluvium

Topsoil/alluvium was identified below the fill in boreholes 303 and 304. Consisting of sandy silt, the topsoil/alluvium had a thickness of 900 and 100 mm in boreholes 303 and 304 respectively. Moisture contents of 15 and 38% were determined.

Silt/Sand

Native deposits of cohesionless silt and sand were revealed below the fill and/or topsoil/alluvium at depths of 0.4 to 4.4 m (elevation 287.3 to 289.1). These deposits were typically compact to dense (loose to very loose in borehole 304) with SPT-"N" values of 21 to 40. The moisture content of the silt/sand varied between 9 and 21%, locally up to 26%. The results of grain size distribution analyses conducted on the silt and sand deposits are presented in Figure 4 (Appendix A).

The hand-augered hole (borehole 304) was terminated in silty sand at 1.5 m depth. The silt/sand was penetrated at depths of 3.3 to 4.9 m (elevation 285.7 to 286.8) in the remaining boreholes.

Clayey Silt

An isolated layer of clayey silt was identified between 4.9 and 6.0 m depth (elevation 286.8 and 285.7) in borehole 303. The clayey silt was very stiff (SPT-"N" value of 26) with a moisture content of 19%. The grain size distribution of this unit is shown in Figure 4 (Appendix A).

Silt Till

A cohesionless silt till was contacted at depths of 3.3 to 6.0 m (elevation 285.7 to 286.5) in boreholes 301 to 303. The till was typically sandy with a trace of clay and gravel. The relative density of the till ranged from compact to very dense (SPT-“N” values ranging from 26 to 103) and moisture contents varied between 9 and 20%. The results of grain size distribution analyses are presented in Figure 4 (Appendix A).

Boreholes 301 to 303 were terminated within the silt till at depths of 6.6 to 9.6 m (elevation 281.7 to 283.6).

Groundwater

Water was observed in three boreholes in the course of the field work. During drilling, it was detected at 4.9 m depth (elevation 286.4) in borehole 302. Upon completion of augering, water was measured to be at depths of 2.1 to 7.9 m (elevation 283.4 to 288.1) in boreholes 301 to 303. Water was at the ground surface (elevation 288.4) in borehole 304 during drilling.

Observed water levels are subject to rainfall patterns and seasonal fluctuations.

CLOSURE

The field work was carried out under the supervision of Mr. M. Rapsey and Mr. F. Portela and direction of Mr. P. Cullen; B.Eng., P.Eng. The equipment was supplied by Geo-Environmental Drilling Inc.

The report was prepared by Mr. G.O. Degil, Ph.D., Senior Project Supervisor, and Mr. M.R. Anderson, M.Eng., P.Eng., Senior Foundation Engineer. It was reviewed by Mr. D.W. Kerr, M. Eng., P.Eng., Chief Foundation Engineer. Mr. B.R. Gray, M.Eng., P.Eng., President, carried out an independent review of the report.



Yours very truly

Peto MacCallum Ltd.

A handwritten signature of Murray R. Anderson in black ink.

Murray R. Anderson, M.Eng., P.Eng.
Senior Foundation Engineer

A handwritten signature of Dennis W. Kerr in black ink.

Dennis W. Kerr, M.Eng., P.Eng.
Chief Foundation Engineer

A handwritten signature of Brian R. Gray in black ink.

