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G.I.-30 SEPT. 1976

GEOCRES No. 40P2-46

DIST. 2 REGION

W.P. No. 479-89-04

CONT. No. 92-06

W. O. No.

STR. SITE No. 23-208

HWY. No. 401

LOCATION Hwy 401 & Culloden Rd.

No of PAGES -

OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

GEOTECHNICAL INVESTIGATION
CULLODEN ROAD NEW UNDERPASS
DISTRICT 2 (LONDON)
SOUTHWESTERN REGION
FOR
MINISTRY OF TRANSPORTATION, ONTARIO
W.P. 479-89-04
SITE 23-208 (NEW STRUCTURE)

CONT 92-06

PetoMacCallumLtd.
CONSULTING ENGINEERS

GEOTECHNICAL INVESTIGATION
CULLODEN ROAD NEW UNDERPASS
DISTRICT 2 (LONDON)
SOUTHWESTERN REGION
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MINISTRY OF TRANSPORTATION, ONTARIO
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CONT 92-06

GEOCRES # 40P2-46

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Job No. 90 TF 098

October, 1990

PetoMacCallum Ltd.
CONSULTING ENGINEERS

Job No. 90 TF 098 October 26, 1990

Mr. M. S. Devata, P.Eng,.
Chief Foundation Engineer
The Ministry of Transportation, Ontario
Foundation Design Section
Room 315, Central Building
1201 Wilson Avenue
Downsview, Ontario
M3M 1J8

Gentlemen

Re: Geotechnical Investigation
Culloden Road New Underpass
District 2 (London) Southwestern Region
W.P. 479-89-04

We are pleased to present our report for the geotechnical investigation carried out for the above noted project as authorized in Agreement number 4240-9190-092.

The stratigraphy encountered at the site generally comprised surficial topsoil overlying a clayey silt fill material. The fill material was underlain by a discontinuous deposit of sand over major deposits of sandy silt glacial till, lower sand and lower sandy silt glacial till.

Perched groundwater was noted in the upper sand layers as well as the water bearing sand seams within the sandy silt glacial till stratum. Groundwater was also observed in the underlying sand stratum.

Considering the relatively heavy foundation loadings and inconsistent strength of the native soils contacted at shallow depth, a driven pile foundation appears to be the preferred means of supporting the proposed bridge structure. In general, the piles may be driven to adequate set into the very dense sand below a depth of about 12.5 to 16.0 m (approximate elevation 276.0 to 272.0), depending on the type of piles to be chosen.

165 Cartwright Avenue, Toronto, Ontario M6A 1V5
Tel: (416) 785-5110 Fax: (416) 785-5120
OFFICES IN TORONTO, HAMILTON, KITCHENER, BARRIE, OSHAWA

The report presents parameters for design of abutments and approach embankments and discusses situations that will be encountered during construction including excavation slopes and groundwater control.

We believe this report has been completed within our terms of reference and trust the information presented herein is sufficient for your present requirements.

Should you have any questions, or when we may be of further assistance to you during the construction phase of the project, please do not hesitate to contact our office. We appreciate this opportunity to be of service to the Ministry of Transportation, Ontario.

Sincerely
Peto MacCallum Ltd.

REGISTERED PROFESSIONAL ENGINEER
A. E. GORMAN
PROVINCE OF ONTARIO

Alastair E. Gorman, P.Eng.
Manager - Toronto
Geotechnical Engineering

AEG:myb

Peto MacCallum Ltd.
CONSULTING ENGINEERS

TABLE OF CONTENTS

1. INTRODUCTION

Peto MacCallum Ltd. was authorized by The Ministry of Transportation, Ontario, Agreement number 4240-9190-092 dated September 4, 1990, to carry out a geotechnical investigation at the site of the proposed bridge structure at Highway 401 and Culloden Road interchange in District 2 (London), Ontario.

The proposed bridge will be a four (4) span structure, approximately 129 m long and will be located on the west side of the existing bridge structure which will not remain in service. Construction of approach fills to the bridge is also required.

The purpose of the investigation was to determine the subsurface soils and groundwater conditions at the site and, based on this information, to provide geotechnical recommendations pertaining to the design and construction of the proposed structure and approach embankments.

2. FIELDWORK

The fieldwork for the investigation was carried out during the period August 27 to 30, 1990, and comprised four (4) sampled boreholes and four (4) dynamic cone penetration tests put down to depths of 14.85 to 18.50 m below existing grade as shown on the appended plan.

The boreholes were advanced using a CT-150 track mounted drillrig equipped with continuous flight hollow stem augers. The drillrig was supplied and operated by London Soil Test.

Representative samples of the overburden were secured at regular intervals throughout the depth explored. Standard penetration resistance tests were carried out during sampling operations using conventional split spoon equipment.

The groundwater conditions in the open boreholes were monitored during and after the completion of drilling. A piezometer was installed in borehole 4 for monitoring the stabilized groundwater conditions.

The fieldwork was supervised throughout by a member of our engineering staff who directed the drilling and sampling operations, documented the soil stratigraphy encountered, monitored groundwater conditions and processed the recovered samples.

The locations and ground surface elevations of the boreholes were established in the field by Peto MacCallum Ltd. The ground surface elevations have been referred to the following benchmark (B.M.), as shown on Ministry of Transport, Ontario Plan E-90-401-1.

B.M.: Department of Highways, Ontario Benchmark number 252-67; circular brass plaque on southeast corner of the existing bridge wall facing north.

Elevation: 288.790 (Geodetic, metric)

3. LABORATORY TESTING PROGRAMME

All recovered samples were brought to our laboratory for detailed visual examination and testing to confirm field classification. The following tests were carried out:

i) Natural moisture content determinations on all recovered samples, with results shown on the appended Record of Borehole sheets;

ii) Nine (9) grain size analyses with results illustrated on Figures 1 through 3 and the appended Record of Borehole sheets;

iii) Two (2) Atterberg limits with results presented on Table 1, Figure 4 and the appended Record of Borehole sheets;

iv) Five (5) unit weight determinations on representative soil samples and the results are shown on the appended Record of Borehole sheets.

