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W.P. No. 87-80-02

CONT. No. 86-15

W. O. No.

STR. SITE No. 29-212

HWY. No. ~~29-2~~ 41

LOCATION Muskrat River Bridge

No of PAGES - 2

OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

FOUNDATION INVESTIGATION REPORT

CONTRACT NO 86-15

Ontario

Ministry of
Transportation and
Communications

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Note: For the purposes of the Contract, these reports supersede all other foundation reports, prepared by or for the Ministry in connection with the above-noted projects.

EXPLANATION OF TERMS USED IN REPORT

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

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

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

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

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

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

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

FOUNDATION INVESTIGATION REPORT
For
Muskrat River Bridge / Hwy. 41
W.P. 87-80-02, Highway 41 Str. Site 29-212
District 9, Ottawa

INTRODUCTION:

This report summarizes the factual information obtained from a preliminary foundation investigation as well as a subsequent investigation carried out at the above site. Field work consisted of 5 sampled boreholes ** advanced between 80 10 21 and 80 10 22 and 3 sampled boreholes and one dynamic cone penetration test* advanced during the period of 83 04 05 and 83 04 06. A track mounted drill equipped with hollow stem augers was employed for both investigations. Borings were advanced for depths ranging from 3.4 metres to 9.6 metres.

SITE DESCRIPTION

The site is located just southeast of the boundary of the Township of Stafford, the Township of Pembroke and the City of Pembroke. Approximately one kilometre north of its intersection with the Highway 17 Bypass, Highway 41 approaches the Muskrat River then curves to follow the river to the northwest. It is planned to eliminate this curve and cross the river at this point.

At the proposed crossing location, the Muskrat River is relatively slow flowing and is approximately 25 m in width and up to 1.2 m in depth. It flows in a broad valley with gentle slopes to the west, steeper slopes to the east, and approximately 23 m wide flood plain on the east side.

The surrounding area is predominantly agricultural. However, on the east side of the river is a row of residences with industrial properties located further to the north and east.

SURFACE CONDITIONS

Subsoil General

Generally, the subsoil consists of a deposit of silty clay of intermediate to high plasticity overlying a thin veneer of granular glacial till which in turn overlies limestone bedrock. The Muskrat River has eroded its valley through the overburden and has produced local deposits of silts and sands with organics in the floodplain adjacent to the river channel.

*NOTE: Boreholes No. 100 to 103.

**NOTE: Boreholes No. 1 to 5.

Reference should be made to the Borehole Logs located in the Appendix which show the boundaries between the different soil types as well as a summary of all field and laboratory tests performed. Reference should also be made to Drawing No. 2 * which shows the location and elevation of all the boreholes as well as an inferred stratigraphical profile. The various soil types encountered are briefly described in the following paragraphs.

Silty Clay

This deposit is the predominant soil type in the vicinity of both abutments and is exposed in the valley slopes. It ranges from zero thickness under the river channel to 2.6 m and 6.7 m in the area of boreholes 2 and 100, and boreholes 5 and 103 respectively.

The results of Atterberg Limit and water content testing are plotted on the Plasticity Chart, Figure 1, and are summarized as follows:

		Range	Average
Water Content	(w)%	26-46	36
Liquid Limit	(W_L)%	29-52	38
Plastic Limit	(W_p)%	15-21	17
Plasticity Index	(I_p)%	13-31	21

These results indicate that the deposit is an inorganic silty clay of intermediate to high plasticity.

Undrained shear strengths, as measured by the field vane test, vary from greater than 105 kPa to as low as 20 kPa. Based on these measurements and unconfined laboratory compression tests, the silty clay has a very stiff to soft consistency. Sensitivities measured in the field and lab ranged from 2 to as high as 19 with an average value of 8. Based on these values, the silty clay is classified as a sensitive soil.

Glacial Till

A thin layer of glacial till lies between the silty clay and the underlying bedrock in the vicinity of the riverbanks. It varies in thickness from 0.6 m to 2.3 m and consists of a heterogeneous mixture of gravel, sand, silt and traces of clay.

* NOTE: Drawing No. 2 of the Contract Drawings.

Standard Penetration 'N' values ranged from 3 to over 100 blows per 0.3 m. This deposit is generally compact to very dense; however, a weaker zone of higher clay and moisture content exists at the contact with the overlying silty clay.

Silt and Sand with Organics

In the floodplain on the east side of the river, is an alluvial deposit consisting of a mixture of silt and sand with organics. This deposit is about 3.2 m in depth at borehole 102 and contains sufficient organic material near the surface to show some plasticity. At greater depth, the deposit is generally coarser with little or no organic material present. Standard Penetration 'N' values ranged between 1 and 3 indicating that this soil may be classified as very loose or very soft to soft.

Limestone Bedrock

The site is underlain by limestone bedrock which dips to the east. Its surface varies in elevation from ±118.5 on the west side of the river to ±114.8 in the vicinity of borehole 5. Generally, the limestone bedrock is sound across the site, except in the area of the channel. In this area, a ±1 m zone of fractured rock or a possible cavity exists.

Groundwater

The groundwater level is located at a depth of approximately 3 m in the vicinity of boreholes 5 and 103, and about 1 m in the vicinity of boreholes 2 and 100. It gradually decreases in depth until it reaches the surface at the river's edge. Artesian water was encountered in the fractured rock or cavity in the vicinity of boreholes 4 and 102. The water rose about 0.5 m above the ground surface during rock coring operations at borehole 102.

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M. Devata

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A P P E N D I X

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 1 METRIC

W P 87-80-02 LOCATION Sta. 20 + 231.9; o/s 3.4 m RT ℄ Hwy. 41 ORIGINATED BY RB
DIST 9 HWY 41 BOREHOLE TYPE Hollow Stem Auger, BXL Rock Core & Cone Test COMPILED BY PJS
DATUM Geodetic DATE 1980 10 21 CHECKED BY BER

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (25 50 75 100 125) ○ UNCONFINED ● QUICK TRIAXIAL ✦ FIELD VANE × LAB VANE	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
124.2	Ground Surface										
0.0	Silty clay Very stiff to stiff Grey		1	SS	14		124				
			2	TW	PH						
			3	SS	11		122				
			4	TW	PH						
			5	SS	11			✦ >105			
			6	TW	PH		120	9 ✦			
119.2			7	SS	2						
5.0			8	SS	27/25cm	Piezometer					
118.5	*						118				
5.7	Limestone bedrock Sound		9	BXL RC	50% REC						RQD=25
116.5			10	BXL RC	80% REC						RQD=37
7.7	End of Borehole *Heterogeneous mixture of gravel sand and silt trace of clay very dense (Glacial till)										

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

$\frac{20}{15}\diamond\frac{}{5}$ (%) STRAIN AT FAILURE

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RECORD OF BOREHOLE No 2 METRIC

W P 87-80-02 LOCATION Sta. 20 + 252.3; o/s 3.7 m RT ℄ Hwy. 41 ORIGINATED BY RB
DIST 9 HWY 41 BOREHOLE TYPE Hollow Stem Auger, BXL Rock Core & Cone Test COMPILED BY PJS
DATUM Geodetic DATE 1980 10 21 CHECKED BY BER

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 (20 25 50 75 100 125)	WATER CONTENT (%) Wp W WL (20 40 60)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
120.7	Ground Surface										
0.0	Silty clay Soft		1	SS	6		120	1.8			
118.7											
2.0	Het. mix. of gravel, sand and silt, trace of clay (Glacial till) Loose to dense		2	SS	7		118				36 24 31 9
117.3			3	SS	44	23 cm					
3.4	Limestone bedrock Sound		4	BXL RC	30% REC		116				RQD=35
115.4											
5.3	End of Borehole										

+3, ×5 : Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

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RECORD OF BOREHOLE No 3 METRIC

W P 87-80-02 LOCATION Sta. 20 + 243.2; o/s 1.5 m RT ℄ Hwy. 41 ORIGINATED BY RB
DIST 9 HWY 41 BOREHOLE TYPE Hollow Stem Auger COMPILED BY PJS
DATUM Geodetic DATE 1980 10 22 CHECKED BY BER

ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (25 50 75 100 125)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
122.1	Ground Surface										
0.0	Silty Clay Stiff to Very Stiff		1	TW	PH		122			19.0	
120.0											
2.1	Het. mix. of gravel, sand and silt, trace of clay (Glacial till) Very loose to compact		2	SS	12		120	+3	o		24 38 31 7
117.7			3	SS	3						
			4	SS	28		118				
4.4	Refusal to auger Probable bedrock End of Borehole										

+³, ×⁵ : Numbers refer to Sensitivity

15 20/10 5 (%) STRAIN AT FAILURE

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RECORD OF BOREHOLE No 4

METRIC

W P 87-80-02 LOCATION Sta. 20 + 280.4; o/s 9.1 m RT ℄ Hwy. 41 ORIGINATED BY RB

DIST 9 HWY 41 BOREHOLE TYPE Hollow Stem Auger & BXL Rock Core COMPILED BY PJS

DATUM Geodetic DATE 1980 10 22 CHECKED BY BER

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 (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
119.5	Ground Surface										
0.0	Silty sand with organics very loose		1	SS	2						
			2	SS	3		118				
117.0			3	SS		Hammer Bounding					
2.5	Limestone bedrock weathered		4	BXL	70%						
115.9			5	BXL	30%		116				
3.6	Sound		6	BXL RC	84% REC						RQD=70
114.3											
5.2	End of Borehole										

+[3], ×[5] : Numbers refer to Sensitivity

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

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RECORD OF BOREHOLE No 5 METRIC

W P 87-80-02 LOCATION Sta. 20 + 310.9; o/s 7.6 m RT ℄ Hwy. 41 ORIGINATED BY RB
DIST 9 HWY 41 BOREHOLE TYPE Hollow Stem Auger & BXL Rock Core COMPILED BY PJS
DATUM Geodetic DATE 1980 10 22 CHECKED BY BER

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL ◆ FIELD VANE × LAB VANE; 25 50 75 100 125	WATER CONTENT (%): 20 40 60	kN/m³	GR SA SI CL
122.9	Ground Surface										
0.0	Silty clay Stiff to soft Sensitive		1	SS	7		122			18.2	
			2	TW	PH						
			3	TW	PH						
			4	TW	PH	▽	120				
			5	TW	PH						
			6	SS	3		118				
116.2			7	SS	3						
6.7	Het. mix. of gravel, sand and silt, trace of clay (Glacial till) V. Dense		8	SS	100/23 cm		116				
114.8											
8.1	Limestone Bedrock Sound		9	BXL RC	97% REC		114				RQD=75
113.3											
9.6	End of Borehole										

+3, ×5 : Numbers refer to Sensitivity

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

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RECORD OF BOREHOLE No 100 METRIC

W P 87-80-02 LOCATION Sta. 20 + 250.0; o/s 5.0 m LT ℄ Hwy. 41 ORIGINATED BY BER
DIST 9 HWY 41 BOREHOLE TYPE Hollow Stem Auger, BXL Rock Core COMPILED BY BER
DATUM Geodetic DATE 1983 04 05 CHECKED BY

SOIL PROFILE ELEV/DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'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 25 50 75 100 125	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
121.0	Ground Surface										
0.0	Silty clay Firm to very soft Sensitive		1	SS	8		120				
			2	SS	2						
118.4			3	TW	PH			8 ×, 8 +		18.9	
2.6	*		4	SS	4		118				19 41 31 9
117.8											
3.2	Limestone - white no recovery-poss. cavity		CR % 70	RQD % 45				Weathering Slight	Strength High	Jointing Close Spaced Bedding	BXL RC
			0	0							
	Limestone with alt black (probably soft) shale seams		78	56			116	unweathered	high	Close Spaced Bedding	
115.4											
5.6	End of Borehole										
	*Heterogeneous mixture of sand and silt, some gravel, trace of clay (Glacial till) loose										

+³, ×³ : Numbers refer to Sensitivity

15 20/10 5 (%) STRAIN AT FAILURE

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RECORD OF BOREHOLE No 101 METRIC

W P 87-80-02 LOCATION Sta. 20 + 251.0; o/s 8.0 m RT ℄ Hwy. 41 ORIGINATED BY BER
DIST 9 HWY 41 BOREHOLE TYPE Cone and Vane Test COMPILED BY BER
DATUM Geodetic DATE 1983 04 05 CHECKED BY GP.