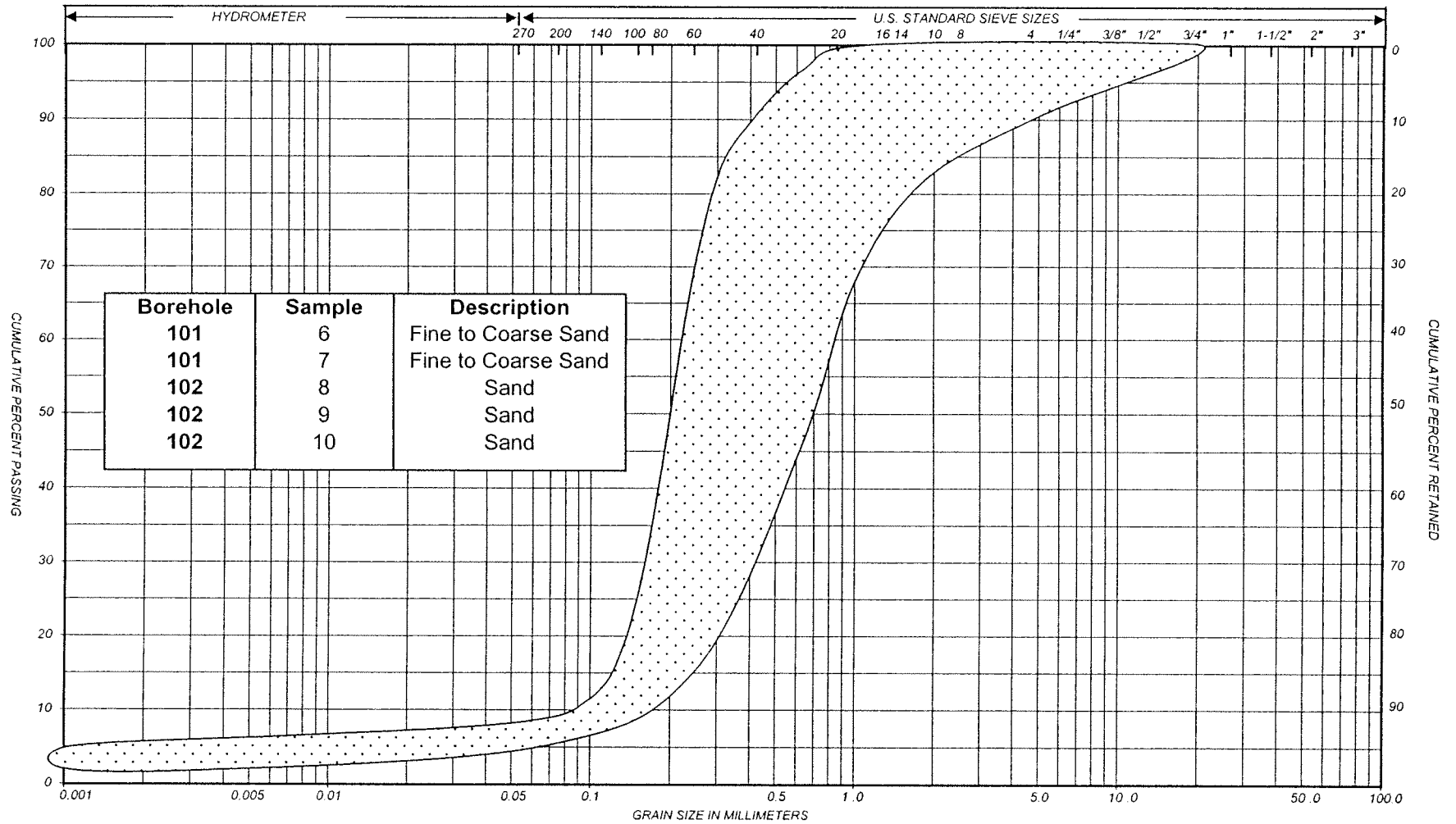
Brian R. Gray, M.Eng., P.Eng.
President

GD:lad

APPENDIX A

FIGURE 1 – PLASTICITY CHART
FIGURES 2 TO 4 – GRAIN SIZE DISTRIBUTION CHARTS

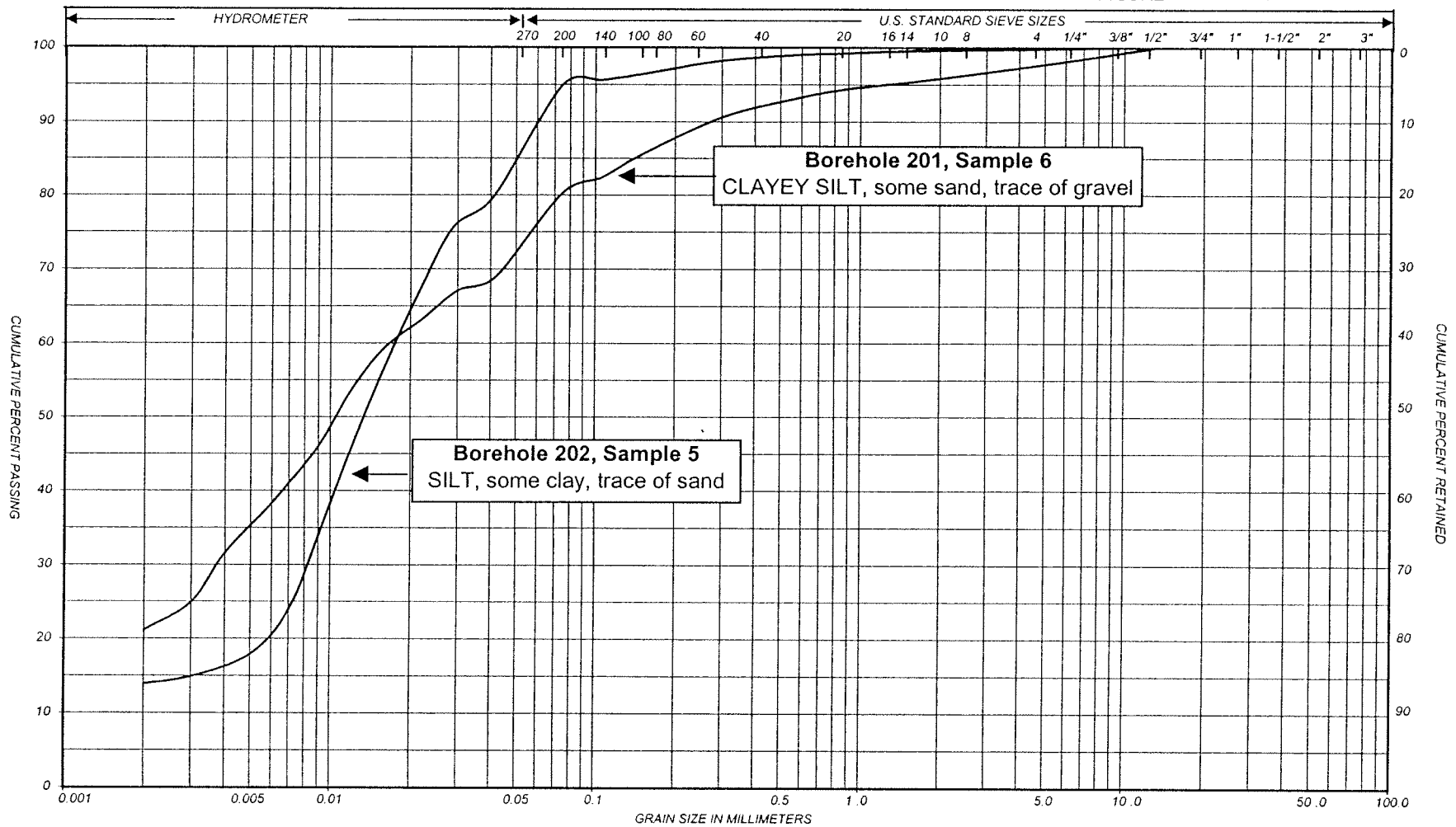
GRAIN SIZE DISTRIBUTION CHART



SILT & CLAY				FINE		MEDIUM		COARSE	GRAVEL		COBBLES	UNIFIED
CLAY	FINE		MEDIUM	COARSE	FINE		MEDIUM	COARSE	GRAVEL		COBBLES	M.I.T.
			SILT			SAND						
CLAY		SILT		VERY FINE	FINE	MEDIUM	COARSE	GRAVEL		U.S. BUREAU		
				SAND								

REMARKS SAND, trace of gravel, silt and clay

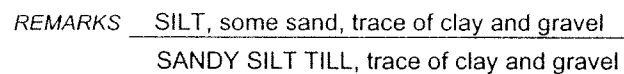
GRAIN SIZE DISTRIBUTION CHART



SILT & CLAY				FINE SAND			MEDIUM SAND		COARSE SAND		GRAVEL		COBBLES	UNIFIED
CLAY	FINE	MEDIUM SILT	COARSE	FINE	MEDIUM SAND	COARSE					GRAVEL		COBBLES	M.I.T.
CLAY	SILT			VERY FINE	FINE	MEDIUM	COARSE			GRAVEL				U.S. BUREAU

REMARKS SILT / CLAYEY SILT

FIGURE



APPENDIX B

CULVERT 1 – RECORD OF BOREHOLE SHEETS, DRAWING 1
CULVERT 2 – RECORD OF BOREHOLE SHEETS, DRAWING 2
CULVERT 3 – RECORD OF BOREHOLE SHEETS, DRAWING 3

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

SS	SPLIT SPOON	TP	THINWALL PISTON
WS	WASH SAMPLE	OS	OSTERBERG SAMPLE
ST	SLOTTED TUBE SAMPLE	RC	ROCK CORE
BS	BLOCK SAMPLE	PH	TW ADVANCED HYDRAULICALLY
CS	CHUNK SAMPLE	PM	TW ADVANCED MANUALLY
TW	THINWALL OPEN	FS	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_a	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
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_f	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
U	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m ³	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	e_{min}	1, %	VOID RATIO IN DENSEST STATE
γ_s	kN/m ³	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m ³	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kN/m ³	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m ³	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	kN/m ³	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m ³	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m ³ /s	RATE OF DISCHARGE
γ_d	kN/m ³	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m ³	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
γ_{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
ρ'	kg/m ³	DENSITY OF SUBMERGED SOIL	e_{max}	1, %	VOID RATIO IN LOOSEST STATE	J	kN/m ³	SEEPAGE FORCE
γ'	kN/m ³	UNIT WEIGHT OF SUBMERGED SOIL						

RECORD OF BOREHOLE No 101

1 of 1 METRIC

G.W.P. 72-00-00 LOCATION Co-ords. 4 796 323 N; 225 132 E Sta. 10+500, 32.5m Left of C/L ORIGINATED BY M.R.
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers and Wash Boring COMPILED BY G.D.
DATUM Geodetic DATE November 08, 2002 CHECKED BY M.R.A.

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 x LAB VANE 20 40 60 80 100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRATPLOT	NUMBER	TYPE	"N" VALUES									
290.1														
0.0	Cobbles and boulders mixed with organic topsoil						290							
0.2	(Fill) Fine to coarse sand, trace of silt and clay													
	Compact Brown Saturated		SS	1	14		289							
	Very Loose		SS	2	1									
			SS	3	1		288							
			SS	4	0		287							
	Compact trace of gravel		SS	5	3		286							
			SS	6	12		285							6 88 2 4
			SS	7	24		284							6 87 5 2
			SS	8	17		283							
			SS	9	19		282							
			SS	10	38		281							
279.9	Silt, non-plastic, dilatant						280							
10.2	Dense Grey		SS	11	71		279							
278.3	Fine silty sand						278							
11.8	Dense Grey		SS	12	120/250mm		277							
277.7	Silt, some sand and gravel, non- to slightly plastic, D.T.P.L., with a layer of sand at 13m depth													
12.4	Very Dense Grey													
276.1	(Till)													
14.0	End of Borehole Water introduced into borehole by drilling method. Stabilized water level not established.													

RECORD OF BOREHOLE No 102

1 of 1 METRIC

G.W.P. 72-00-00 LOCATION Co-ords. 4 796 312 N; 225 145 E
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers ORIGINATED BY F.P.
DATUM Geodetic DATE November 07, 2002 COMPILED BY G.D.
CHECKED BY M.R.A.

