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DIST. 6 REGION

W.P. No. 142-87-00 (B)

CONT. No.

W. O. No.

STR. SITE No.

HWY. No. 400

LOCATION CONCRETE CULVERTS

HWY 400/407 IC.

No of PAGES -

OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

G.T.-30 SEPT. 1976

ENGINEERING MATERIALS OFFICE
FOUNDATION DESIGN SECTION

WP 142-87-00(B) DIST 6

HWY 400 STR SITE -

Highway 400/407 Culverts

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GEOCRES 30M13-122 DATE AUG 27 1991

memorandum

Ontario

235-3731

To: Mr. V. F. Boehnke
Head, Structural Section
Central Region

Date: 1991 08 20

Attn: John K. Lam

From: Foundation Design Section
Room 315, Central Building

Subject: Foundation Design Report
Concrete Culvert (Sta. 11+855, Hwy. 400), Rt. Extension
Concrete Culvert (Sta. 11+855, Hwy. 400), Lt. Extension
Concrete Culvert (Sta. 21+590, Hwy. 400 NBL)
W.P. 142-87-00(B), Hwy. 400/407 Interchange
Hwy. 400, District 6, Toronto

This report presents the foundation design recommendations for the construction of above mentioned concrete culverts. The investigation was carried out at the request of Structural Section of Central Region. In addition to new foundation investigation near a proposed concrete box culvert at Sta. 21+590 (Hwy. 400, NBL Chainage), soil data from previous investigation at this site were studied for recommendations. Previous investigations were carried out in 1985 and 1988 in the vicinity of the proposed structures.

The borehole locations are shown on Drawing 1428700B-A which is attached to this report. The subsurface conditions are presented on Record of Boreholes (BH 1 through BH 7) attached. The survey information (coordinates and elevations) of the new boreholes were provided by the Survey and Plan Section of Central Region.

This report is applicable to the proposed new culvert and two culvert extensions.

SITE DESCRIPTION AND GEOLOGY

The site is in the area of proposed Hwy. 400 and Hwy. 407 intersection, in the Regional Municipality of York. The ground surface tends to slope to the south.

Physiographically, the site is located in the 'Peel Plain' region which is characterized by bevelled till plains composed of level to undulating tracts of clay soils. Much of the plain has been modified by a veneer of clay which, when deep enough takes on a varved appearance (Reference: Chapman and Putnam, "The Physiography of Southern Ontario; 3rd Edition, 1984).

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SUBSURFACE CONDITIONS

Based on the information obtained from previous boreholes, and two boreholes BH 6 and BH 7 recently drilled for this investigation, reasonably uniform subsurface conditions with varying in situ consistency/denseness were encountered across the site. The recent investigation encountered fill material in the vicinity of new culvert location (BH 6 and BH 7). Underlying the fill material (BH 6 and BH 7) at the proposed new culvert location and immediately below ground surface near two proposed culvert extensions the material consists of clayey silt till. Occasional pockets and layers of silty sand to sandy silt material up to 0.8 m thick were also encountered within the clayey silt till deposit. Details of the subsurface condition at all culvert locations are as follows:

Fill Material

This cohesive material was encountered in the new boreholes BH 6 and BH 7. The fill material consisted of clayey silt mixed with sand and sandy silt material. Trace of organics and roots were also present within the fill. The thickness of the fill was 1.4 m and 2.9 m in BH 6 and BH 7 respectively. The Standard Penetration 'N' value ranged from 12 to 24 blows/0.3 m penetration, which suggest that the fill is stiff to very stiff.

Clayey Silt (Glacial Till)

This cohesive material was encountered in all boreholes. In boreholes BH 6 and BH 7 this material was underlying the fill material. In previous boreholes (BH 1 through BH 5) this material was encountered below the ground surface. Occasional pockets and layers of silty sand to sandy silt up to 0.8 m thick was encountered within this deposit. All boreholes were terminated within this deposit. The maximum penetration within this material took place in BH 5, where the borehole was advanced 24.4 m within this deposit. The 'N' values ranged from 8 to 143 blows/0.3 m penetration indicating the till to be of stiff to hard consistency. Generally within the upper 2 m to 4 m (above elevation 188 m) the 'N' value ranged from 8 to 25 blows/0.3 m. At depths exceeding 4 m below the ground surface (below elevation 188 m) the 'N' value was generally in excess of 50 blows/0.3 m and frequently exceeded 100 blows, indicating the clayey silt till to be of hard consistency.

Groundwater Conditions

Based on the record of groundwater in previous study (1985 and 1988) and recent study, the groundwater table was recorded at depths ranging from 1.2 m to 2.4 m below the ground surface which corresponds to elevations 189.4 m to 190.6 m. It should be noted that the groundwater table is subject to seasonal fluctuation.

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RECOMMENDATIONS

General

It is proposed to construct three concrete box culverts under Hwy. 400 and Hwy. 407 interchange.