SOIL PROFILE			SAMPLES			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 25 50 75 100 125	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
120.7	Ground Surface										
0.0	Probable Silty clay						120				
118.1											
2.6	Probable sand and gravel till						118				
117.3											
3.4	End of Cone Test										

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

$\frac{20}{15}\diamond\frac{5}{10}$ (%) STRAIN AT FAILURE

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 102 METRIC

W P 87-80-02 LOCATION Sta. 20 + 284.0; o/s 4.5 m LT ℄ Hwy. 41 ORIGINATED BY BER
DIST 9 HWY 41 BOREHOLE TYPE Hollow Stem Auger - BXL Rock Core COMPILED BY BER
DATUM Geodetic DATE 1983 04 06 CHECKED BY GP.

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 (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
119.7	Ground Surface										
0.0	Silt and sand with organics very loose		1	SS	1	Artesian Head					
			2	SS	1		118				
			3	SS	2						
	Coarser with traces fine gravel		4	SS	2	Hammer Bouncing					9 74 13 4
116.5			5	SS							
3.2	Limestone - brn grey brn-poss cavity-probable aquifer		CR% 63	RQD% 42			116	Weathering: SW at top to HW at prob aquifer zone	Strength: High	Jointing	BXL RC
	Limestone - grey with occasional solution features (mainly small holes 8-15 mm ϕ)		89	77		Artesian Encountered	114	Weathering: unweathered	Strength: High	Jointing: Predominantly bedding, close to moderate spacing	
112.6											
7.1	End of Borehole										

NOTE:
SW = slightly weathered
HW = highly weathered

+3, ×5 : Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 103

METRIC

W P 87-80-02 LOCATION Sta. 20 + 310.6; o/s 4.0 m LT ℄ Hwy. 41 ORIGINATED BY BER

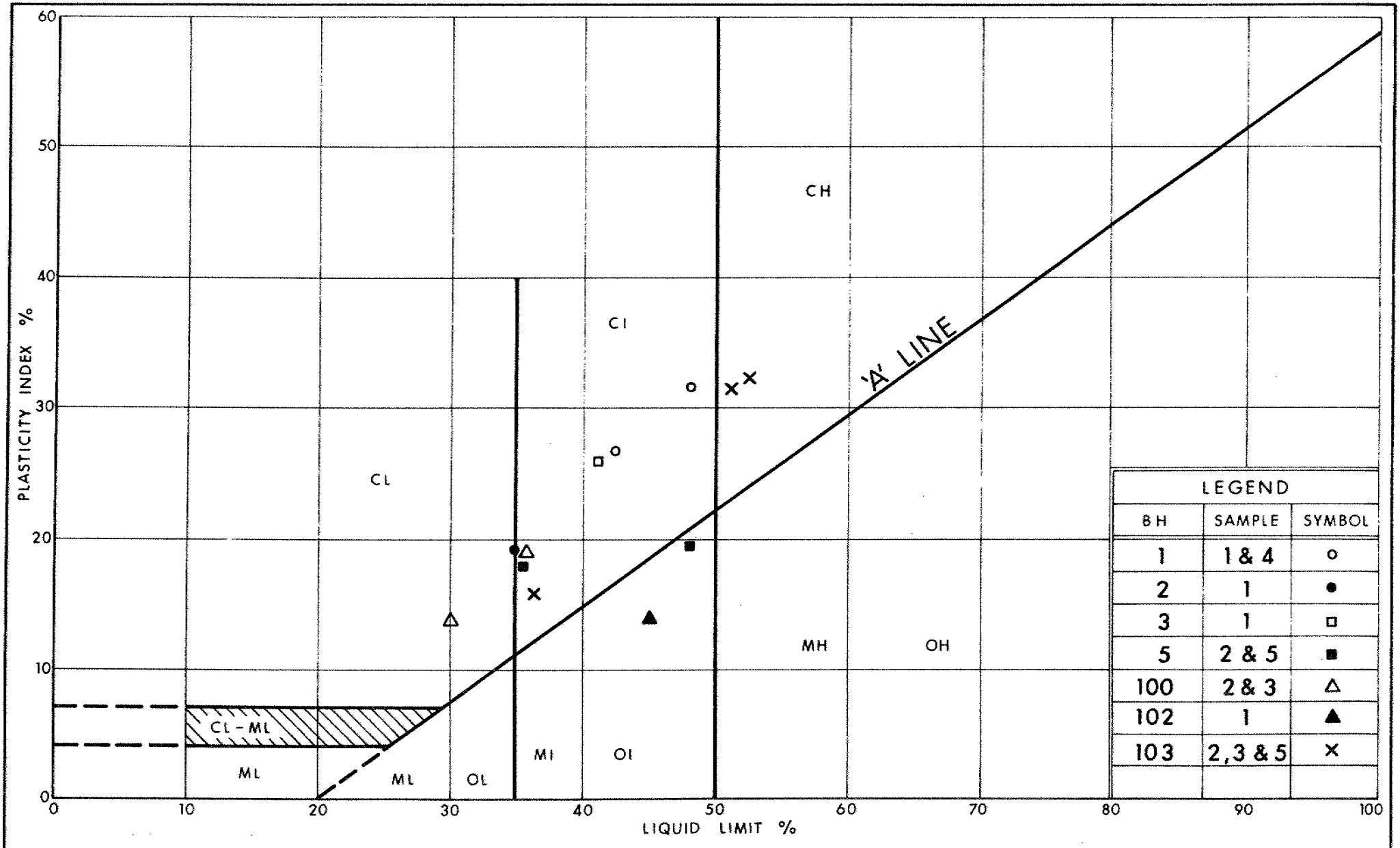
DIST 9 HWY 41 BOREHOLE TYPE Hollow Stem Auger - BXL Rock Core COMPILED BY BER

DATUM Geodetic DATE 1983 04 06 CHECKED BY

SOIL PROFILE			SAMPLES			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 25 50 75 100 125	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT Wl / WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						GR SA SI CL
122.4	Ground Surface										
0.0	Fill- silty sand with organics and some clay loose		1	SS	5		122				
121.2											
1.2	Silty clay Stiff to soft Sensitive		2	SS	9						
			3	TW	PH		120				
			4	TW	PM			19		17.7	
			5	TW	PM	▼	118	+5.5 ×5.5		17.4	
116.7			6	TW	PM			+16 σ ×3.5		18.1 18.5	
5.7	Het. mix. of gravel, sand and silt, trace of clay, occ. boulder (Glacial till) Compact		7	SS	24		116	Weathering / Strength	Jointing		28 36 27 9
115.2											
7.2			CRZ		RQDX			unweathered / high	Close Spaced Bedding		BXL RC
	Limestone-white-grey with occ. solution cavities (8-15 mm ϕ)		90		82		114	unweathered / high	Moderate Spaced Bedding		
113.6											
8.8	End of Borehole										
	*Limestone - grey with occasional thin black shale partings										

+³, ×⁵ : Numbers refer to Sensitivity

15 ◇ 20 / 10 5 (%) STRAIN AT FAILURE



LEGEND		
BH	SAMPLE	SYMBOL
1	1 & 4	○
2	1	●
3	1	□
5	2 & 5	■
100	2 & 3	△
102	1	▲
103	2,3 & 5	×

Ministry of Transportation and Communications
Ontario

PLASTICITY CHART
SILTY CLAY

FIG No 1
WP 87-80-02

FOUNDATION INVESTIGATION REPORT
For
Muskrat River Bridge/Co. Rd. 19
W.P. 87-80-04, Str. Site 29-13
County Road 19, District 9, Ottawa

1.0 INTRODUCTION

Golder Associates has been retained by the Ontario Ministry of Transportation and Communications to carry out a geotechnical investigation at the existing Muskrat River Bridge No. 29-33 in the Township of Pembroke, Ontario.

The purpose of the investigation was to determine the subsurface conditions at the site and based on the assessment and interpretation of this data, to provide geotechnical recommendations for the replacement of the existing bailey bridge structure.

The field work was carried out and this report was prepared in accordance with the terms of reference as outlined during telephone conversations between Mr. M. S. Devata of MTC and Mr. F. J. Heffernan of Golder Associates.

2.0 SITE AND PROJECT DESCRIPTION

The project site is located on County Road No. 19 at Bridge No. 29-33 over Muskrat River. The natural river banks are approximately 3 m in height sloping at about 20 degrees on the east side of the river while the west banks range from 5 to 5.5 m in height with slopes of about 30 to 45 degrees. The banks are generally well vegetated and do not display evidence of recent movement.

A drainage gully, present immediately south of the existing bridge structure on the west bank, has been protected by placement of rip rap and shows signs of recent erosion.

The soils exposed in the west slope consist of grey silty clay overlying grey silty sand till which outcrops at about river water level. No signs of groundwater seepage were apparent in the slopes at the time of the investigation.

The existing bridge at the site is a three span steel girder bailey bridge (51.7 m in length). The concrete in the piers and abutments exhibit considerable deterioration at about river water level. The wooden deck had been replaced recently and it is understood that such replacement is required at regular intervals.

3.0 SUBSURFACE CONDITIONS

3.1 Site Geology

From published geological information*, the site lies within the physiographic region known as the Petawawa Sand Plain and is adjacent to an area which is part of the Muskrat Lake Ridges. The former is a delta in origin built in the Champlain Sea during the Fossmill stage of Lake Algonquin. The latter is an area of fault blocks which generally are not overlain by clay but instead by a thin veneer of sand and gravel.