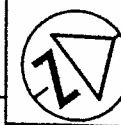
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
294.4	Sand and gravel													
0.0	Loose Brown		SS	1	4		294							
0.2	(Fill)													
0.1	Sandy silty topsoil		SS	2	6		293							
	Loose Dark Brown													
	(Fill)													
	Sand, with inclusions of gravel and topsoil		SS	3	6		292							
	Very Loose to Compact													
	Brown		SS	4	3		291							
	(Fill)													
			SS	5	3		290							
			SS	6	11		289							
			SS	7	6		288							
288.7														
3.7	Sand, trace of gravel, silt and clay													
	Compact Grey Wet		SS	8	3		287							0 92 2 6 * Low SPT-N due to hydraulic disturbance
			SS	9	12		286							2 89 4 5
			SS	10	20		285							10 83 3 4
			SS	11	32		284							
383.1	Dense													
11.3	End of Borehole													
	Water level observed during drilling													

METRIC

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

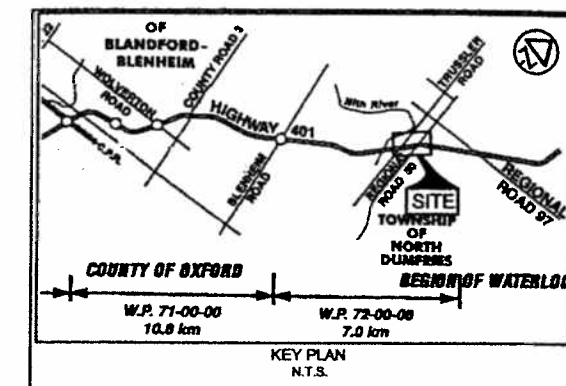
CONT No
WP No 72-00-00

HIGHWAY 401
Culvert Extension/Replacement
at Station 10+500
Township of North Dumfries
BOREHOLE LOCATIONS



SHEET

Peto MacCallum Ltd.
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LEGEND

- ◆ Borehole
- ⊕ Dynamic Cone Penetration Test (Cone)
- ⊕ Borehole & Cone
- W Blows/0.3m (Std. Pen Test, 475 J / blow)
- CON Blows/0.3m (60 Cone, 475 J / blow)
- W.L. at time of investigation
- Head
- ARTESIAN WATER Encountered

BH No.	ELEVATION	CO-ORDINATES	
		NORTH	EAST
101	290.1	4 796 323	225 132
102	294.4	4 796 312	225 145

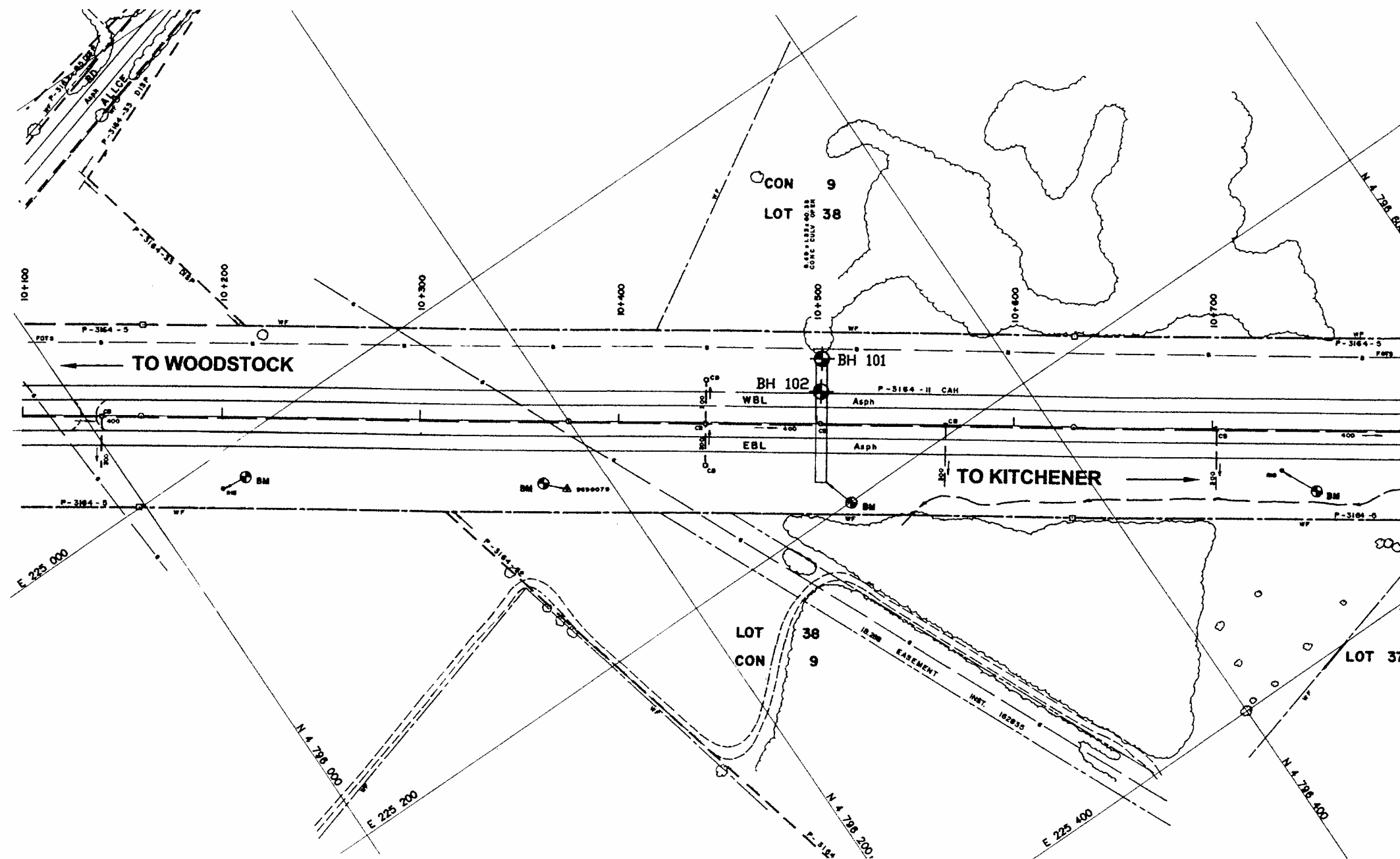
NOTE

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

REVISIONS	DATE	BY	DESCRIPTION

Geocres No.

HWY No.	401	DIST	31
SUBMIT	GD	CHECKED	GD
DATE	DEC. 16, 2002	SITE	33-374
DRAWN	TK	CHECKED	MFA
APPROVED	DMK	DWG	1



SCALE



RECORD OF BOREHOLE No 201

1 of 1 METRIC

G.W.P. 72-00-00 LOCATION Co-ords. 4 792 809 N; 220 759 E
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Solid Stem Augers ORIGINATED BY P.C.
DATUM Geodetic DATE December 17, 2002 COMPILED BY G.D.
CHECKED BY M.R.A.

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	STRATPLOT	NUMBER	TYPE	"N" VALUES								
288.9	Dark brown sandy silt topsoil		SS 1	1	8								
0.1	(Fill) Silty sand, trace of clay		SS 2	2	2								
287.5	Loose to Very Loose Brown Wet												
1.4	(Fill)												
287.1	Fibrous peat		SS 3	3	15								
1.8	Black Moist												
286.9	Clayey silt, some sand, slightly plastic		SS 4	4	25								
2.1	Very Stiff Grey												
	Moist to Wet												
	Fine to coarse silty sand and gravel, trace of clay		SS 5	5	13								
284.9	Compact Grey												
4.0	Moist to Wet												
	Clayey silt, some sand, trace of gravel, low to medium plastic, D.T.P.L.		SS 6	6	22								
	Very Stiff Grey												
	(Till)												
283.3	Fine to medium silty sand, trace of clay												
5.6	Compact Grey												
282.3	Moist to Wet		SS 7	7	22								
6.6	End of Borehole												
	Water level measured after drilling												

RECORD OF BOREHOLE No 202

1 of 1 METRIC

G.W.P. 72-00-00 LOCATION Co-ords. 4 792 743 N; 220 779 E
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Solid Stem Augers ORIGINATED BY P.C.
DATUM Geodetic DATE December 17, 2002 COMPILED BY G.D.
CHECKED BY M.R.A.