Two culverts will be the extensions of the existing culverts at Sta. 11+855 Hwy. 400 chainage. The culvert extensions are designated as right extension and left extension. The left extension will be situated under proposed Hwy. 400 collector lanes and proposed ramp 400 N-407 EW. This extension will connect two existing culverts. One of the existing culverts to be connected is situated under present ramp 7 W-400 S and the other underlies Hwy. 400 NBL and 400 SBL. The right extension will extend the present culvert under existing 400 S-7E,W ramp and will be situated under new 400 S-7 E,W ramp. The dimension of the culvert extensions will be 4.27 m wide and 3.05 m high. The left extension will be 109 m long and the right extension will will be 36 m long. Maximum earth cover over the culvert obvert will be 7.2 m. The flow in the culert will be from west to east. The invert elevations of the left extension will vary from 188.3 m to 188.4 m, and for the right extension the invert elevations will be at 188.1 m.

A new concrete box culvert is proposed to be constructed at Sta. 21+590 (Hwy. 400, NBL chainage). This culvert will be constructed under Hwy. 400 NBL, Hwy. 400 SBL and Hwy. 400 NB collector. The flow in the culvert will be from west to east. The invert elevation will vary from 186.9 m to 190.0 m. The culvert will be 1 m wide, 1.5 m high and 123 m long. Maximum earth cover over the culvert obvert will be 6.6 m high.

Structure Foundations

All proposed culverts may be designed with the following recommendations.

The soil at proposed culvert invert elevation is a competent native soil. The culverts can be founded on 0.6 m thick granular bedding constructed on native soil.

The following design values can be utilized for the design of proposed culvert extensions and the new culvert foundations.

Factored Bearing Capacity at U.L.S. = 450 kPa
Bearing Capacity at S.L.S. Type II = 300 kPa

Backfilling/Lateral Pressure

Above the bedding level, backfilling to the culverts should

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consist of suitable material compacted in accordance with MTO Standards and conform to OPSD 803.02. For fill below groundwater level or below pavement within frost line, it is recommended that Granular 'A' or 'B' should be used. The backfill operations should be carried out simultaneously on both sides of the culverts as per MTO specifications. The following properties are recommended for the calculation of lateral pressure if any cut-off or retaining walls are required.

Granular 'A'	γ = 22.8 kN/m^3,	ϕ = 35°,	Ko = 0.43,	Ka = 0.27
Granular 'B'	γ = 21.2 kN/m^3,	ϕ = 30°,	Ko = 0.50,	Ka = 0.33
Native Soil	γ = 19.2 kN/m^3,	ϕ = 26°,	Ko = 0.56,	Ka = 0.39

For structural elements rigidly connected to concrete box culverts, at rest condition (Ko) should be used to calculate lateral pressure.

Lateral Resistance

Lateral resistance calculations will not be required for the culvert foundations.

Stability and Settlement

There is no concern of deep seated slope failure. The highway embankments should be sloped at 2H:1V. Total and differential settlement will be less than 25 mm if the foundation is constructed in accordance with the recommendation provided.

CONSTRUCTION CONSIDERATIONS

Temporary Division

To facilitate the construction of the proposed extensions, a temporary diversion of the water courses could be considered.

Dewatering

Dewatering will be required at both the proposed culvert extensions and the new culvert.

The subsurface information at the proposed culvert extensions is based on previous site investigations which were conducted in 1985 and 1988 somewhat away from the proposed culvert locations. The boreholes at the proposed culvert extensions show the presence of a non-cohesive material which is about 0.8 m thick and is situated at depths ranging from 3 m to 10 m below the ground surface. This layer is likely to be encountered at the founding elevations (188.1 m to 188.4 m) of culverts at Sta. 11+855 (Hwy. 400 chainage). Groundwater level is about 1 m higher than the proposed culvert invert elevations. At the new culvert location,

due to cohesive nature of the soil, seepage will be minor and could be handled by sump pump technique. However, in view of the large excavation which will be involved at this site, it will be necessary to plan a dewatering scheme at this site as well.

A special provision should be in the contract requiring the contractor to lower the groundwater below base of any excavation prior to excavation. The contractor should be advised that cohesionless material may be encountered at the proposed culvert foundation elevations and it would be susceptible to disturbance under conditions of unbalanced hydrostatic head. The contractor should also be advised to construct without disturbance to the underlying foundation soil or any existing structure. Although the dewatering method is the responsibility of the contractor, it is anticipated that if a granular layer is encountered at the proposed culvert foundation elevations then the groundwater can be lowered by a system of oversize perimeter ditches and sumps. If granular layer is not encountered at the founding elevations, then seepage could be controlled by sump pump technique. In any case, the contractor should submit his dewatering proposal for review a minimum of 15 working days prior to construction.

Excavation

Temporary excavations will be stable at 1H:1V above the water table and 2H:1V below the water table.

Bedding

Bedding under the culvert foundation shall consist of a 0.6 m thick layer of Granular 'A' material. The bedding should be constructed as per MTO standards.

Cambering

Due to competent soil condition, no significant settlements are anticipated. Therefore, cambering is not required.

Construction Joints

Construction joints will be required at connections between the old and new culverts to accommodate any differential movement that may occur. Such joints should be able to accommodate differential settlement up to 12 mm and provide proper seal.