3.2 Soil Stratigraphy

The detailed stratigraphy encountered in each of the boreholes put down during this investigation, is given on the attached Record of Borehole sheets. It should be noted that the stratigraphic boundaries indicated on the Record of Borehole sheets and stratigraphic section are not intended to define exact planes of geological change but represent transitions from one soil type to another. Subsurface conditions have been established at the borehole locations only and may vary between the boreholes. The locations of the boreholes and stratigraphic sections showing the inferred subsurface conditions are given on the attached Dwg. No. ~~878004-A.~~** The results of laboratory testing carried out on representative samples are given on the Record of Borehole sheets and on Figures 1 to 4 inclusive.

In general, at the crest of the river banks, the site is underlain by sand and gravel fill which overlies up to 4.0 m of silty clay. The silty clay is underlain by up to 2.7 m of a till material which consists generally of sand with

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* The Physiography of Southern Ontario, Chapman & Putnam, 1973.

** Note: Refer to Drawing No. 2 of the Contract Drawings.

some gravel and silt. The river bed material grades from silty sand and gravel to a sand till which overlies about 0.5 m of sand and gravel. Limestone bedrock was encountered at approximately constant elevation (elevation 117) across the site at all borehole locations.

3.2.1 River Banks

In Borehole 3, about 0.3 m of brown sand and gravel fill was encountered at ground surface.

About 4.0 to 4.3 m of grey/brown to grey silty clay with a trace of sand (Figure 1) was encountered below the fill in Borehole 3 and at ground surface in Borehole 1. The silty clay has a soft to very stiff consistency as measured by in situ field vane tests. The undrained shear strength, C_u, generally ranged from 80 to greater than 95 kPa in the upper 2.7 m of the deposit and this upper zone was grey/brown in colour indicating the presence of a weathered crust. Below the crustal zone, the silty clay became grey in colour and the C_u values decreased to about 20 kPa at the base of the deposit in Borehole 3. The vane strengths obtained throughout the deposit indicated a sensitivity of about 3 to 9 indicating the material to be moderately to highly sensitive.

Atterberg Limits tests gave liquid limits and plasticity limits of 41 to 50 and 23 to 27, respectively (see Figure 2) indicating a clay of intermediate plasticity. The natural water content of the samples of the silty clay ranged from 37 to 45 per cent and were generally close to or in excess of the liquid limit, reflecting the sensitivity noted in the vane tests.

Underlying the silty clay in Boreholes 1 and 3 and at ground surface in Borehole 4, 1.7 to 2.7 m of grey till was encountered. The composition of the till is variable and ranges from clayey silty sand with some gravel (Figure 3) to sand with some silt and gravel and a trace of clay (Figure 4). The natural water content of samples of the sand till ranged from 12 to 9 per cent. The till is in a loose to dense state of packing with 'N'* values ranging from 8 to 34 blows per 0.3 metres and these values increase with depth.

3.2.2 River Bottom

Borehole 2 was advanced through the bridge deck and B size casing was extended to the river bottom. Below the wooden plank bridge deck about 0.35 m of concrete was encountered. The upper 0.15 m was composed of a dirty sandy, highly weathered, slightly cemented material containing some wood fibres. About 0.15 m of wood timber was encountered below this and the wood was underlain by about 0.05 m of well cemented concrete.

At the river bed, about 0.6 m of grey silty sand and gravel was found to overlie about 0.25 m of sand till with a trace of gravel. These upper layers are in a dense state of packing with one 'N' value obtained of 31 blows per 0.3 metres. The natural water content of the sample of the till was measured at 8 per cent.

The till is underlain by about 0.4 m of gravel and grey sand with a trace of silt and clay. (See Figure 5.) One 'N' value of 34 blows per 0.3 metres was obtained indicating a dense state of packing. The water content of this sample was 9 per cent.

---

* 'N' value - Standard Penetration Index - see Explanation of Terms Used in Report.

3.3 Bedrock

Boreholes 2 and 4 were advanced 3 metres into the bedrock which underlies the site. Borehole 1 and 3 were terminated at refusal to the auger and the smooth grinding at this point indicated probable bedrock, although no attempt was made to drive the spoon sampler into bedrock.

The bedrock core samples obtained are grey fine grained to aphanitic limestone with occasional 50 to 200 mm thick shaley interbeds and minor solution cavities up to 25 mm in diameter. Generally core recovery values ranged from 70 to 100 per cent and RQD* values ranged from 15 to 52 per cent. The core samples from Borehole 4 reflect the upper range of RQD values while the top 1.5 m of bedrock in Borehole 2 is highly fractured with RQD values of about 15 per cent. Occasional chlorite filled fractures were noted throughout the bedrock at both borehole locations.

3.4 Groundwater Conditions

Following completion of Boreholes 1 and 4, a piezometer and a standpipe was installed in each of the holes, respectively. The details of the piezometer installations are given on the Record of Borehole sheets.

The water level in the piezometer in Borehole 1 was monitored on the day of and after the installation. The elevation of the water level on the day following installation was at about 118.7 m which coincides with the base of the silty clay deposit. The water level in the standpipe in Borehole 4 was at about elevation 119.2 m on the day of installation.

---

* RQD - Modified Recovery - See Explanation of Terms Used in Report.
It should be noted that the RQD values of the bedrock are based on Bx core size.

The river water level was at elevation 118.7 m and the readings in the installation are consistent with a groundwater table sloping to river level. However, an additional reading will be taken to determine if the recorded levels have stabilized and the results will be reported by letter.

NOTE: The preceding report is a copy of the factual information from the Foundation Investigation Report prepared by Golder Associates, the consulting geotechnical engineers for this project, under the technical supervision of the M.T.C. Foundation Design Section.

D.H. Dundas

D.H. Dundas, P. Eng.
Foundations Engineer

APPENDIX A

FIELD WORK PROCEDURES

FIELD WORK PROCEDURES

The field work for this investigation was carried out on July 7 and 8, 1983, at which time a total of 4 boreholes (numbered 1 to 4) were put down at the locations shown on Drawing No. 878004-A.* A bombardier mounted CME 55 power auger (supplied by F.E. Johnston Drilling Ltd.) was used with 114 mm inside diameter hollow stem augers and Bw casing size. Bedrock samples were obtained in Bx core size. A total of 22 m of sampled and/or vane test borings and corings were put down to depths of between 4.5 to 6.1 m.

Samples were obtained at 0.75 to 1.5 m intervals of depths using a conventional 50 mm O.D. split barrel sampler in conjunction with Standard Penetration tests. One 75 mm O.D. Shelby sample was taken in Borehole 1. In Borehole 3, continuous vane testing was carried out within the soft cohesive soils. In Boreholes 2 and 4, bedrock was cored for a depth of 3 m. Details of the drilling and sampling operations are summarized on the Record of Borehole sheets.

The field work was supervised throughout by a member of Golder Associates engineering staff who located the borings in the field, directed the drilling and sampling operations, and logged the borings.

The borehole locations and elevations were surveyed by Golder Associates. The elevations were referenced to Geodetic datum (B.M. Elevation 125.752 m - South end of concrete window sill, 21.8 m Right of Station 20+762.2).

* Note: Refer to Drawing No. 2 of the Contract Drawings.

APPENDIX

Ministry of Transportation and Communications
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RECORD OF BOREHOLE No 1

W P 87-80-04 LOCATION Stn. 20+736.1 o/s 5.0m Lt. Line 'A' ORIGINATED BY ASP
DIST HWY BOREHOLE TYPE Hollow Stem Auger COMPILED BY MKW
DATUM Geodetic DATE July 7, 1983 CHECKED BY RSP

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 Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
122.64	Ground Surface										
0.00	Silty Clay, trace sand						122				
			1	SS	6						
	Firm to very stiff										
	Grey/brown		2	TW	PH						0 0 50 50
			3	SS	4		120				
			4	SS	3						0 1 50 49
118.65											
3.99	Clayey Silty Sand Till, some gravel		5	SS	34		118				14 34 26 26
	Dense Grey										
116.79											
5.85	End of Hole Refusal to Auger at Probable Bedrock					July 8, 1983	116				

+3, ×5 : Numbers refer to Sensitivity

15 20 5 (%) STRAIN AT FAILURE

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 2

W P 87-80-04 LOCATION Sta. 20+712.5 o/s 0.9m Lt. Line 'A' ORIGINATED BY ASP

DIST ____ HWY ____ BOREHOLE TYPE Hollow Stem Auger, Bx Rock Core COMPILED BY MKW

DATUM Geodetic DATE July 7, 1983 CHECKED BY BJF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
118.69	River Level										
0.00 / 118.07	Water										
0.62	Silty Sand and Gravel		1	SS	31		118		o		
0.87	Sand Till Grey										
1.07 / 117.18	Gravel and Sand, trace silt and clay. Dense Grey		2	SS	34				o		50 45 5 1
1.51	Limestone Bedrock, fine grained to aphanitic, very to moderately close jointing, very poor to poor RQD. Occasional solution cavities (less than 25 mm)		3	Bx RC	REC 70%		116				
114.21			4	Bx RC	REC 100%						
4.48	End of Hole						114				

+3, ×5 : Numbers refer to Sensitivity

15 20 5 (%) STRAIN AT FAILURE

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 3

W P 87-80-04 LOCATION Sta. 20+740.9 o/s 6.0m Rt Line 'A' ORIGINATED BY ASP
DIST ____ HWY ____ BOREHOLE TYPE Hollow Stem Auger, N Vane COMPILED BY MKW
DATUM Geodetic DATE July 7, 1983 CHECKED BY RSF

SOIL PROFILE ELEV/DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (o UNCONFINED, • QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL — WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
123.05	Ground Surface										
0.00 / 122.75	Fill - sand and gravel Brown										
0.30	Silty Clay, trace sand Very Stiff to Soft Grey/Brown to Grey						122	+8; >95 6kPa; +5; >95 6kPa			
118.73						▽	120	+9; +8; +3			
4.32	Silty Sand Till, some gravel, trace clay						118				
116.99											
6.06	End of Hole Refusal to Auger at Probable Bedrock					July 8, 1983	116				