4. SITE DESCRIPTION

The site is located on the existing Highway 401 approximately 2.7 km west of Highway 19 in the Township of Southwest Oxford in Oxford County. The natural ground surface at the site is relatively flat, ranging from elevation 287.55 to 288.46 at the borehole locations.

Based on the available geological mapping, the surficial material at the site comprises Port Stanley Till. This Port Stanley Till sheet overlies Erie Interstadial glaciolacustrine sediments.

5. SUMMARIZED SUBSURFACE CONDITIONS

5.1 General

Reference is made to the appended Record of Borehole sheets for details of the fieldwork, including soil classification, inferred stratigraphy, standard penetration 'N' values, dynamic cone penetration tests, moisture content determinations and Atterberg limit test results, together with groundwater observations in the open boreholes and installed piezometer. Ground surface elevations and locations are also marked on the Record of Borehole sheets.

The summarized subsurface conditions are presented on a profile included on the appended plan.

The stratigraphy at the site, as revealed in the boreholes, generally comprised surficial topsoil overlying a clayey silt fill material. The fill material was underlain by a discontinuous sand deposit over major deposits of sandy silt glacial till, lower sand and lower sandy silt glacial till.

5.2 Overburden

5.2.1 Topsoil

Surficially, 600 to 900 mm of brown clayey silt topsoil with organic content was contacted throughout the site.

5.2.2 Clayey Silt (Fill)

Underlying the surficial topsoil at the site, a clayey silt fill material was contacted to depths of 2.70 to 3.70 m. The fill typically comprised brown clayey silt with trace sand and gravel. Scattered topsoil inclusions were noted at borehole 1. Moisture contents ranged between 9 and 28%.

Based on standard penetration 'N' values, the consistency of the fill stratum was typically stiff.

5.2.3 Sand

At borehole 4, a discontinuous deposit of sand was contacted below the clayey silt fill, and extended to 6.10 m depth. The material comprised brown fine to medium sand, some silt and some gravel. A grain size distribution curve for a representative sample of the material is presented on Figure 1. Natural moisture contents ranged from 8 to 18%.

Based on standard penetration 'N' values, the denseness of the sand deposit was compact to very dense.

5.2.4 Sandy Silt (Glacial Till)

A major stratum of sandy silt glacial till was contacted in all the boreholes beneath the clayey silt fill or sand, and extended to depths of 9.00 to 12.95 m. This till stratum typically consisted of brown to grey sandy silt, some clay and trace to some gravel. Grain size distribution envelope for five (5) representative samples of the material are shown on Figure 2.

Atterberg limit tests were carried out on a representative sample of the stratum. Test results are summarized on Table 1 and illustrated on Figure 4. Atterberg limits gave values of 16 for the liquid limit and 11 for the plastic limit resulting in a plasticity index of 5. Moisture contents varied between 9 and 18% but were typically in the 12 to 15% range.

The denseness of the sandy silt glacial till stratum, as determined from the field standard penetration tests, varied from loose to very dense but was typically in the compact state.

5.2.5 Sand

The sandy silt glacial till was underlain throughout the site by a lower sand deposit which extended down to depths of 14.87 to 17.00 m. In general, the stratum was described as brown to grey fine to medium sand, trace to some silt, with some gravel. Grain size distribution curves for two (2) representative samples of the sand material are shown on Figures 1 and 3. Moisture contents ranged between 9 and 22% indicating wet to saturated conditions.

The denseness of the sand stratum, as determined from the field standard penetration tests, was typically compact to very dense. Boreholes 3 and 4 were terminated within the sand stratum at depths of 15.69 and 14.87 m respectively.

5.2.6 Sandy Silt (Glacial Till)

In boreholes 1 and 2, the sand stratum was fully penetrated at depths of 17.00 to 16.70 m, respectively, and was underlain by the second occurrence of the sandy silt glacial till sheet which extended down to the termination depth of the boreholes. A grain size distribution envelope for representative samples of the sandy silt glacial till material is provided on Figure 2. Atterberg limit tests results are shown on Table 1 and Figure 4. The material was typically very dense with moisture contents ranging between 7 and 9%.

5.3 Groundwater Conditions

Observations of groundwater in the boreholes during and upon completion of drilling, as well as piezometer readings are noted on the individual borehole records. Upon completion of drilling, groundwater was recorded at depths of about 3.0 to 7.6 m below existing grade (elevation 280.5 to 284.8) in all the boreholes. The piezometer installed in borehole 4 indicated the stabilized groundwater level lies about elevation 285.2. The water appeared to come from random wet sand layers within the sandy silt glacial till as well as the saturated sand deposit at depth. Seasonal fluctuations should be expected.

The results of pH and sulphate content determinations conducted on a groundwater sample showed a pH value of 7.3 and a sulphate content of 70 ppm as SO_4. The measurements indicate a 'negligible' degree of sulphate attack on buried concrete structures. For information regarding the type of cement for concrete structure below water table, reference is made to CSA-A23.

6. ENGINEERING DISCUSSION AND RECOMMENDATIONS

6.1 General

It is proposed to construct a new underpass just west of the existing structure on Highway 401 and Culloden Road interchange as part of the Highway 401 widening programme. It is understood that the proposed bridge will be a four (4) span structure. Construction of approach fills to the bridge is also required.