Erosion Protection

Erosion protection will be required at the outlet of the right culvert extension (Sta. 11+855, Hwy. 400) and at the inlet and outlet of the new culvert (Sta. 21+590, Hwy. 400 NBL).

A seal of cohesive material (CI-CH clay) with a minimum thickness of 0.6 m should be constructed at the culvert inlet at Sta. 21+590, Hwy. 400 NBL chainage. The seal should extend a minimum of 2 m on each side of the culvert inlet, and from the high water level down the embankment to the creek bed. Erosion protection, in the form of rock protection (minimum blanket thickness = 0.6 m) should be placed to protect the embankment. It should extend from the high water level to the toe of the slope and 2 m along the creek bed. In transverse direction, the erosion protection should extend a minimum of 5 m on each side of the culvert.

The culvert outlet should be protected with 0.6 m thick rock protection.

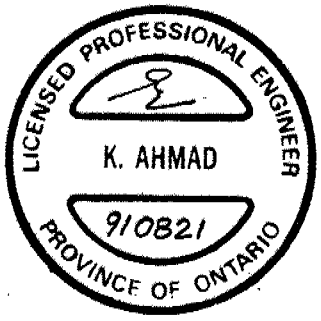
Rock protection will not be required if head walls are used but the bases of the channel should be armoured at both outlet and inlet.

MISCELLANEOUS

The recommendations given in this report are based on both previous investigations in the site vicinity and a recent investigation which consisted of drilling two boreholes BH 6 and BH 7 at the new culvert location. The previous investigations were carried out at the site in 1985 and 1988 (Re: W.P. 164-79-04/05 and W.P. 142-87-02).

The recent field work for this project was carried out under the supervision of C. Davidson, Engineer Student. The equipment used was owned and operated by Master Soil Investigation Ltd.

The report was written by K. Ahmad, Foundation Engineer, reviewed by D. Dundas, Senior Foundation Engineer and approved by M. Devata, Chief Foundation Engineer.



K. Ahmad, P.Eng.
Foundation Engineer

for

D. Dundas, P.Eng.
Senior Foundation Engineer

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 (R Q D), FOR MODIFIED RECOVERY, IS:

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_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

MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	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_t	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES
ρ_w	kg/m^3	DENSITY OF WATER
γ_w	kN/m^3	UNIT WEIGHT OF WATER
ρ	kg/m^3	DENSITY OF SOIL
γ	kN/m^3	UNIT WEIGHT OF SOIL
ρ_d	kg/m^3	DENSITY OF DRY SOIL
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL

e	1, %	VOID RATIO
n	1, %	POROSITY
w	1, %	WATER CONTENT
S_r	%	DEGREE OF SATURATION
w_L	%	LIQUID LIMIT
w_P	%	PLASTIC LIMIT
w_S	%	SHRINKAGE LIMIT
I_P	%	PLASTICITY INDEX = $w_L - w_P$
I_L	1	LIQUIDITY INDEX = $\frac{w - w_P}{I_P}$
I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_P}$
e_{max}	1, %	VOID RATIO IN LOOSEST STATE
e_{min}	1, %	VOID RATIO IN DENSEST STATE
I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
D	mm	GRAIN DIAMETER
D_n	mm	n PERCENT - DIAMETER
C_U	1	UNIFORMITY COEFFICIENT
h	m	HYDRAULIC HEAD OR POTENTIAL
q	m^3/s	RATE OF DISCHARGE
v	m/s	DISCHARGE VELOCITY
i	1	HYDRAULIC GRADIENT
k	m/s	HYDRAULIC CONDUCTIVITY
j	kN/m^3	SEEPAGE FORCE

APPENDIX

RECORD OF BOREHOLE No 1 (Previous C13)* 1 OF 1 METRIC

W.P. 142-87-00 LOCATION Co-ords: N 4 849 678.0 E 301 516.0 ORIGINATED BY FS

DIST 6 HWY 400 BOREHOLE TYPE SS Auger COMPILED BY FS

DATUM Geodetic DATE 1985 06 11 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
191.9	Ground Surface										
0.0											
			1	SS	11	▼	191				
			2	SS	28		190				
			3	TW	PH		189				
	Silty Sand to Sandy Silt Compact		4	SS	13		188				
	Silty Clay Trace to With Sand Trace Gravel Stiff to Hard		5	SS	54		187				
			6	SS	135		186				
							185				
183.8			7	SS	95		184				
8.1	End of Borehole										

* This Borehole Log has been reproduced from previous Borehole C13
Re: W.P. 164-79-04/05
Dated: June 11, 1985

+3, ×5 : Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 2 (Previous C3)* 1 OF 1 METRIC

W.P. 142-87-00 LOCATION Co-ords: N 4 849 710.0 E 301 612.0 ORIGINATED BY FS

DIST 6 HWY 400 BOREHOLE TYPE SS Auger COMPILED BY FS

DATUM Geodetic DATE 1985 06 12 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						GR SA SI CL
192.1	Ground Surface										
0.0											
			1	SS	8						
			2	TW	PH						7 34 41 18
			3	SS	18						
	Silty Sand to Sandy Silt Compact		4	SS	15						0 1 97 2
			5	SS	55						
	Silty Clay Trace to With Sand Trace Gravel Stiff to Hard		6	SS	143						0 8 73 19
			7	SS	91						
			8	SS	65						0 1 50 49
			9	SS	70						
179.5			10	SS	68						0 1 43 56
12.6	End of Borehole										