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Ontario

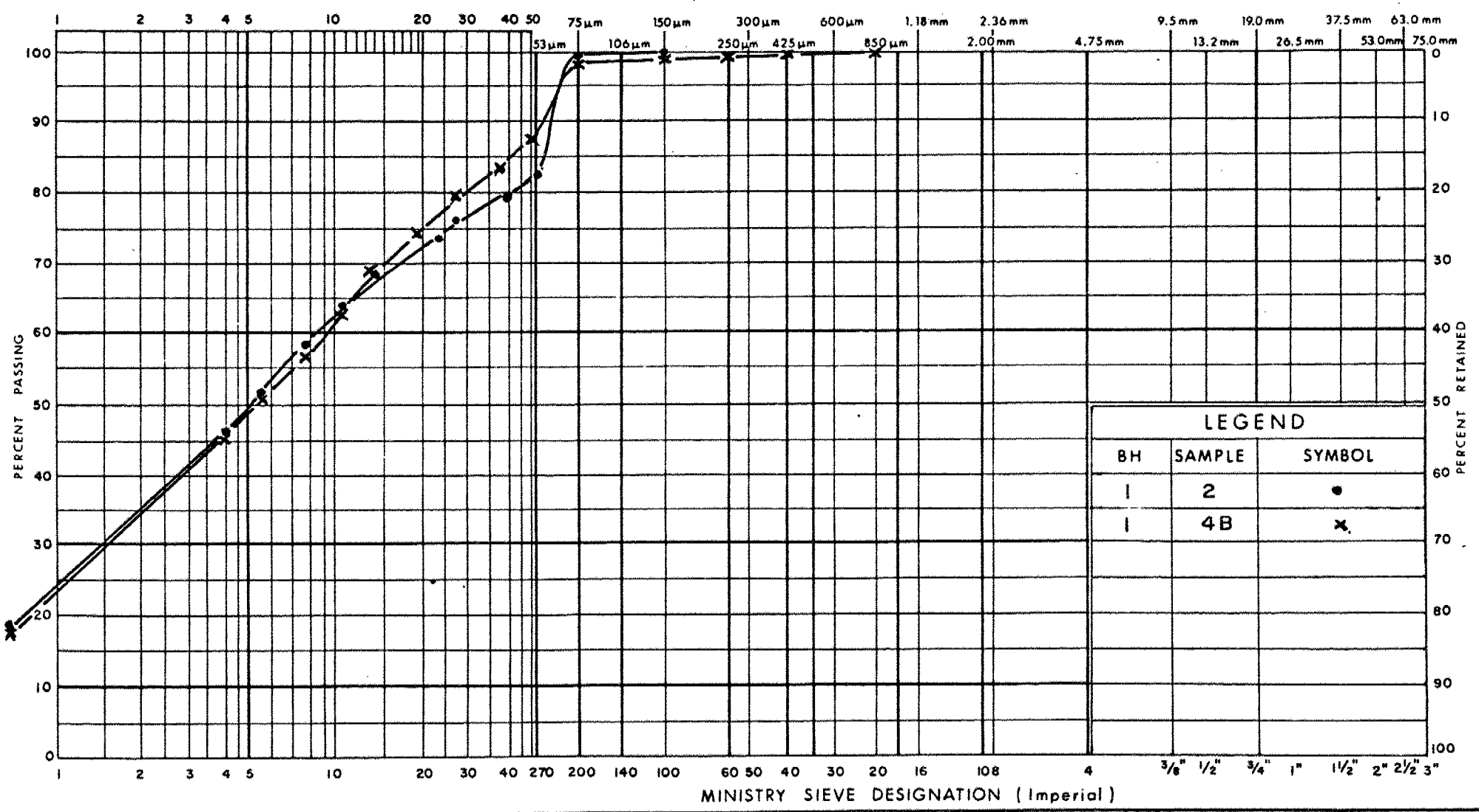
RECORD OF BOREHOLE No 4

W P 87-80-04 LOCATION Sta. 20+697.7 o/s 4.8m Rt Line 'A' ORIGINATED BY ASP
DIST ____ HWY ____ BOREHOLE TYPE Hollow Stem Auger, Bx Rock Core COMPILED BY MKW
DATUM Geodetic DATE July 8, 1983 CHECKED BY ASP

SOIL PROFILE ELEV/DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH o UNCONFINED + FIELD VANE • QUICK TRIAXIAL × LAB VANE	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
119.55	Ground Surface										
0.00	Sand Till, some silt and gravel, trace clay		1	SS	8				o		
	Loose to Dense		2	SS	18		118		o		19 45 17 9
116.84	Grey/Brown to Grey		3	SS	45 @ 250mm				o		
2.71	Limestone Bedrock, fine grained to aphanitic, occasional shaley interbeds, very close to moderately close jointing, poor to fair RQD. Occasional solution cavities (5 25 mm).		4	Bx RC	REC 88%		116				
113.81			5	Bx RC	REC 52%		114				
5.74	End of Hole					July 8, 1983					

UNIFIED SOIL CLASSIFICATION SYSTEM

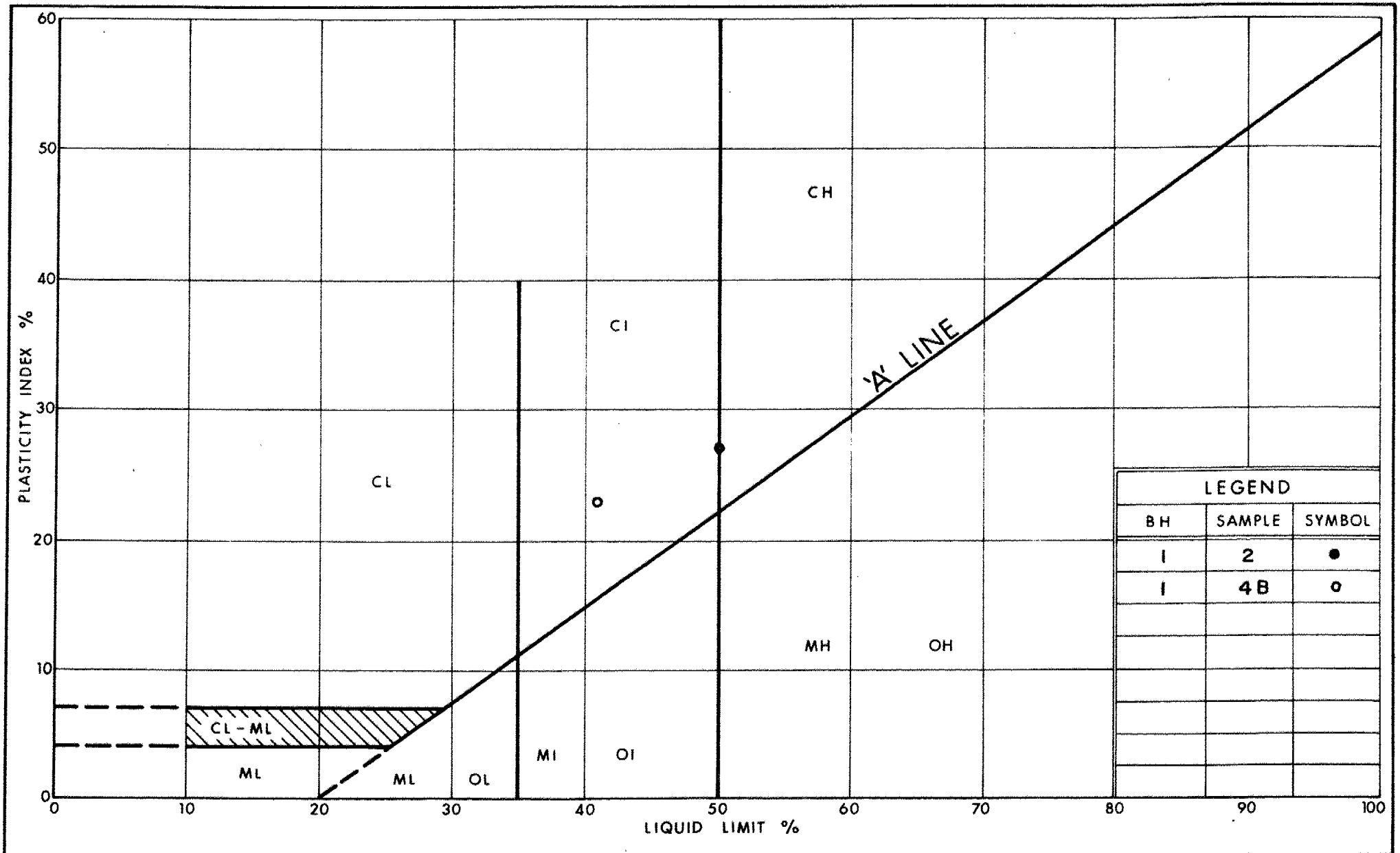
CLAY & SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



Ministry of Transportation and Communications
Ontario

GRAIN SIZE DISTRIBUTION
SILTY CLAY

FIG No 1
W P 87 – 80 – 04



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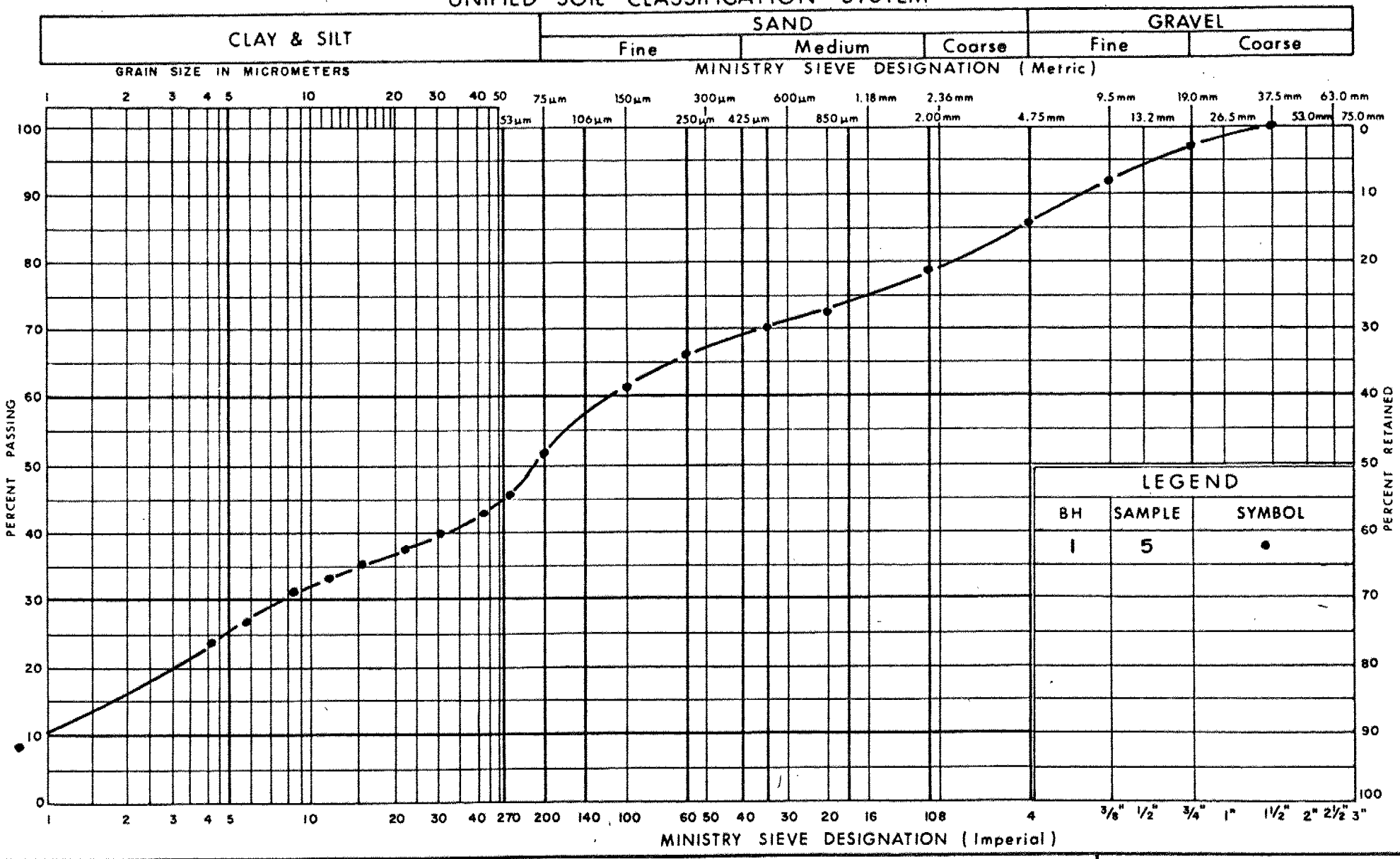
PLASTICITY CHART
SILTY CLAY