6.1.1 Foundations

Based on the information revealed in the boreholes drilled at the site, it is considered that the site is generally suitable for construction of the proposed structure. However, in view of the relatively heavy foundation loadings and inconsistent strength of the native soils encountered at shallow depths, it is recommended to support the proposed structure on a driven pile foundation. It is considered that high capacity end bearing piles such as steel tube pipe (concrete filled) or 'H' piles driven into the underling dense to very dense sand stratum will be most practical to support the proposed piers and abutments. The suggested design capacities for various piles and anticipated founding levels are given below:

Pile Type	Location	Anticipated Founding Depth (m)	Anticipated Tip Elevation	Design Capacity (kN) ULS	Design Capacity (kN) SLS
Steel tube 406 O.D. x 12.7 Wall	North Abutment, and North Pier	12.5-14.5	274-276	700	445
	South Abutment, South and North Piers	15.0-16.0	273-272	700	445
Steel tube 324 O.D x 6.3 Wall	North Abutment, and North Pier	12.5-14.5	274-276	445	356
	South Abutment, South and Centre Piers	15.0-16.0	273-272	445	356
HP310 x 79	North Abutment, and North Pier	17.5-20.5	270-268	400	350
	South Abutment, South and Centre Piers	20.0	268	400	350

In the vicinity of borehole 4 (south abutment), excavation of surficial dense soil or pre-augering may be required in order to achieve the minimum required penetration. The piles should be driven to adequate set considering the pile driving equipment chosen. During construction, the capacity of each pile should be verified by Hiley Formula, or other means as per Ministry practice.

The pile cap bases should have a minimum 1.2 m of earth cover to limit the effect of frost action.

6.1.2 Abutment Walls

The abutment walls should be designed to resist the unbalanced lateral forces acting on the wall. In this regard, provided that MTO standard practice is followed involving the provision of free draining granular backfill and the installation of weepholes or weeping tiles behind the abutment walls to prevent the build-up of hydrostatic pressures, design may be based on the following geotechnical parameters:

Friction angle of compacted granular backfill, = 35° (OPSS Granular A)
= 30° (OPSS Granular B)

Friction angle between Granular backfill and concrete = 24° (OPSS Granular A or B).

Bulk unit weight for compacted granular backfill behind the abutment walls,
= 22.8 kN/m^3 (OPSS Granular A)
= 21.2 kN/m^3 (OPSS Granular B)

Alternatively, lateral earth pressures for level granular backfill may be determined from the Ontario Highway bridge Design Code. The equivalent fluid pressures are given in Section 6.6.1.2.2 of the Ontario Highway Bridge Design Code.

6.1.3 Excavation and Groundwater Control

Excavation for the pile caps, piers, and abutment construction should be relatively straightforward using conventional equipment. All construction work should be carried out in accordance with The Occupation Health and Safety Act, 1981, and local regulations.

Provided the excavation is not extended into the underlying saturated sand deposit, no major groundwater control problems are expected during construction. Seepage from perched groundwater or surface run-off should be controlled by conventional sump pumping techniques.

Where it becomes necessary to extend the excavation down into the saturated sand deposit, a groundwater control method such as vacuum well points or interlocking steel sheeting will be required to lower the groundwater table below the base of the excavation during the construction period.

If interlocking steel sheeting is considered, the contractor should be aware that difficulty may be encountered advancing the sheeting due to the denseness of the sand stratum. The sheeting should be taken down below the bottom of the excavation for a distance equal to 1.5 times the unbalanced water head as determined at the time of construction, with a minimum penetration of 1.5 m.

6.1.4 Approach Embankments

The proposed construction will involve placement of fill up to 6 m in height. Prior to construction of the embankments, all topsoil, and any obviously deleterious materials should be removed. The exposed subgrade surface should be proof rolled with a heavy roller and inspected by qualified geotechnical personnel from MTO. Any soft/loose spots encountered during the process should be subexcavated and replaced with approved material, compacted to MTO specified standard Proctor maximum dry density.

The existing slopes should be benched in order to facilitate fill placement and to achieve adequate compaction in the construction area adjacent to existing slopes. The area can then be brought up to the required level with approved material placed in lifts not exceeding 200 mm and compacted to MTO specified standard Proctor maximum dry density.

We recommend slopes no steeper than 2 horizontal to 1 vertical for the approach embankment. Standard MTO Slope protection involving seeding or sodding should be observed to control erosion due to surface run-off.

All backfilling and compaction operations should be supervised by geotechnical personnel from MTO to approve material and ensure the specified degree of compaction has been obtained.

Peto MacCallum Ltd.

REGISTERED PROFESSIONAL ENGINEER
P. T-L. CHAN
PROVINCE OF ONTARIO

P. Chan, P.Eng.
Senior Engineer

G. D. Prasad, P.Eng.
Senior Engineer

REGISTERED PROFESSIONAL ENGINEER
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PC:myb