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	STRATPLOT	NUMBER	TYPE	"N" VALUES								
292.2	Dark brown sandy silt topsoil						292						
291.2	Silty sand, trace of clay						291						
290.2	Loose to Compact Brown Moist to Wet		SS	1	7		290						
289.7	Fine to coarse silty sand and gravel		SS	2	15		289						
289.3	Compact to Loose Brown Wet		SS	3	7		289						
288.1	Layered clayey silts and silty sands, some clay		SS	4	6		288						
286.6	Firm/Loose Brown Moist						287						
285.6	Fine to coarse silty sand and gravel		SS	5	58		286						0 5 81 14
285.6	Silt, some clay, trace of sand												
285.6	Very Dense Brown (Till)												
285.6	Fine to medium silty sand, trace of clay												
285.6	Very Dense Grey Moist		SS	6	60								
285.6	End of Borehole												
	Water level measured after drilling												

METRIC

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AND/OR MILLIMETRES UNLESS
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IN KILOMETRES - METRES

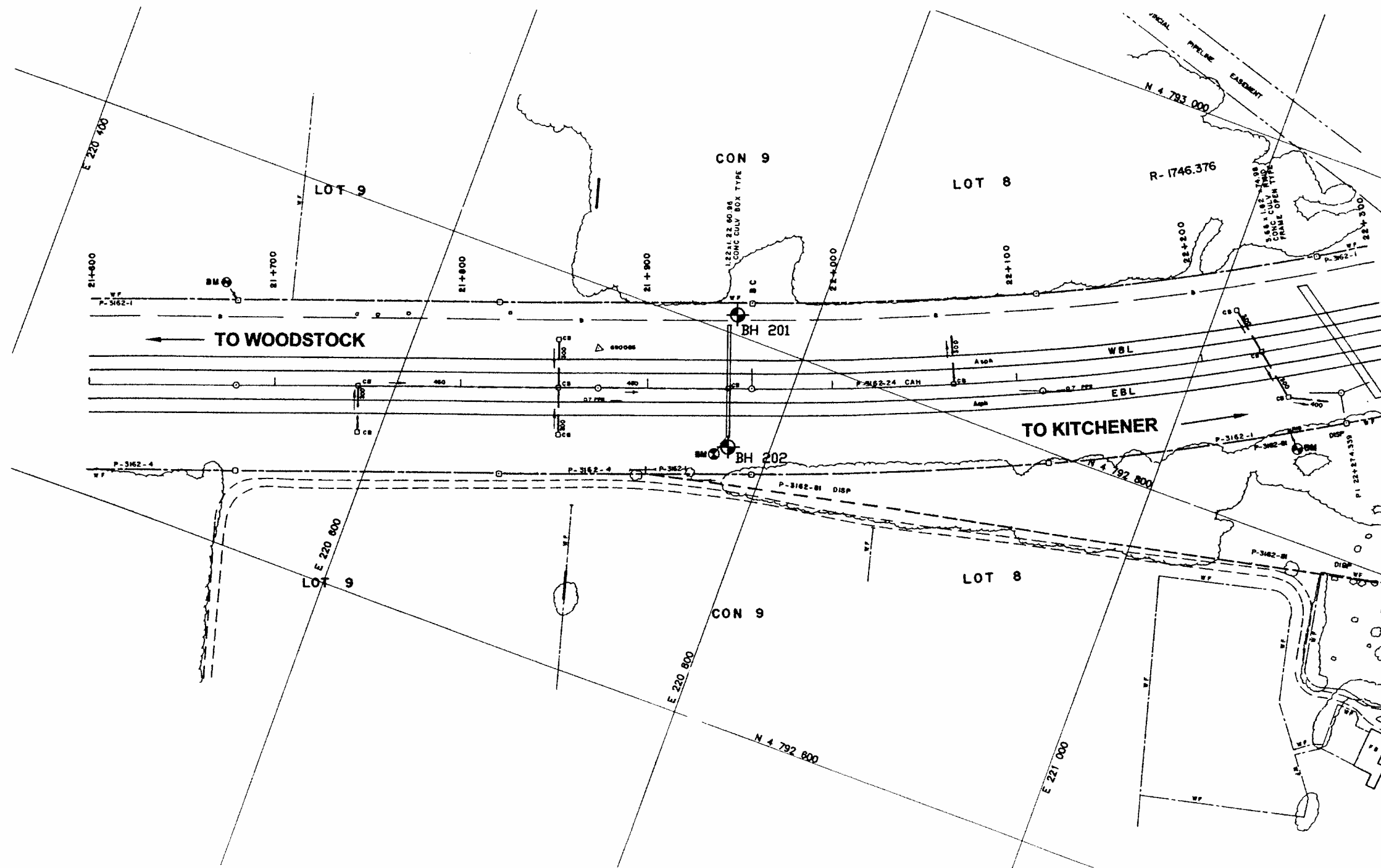
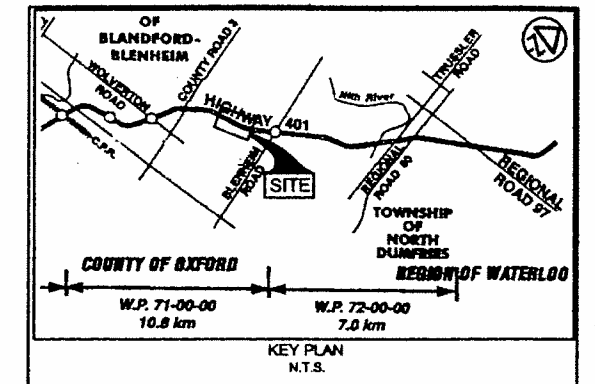
CONT No
WP No 72-00-00

HIGHWAY 401
Culvert Extension
Station 21+950
Township of Blandford-Blenheim
BOREHOLE LOCATIONS



SHEET

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CONSULTING ENGINEERS



LEGEND

- Borehole
- ⊕ Dynamic Cone Penetration Test (Cone)
- ⊕ Borehole & Cone
- W Blows/0.3m (Std. Pen Test, 475 J / blow)
- cone Blows/0.3m (80 Cone, 475 J / blow)
- W L at time of investigation
- Head
- ARTESIAN WATER
Encountered

BH No.	ELEVATION	CO-ORDINATES	
		NORTH	EAST
201	288.9	4 792 809	220 759
202	292.2	4 792 743	220 779

NOTE

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

REVISIONS	DATE	BY	DESCRIPTION

Geocres No.

HWY No.	401	DIST	31
SUBMD	GD	CHECKED	GD
DATE	DEC. 18, 2002	SITE	
DRAWN	TK	CHECKED	MRA
APPROVED	DWK	DWG	2

SCALE



RECORD OF BOREHOLE No 301

1 of 1 METRIC

G.W.P. 72-00-00 LOCATION Co-ords. 4 795 590 N; 224 579 E Sta. 26+715, 29m Left of C/L ORIGINATED BY M.R.
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.
DATUM Geodetic DATE December 13, 2002 CHECKED BY M.R.A.

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							
289.0 0.0 288.6 0.4	Cobbles in a dark brown sandy silt matrix (Fill) Silt, trace of sand and clay, dilatent, with occ. small inclusions of clay Compact to Dense Grey Wet	 becoming fine sandy Fine to coarse sand, some gravel and silt, with lenses of sandy silt Compact Grey Saturated Sandy silt, trace of gravel and clay Dense Grey (Till) Wet													
286.1 2.9 285.7 3.3			SS 1		21										
			SS 2		40										0 2 91 7
			SS 3		34										
			SS 4		25										
			SS 5		46										
			SS 6		103										
282.4 6.6	End of Borehole ▼ Water level measured after drilling		SS 7		84										8 33 51 8

RECORD OF BOREHOLE No 302

1 of 1 METRIC

G.W.P. 72-00-00 LOCATION Co-ords. 4 795 568 N; 224 596 E
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Solid Stem Augers ORIGINATED BY F.P.
DATUM Geodetic DATE November 24, 2002 COMPILED BY G.D.
CHECKED BY M.R.A.