FIG No 2
W P 87 - 80 - 04

UNIFIED SOIL CLASSIFICATION SYSTEM



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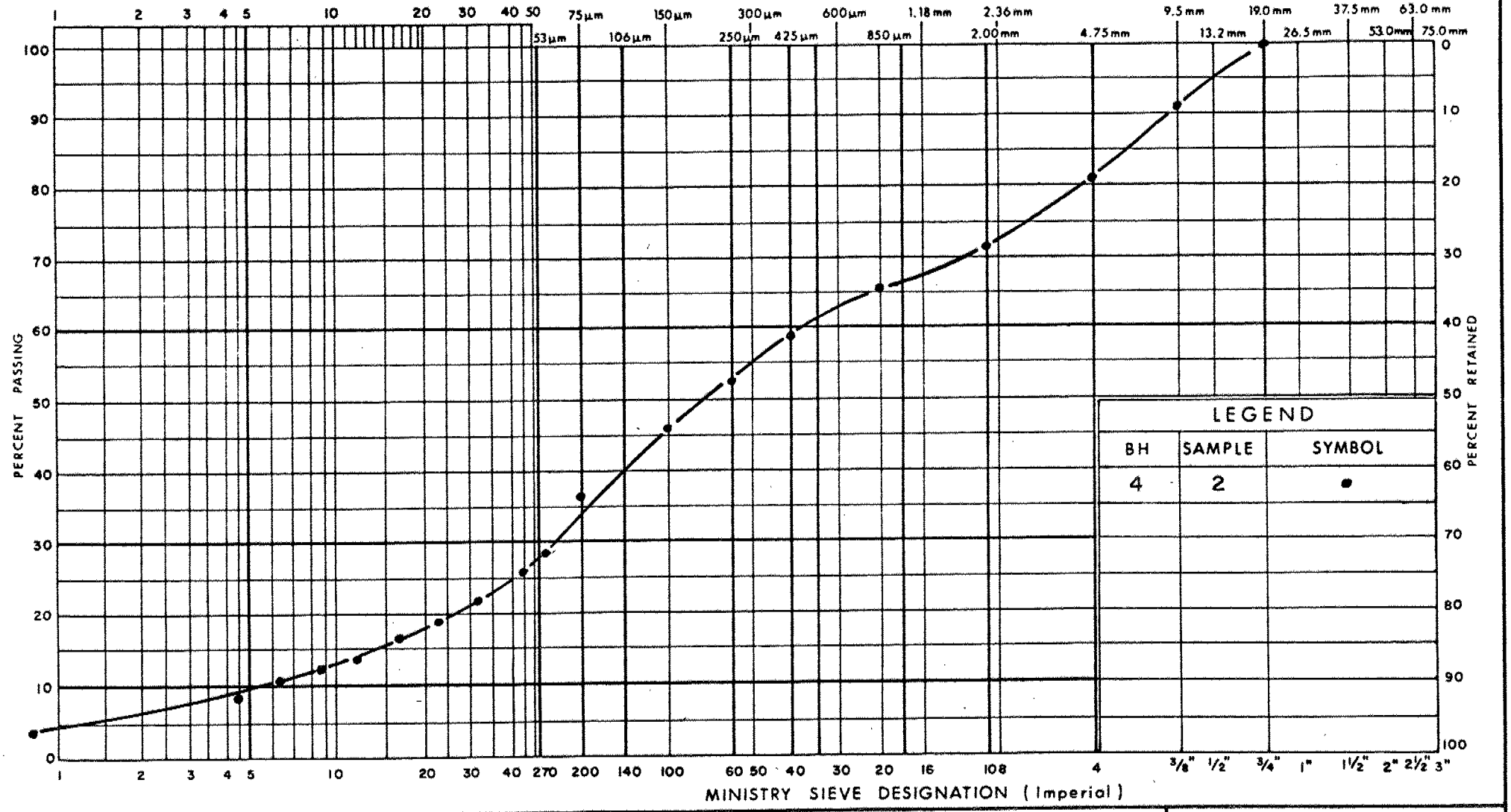
GRAIN SIZE DISTRIBUTION
CLAYEY SILTY SAND TILL

FIG No 3
W P 87 – 80 – 04

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



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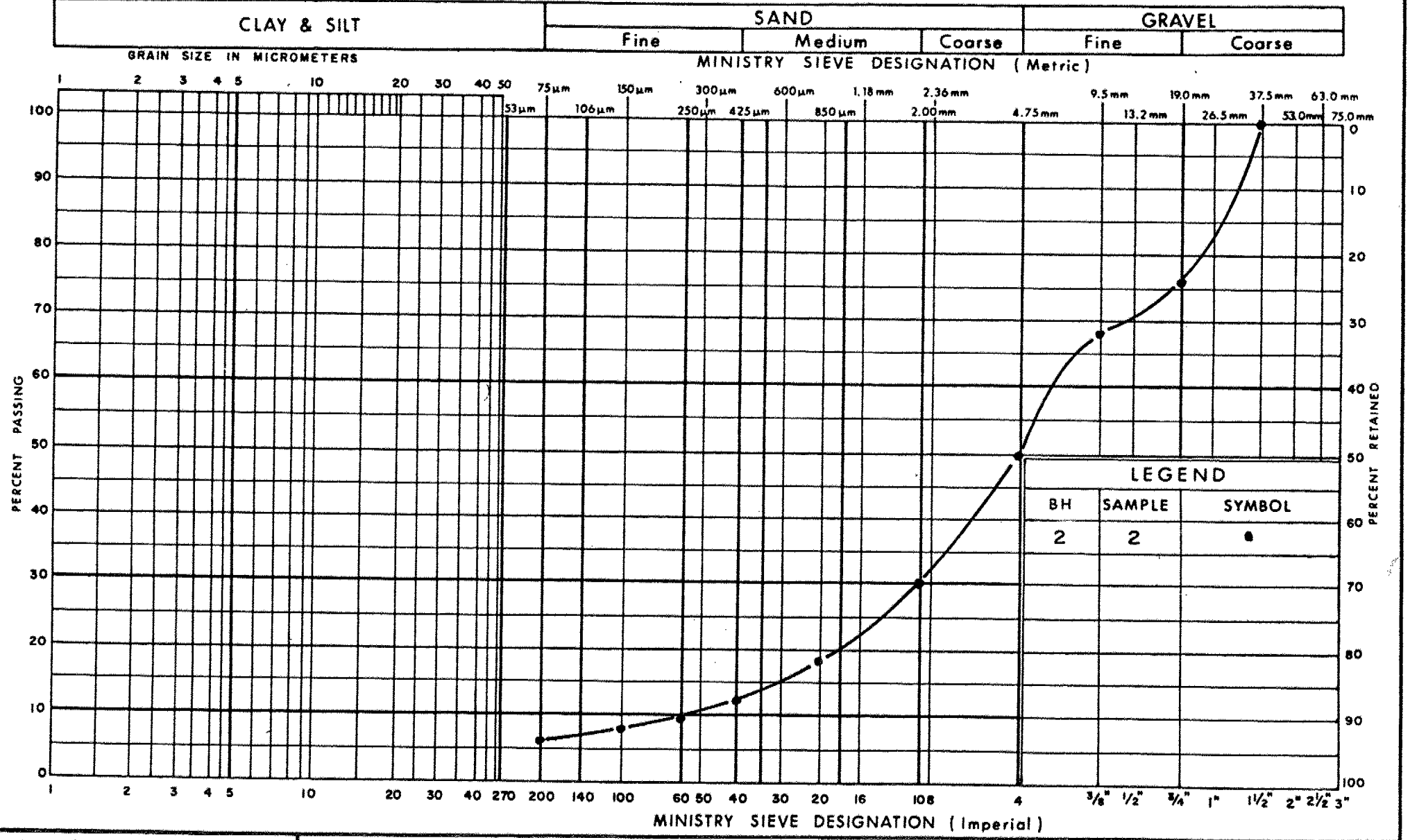
GRAIN SIZE DISTRIBUTION
SAND TILL

FIG No 4
WP 87 – 80 – 04

34

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of Transportation and Communications
Ontario

GRAIN SIZE DISTRIBUTION
SAND AND GRAVEL

FIG No 5
W P 87 - 80 - 04

ENGINEERING MATERIALS OFFICE
PAVEMENT & FOUNDATION DESIGN SECTION

WP 87-80-02 DIST 9

HWY 41 STR SITE 29-212

MUSKRAT RIVER BRIDGE

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FOUNDATION INVESTIGATION REPORT
For
Muskrat River Bridge
W.P. 87-80-02, Highway 41
District 9, Ottawa

INTRODUCTION:

This report summarizes the factual information obtained from a preliminary foundation investigation as well as a subsequent investigation carried out at the above site. Field work consisted of 5 sampled boreholes advanced between 80 10 21 and 80 10 22 and 3 sampled boreholes and one dynamic cone penetration test advanced during the period of 83 04 05 and 83 04 06. A track mounted drill equipped with hollow stem augers was employed for both investigations. Borings were advanced for depths ranging from 3.4 metres to 9.6 metres.

SITE DESCRIPTION

The site is located just southeast of the boundary of the Township of Stafford, the Township of Pembroke and the City of Pembroke. Approximately one kilometre north of its intersection with the Highway 17 Bypass, Highway 41 approaches the Muskrat River then curves to follow the river to the northwest. It is planned to eliminate this curve and cross the river at this point.

At the proposed crossing location, the Muskrat River is relatively slow flowing and is approximately 25 m in width and up to 1.2 m in depth. It flows in a broad valley with gentle slopes to the west, steeper slopes to the east, and approximately 23 m wide flood plain on the east side.

The surrounding area is predominantly agricultural. However, on the east side of the river is a row of residences with industrial properties located further to the north and east.

SURFACE CONDITIONS

Subsoil General

Generally, the subsoil consists of a deposit of silty clay of intermediate to high plasticity overlying a thin veneer of granular glacial till which in turn overlies limestone bedrock. The Muskrat River has eroded its valley through the overburden and has produced local deposits of silts and sands with organics in the floodplain adjacent to the river channel.

Reference should be made to the Borehole Logs located in the Appendix which show the boundaries between the different soil types as well as a summary of all field and laboratory tests performed. Reference should also be made to Drawing #878002-A which shows the location and elevation of all the boreholes as well as an inferred stratigraphical profile. The various soil types encountered are briefly described in the following paragraphs.