PetoMacCallum Ltd.
CONSULTING ENGINEERS

Job No. 90 TF 098

Date: October, 1990

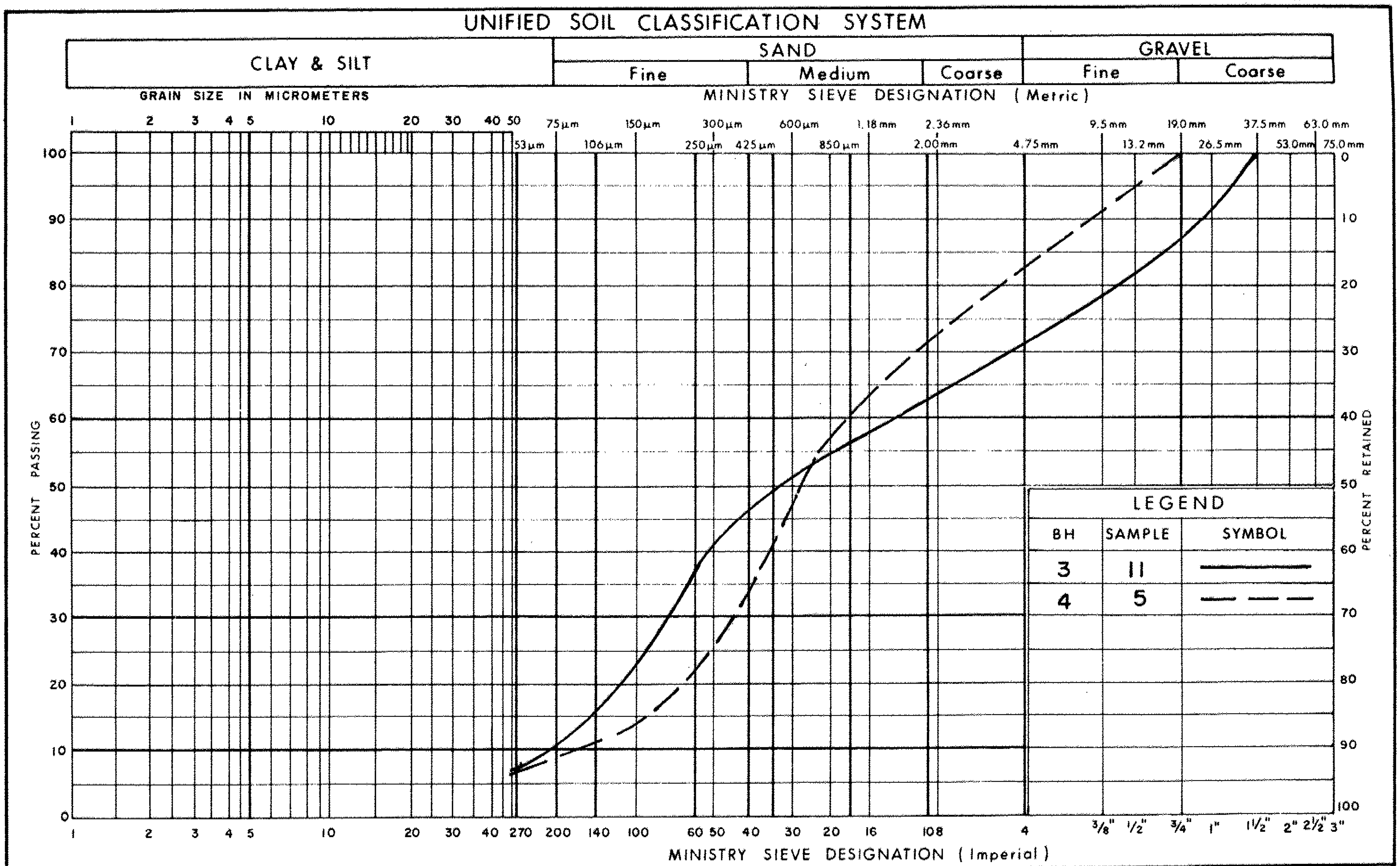
TABLE I

ATTERBERG LIMIT TEST RESULTS

CULLODEN ROAD NEW UNDERPASS
DISTRICT 2 (LONDON), SOUTHWESTERN REGION

BOREHOLE NO.	SAMPLE NO.	DEPTH (m)	NATURAL WATER CONTENT (w) %	LIQUID LIMIT (w_L)	PLASTIC LIMIT (w_p)	PLASTICITY INDEX (I_p)	REMARKS
2	6	4.55-5.00	10.8	16	11	5	Sandy Silt Glacial Till (ML)
2	10	16.70-17.15	9.5	17	11	6	" "