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			20 40 60 80 100	20 40 60 80 100					
291.3 0.0	Topsoil					291							
0.2	(Fill) Sand, with inclusions of silt and gravel Loose to Very Loose Brown (Fill) Wet		SS 1	6		290							
289.1			SS 2	0		289							
2.2	Silt, trace of sand and gravel Compact Brown Grey Moist		SS 3	27		288							
			SS 4	28		287							
286.5			SS 5	27		286							
4.8	Silt, some sand, trace of clay and gravel Compact to Very Dense Grey Moist to Damp (Till)		SS 6	44		285							
			SS 7	26		284							
			SS 8	58		283							
281.7						282							
9.6	End of Borehole												
	Water level measured after drilling												

RECORD OF BOREHOLE No 303

1 of 1 METRIC

G.W.P. 72-00-00 LOCATION Co-ords. 4 795 559 N; 224 609 E Sta. 26+715, 14m Right of C/L (South Shoulder) ORIGINATED BY P.C.
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.
DATUM Geodetic DATE December 17, 2002 CHECKED BY M.R.A.

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	STRATPLOT	NUMBER	TYPE			20 40 60 80 100	20 40 60 80 100					
291.7 0.0	Sand and gravel, trace to some silt												
0.3	Brown (Fill) Silty fine to medium sand, trace of clay Dense												
	Brown (Fill) Moist		SS	1	42								
288.2 3.5	Sandy silt topsoil/alluvium Loose		SS	2	33								
287.3 4.4	Dark Brown to Black Moist		SS	3	7								
286.8 4.9	Fine to coarse silty sand Compact Brown Moist to Wet Clayey silt, some sand, trace of gravel Very Stiff		SS	4	22								
	Grey		SS	5	26								1 12 58 29
285.7 6.0	Sandy silt, trace of clay and gravel Dense		SS	6	38								
	Grey (Till) Moist to Wet		SS	7	31								4 30 56 10
283.6 8.1	End of Borehole Water level measured after drilling												

RECORD OF BOREHOLE No 304

1 of 1 METRIC

G.W.P. 72-00-00 LOCATION Co-ords. 4 795 544 N; 224 616 E
DIST 31 HWY 401 BOREHOLE TYPE Hand Auger ORIGINATED BY P.C.
DATUM Geodetic DATE December 17, 2002 COMPILED BY G.D.
CHECKED BY M.R.A.

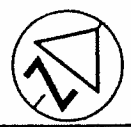
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIMIT MOISTURE CONTENT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	SIRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	w _p	w		
288.4 0.0	Silty fine to coarse sand												
287.7 0.7	Dark Brown (Fill) Sandy silt alluvium, trace of clay						288						
286.9 1.5	Dark Brown Wet Silt, some clay, trace to some sand Loose Grey Wet Silty sand, trace of clay Very Loose Grey Saturated End of Borehole Refusal on probable cobbles						287						
	Water level at ground surface												

METRIC

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

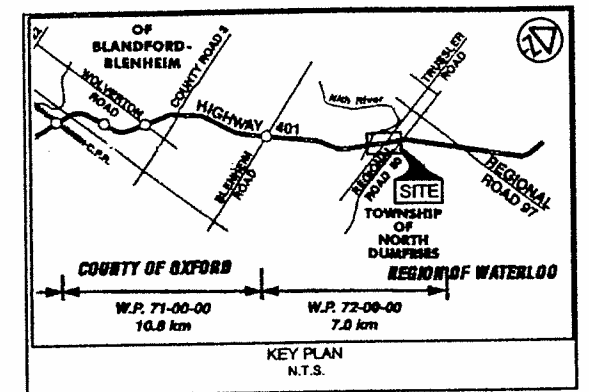
CONT No
WP No 72-00-00

HIGHWAY 401
Culvert Extension/Replacement
at Station 26+715
Township of Blandford-Blenheim
BOREHOLE LOCATIONS



SHEET

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CONSULTING ENGINEERS

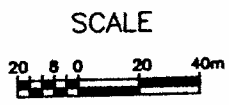
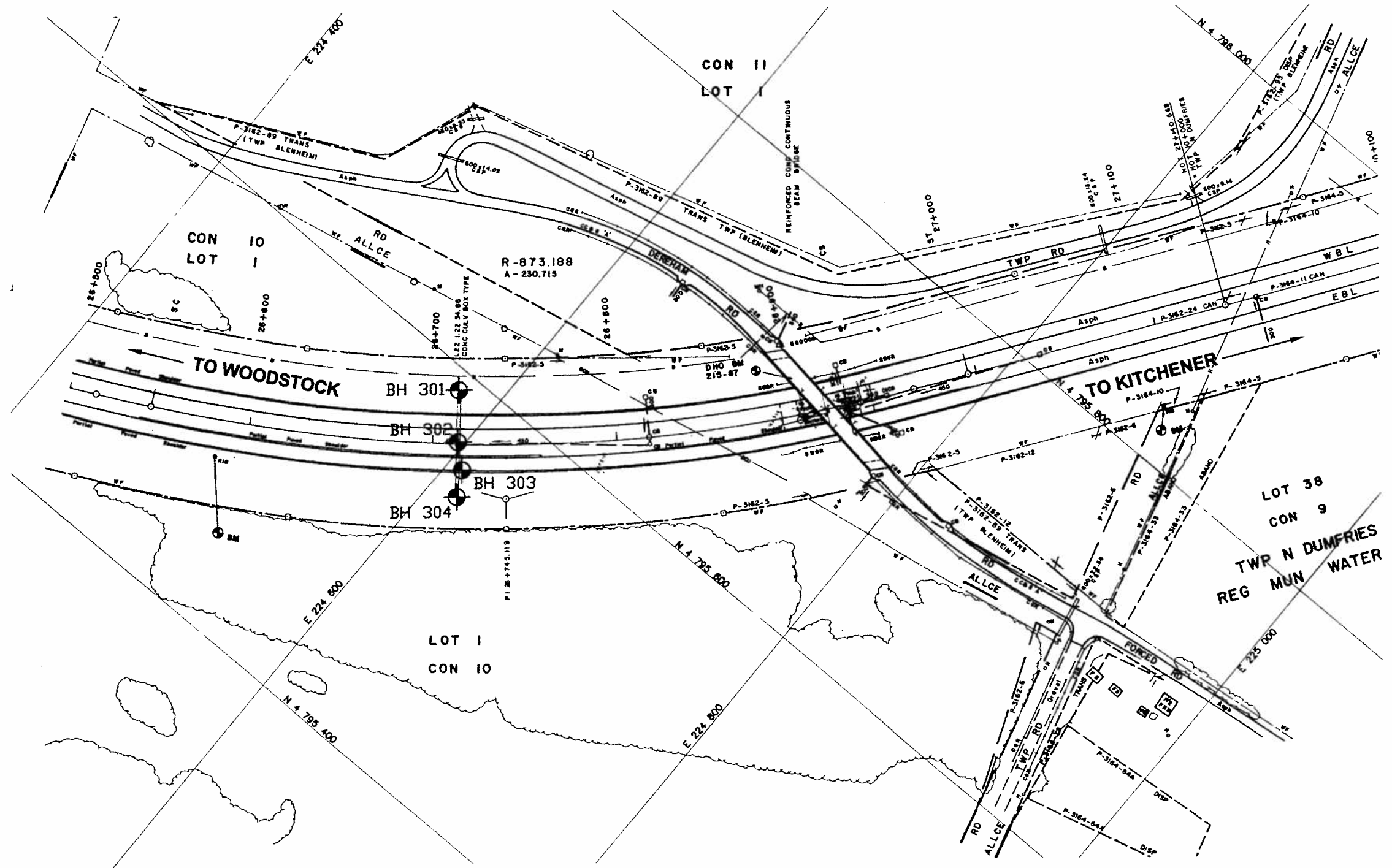