Silty Clay

This deposit is the predominant soil type in the vicinity of both abutments and is exposed in the valley slopes. It ranges from zero thickness under the river channel to 2.6 m and 6.7 m in the area of boreholes 2 and 100, and boreholes 5 and 103 respectively.

The results of Atterberg Limit and water content testing are plotted on the Plasticity Chart, Figure 1, and are summarized as follows:

		Range	Average
Water Content	(w)%	26-46	36
Liquid Limit	(W_L)%	29-52	38
Plastic Limit	(W_p)%	15-21	17
Plasticity Index	(I_p)%	13-31	21

These results indicate that the deposit is an inorganic silty clay of intermediate to high plasticity.

Undrained shear strengths, as measured by the field vane test, vary from greater than 105 kPa to as low as 20 kPa. Based on these measurements and unconfined laboratory compression tests, the silty clay has a very stiff to soft consistency. Sensitivities measured in the field and lab ranged from 2 to as high as 19 with an average value of 8. Based on these values, the silty clay is classified as a sensitive soil.

Glacial Till

A thin layer of glacial till lies between the silty clay and the underlying bedrock in the vicinity of the riverbanks. It varies in thickness from 0.6 m to 2.3 m and consists of a heterogeneous mixture of gravel, sand, silt and traces of clay.

Standard Penetration 'N' values ranged from 3 to over 100 blows per 0.3 m. This deposit is generally compact to very dense; however, a weaker zone of higher clay and moisture content exists at the contact with the overlying silty clay.

Silt and Sand with Organics

In the floodplain on the east side of the river, is an alluvial deposit consisting of a mixture of silt and sand with organics. This deposit is about 3.2 m in depth at borehole 102 and contains sufficient organic material near the surface to show some plasticity. At greater depth, the deposit is generally coarser with little or no organic material present. Standard Penetration 'N' values ranged between 1 and 3 indicating that this soil may be classified as very loose or very soft to soft.

Limestone Bedrock

The site is underlain by limestone bedrock which dips to the east. Its surface varies in elevation from ±118.5 on the west side of the river to ±114.8 in the vicinity of borehole 5. Generally, the limestone bedrock is sound across the site, except in the area of the channel. In this area, a ±1 m zone of fractured rock or a possible cavity exists.

Groundwater

The groundwater level is located at a depth of approximately 3 m in the vicinity of boreholes 5 and 103, and about 1 m in the vicinity of boreholes 2 and 100. It gradually decreases in depth until it reaches the surface at the river's edge. Artesian water was encountered in the fractured rock or cavity in the vicinity of boreholes 4 and 102. The water rose about 0.5 m above the ground surface during rock coring operations at borehole 102.

DISCUSSION AND RECOMMENDATIONS

General

It is proposed to realign Highway 41 as it approaches the Muskrat River approximately 1 km north of the Highway 17 Bypass, so that it crosses the river at this point. A two span (29 m - 29 m) structure has been proposed with two N.B.L. of 3.25 m and 3.50 m width, one 3.5 m wide S.B.L., and 2.0 m shoulders.

The proposed profile grade at the west abutment is about elevation 126.1 and at the east abutment is about 125.4. These grades will necessitate approach fill heights of about 5.6 m and 2.8 m respectively.

The predominant deposit in the vicinity of the proposed abutments and approach fills is a very stiff to soft sensitive silty clay varying from 2.0 m to 6.7 m in thickness. The silty clay is underlain by up to 2.3 m of compact to very dense glacial till, which in turn is followed by limestone bedrock.

The presence of the deposit of very stiff to soft highly compressible clay at the ground surface requires that steps be taken to ensure the overall stability of the approach embankments, and that settlements be taken into account. Hence, these factors will be discussed first.

Approach Embankments

Stability Considerations

1. West Approach

In order to achieve an adequate factor of safety against embankment failure with the abutment in its proposed location, it will be necessary to remove some of the silty clay from beneath the approach fill (as shown in Fig. 2, Sketch 1A) and replace it with a non cohesive granular type backfill. The excavation must be carried out in longitudinal strips, with the width of the base not exceeding 3 m (as shown in Fig. 2, Sketch 1B). The elevations given in the figure are approximate and depend on the prevailing river level elevation. It is desirable to excavate to as low an elevation as the water level will allow.

Alternatively, a midheight berm of minimum 6 m length with a forward slope of 2-1/2:1 will be necessary. This berm will necessitate lengthening the structure by about 6 m to ensure that the approach fill and berm will not encroach upon the river.

The berm should extend in both the longitudinal and transverse directions. It should be tapered to nil in the transverse direction at about station 20+235.

2) East Approach

To ensure the stability of the east approach, it is recommended to place free draining sand type fill approximately from station 20+278 at about elevation 120.7, to station 20+307 at elevation 122.0. This fill should be in place prior to placing the approach fill of the east abutment.

The slope of the approaches should not be steeper than 2-1/2:1.

Settlement Considerations

West Approach

If the berm option is chosen, settlements of up to 18 cm can be expected.

For the excavation option, settlements of up to 10 cm can be expected.

East Approach

Settlement of up to 8 cm can be expected.

In view of the anticipated settlements, it is recommended that the fills be in place for as long as possible prior to construction of the approach slabs and the paving operations.

All organic or softened material should be stripped from within the planned limits of the approach embankment and berms prior to placement of any fill.

Structure Foundations

In view of the artesian water conditions encountered at the proposed pier location, and the relatively low strength and high sensitivity of the silty clay at the proposed abutment locations, it is recommended that the pier as well as the abutments be supported on end bearing concrete caissons socketted into sound limestone bedrock.

Assuming a 0.762 m 0 concrete caisson (30 in.), the pier and abutments can be designed to the following O.H.B.D.C. parameters at the following elevations given.

	Founding Elevation	Factored Capacity at U.L.S.	Capacity at S.L.S.
West Abutment (BH 2 and 100 location)	117.0	4450 kN	1780 kN
Pier (BH 4 and 102 location)	115.3	4450 kN	1780 kN
East Abutment (BH 5 and 103 location)	115.2	4450 kN	1780 kN

Other Considerations

The caissons should be advanced with the aid of a steel liner of sufficient length so as to extend above the artesian head. Once the caisson has been extended to its proper elevation, concrete can be tremmied into the caisson within the liner.

In view of the difficulty of constructing the pile cap in the dry for the pier, it is recommended to extend the caissons to immediately below the bridge deck.

The base of all foundation elements should be protected from frost action by a minimum of 1.7 m of earth cover.

The forward slopes of the approach fills should be protected from erosion by placing rip-rap at the river banks.

Backfill to the structure abutments should consist of free draining granular material.

MISCELLANEOUS

The fieldwork for this investigation was carried out in 1980 under the supervision of Mr. Richard Burgess, Student Technician, utilizing equipment owned and operated by Atcost Soil Drilling, Concord, and by Mr. Brian Ruck, Trainee Engineer in 1983, utilizing equipment owned and operated by Johnston Drilling Co., Ottawa. This report was written by Mr. Ruck and was reviewed by Mr. M. Devata, Senior Foundations Engineer.

Brian Ruck

Brian Ruck
Project Engineer

M. Devata

M. Devata, P.Eng.,
Senior Foundations Engineer

A P P E N D I X

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 1 METRIC

W P 87-80-02 LOCATION Sta. 20 + 231.9; o/s 3.4 m RT ℄ Hwy. 41 ORIGINATED BY RB
DIST 9 HWY 41 BOREHOLE TYPE Hollow Stem Auger, BXL Rock Core & Cone Test COMPILED BY PJS
DATUM Geodetic DATE 1980 10 21 CHECKED BY BER

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) (25 50 75 100 125)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
124.2	Ground Surface										
0.0	Silty clay Very stiff to stiff Grey		1	SS	14		124				
			2	TW	PH						
			3	SS	11		122				
			4	TW	PH						
			5	SS	11			+ >105			
			6	TW	PH		120	9 +			
119.2											
5.0			7	SS	2						
118.5	*		8	SS	27	25cm		Piezometer			
5.7			9	BXL RC	50% REC		118				RQD=25
	Limestone bedrock Sound		10	BXL RC	80% REC						RQD=37
116.5											
7.7	End of Borehole										
	*Heterogeneous mixture of gravel sand and silt trace of clay very dense (Glacial till)										

+3, ×5 : Numbers refer to Sensitivity

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

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 2 METRIC

W P 87-80-02 LOCATION Sta. 20 + 252.3; o/s 3.7 m RT ℄ Hwy. 41 ORIGINATED BY RB
DIST 9 HWY 41 BOREHOLE TYPE Hollow Stem Auger, BXL Rock Core & Cone Test COMPILED BY PJS
DATUM Geodetic DATE 1980 10 21 CHECKED BY BER

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) (25 50 75 100 125)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
120.7	Ground Surface										
0.0 / 118.7	Silty clay Soft		1	SS	6		120	1.8 +	o		
2.0 / 117.3	Het. mix. of gravel, sand and silt, trace of clay (Glacial till) Loose to dense		2	SS	7		118				36 24 31 9
			3	SS	44/23 cm						
3.4 / 115.4	Limestone bedrock Sound		4	BXL RC	30% REC		116				RQD=35
5.3	End of Borehole										

OFFICE REPORT ON SOIL EXPLORATION

+3, ×5 : Numbers refer to Sensitivity

15 20/10 5 (%) STRAIN AT FAILURE

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RECORD OF BOREHOLE No 3 — METRIC

W P 87-80-02 LOCATION Sta. 20 + 243.2; o/s 1.5 m RT ℄ Hwy. 41 ORIGINATED BY RB
DIST 9 HWY 41 BOREHOLE TYPE Hollow Stem Auger COMPILED BY PJS
DATUM Geodetic DATE 1980 10 22 CHECKED BY BER

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) (25 50 75 100 125)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
122.1	Ground Surface						122				
0.0	Silty Clay Stiff to Very Stiff		1	TW	PH					19.0	
120.0							120				
2.1	Het. mix. of gravel, sand and silt, trace of clay (Glacial till) Very loose to compact		2	SS	12						
			3	SS	3			+3			24 38 31 7
117.7			4	SS	28		118				
4.4	Refusal to auger Probable bedrock End of Borehole										

+3, ×5 : Numbers refer to Sensitivity

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

OFFICE REPORT ON SOIL EXPLORATION

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RECORD OF BOREHOLE No 4

METRIC

W P 87-80-02 LOCATION Sta. 20 + 280.4; o/s 9.1 m RT ℄ Hwy. 41 ORIGINATED BY RB

DIST 9 HWY 41 BOREHOLE TYPE Hollow Stem Auger & BXL Rock Core COMPILED BY PJS

DATUM Geodetic DATE 1980 10 22 CHECKED BY BER

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
119.5	Ground Surface										
0.0	Silty sand with organics very loose		1	SS	2		118				
			2	SS	3						
117.0			3	SS		Hammer Bounding					
2.5	Limestone bedrock weathered		4	BXL	70%						
115.9			5	BXL	30%		116				
3.6	Sound		6	BXL RC	84% REC						RQD=70
114.3											
5.2	End of Borehole										