78 12 M



Ministry of Transportation

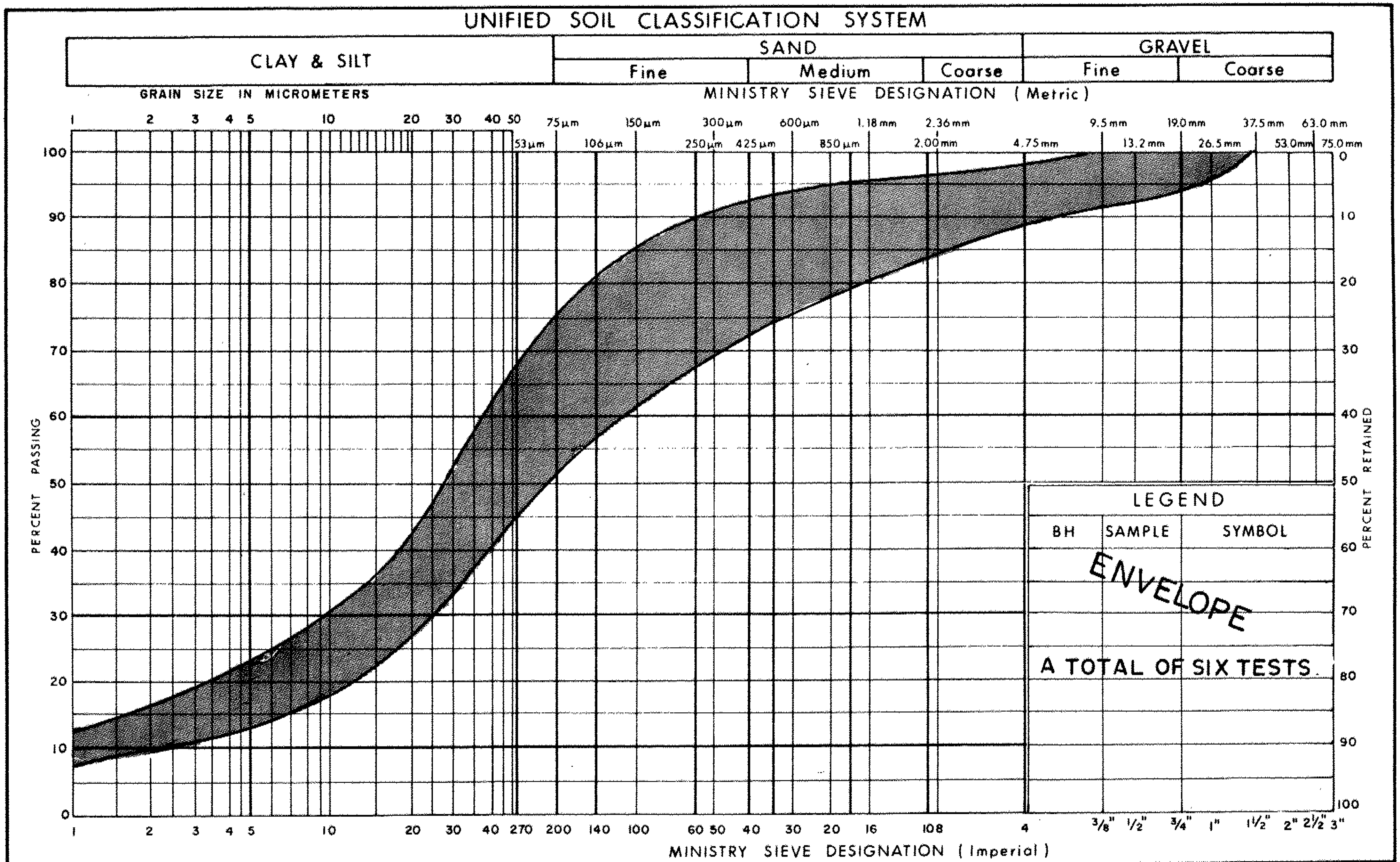
Ontario

GRAIN SIZE DISTRIBUTION
SAND
SOME GRAVEL

FIG No 1

W P 479 - 89 - 04

78 12 M



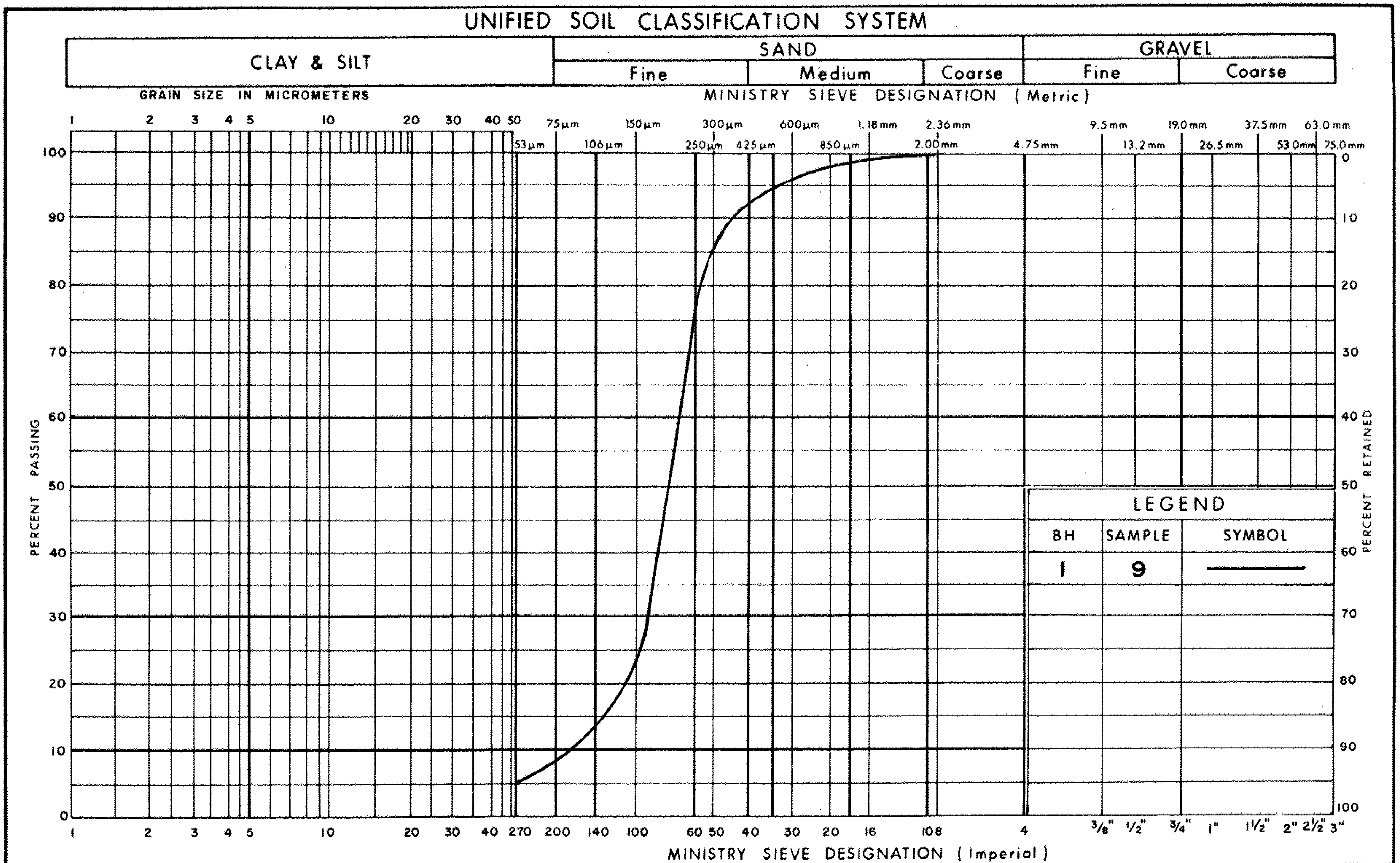
Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION
SANDY SILT (GLACIALTILL)
SOME CLAY, TRACE TO SOME GRAVEL