LEGEND			
	Borehole		
	Dynamic Cone Penetration Test (Cone)		
	Borehole & Cone		
	Blows/0.3m (Std. Pen Test, 475 J / blow)		
	Blows/0.3m (60 Cone, 475 J / blow)		
	W L at time of investigation		
	Head ARTESIAN WATER Encountered		
CO-ORDINATES			
BH No.	ELEVATION	NORTH	EAST
301	289.0	4 795 590	224 579
302	291.3	4 795 568	224 596
303	291.7	4 795 559	224 609
304	288.4	4 795 544	224 616

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

REVISIONS	DATE	BY	DESCRIPTION

Geocres No.			
HWY No.	401	DIST	31
SUBMD	GD	CHECKED	GD
DRAWN	TK	CHECKED	MRA
DATE	DEC. 16, 2002	APPROVED	DWK
SITE		DWG	3



**FOUNDATION DESIGN REPORT
FOR
CULVERT EXTENSIONS
W.P. 72-00-00
HIGHWAY 401, DISTRICT 31
TOWNSHIPS OF NORTH DUMFRIES AND BLANDFORD-BLENHEIM
ONTARIO**

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PML Ref: 02KF137D
Geocres No. 40P8-128

July 2003

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APPENDICES

FIGURE 1	-	LATERAL EARTH PRESSURE DISTRIBUTION: SINGLY-BRACED CUTS IN COHESIONLESS SOILS
FIGURE 2	-	LATERAL EARTH PRESSURE DISTRIBUTION: MULTI-BRACED CUTS IN COHESIONLESS SOILS
FIGURE 3	-	GENERAL RECOMMENDATIONS REGARDING UNDERPINNING OF FOUNDATIONS/UTILITIES LOCATED CLOSE TO EXCAVATION

FOUNDATION DESIGN REPORT
For
Culvert Extensions
W.P. 72-00-00
Highway 401, District 31
Townships of North Dumfries and Blandford-Blenheim
Ontario

INTRODUCTION

This report provides geotechnical comments and recommendations regarding extension and/or replacement of culverts at three locations along the Highway 401 alignment from 4.1 km east of Drumbo Road (County Road 29) easterly to 2.0 km west of Cedar Creek Road (Regional Road 97) in the Townships of North Dumfries and Blandford-Blenheim, Ontario. The investigation was conducted for Delcan Corporation on behalf of the Ontario Ministry of Transportation.

For the purposes of this report, the culverts have been given reference numbers 1 to 3. The locations, type and proposed works at each culvert are as follows:

CULVERT NO.	SITE NO.	LOCATION (HIGHWAY 401 CHAINAGE)	EXISTING CULVERT TYPE	PROPOSED WORKS
1	33-374	Station 10+500 Township of North Dumfries	5.49 x 1.83 m Concrete Open Box	Replacement of northerly 14 m
2	Not assigned	Station 21+950 Township of Blandford-Blenheim	1.22 x 1.22 m Concrete Box	Extension at both ends
3	Not assigned	Station 26+715 Township of Blandford-Blenheim	1.22 x 1.22 m Concrete Box	North extension or possible replacement

The subsurface stratigraphy revealed in the boreholes drilled at the culvert locations generally comprised a surficial fill and/or topsoil underlain by native deposits of sand and silt.

FOUNDATIONS

Culvert 1

The centreline profile drawings along Highway 401 (Plate 115 of Preliminary Design Study and Class EA, W.P. 3-00-00) indicate the invert level of Culvert 1 is near elevation 289.5. Based on the information revealed in borehole 102 drilled on the shoulder of the road, the base of this culvert appears to be near elevation 288.7.

The subsurface stratigraphy below this level revealed in borehole 101 drilled near the north limit of the culvert comprised very loose to loose sand to near elevation 286.5. In borehole 102, the subgrade soil consisted of compact sand. The groundwater level was about elevation 289.3 at the time of the field investigation.

The embankment height at this location is about 4.5 m.

It is considered that the very loose to loose sand exposed in borehole 101 is not a competent subgrade soil, while that encountered below the fill in borehole 102 is capable of supporting the stress imposed by the embankment and culvert foundation.

It is recommended, therefore, that the loose to very loose soil beyond the north limit of the embankment is excavated to elevation 286.5 and replaced with engineered fill. The depth of excavation should continue at this level southerly to the toe of slope of the existing embankment and then gradually decrease to match the invert of the existing culvert at the south limit of the portion to be replaced.

Fill placed under the culvert should comprise granular material compacted to at least 95% of the target density in conformance with OPSS 501 and SP105S10. The granular fill zone should extend beyond the culvert base a minimum 0.5 m and down to the subgrade at 45° to the horizontal.

FINAL FOUNDATION DESIGN REPORT

It is noted that the depth of excavation will be about 3.5 m beyond the toe of the existing embankment and up to 6 m within the existing embankment fill.

Further, the excavation will be about 3 m below the groundwater level and extend into the existing embankment. A positive groundwater control system will be needed and bracing will be required to support the cut slopes. Further comments in this regard are provided in subsequent sections of this report.

The culvert foundations constructed on the engineered fill pad should be designed using the following geotechnical resistance for a 1.5 m wide footing:

Factored Geotechnical Resistance at ULS	=	350 kPa
Geotechnical Resistance at SLS	=	150 kPa

Culvert 2

Extension of the north and south ends of the culvert is planned to accommodate a 500 mm increase in the height of the embankment. The invert of the culvert at the north extension is near elevation 287.7, and 291.8 at the south extension (interpolated from Plate 93 of the Preliminary Design Study and Class EA, W.P. 3-00-00 prepared by McCormick Rankin Corporation in May 2002).

Based on the borehole data, the invert level of the culvert and the concrete culvert base thickness, it is believed the existing culvert is founded on very stiff clayey silt (contacted at elevation 287.1) at the north extension and loose to compact silty sand at the south end. The foundation of the culvert extension on both the north and south ends should be founded at the same level as the existing culvert. Construction of the culvert extension foundations on the silt/sand is considered to be appropriate.

We believe the north extension is founded on engineered fill. The north extension should also be founded on engineered fill following excavation of the silty sand fill and peat to expose the very stiff clayey silt identified at elevation 287.1.

Fill placed under the culvert to accommodate any variation in the level of the native surface and/or replace any peat deposits extending below the design founding level should comprise granular material compacted to at least 95% of the target density in conformance with OPSS 501 and SP105S10. The granular fill zone should extend beyond the culvert base a minimum 0.5 m and down to the subgrade at 45° to the horizontal.

The foundations of the culvert extensions should be designed for a footing width of 1.5 m using the following information:

	<u>North Extension</u>	<u>South Extension</u>
Factored Geotechnical Resistance at ULS =	400 kPa	300 kPa
Geotechnical Resistance at SLS =	200 kPa	100 kPa

Culvert 3

Realignment of the road at this location will require extension of the north end of the culvert; replacement of the culvert is also being considered.

The invert of the existing culvert is near elevation 288.1 (interpolated from Plate 107 of the Preliminary Design Study and Class EA, W.P. 3-00-00 prepared by McCormick Rankin Corporation in May 2002). The base of the concrete box is likely some 0.3 m below this level.

The data from boreholes 301 and 302 indicates that the existing culvert is founded on compact to dense native silt. At the location of borehole 303, it is likely that the culvert is founded on the native compact soil as well, at elevation 287.3. The native inorganic silt was contacted at elevation 287.7 in the shallow auger hole (borehole 304) placed beyond the south end of the culvert.

Construction of the foundations for the culvert extension/replacement on the compact silt is considered to be feasible. If present below the exposed culvert subgrade, the sandy silt topsoil/alluvium should be excavated and replaced with engineered fill.

Fill placed under the culvert should comprise granular material compacted to at least 95% of the target density in conformance with OPSS 501 and SP105S10. The granular fill zone should extend beyond the culvert base a minimum 0.5 m and down to the subgrade at 45° to the horizontal.