* This Borehole Log has been reproduced from previous Borehole C3

Re: W.P. 164-79-04/05
Dated: June 12, 1985

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L

WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m^3

$+^3$, $\times^5$: Numbers refer to Sensitivity

20
15 ⊕ 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 3 (Previous C4)** 1 OF 1 METRIC

W.P. 142-87-00 LOCATION Co-ords: N 4 849 754.0 E 301 763.0 ORIGINATED BY FS

DIST 6 HWY 400 BOREHOLE TYPE SS Auger COMPILED BY FS

DATUM Geodetic DATE 1985 06 13 CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L / WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
196.1	Ground Surface										
0.0						*					
			1	SS	26		195				
			2	SS	28		194				
			3	SS	27						
	Silty Sand to Sandy Silt Dense		4	SS	49		193				
			5	SS	60		192				
	Silty Clay Trace to With Sand Trace Gravel Very Stiff to Hard						191				
			6	SS	126	/20cm	190				
188.4			7	SS	80	/8cm	189				
7.7	End of Borehole										

* Groundwater Level not established

** This Borehole Log has been reproduced from previous borehole C4
Re: W.P. 164-79-04/05
Dated: June 13, 1985

+3, ×5 : Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 4 (Previous C1)* 1 OF 1 METRIC

W.P. 142-87-00 LOCATION Co-ords: N 4 849 466.0 E 301 738.0 ORIGINATED BY FS

DIST 6 HWY 400 BOREHOLE TYPE SS Auger, Cone COMPILED BY FS

DATUM Geodetic DATE 1985 06 12 CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE
190.7	Ground Surface						
0.0	Firm						190
	Very Stiff		1	SS	4		
			2	SS	19		189
			3	SS	15		188
	Silty Sand to Sandy Silt Compact		4	SS	13		
	Hard						187
			5	SS	81		186
	Silty Clay Trace to with Sand Trace Gravel		6	SS	80		185
	Firm to Hard						184
			7	SS	128		183
181.1			8	SS	53		182
9.6	End of Borehole						

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa
o UNCONFINED + FIELD VANE
• QUICK TRIAXIAL × LAB VANE
20 40 60 80 100

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L

WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m^3

REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

* This Borehole Log has been reproduced from previous Borehole C1
Re: W.P. 164-79-04/05
Dated: June 12, 1985

+3, ×5 : Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 5 (Previous 1)* 1 OF 2 METRIC

W.P. 142-87-00 LOCATION Co-ords: N 4 849 458.0 E 301 779.0 ORIGINATED BY RB

DIST 6 HWY 400 BOREHOLE TYPE HS Auger COMPILED BY JFW

DATUM Geodetic DATE 1988 01 26,27 CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS
190.9	Ground Surface					
0.0 / 190.5	Topsoil, Clayey Silt, Low Organic, Black					
0.4	Het. Mixture of Clay, Silt and Sand, Trace Gravel, Low to Intermediate Plasticity, Brown, Stiff (Glacial Till)		1	SS	8	
			2	SS	12	
			3	SS	12	
187.5			4	SS	19	
3.4	Very Stiff / Hard		5	SS	22	
			6	SS	28	
	Het. Mixture of Clayey Silt With Sand, Trace Gravel, Low Plasticity, Grey (Glacial Till)		7	SS	56	
			8	SS	32	
180.4			9	SS	39	
10.5	Het. Mixture of Sandy Silt With Gravel, Grey, Very Dense (Glacial Till)		10	SS	60	/15cm
179.4						
11.5	Silty Clay, Trace Sand, Intermediate Plasticity, With Layers of Silty Clay and Clayey Silt, Low Plasticity, Grey, Hard		11	SS	60	
			12	SS	70	

ELEVATION SCALE: 190, 189, 188, 187, 186, 185, 184, 183, 182, 181, 180, 179, 178, 177, 176

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa
o UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB VANE
50 100 150 200 250

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L

WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m^3

21.4

REMARKS & GRAIN SIZE DISTRIBUTION (%)

GR SA SI CL

6 37 33 24

Continued

$+^3$, $\times^5$: Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

Continued

RECORD OF BOREHOLE No 5 (Previous 1) • 2 OF 2 METRIC

W.P. 142-87-00 LOCATION Co-ords: N 4 849 458.0 E 301 779.0 ORIGINATED BY RB
DIST 6 HWY 400 BOREHOLE TYPE HS Auger COMPILED BY JFW
DATUM Geodetic DATE 1988 01 26,27 CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (o UNCONFINED, • QUICK TRIAXIAL, + FIELD VANE, × LAB VANE) (50 100 150 200 250)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued										
	Silty Clay, Trace Sand Intermediate Plasticity With Layers of Silty Clay and Clayey Silt, Low Plasticity Grey Hard		13	SS	55		175		o		
			14	SS	53		174		o		
			15	SS	78		173		o		
			16	SS	49		172		o		
			17	SS	45		171		o		
			18	SS	70		170		o		
166.1			19	SS	37	P1	169		o		
24.8	End of Borehole						168				
							167				