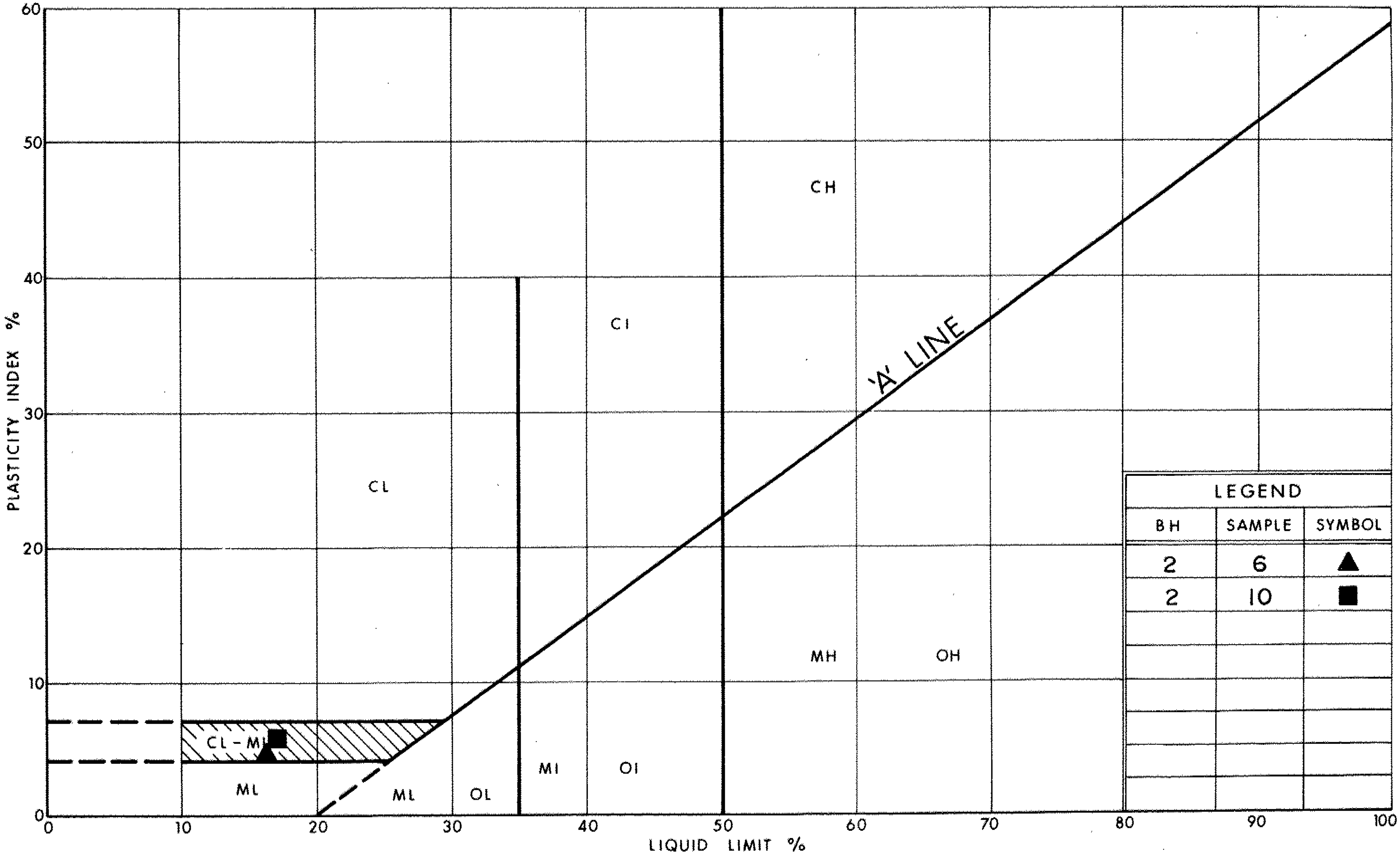
FIG No 2

W P 479 - 89 - 04

78 12 M



Ministry of Transportation Ontario	GRAIN SIZE DISTRIBUTION SAND	FIG No 3
		W P 479 - 89 - 04



LEGEND		
BH	SAMPLE	SYMBOL
2	6	▲
2	10	■

Ministry of Transportation
Ontario

PLASTICITY CHART
SANDY SILT (GLACIAL TILL)
SOME CLAY, TRACE TO SOME GRAVEL

FIG No 4
W P 479 - 89 - 04

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 1 — METRIC

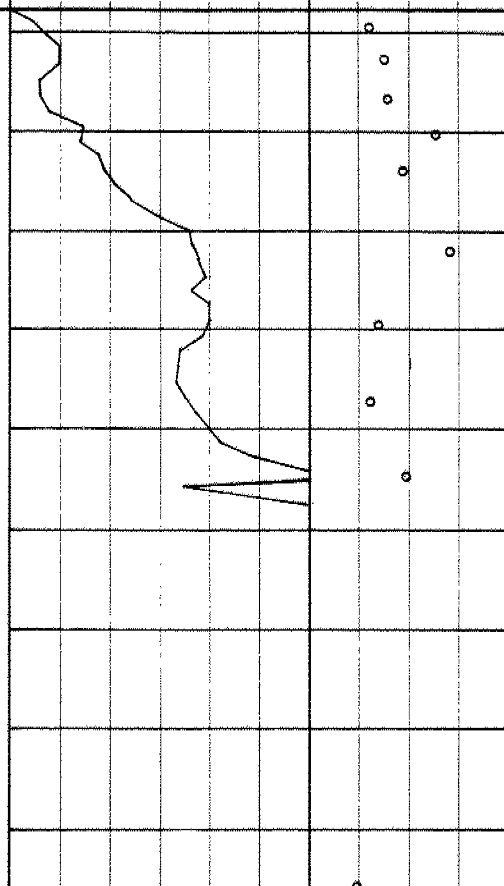
W P 479 - 89 -04 — LOCATION Co-ords, 4764,351.8 N; 192,467.5E — ORIGINATED BY DS

DIST 2 HWY 401 — BOREHOLE TYPE Hollow Stem Augers and Dynamic Cone Penteration Test — COMPILED BY GDP

DATUM Geodetic — DATE August 30/31, 1990 — CHECKED BY PC

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ KN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
288.46	Ground Level							
0.00 / 287.56	Topsoil, clayey silt, medium organic, brown	1	SS	9		288		
0.90	Clayey Silt (Fill) trace sand, trace gravel topsoil inclusions	2	SS	11				
		3	SS	10				
		4	SS	17		286	19.2	
284.86	Brown Stiff	5	SS	9				
3.60	Sandy Silt, some gravel some clay, (Glacial Till)					284	19.2	
		6	SS	13				
	Brown							9 39 42 10
	Fine sand seams	7	SS	10		282		
		8	SS	5	▽			0 95 5 0
279.46	Grey Compact					280		
9.00	Sand, fine to medium, trace gravel, trace silt	9	SS	87				
						278		
						276		
						274		
						272		
271.46	Brown Very Dense							
17.00	Sandy Silt (Glacial Till)							
270.79	Grey Very Dense	10	SS	163/150mm				
17.67	End of Borehole							