The culvert foundation should be designed using the following resistance for a 1.5 m wide footing:

Factored Geotechnical Resistance at ULS	=	600 kPa
Geotechnical Resistance at SLS	=	275 kPa

General Comments

The resistance at SLS allows for 25 mm of settlement of the founding medium. Differential settlement along the culvert length is expected to be less than 75% of this value.

Subgrade preparation, cover, backfill and frost treatment for the culverts should be carried out in accordance with the Ontario Provincial Standards – OPSD 803.010 and OPSS 422. The bedding material for precast box culverts, if employed, should be at least 300 mm thick. A frost penetration depth of 1.2 m should be employed.

CULVERT BACKFILL

Backfill adjacent to the culverts should be placed in accordance with the Ontario Provincial Standard specifications and drawings (OPSD 803.010 and OPSS 422). Backfill should be brought up simultaneously on each side to minimize the potential for movement of the culvert.

The box culverts must be designed to support the stress exerted by the overlying fill as well as the unbalanced lateral earth pressure imposed on the walls of the culverts by the adjacent backfill. The lateral earth pressure, p , may be computed using the equivalent fluid pressures presented in Section 6.9 of the Canadian Highway Bridge Design Code (CAN/CSA-S6-00) or employing the following equation, assuming a triangular pressure distribution, free draining granular backfill and negligible build-up of hydrostatic pressure behind the wall:

$$p = K (\gamma h + q)$$

where K = lateral earth pressure coefficient

γ = unit weight of free draining
granular material (kN/m^3)

h = depth below final grade (m)

q = surcharge load (kN/m^2), if present

The following parameters are recommended for design:

	Granular "A"	Granular "B"	On-Site Material
Angle of Internal Friction (degrees)	35	32	30
Unit Weight (kN/m^3)	22.8	21.2	20.0
Active Earth Pressure Coefficient (K_a)	0.27	0.31	0.33
At-Rest Earth Pressure Coefficient (K_o)	0.43	0.47	0.50
Passive Earth Pressure Coefficient (K_p)	3.69	3.25	3.00

The at-rest earth pressure coefficient should be employed if movement of the wall is restrained, the active earth pressure coefficient if the wall is designed to accommodate some movement.

Weep holes should be provided in the walls of the new culvert to minimize the build-up of hydrostatic pressure.

The protective measures to deal with erosion (inlet/outlet treatment, headwalls, etc.) included in the Ontario Provincial Standards OPSD 800 Series are considered to be appropriate. End treatment requirements for the culverts are dictated by the stream hydraulics, stream configuration, culvert type and soil type.

A cut-off wall should be provided at each end of the concrete box culverts. Provision of rip-rap for erosion/scour protection is recommended for all culverts outlets. The subgrade soil at the culvert locations typically consists of silt/sand soils. A geotextile should be placed below the rip-rap in areas of silt subgrade (Culverts 2 and 3) to minimize the potential for erosion of fine particles from below the treatment.

EMBANKMENT FILL

It is anticipated that the embankment height at the culvert locations will not exceed 6 m.

The anticipated subgrade for the embankments typically comprises compact sand or silt. Peat and sandy topsoil/alluvium was encountered locally in boreholes 201 and 303 drilled at Culverts 2 and 3 respectively. These organic soils and other excessively loose, soft, organic or otherwise deleterious materials within the limits of the embankment fill should be subexcavated prior to placement of the fill.

The embankment widening should be constructed in accordance with OPSD 208.010. The embankment side slopes should be inclined no steeper than 2 horizontal to 1 vertical. A vegetation cover or other measures should be established to control surface runoff and minimize erosion of the embankment slopes.

It is considered that the subgrade soil is capable of supporting the embankment widening. Settlement of the fill is expected to be less than 10 mm at Culvert 3 and the north side of Culvert 2. Settlement of the embankment material placed at Culvert 1 and the widening on the

south side of Culvert 2 could be in the order of 25 mm. The settlement is expected to occur as the fill is placed and be essentially complete within two weeks following placement of the fill.

EXCAVATION AND GROUNDWATER CONTROL

Excavation for culvert installation is expected to extend through the fill (as well as the peat and topsoil identified locally at Culverts 2 and 3) and into native deposits of sand and silt. Excavation of these materials should be feasible using conventional equipment. The loose to compact silt/sand materials are typically classified as Type 3 soils according to Occupational Health and Safety Act criteria. Temporary cut slopes inclined at 1 horizontal to 1 vertical should generally be stable.

Very loose materials were revealed to a depth of about 3.5 m at Culvert 1 and to approximate depths of 1.8 and 2.2 m at Culverts 2 and 3 respectively. The very loose soils are classified as Type 4 soils; temporary cut slopes of 3 horizontal to 1 vertical should be employed.

Depending on seasonal conditions and recent precipitation patterns, the loose silty soils present at the sites are likely to be saturated at the time of construction, and significant sloughing of the excavation sidewalls may be experienced as a result. Flatter side slopes may be required if excessively soft/wet materials or concentrated seepage zones are encountered.

It is anticipated that shoring will be required to support the walls of the excavation and adjacent traffic lanes during construction.

The magnitude and distribution of the lateral earth pressures acting on a braced excavation wall is dependent upon the support system used, the number of supports, the allowable movements and the construction sequence. The recommended design earth pressure distribution for singly and multi-braced walls, for the conditions that exist at the site, are presented in Figures 1 and 2 respectively. Recommendations concerning design and construction of the braced excavation support systems are provided in the figures.

FINAL FOUNDATION DESIGN REPORT

A soldier pile and lagging system may be considered. Provided the spacing between soldier piles is at least five pile diameters, the unfactored lateral passive resistance developed on the face of the soldier pile below the base of the excavation may be taken as the passive earth pressure developed over an equivalent wall area of width three times the pile diameter and depth of six times the pile diameter. A passive earth pressure coefficient K_p of 3.0 is recommended for this computation.

Additional lateral resistance could be provided by installing tiebacks anchored in the compact sand. The unfactored pull-out resistance (R) of anchors grouted in cohesionless material can be estimated using the following equation:

	R	=	$K_f \sigma'_z L_s A_s$
where	K_f	=	anchorage coefficient
		=	0.8 for compact sand/silt
	σ'_z	=	effective vertical stress at midpoint of anchor
		=	$\gamma' z$
	γ'	=	effective unit weight of overburden soil
		=	20 kN/m ³ above groundwater level
		=	10.2 kN/m ³ below groundwater level
	z	=	depth to midpoint of anchor (m)
	L_s	=	fixed length of anchor (m)
	A_s	=	circumference of cross-section of fixed length of anchor (m ² /m)

A resistance factor of 0.4 should be applied to the computed anchor capacity to determine the ULS resistance.

The ground surface adjacent to the excavation is expected to experience some inward movement and vertical settlement. The magnitude of movements adjacent to a braced cut can be limited by selection of an appropriate lateral earth pressure coefficient (see Figures 1 and 2) provided good quality workmanship and construction practice is employed. The anticipated magnitude of movements is as follows:

<u>Movement (% of Excavation Depth)</u>	
Lateral Movement	
Braced Excavation	0.2
Anchored Wall	0.1
Vertical Movement	0.05

Construction procedures should be specifically suited to limit any consequent settlement of the pavement subgrade behind the excavation face.

Foundations of heavily loaded/settlement sensitive structures and/or utilities, if located within close proximity to the excavation, may require underpinning to preserve the integrity of these structures. Further comments and general recommendations in this regard are provided in Figure 3.

Water was observed at depths of 0.7 to 7.9 m in six boreholes drilled for this investigation. The observed water levels are some 3.0 m above the anticipated excavation depth at the north end of Culvert 1 and some 1.0 m above the excavation depths at the north end of Culvert 2 and south end of Culvert 3. Cognizant of the observed water levels, the permeability characteristics of the on-site soils and the anticipated depth of excavation required to construct the culvert extensions, it is expected that well points or strategically placed wells will be required to control groundwater seepage entering the excavations.