* This Borehole Log has been reproduced from previous Borehole 1

Re: W.P. 142-87-02
Dated: Jan. 26,27,1988

1985 01 27
* GROUND WATER CONDITIONS

PIEZO. NO.	GROUND WATER ELEVATION (Metres)
1	180.6

+³, ×⁵ : Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 6 1 OF 1 METRIC

W.P. 142-87-00 LOCATION Co-ords: N 4 849 430.0 E 301 665.5 ORIGINATED BY CD

DIST 5 HWY 400 BOREHOLE TYPE HS Auger COMPILED BY CD

DATUM Geodetic DATE 1991 06 10 CHECKED BY KA

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa (DYNAMIC CONE PENETRATION RESISTANCE PLOT; ○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	WATER CONTENT (%) (w_P PLASTIC LIMIT, w NATURAL MOISTURE CONTENT, w_L LIQUID LIMIT)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
191.5	Ground Surface										
0.0	Clayey Silt Trace Roots, Trace Organics Dark Brown Very Stiff (Fill)		1	SS	16	▼	190				
190.1			2	SS	35						
1.4	Sandy Silt Till Dense		3	SS	44		189				19 33 39 9
			4	SS	103		188	120/28cm			
	Silt Trace Clay Very Dense (Glacial Till)		5	SS	114		187				7 18 47 28
			6	SS	133		186				
			7	SS	132	/28cm					
	Clayey Silt Trace Sand, Trace Gravel Grey Hard (Glacial Till)		8	SS	125	/23cm	185				
							184				
183.4			9	SS	134		183				
8.1	End of Borehole										

+3, ×5 : Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 7 1 OF 1 METRIC

W.P. 142-87-00 LOCATION Co-ords: N 4 849 423.5 E 301 731.9 ORIGINATED BY CD

DIST 6 HWY 400 BOREHOLE TYPE SS Auger COMPILED BY CD

DATUM Geodetic DATE 1991 06 10 CHECKED BY KA

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (o UNCONFINED, • QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	WATER CONTENT (%) (PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
192.5	Paved Surface										
0.0	Asphalt										
	Mixture of Clayey Silt, Sand and Sandy Silt Brown Stiff to Very Stiff (Fill)		1	SS	24						
			2	SS	12						
190.4											
2.1	Clayey Silt, Trace Organics Dark Brown, Stiff		3	SS	13						
189.6											
2.7											
2.9	Brown		4	SS	26						
	Sandy Silt Very Dense (Glacial Till)		5	SS	59						7 42 46 5
	Grey		6	SS	39						
	Clayey Silt Occ. Sand Zones Trace Gravel Grey Very Stiff to Hard (Glacial Till)		7	SS	73						
			8	SS	75						
184.6			9	SS	123	/31cm					
7.9	End of Borehole										