Dynamic Cone Penetration Resistance Plot (20 40 60 80 100); Shear Strength kPa: ○ Unconfined, + Field Vane, ● Quick Triaxial, × Lab Vane; Plastic Limit W_p, Natural Moisture Content W, Liquid Limit W_L; Water Content (%) 10 20 30



Note:
Borehole at 10m, sand blow back inside hollow stem augers
Upon completion of augering, water at elevation 280.84

▽ Water level in open borehole — +3, ×5 : Numbers refer to Sensitivity — 20 / 15 ◇ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 2 METRIC

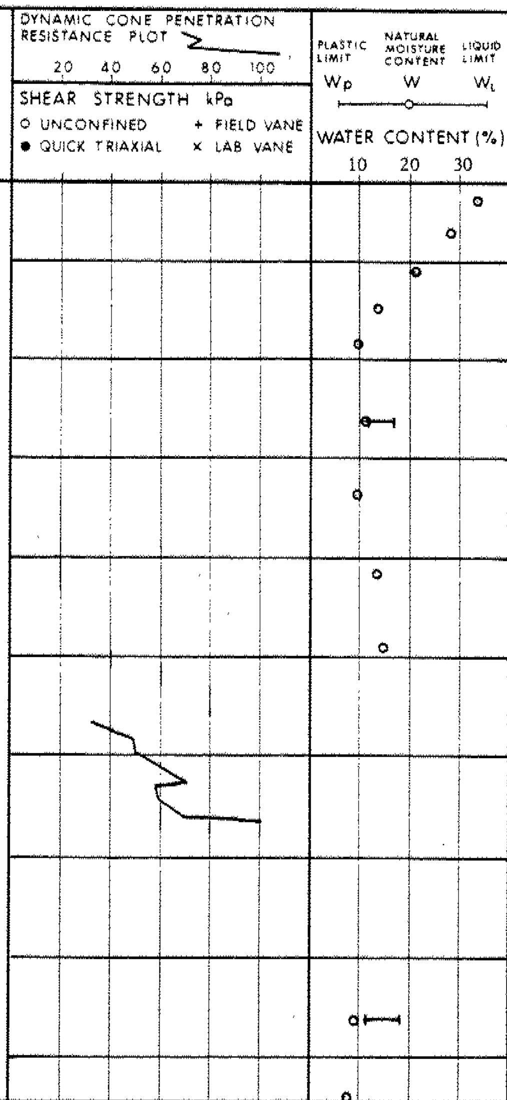
W P 479 - 89 - 04 LOCATION 4764,331.5 N., 192,479.35 ORIGINATED BY DS

DIST 2 HWY 401 BOREHOLE TYPE Hollow Stem Augers and Dynamic Cone Penetration Test COMPILED BY GDP

DATUM Geodetic DATE August 29, 1990 CHECKED BY PC

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
287.55	Ground Level							
286.95 / 0.00	Topsoil, some sand, some gravel, medium organic, brown	1	SS	8				
0.60	Clayey Silt, (Fill) with some sand, some gravel	2	SS	4		286		
		3	SS	9				
		4	SS	12				
283.85	Brown Stiff	5	SS	15		284		
3.70	Sandy Silt, some gravel, some clay, (Glacial Till)				▽			
		6	SS	18				12 33 40 15
	Compact / Loose					282		
		7	SS	9				
	Brown / Gray					280		
		8	SS	3				
277.34		9	SS	10		278		
10.21	Sand, fine to medium, some gravel (From auger samples)					276, 274, 272		
270.85	Grey Very Dense							
16.70	Sandy Silt, some gravel, some clay, (Glacial Till)	10	SS	161/150mm		270		11 35 38 16
269.05	Grey Very Dense	11	SS	133/200mm				
18.50	End of borehole							

Note: After sample 9, water inside hollow stem augers at elevation 280.55
Borehole at elevation 277.34, sand blow back inside hollow stem augers
Drove cone below. Borehole augered down without sampling to elevation 270.85



▽ Water level in open borehole $+^3$, $\times^5$: Numbers refer to Sensitivity 15 ◇ 5 (%) STRAIN AT FAILURE (20 / 10)

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 2A — METRIC

W P 479 - 89 - 04 | LOCATION Co-ords. 4764,331.5 N. 192,479.35 | ORIGINATED BY D.S.
DIST 2 HWY 401 | BOREHOLE TYPE Hollow Stem Auger and Dynamic Cone Penetration Test | COMPILED BY G.D.P.
DATUM Geodetic | DATE August 29, 1990 | CHECKED BY P.C.

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, + FIELD VANE, ● QUICK TRIAXIAL, × 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
287.55	Ground Level										
0.00	(Pre - Augered)						286				
							284				
282.80 / 4.75							282				
							280				
							278				
							276				
274.30 / 13.25	End of Dynamic Cone Penetrationt Test								130/300mm		

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

15 ◇ 5 (%) STRAIN AT FAILURE (20 above, 10 below)

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 3 — METRIC

W P 479 - 89 -04 LOCATION Co-ords, 4764,281.4N; 192,486.8E ORIGINATED BY DS

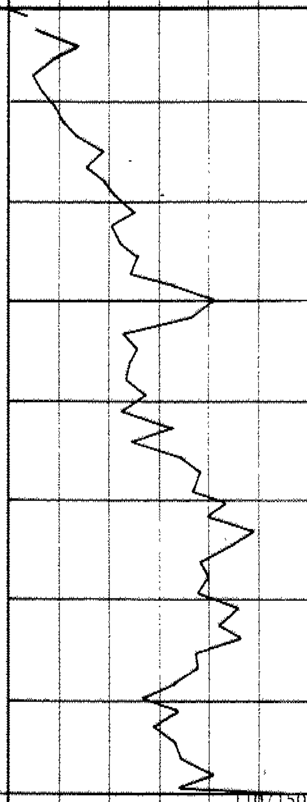
DIST 2 HWY 401 BOREHOLE TYPE Hollow Stem Augers and Dynamic Cone Penetration Test COMPILED BY GDP