It will be necessary to implement measures to control water flow in the streams. Conventional procedures such as perimeter ditches and/or diversion of the stream should be sufficient.

The stabilized groundwater level is subject to seasonal fluctuations and rainfall patterns. It is recommended that the work be carried out during the dry summer months to minimize the potential for sloughing of the soils, the amount of groundwater inflow to be handled and the volume of surface water, if any, to be diverted from the construction area.

All construction work should be carried out in accordance with the Occupational Health and Safety Act (Ontario Regulation 213/91) and with local / MTO regulations.

CLOSURE

The report was prepared by Mr. G.O. Degil, Ph.D., Senior Project Supervisor, and Mr. M.R. Anderson, M.Eng., P.Eng., Senior Foundation Engineer. It was reviewed by Mr. D.W. Kerr, M.Eng., P.Eng., Chief Foundation Engineer. Mr. B.R. Gray, M.Eng., P.Eng., President, carried out an independent review of the report.



Yours very truly

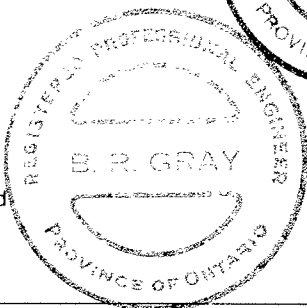
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A handwritten signature of Murray R. Anderson in black ink.

Murray R. Anderson, M.Eng., P.Eng.
Senior Foundation Engineer

A handwritten signature of Dennis W. Kerr in black ink.

Dennis W. Kerr, M.Eng., P.Eng.
Chief Foundation Engineer



A handwritten signature of Brian R. Gray in black ink.

Brian R. Gray, M.Eng., P.Eng.
President

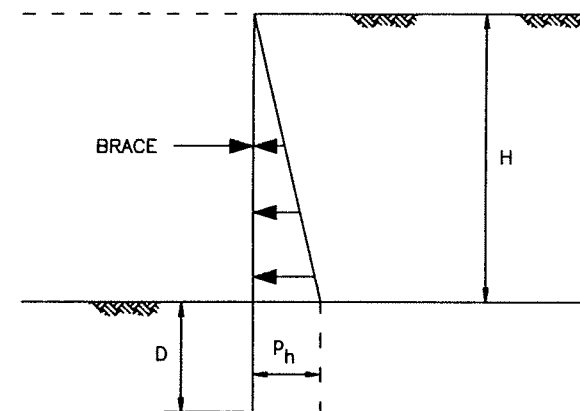
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FINAL FOUNDATION DESIGN REPORT

Culvert Extensions
Highway 401
Delcan Corporation

NOTES

1. The actual magnitude and distribution of the horizontal earth pressures which will act on the bracing system are dependent upon the permissible lateral/vertical movements adjacent to the excavation, the soil type, groundwater conditions, drainage provisions, temporary/permanent surcharge loads, the type of bracing system adopted, weather conditions, quality of workmanship and length of time the excavation will be supported. Hence, the recommended pressure diagram and design parameters should be reviewed when construction details, schedule and type of support system are established.
2. Stability of base of excavation must be confirmed when bracing system design, excavation geometry and surcharge loads are established.
3. Earth pressure diagram is applicable to maximum depth of cut of 12m (40 ft.).
4. Structural components of bracing system should be confirmed adequate for each level of excavation.
5. If sheeting will not permit drainage, bracing system must be designed to resist water pressure.
6. Surcharge loads such as street/construction traffic, supported utilities, adjacent foundations, temporary stockpiles and other loads carried by bracing system are not included in earth pressure diagram.
7. Temporary surcharge loading should not be closer to the face of the excavation than half the depth of excavation unless accounted for in bracing design.
8. If settlement sensitive structures are located near the excavation, special measures should be undertaken to control settlements. A condition survey should be conducted prior to construction and appropriate monitoring (surface and insitu) carried out during construction.
9. Earth pressure diagram is applicable for relatively short construction periods. If excavation is to be open for long periods, monitoring of deformation is essential, the earth pressure diagram must be reviewed, and remedial works may be required.
10. Earth pressure diagram does not account for extended periods of exposure of the excavation to freezing temperatures.
11. Bracing system should be regularly examined for signs of distress.
12. All work should be carried out in accordance with the Occupational Health and Safety Act and local regulations. Good quality workmanship and construction practices are to be employed.
13. This sheet should be read in conjunction with text of report for this project. Additional comments and recommendations concerning these general guidelines will be provided if required.

EARTH PRESSURE DIAGRAM

p_h = design lateral earth pressure
 $= K\gamma H$

K = lateral earth pressure coefficient

γ = unit weight of soil

H = depth of excavation

D = depth of embedment of soldier piles (if used).

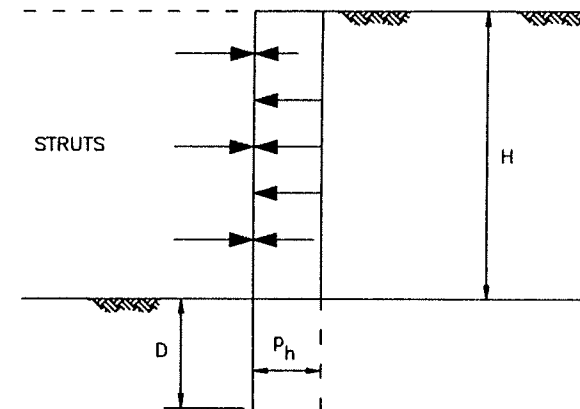
RECOMMENDED DESIGN PARAMETERS

$\gamma = 20.0 \text{ kN/m}^3$

$K = 0.35$

NOTES

1. The actual magnitude and distribution of the horizontal earth pressures which will act on the bracing system are dependent upon the permissible lateral/vertical movements adjacent to the excavation, the soil type, groundwater conditions, drainage provisions, temporary/permanent surcharge loads, the type of bracing system adopted, weather conditions, quality of workmanship and length of time the excavation will be supported. Hence, the recommended pressure diagram and design parameters should be reviewed when construction details, schedule and type of support system are established.
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EARTH PRESSURE DIAGRAM

$$p_h = \text{design lateral earth pressure} \\ = 0.65K\gamma H$$

K = lateral earth pressure coefficient

γ = unit weight of soil

H = depth of excavation

D = depth of embedment of soldier piles (if used).

RECOMMENDED DESIGN PARAMETERS

$$\gamma = 20.0 \text{ kN/m}^3$$

$K = 0.35$ (movement of retained soil acceptable)
 0.50 (movement of adjacent structures/facilities unacceptable)

NOTES

1. The need to underpin existing footings/utilities is dependent upon soil type, proximity of the existing facility to the face of the excavation, loads imposed on the foundation and permissible movements.

ZONE A:

Foundations of relatively heavy and/or settlement sensitive structures/utilities located in Zone A generally require underpinning.

ZONE B:

Foundations of structures located within Zone B generally do not require underpinning. Consideration should be given to underpinning of settlement sensitive utilities or heavy foundation units located in this zone.

ZONE C:

Utilities and foundations located within Zone C do not normally require underpinning.

Underpinning of foundations located in Zones A and B should extend at least into Zone C.

2. As an alternative to underpinning, it may be possible to control movement of existing utilities and foundations by supporting the face of the excavation with bracing/tiebacks or a rigid (caisson) wall. Horizontal and vertical earth pressures imposed on the excavation wall by non-underpinned foundations must be considered in the design of the support system.
3. A condition survey should be conducted prior to construction and appropriate monitoring (surface and insitu) carried out during construction to monitor any movement which may occur.
4. All work should be carried out in accordance with the Occupational Health and Safety Act and local regulations. Good quality workmanship and construction practices are to be employed.
5. This sheet is to be read in conjunction with text of report for this project. Additional comments and recommendations concerning these general guidelines will be provided if required.