ELEVATION SCALE: 192, 191, 190, 189, 188, 187, 186, 185

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: 20 40 60 80 100

120/25cm

WATER CONTENT (%): 10 20 30

+³, ×⁵ : Numbers refer to Sensitivity

20 / 15 ◇ 5 / 10 (%) STRAIN AT FAILURE

MINISTRY OF TRANSPORTATION, ONTARIO PH-0-207 88 10

METRIC

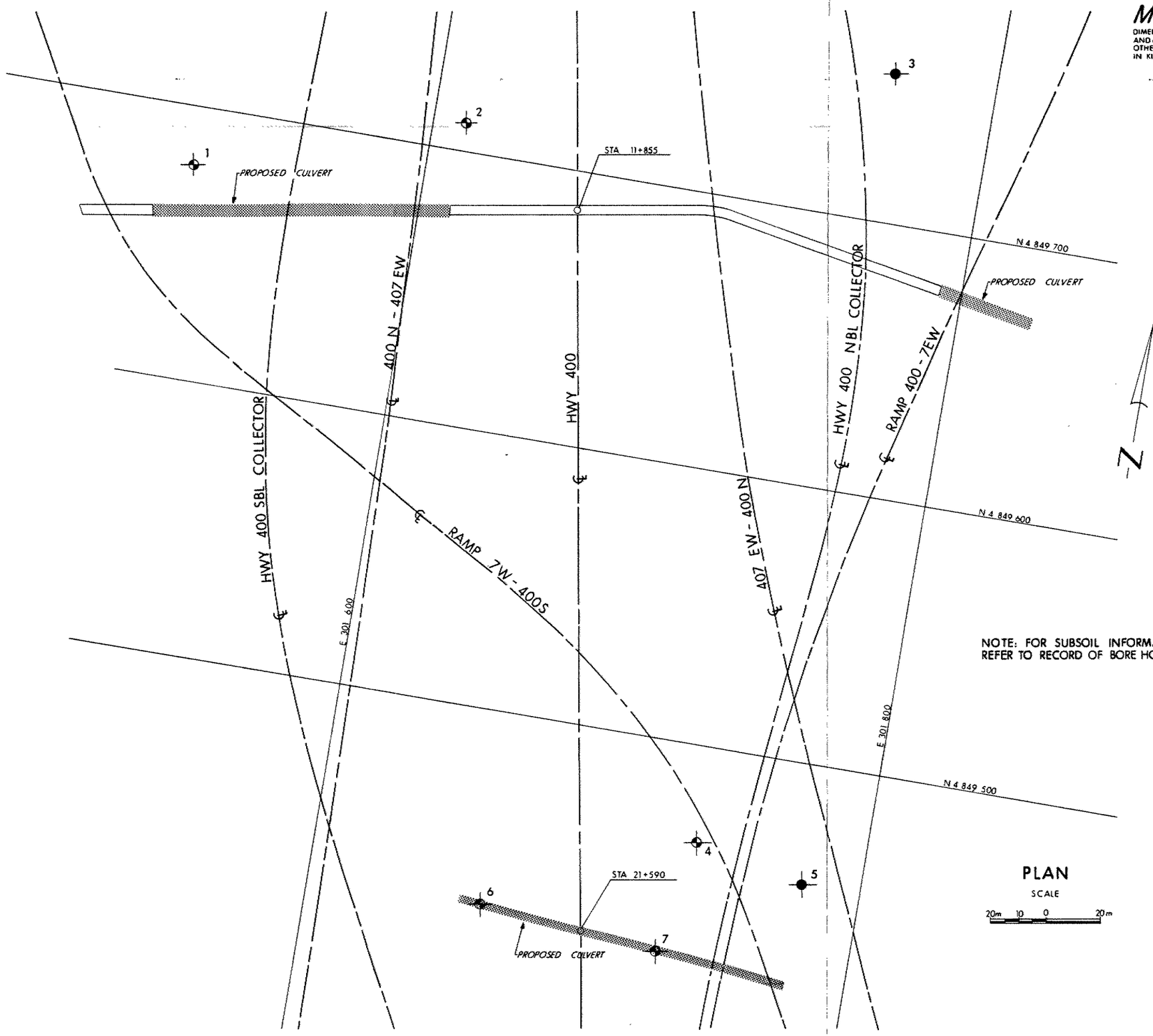
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No
WP No 145-87-00

HWY 400/407 INTERCHANGE

BORE HOLE LOCATIONS & SOIL STRATA

SHEET

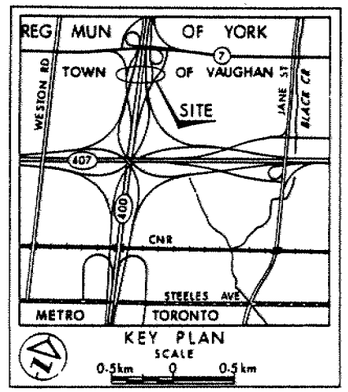


PLAN

SCALE

20m 10 0 20m

NOTE: FOR SUBSOIL INFORMATION REFER TO RECORD OF BORE HOLE



KEY PLAN
SCALE
0.5km 0 0.5km

LEGEND

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

No	ELEVATION	CO-ORDINATES NORTH	EAST
1	191.9	4 849 678.0	301 516.0
2	192.1	4 849 710.0	301 612.0
3	196.1	4 849 754.0	301 763.0
4	190.7	4 849 466.0	301 738.0
5	190.9	4 849 458.0	301 779.0
6	191.5	4 849 430.0	301 665.5
7	192.5	4 849 423.5	301 731.9

NOTE

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

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

REV.	DATE	BY	DESCRIPTION

Geocres No 30M13-122

HWY No 400 & 407			DIST 6
SUBM'D KA	CHECKED	DATE 1991 08 26	SITE
DRAWN KM	CHECKED	APPROVED	DWG 1458700-A

memorandum

235-3731

Ontario

To: Mr. V. F. Boehnke
Head, Structural Section
Central Region

Date: 1991 07 16

Attn: John K. Lam

From: Foundation Design Section
Room 315, Central Building

Subject: Foundation Recommendations
Concrete Culvert (Sta. 11+855, Hwy. 400), Rt. Extension
Concrete Culvert (Sta. 11+855, Hwy. 400), Lt. Extension
Concrete Culvert (Sta. 21+590, Hwy. 400 NBL)
W.P. 142-87-00(B), Hwy. 400/407 Interchange
Hwy. 400, District 6, Toronto

As requested, we are pleased to provide you the foundation design recommendations for the above-captioned project. The recommendations are based on some information obtained from old subsurface investigations at the site which was carried out in 1985 and 1988, and a recent investigation for this project. These recommendations are intended to be sufficient for design to proceed. If there are any questions or if additional details are required, please advise.

The subsurface conditions will be presented on borehole logs at later date. The locations of the boreholes and proposed culverts will be shown on a drawing which will be provided in the final report. The final report will be provided by July 31, 1991 when the drawing is ready and the lab test results are available.

This report is applicable to the proposed culverts only.