+3, ×5 : Numbers refer to Sensitivity

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

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 5 METRIC

W P 87-80-02 LOCATION Sta. 20 + 310.9; o/s 7.6 m RT ℄ Hwy. 41 ORIGINATED BY RB
DIST 9 HWY 41 BOREHOLE TYPE Hollow Stem Auger & BXL Rock Core COMPILED BY PJS
DATUM Geodetic DATE 1980 10 22 CHECKED BY BER

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa 25 50 75 100 125 (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
122.9	Ground Surface										
0.0	Silty clay Stiff to soft Sensitive		1	SS	7		122			18.2	
			2	TW	PH						
			3	TW	PH						
			4	TW	PH	▽	120				
			5	TW	PH						
			6	SS	3		118				
116.2			7	SS	3						
6.7	Het. mix. of gravel, sand and silt, trace of clay (Glacial till) V. Dense		8	SS	100/23 cm		116				
114.8											
8.1	Limestone Bedrock Sound		9	BXL RC	97% REC		114				RQD=75
113.3											
9.6	End of Borehole										

+3, ×5 : Numbers refer to Sensitivity

15 20 10 5 (%) STRAIN AT FAILURE

OFFICE REPORT ON SOIL EXPLORATION

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RECORD OF BOREHOLE No 100 METRIC

W P 87-80-02 LOCATION Sta. 20 + 250.0; o/s 5.0 m LT ℄ Hwy. 41 ORIGINATED BY BER
DIST 9 HWY 41 BOREHOLE TYPE Hollow Stem Auger, BXL Rock Core COMPILED BY BER
DATUM Geodetic DATE 1983 04 05 CHECKED BY

SOIL PROFILE ELEV/DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
121.0 Ground Surface								20 40 60 80 100 / 25 50 75 100 125	20 40 60		
0.0	Silty clay Firm to very soft Sensitive		1	SS	8	▽	120				
			2	SS	2						
118.4			3	TW	PM			$8_{\times}$ $+^{8}$		18.9	
2.6	*		4	SS	4						19 41 31 9
117.8			5	SS	-		118				
3.2	Limestone - white		CR% 70		RQD% 45			Weathering: Slight	Strength: High	Jointing: Close Spaced Bedding	BXL RC
	no recovery-poss. cavity		0		0			—	—	—	
	Limestone with alt black (probably soft) shale seams		78		56		116	unweathered	high	Close Spaced Bedding	
115.4											
5.6	End of Borehole										
	*Heterogeneous mixture of sand and silt, some gravel, trace of clay (Glacial till) loose										

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

$15 \overset{20}{\underset{10}{\diamond}} 5$ (%) STRAIN AT FAILURE

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

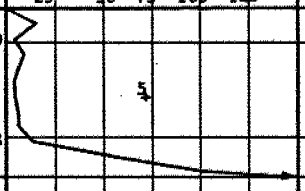
RECORD OF BOREHOLE No 101 METRIC

W P 87-80-02 LOCATION Sta. 20 + 251.0; o/s 8.0 m RT ℄ Hwy. 41 ORIGINATED BY BER

DIST 9 HWY 41 BOREHOLE TYPE Cone and Vane Test COMPILED BY BER

DATUM Geodetic DATE 1983 04 05 CHECKED BY BP.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa: o UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE; 25 50 75 100 125	WATER CONTENT (%)		GR SA SI CL
120.7	Ground Surface										
0.0	Probable Silty clay						120				
118.1											
2.6	Probable sand and gravel till						118				
117.3											
3.4	End of Cone Test										



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

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

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RECORD OF BOREHOLE No 102 METRIC

W P 87-80-02 LOCATION Sta. 20 + 284.0; o/s 4.5 m LT ℄ Hwy. 41 ORIGINATED BY BER
DIST 9 HWY 41 BOREHOLE TYPE Hollow Stem Auger - BXL Rock Core COMPILED BY BER
DATUM Geodetic DATE 1983 04 06 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 (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
119.7	Ground Surface										
0.0	Silt and sand with organics very loose		1	SS	1		Artesian Head				
			2	SS	1		118				
			3	SS	2						9 74 13 4
116.5	Coarser with traces fine gravel		4	SS	2	Hammer Bouncing					
3.2	Limestone - brn grey brn-poss cavity-probable aquifer		CRZ 63	RQDZ 42		Artesian Encountered	116	Weathering: SW at top to HW at prob aquifer zone	Strength: High	Jointing	BXL RC
	Limestone - grey with occasional solution features (mainly small holes 8-15 mm ø)		89	77			114	unweathered	High	Predominantly bedding, close to moderate spacing	
112.6											
7.1	End of Borehole										

NOTE:
SW = slightly weathered
HW = highly weathered

+3, ×5 : Numbers refer to Sensitivity

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

OFFICE REPORT ON SOIL EXPLORATION

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RECORD OF BOREHOLE No 103 METRIC

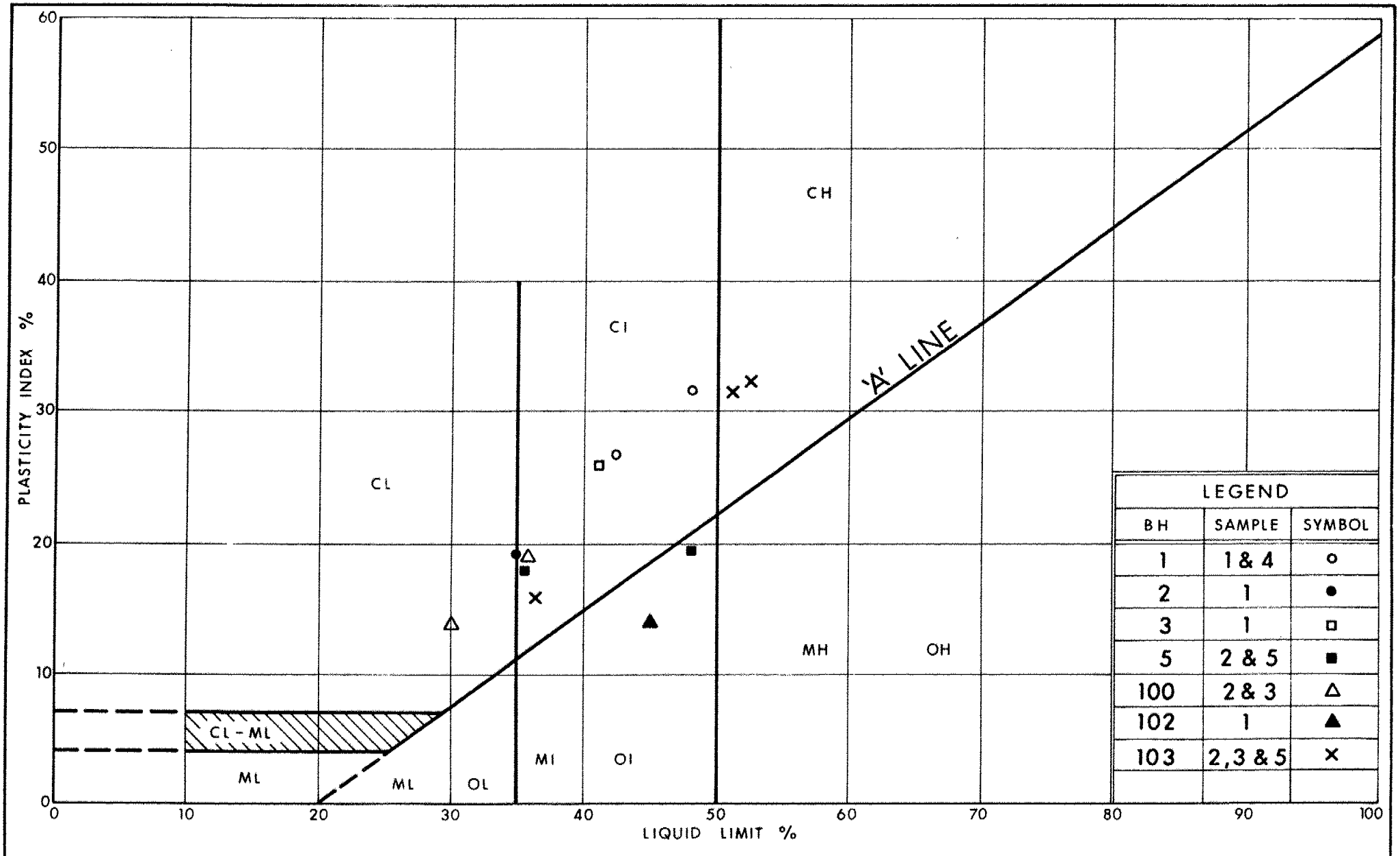
W P 87-80-02 LOCATION Sta. 20 + 310.6; o/s 4.0 m LT ℄ Hwy. 41 ORIGINATED BY BER
DIST 9 HWY 41 BOREHOLE TYPE Hollow Stem Auger - BXL Rock Core COMPILED BY BER
DATUM Geodetic DATE 1983 04 06 CHECKED BY GP

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) (25 50 75 100 125)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
122.4	Ground Surface										
0.0 / 121.2	Fill- silty sand with organics and some clay loose		1	SS	5		122				
1.2	Silty clay Stiff to soft Sensitive		2	SS	9						
			3	TW	PH		120				
			4	TW	PM					17.7	
			5	TW	PM		118			17.4	
116.7			6	TW	PM					18.1 18.5	
5.7 / 115.2	Het. mix. of gravel, sand and silt, trace of clay, occ. boulder (Glacial till) Compact		7	SS	24		116				28 36 27 9
7.2 / 113.6	* Limestone-white-grey with occ. solution cavities (8-15 mm ϕ)		CR% 90		RQD% 82		114	Weathering: unweathered / unweathered; Strength: high / high	Jointing: Close Spaced Bedding / Moderate Spaced Bedding		BXL RC
8.8	End of Borehole										