SITE DESCRIPTION AND GEOLOGY

The site is in the area of proposed Hwy. 400 and Hwy. 407 intersection, in the Regional Municipality of York. The ground surface tends to slope to the south.

Physiographically, the site is located in the 'Peel Plain' region which is characterized by bevelled till plains composed of level to undulating tracts of clay soils. Much of the plain has been modified by a veneer of clay which, when deep enough takes on a varved appearance (Reference: Chapman and Putnam, "The Physiography of Southern Ontario; 3rd Edition, 1984).

.../2

SUBSURFACE CONDITIONS

Based on the information obtained from previous boreholes, and two boreholes BH 6 and BH 7 recently drilled for this investigation, reasonably uniform subsurface conditions with varying in situ consistency/denseness were encountered across the site. The recent investigation encountered fill material in the vicinity of new culvert location (BH 6 and BH 7). Underlying the fill material (BH 6 and BH 7) and immediately below ground surface elsewhere the material consists of clayey silt till. Occasional pockets and layers of silty sand to sandy silt material up to 0.8 m thick were also encountered within the clayey silt till deposit. Details of the subsurface condition are as follows:

Fill Material

This cohesive material was encountered in the new boreholes BH 6 and BH 7. The fill material consisted of clayey silt mixed with sand and sandy silt material. Trace of organics and roots were also present within the fill. The thickness of the fill was 1.4 m and 2.9 m in BH 6 and BH 7 respectively. The Standard Penetration 'N' value ranged from 12 to 24 blows/0.3 m penetration, which suggest that the fill is stiff to very stiff.

Clayey Silt (Glacial Till)

This cohesive material was encountered in all boreholes. In boreholes BH 6 and BH 7 this material was underlying the fill material. In previous boreholes (BH 1 through BH 5) this material was encountered below the ground surface. Occasional pockets and layers of silty sand to sandy silt up to 0.8 m thick was encountered within this deposit. All boreholes were terminated within this deposit. The maximum penetration within this material took place in BH 5, where the borehole was advanced 24.4 m within this deposit. The 'N' values ranged from 8 to 143 blows/0.3 m penetration indicating the till to be of stiff to hard consistency. Generally within the upper 2 m to 4 m (above elevation 188 m) the 'N' value ranged from 8 to 25 blows/0.3 m. At depths exceeding 4 m below the ground surface (below elevation 188 m) the 'N' value was generally in excess of 50 blows/0.3 m and frequently exceeded 100 blows, indicating the clayey silt till to be of hard consistency.

Based on the record of groundwater in previous study (1985 and 1988) and recent study, the groundwater table was recorded at depths ranging from 1.2 m to 2.4 m below the ground surface which corresponds to elevations 189.4 m to 190.6 m. It should be noted that the groundwater table is subject to seasonal fluctuation.

.../3

RECOMMENDATIONS

General

It is proposed to construct three concrete box culverts under Hwy. 400 and Hwy. 407 interchange.

Two culverts will be the extensions of the existing culverts at Sta. 11+855 Hwy. 400 chainage. The culvert extensions are designated as right extension and left extension. The left extension will be situated under proposed Hwy. 400 collector lanes and proposed ramp 400 N-407 EW. This extension will connect two existing culverts. One of the existing culverts to be connected is situated under present ramp 7 W-400 S and the other underlies Hwy. 400 NBL and 400 SBL. The right extension will extend the present culvert under existing 400 S-7E,W ramp and will be situated under new 400 S-7 E,W ramp. The dimension of the culvert extensions will be 4.27 m wide and 3.05 m high. The left extension will be 109 m long and the right extension will will be 36 m long. Maximum earth cover over the culvert obvert will be 7.2 m. The flow in the culert will be from west to east. The invert elevations of the left extension will vary from 188.3 m to 188.4 m, and for the right extension the invert elevations will be at 188.1 m.

A new concrete box culvert is proposed to be constructed at Sta. 21+590 (Hwy. 400, NBL chainage). This culvert will be constructed under Hwy. 400 NBL, Hwy. 400 SBL and Hwy. 400 NB collector. The flow in the culvert will be from west to east. The invert elevation will vary from 186.9 m to 190.0 m. The culvert will be 1 m wide, 1.5 m high and 123 m long. Maximum earth cover over the culvert obvert will be 6.6 m high.

Structure Foundations

All proposed culverts may be designed with the following recommendations.

The soil at proposed culvert invert elevation is a competent native soil. The culverts can be founded on 0.6 m thick granular bedding constructed on native soil.

The following design values can be utilized for the design of proposed culvert extensions and the new culvert foundations.

Factored Bearing Capacity at U.L.S. = 450 kPa
Bearing Capacity at S.L.S. Type II = 300 kPa

Backfilling/Lateral Pressure

Above the bedding level, backfilling to the culverts should

.../4

consist of suitable material compacted in accordance with MTO Standards and conform to OPSD 803.02. For fill below groundwater level or below pavement within frost line, it is recommended that Granular 'A' or 'B' should be used. The backfill operations should be carried out simultaneously on both sides of the culverts as per MTO specifications. The following properties are recommended for the calculation of lateral pressure if any cut-off or retaining walls are required.

Granular 'A'	γ = 22.8 kN/m^3,	ϕ = 35°,	Ko = 0.43,	Ka = 0.27
Granular 'B'	γ = 21.2 kN/m^3,	ϕ = 30°,	Ko = 0.50,	Ka = 0.33
Native Soil	γ = 19.2 kN/m^3,	ϕ = 26°,	Ko = 0.56,	Ka = 0.39

For structural elements rigidly connected to concrete box culverts, at rest condition (Ko) should be used to calculate lateral pressure.

Lateral Resistance

Lateral resistance calculations will not be required for the culvert foundations.

Stability and Settlement

There is no concern of deep seated slope failure. The highway embankments should be sloped at 2H:1V. Total and differential settlement will be less than 25 mm if the foundation is constructed in accordance with the recommendation provided.

CONSTRUCTION CONSIDERATIONS

Temporary Division

To facilitate the construction of the proposed extensions, a temporary diversion of the water courses could be considered.

Dewatering

Dewatering will be required at both the proposed culvert extensions and the new culvert.

The subsurface information at the proposed culvert extensions is based on previous site investigations which were conducted in 1985 and 1988 somewhat away from the proposed culvert locations. The boreholes at the proposed culvert extensions show the presence of a non-cohesive material which is about 0.8 m thick and is situated at depths ranging from 3 m to 10 m below the ground surface. This layer is likely to be encountered at the founding elevations (188.1 m to 188.4 m) of culverts at Sta. 11+855 (Hwy. 400 chainage). Groundwater level is about 1 m higher than the proposed culvert invert elevations. At the new culvert location,

due to cohesive nature of the soil, seepage will be minor and could be handled by sump pump technique. However, in view of the large excavation which will be involved at this site, it will be necessary to plan a dewatering scheme at this site as well.

A special provision should be in the contract requiring the contractor to lower the groundwater below base of any excavation prior to excavation. The contractor should be advised that cohesionless material may be encountered at the proposed culvert foundation elevations and it would be susceptible to disturbance under conditions of unbalanced hydrostatic head. The contractor should also be advised to construct without disturbance to the underlying foundation soil or any existing structure. Although the dewatering method is the responsibility of the contractor, it is anticipated that if a granular layer is encountered at the proposed culvert foundation elevations then the groundwater can be lowered by a system of oversize perimeter ditches and sumps. If granular layer is not encountered at the founding elevations, then seepage could be controlled by sump pump technique. In any case, the contractor should submit his dewatering proposal for review a minimum of 15 working days prior to construction.

Excavation

Temporary excavations will be stable at 1H:1V above the water table and 2H:1V below the water table.

Bedding

Bedding under the culvert foundation shall consist of a 0.6 m thick layer of Granular 'A' material. The bedding should be constructed as per MTO standards.

Cambering

Due to competent soil condition, no significant settlements are anticipated. Therefore, cambering is not required.

Construction Joints

Construction joints will be required at connections between the old and new culverts to accommodate any differential movement that may occur. Such joints should be able to accommodate differential settlement up to 12 mm and provide proper seal.

Erosion Protection

Erosion protection will be required at the outlet of the right culvert extension (Sta. 11+855, Hwy. 400) and at the inlet and outlet of the new culvert (Sta. 21+590, Hwy. 400 NBL).

.../6

A seal of cohesive material (CI-CH clay) with a minimum thickness of 0.6 m should be constructed at the culvert inlet at Sta. 21+590, Hwy. 400 NBL chainage. The seal should extend a minimum of 2 m on each side of the culvert inlet, and from the high water level down the embankment to the creek bed. Erosion protection, in the form of rock protection (minimum blanket thickness = 0.6 m) should be placed to protect the embankment. It should extend from the high water level to the toe of the slope and 2 m along the creek bed. In transverse direction, the erosion protection should extend a minimum of 5 m on each side of the culvert.

The culvert outlet should be protected with 0.6 m thick rock protection.

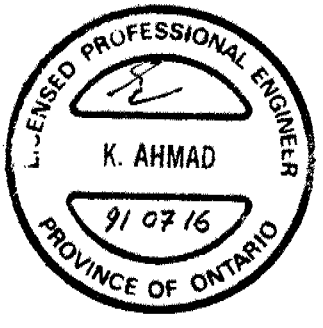
Rock protection will not be required if head walls are used but the bases of the channel should be armoured at both outlet and inlet.

MISCELLANEOUS

The recommendations given in this report are based on both previous investigations in the site vicinity and a recent investigation which consisted of drilling two boreholes BH 6 and BH 7 at the new culvert location. The previous investigations were carried out at the site in 1985 and 1988 (Re: W.P. 164-79-04/05 and W.P. 142-87-02).

The recent field work for this project was carried out under the supervision of C. Davidson, Engineer Student. The equipment used was owned and operated by Master Soil Investigation Ltd.

The report was written by K. Ahmad, Foundation Engineer, reviewed by D. Dundas, Senior Foundation Engineer and approved by M. Devata, Chief Foundation Engineer.



K. Ahmad, P.Eng.
Foundation Engineer

for

D. Dundas, P.Eng.
Senior Foundation Engineer