*Limestone - grey with occasional thin black shale partings

+3, ×5 : Numbers refer to Sensitivity

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



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PLASTICITY CHART
SILTY CLAY

FIG No 1
WP 87-80-02

OVERSIZE DRAWING

EXPLANATION OF TERMS USED IN REPORT

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

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

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

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

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

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

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

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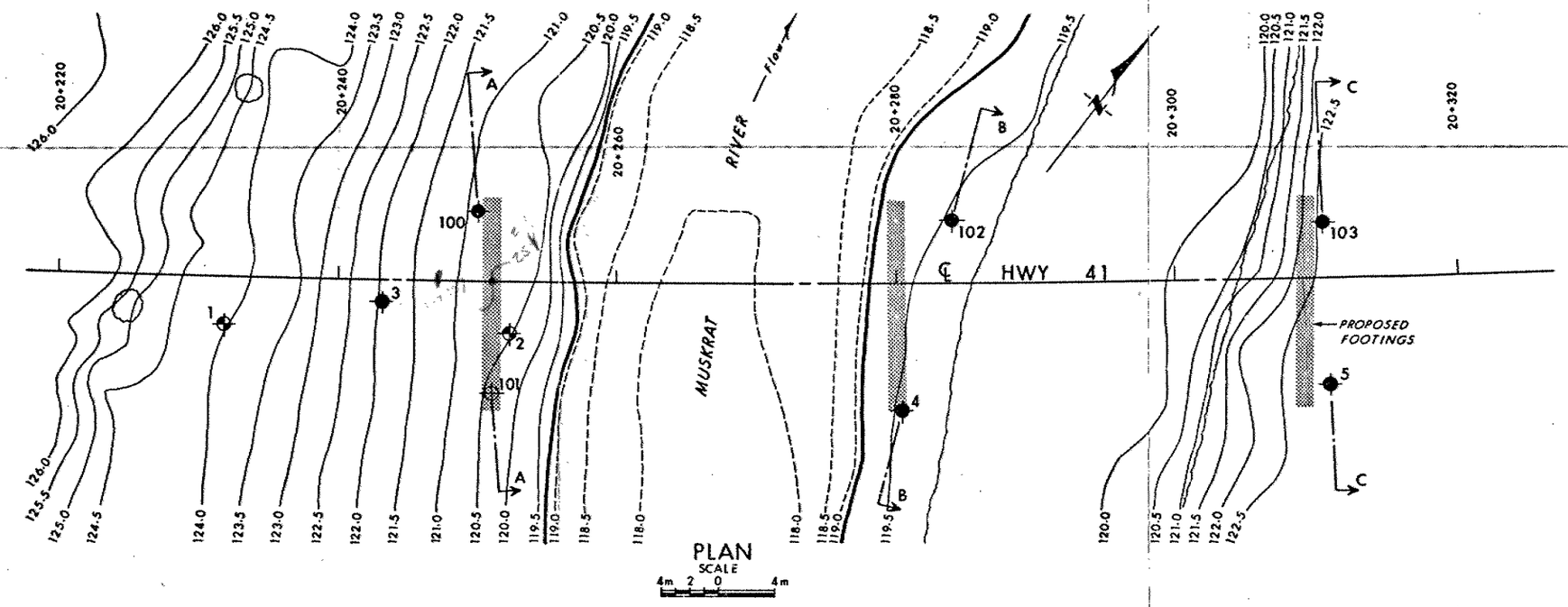
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No
WP No 87-80-02

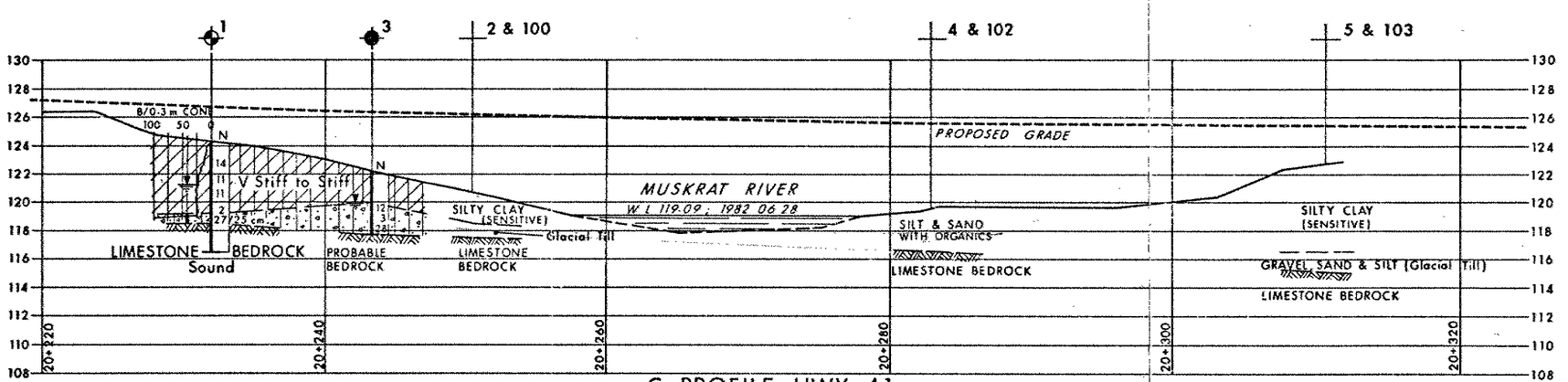
MUSKRAT RIVER

BORE HOLE LOCATIONS & SOIL STRATA

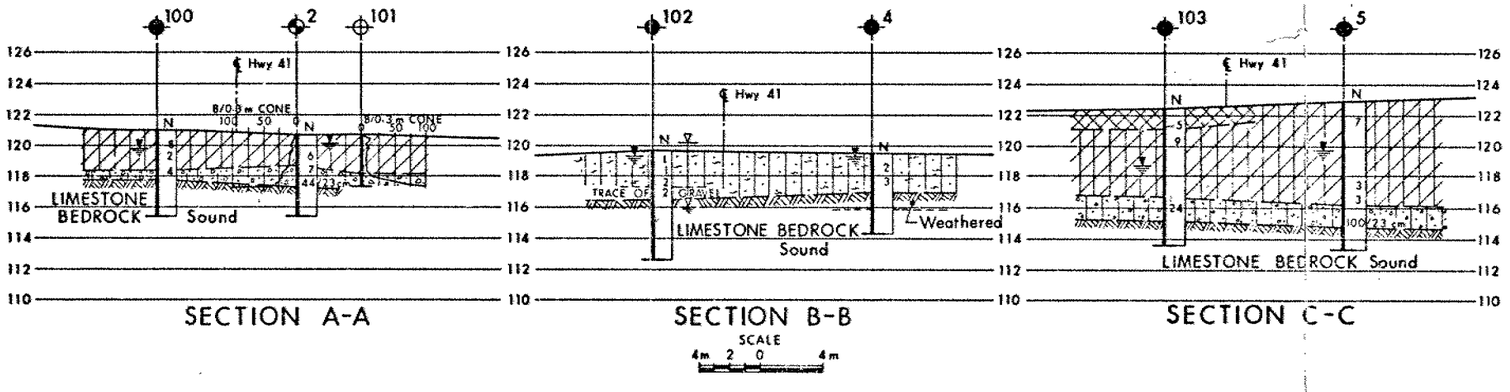
SHEET



PLAN
SCALE 4m 2 0 4m



℄ PROFILE HWY 41
SCALE 4m 2 0 4m



SECTION A-A
SECTION B-B
SECTION C-C
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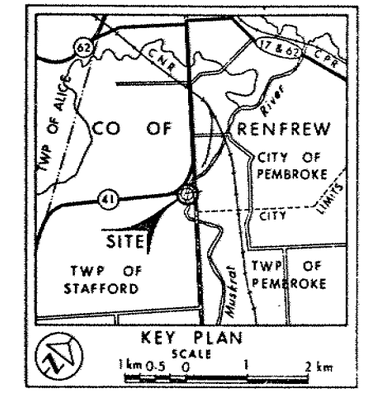


LEGEND

- Bore Hole
- Dynamic Cone Penetration Test (Cone)
- Bore Hole & Cone
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- W L at time of investigation 1980 10 and 1983 04
- Piezometer
- Artesian Head
- Artesian Encountered

No	ELEVATION	STATION	OFFSET
1	124.2	20+231.9	3.4m Rt
2	120.7	20+252.3	3.7m Rt
3	122.1	20+243.2	1.5m Rt
4	119.5	20+280.4	9.1m Rt
5	122.9	20+310.9	7.6m Rt
100	121.0	20+250.0	5.0m Lt
101	120.7	20+251.0	8.0m Rt
102	119.7	20+284.0	4.5m Lt
103	122.4	20+310.6	4.0m Lt

SOIL STRATIGRAPHY LEGEND

- FILL, SILTY SAND WITH ORGANICS & SOME CLAY Loose
- SILTY CLAY (SENSITIVE) Stiff to Very Soft
- SILT AND SAND WITH ORGANICS Very Loose
- HET MIXTURE OF GRAVEL, SAND & SILT TRACE OF CLAY (Glacial Till) Very Loose to Very Dense

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

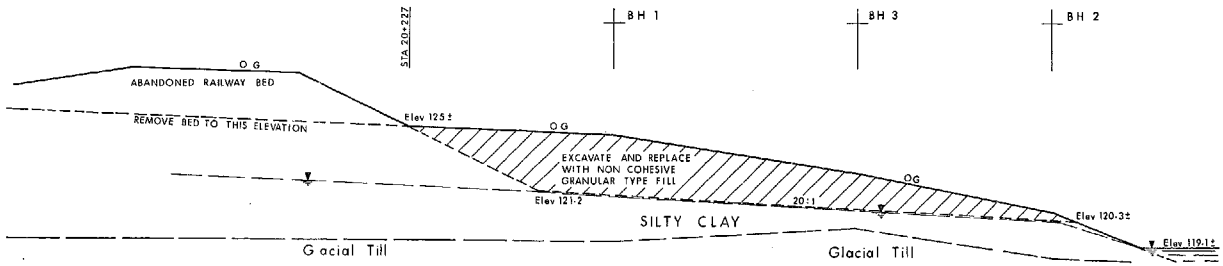
NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2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

REV	DATE	BY	DESCRIPTION

Geocres No 31F-100

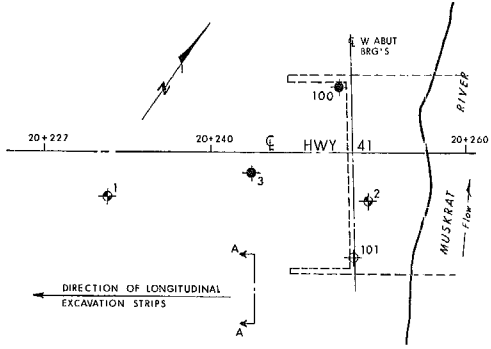
HWY No 41			DIST 9
SUBMITTED	CHECKED	DATE 1983 05 18	SITE 29-212
DRAWN	CHECKED	APPROVED	DWG 878002-A

REF No E-7007-1 ; 1982 09

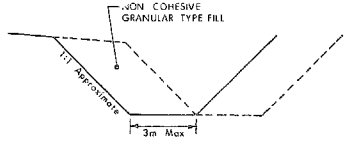


SKETCH 1A: EXCAVATION FOR WEST APPROACH

NTS



SKETCH 1B: RECOMMENDED EXCAVATION METHOD FOR WEST APPROACH



SECTION A-A

NTS

NOTES

1. First step is to remove the abandoned Railway bed to elevation 125 ±
2. Elevations given are minimum excavation limits and it would be desirable to excavate to as low an elevation as the groundwater will allow.
3. Excavations should be carried out in longitudinal strips as shown in sketch 1B

Geocres No 31F-100

Ministry of Transportation and Communications, Ontario	MUSKRAT RIVER EXCAVATION DETAILS WEST APPROACH		
	HWY 41 CO OF RENFREW	TWP OF STAFFORD	
DATE 1983 05 17	W P 87-80-02	DIST 9	Figure No 2