DATUM Geodetic DATE August 27, 1990 CHECKED BY PC

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ KN/m³	GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
287.85	Ground Level							
0.00 287.15 0.70	Topsoil, clayey silt, trace sand, medium organic, brown							
	Clayey Silt (Fill) with trace sand, trace gravel — Stiff	1	SS	18		o		
		2	SS	10	286	o		
284.95	Brown — Firm	3	SS	5		o	22.1	
2.90	Sandy Silt, some gravel, some clay, (Glacial Till)	4	SS	9	284	o		
		5	SS	16		o		6 44 35 15
					282			
	Brown	6	SS	16		o		
	— — — Fine sand seam	7	SS	5	280	o		4 46 35 15
		8	SS	14	278	o		
		9	SS	19		o		
276.12	Grey — Compact				276			
11.73	Sand, fine to medium some gravel, trace silt	10	SS	19		o		
	Compact	11	SS	18	274	o		
272.16	Grey — Dense	12	SS	40		o		
15.69	End of Borehole End of Dynamic Cone Penetration Test Note: Upon completion of auger. water at elevation 280.84							

Ground water conditions: water level symbol at approx. elevation 280.84.

DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE



Plastic limit W_p — Natural moisture content W — Liquid limit W_L; Water content (%) 10 20 30

OFFICE REPORT ON SOIL EXPLORATION

Water level in open borehole

+3, ×5 : Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 4

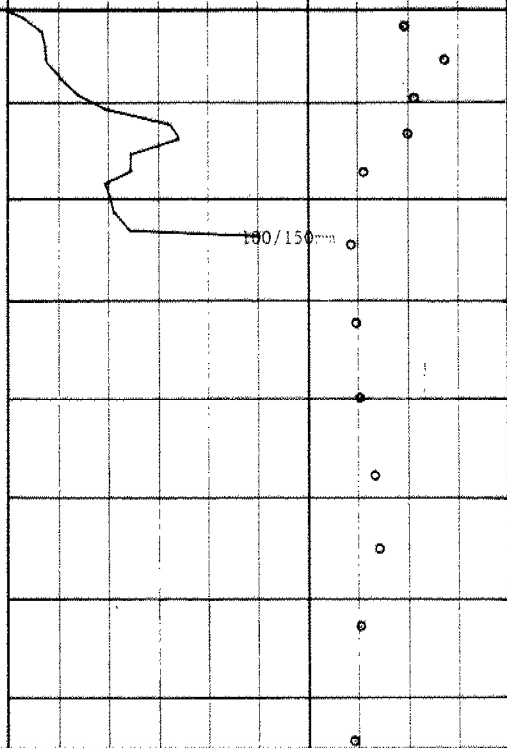
METRIC

W P 479 - 89 -04 LOCATION Co-ords. 4764.258.4N· 192,491.6E ORIGINATED BY DS

DIST 2 HWY 401 BOREHOLE TYPE Hollow Stem Augers and Dynamic Cone Penetration Test COMPILED BY GDP

DATUM Geodetic DATE August 28, 1990 CHECKED BY PC

ELEV DEPTH	SOIL PROFILE: DESCRIPTION	SAMPLES: NUMBER	TYPE	'N' VALUES	ELEVATION SCALE	UNIT WEIGHT γ KN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
287.86	Ground level						
287.26 / 0.00	Topsoil, clayey silt, medium organic, brown	1	SS	5			
0.60	Clayey Silt, (Fill) with trace sand, trace gravel	2	SS	13		20.1	
		3	SS	15	286		
285.16	Brown Stiff	4	SS	20			
2.70	Sand, fine to medium some silt, some gravel	5	SS	16	284		20 70 10 0
	Compact	6	SS	61			
281.76	Brown Very Dense				282		
6.10	Sandy Silt, trace gravel, some clay	7	SS	53			
	Brown Dense to Very Dense	8	SS	40	280	23.2	
		9	SS	26	278		
	Compact	10	SS	22	276		3 22 60 15
274.91	Grey Dense	11	SS	43		22.8	
12.95	Sand, fine to medium, some gravel, some silt				274		
272.99	Grey Compact	12	SS	27			
14.87	End of borehole						



Note:
Before sample 8 water at elevation 280.63 inside hollow stem augers. Upon completion of augering water at elevation 284.81. Piezometer installed with tip at elevation 272.92 with seals at elevations 283.28 and 287.80

DATE	Water Elevation
Aug. 28	286.13
Aug. 31	285.24

OFFICE REPORT ON SOIL EXPLORATION

Water level in open borehole
Piezometer level

+3, ×5 : Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 4A

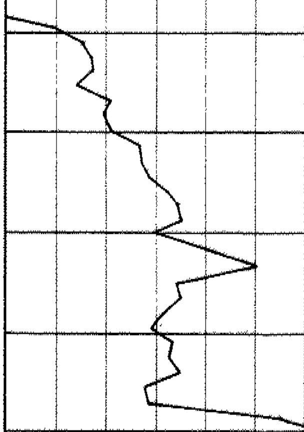
METRIC

W P 479 - 89 - 04 LOCATION Co-Ords. 4764,258.4N; 192,491.6E ORIGINATED BY D.S.

DIST 2 HWY 401 BOREHOLE TYPE Hollow Stem Auger and Dynamic Cone Penetration Test COMPILED BY G.D.P

DATUM Geodetic DATE August 31, 1990 CHECKED BY P.C.

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)	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						
287.86 / 0.00	Ground Level										
	(Pre - Augered)						286, 284, 282				
280.26 / 7.60							280, 278, 276, 274, 272				
271.80 / 16.06	End of Dynamic Cone Penetration Test							100/200mm			



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

15 ⌖ 5 (%) STRAIN AT FAILURE (20 above, 10 below)

OFFICE REPORT ON SOIL EXPLORATION

CONT No
WP No 479-89-04

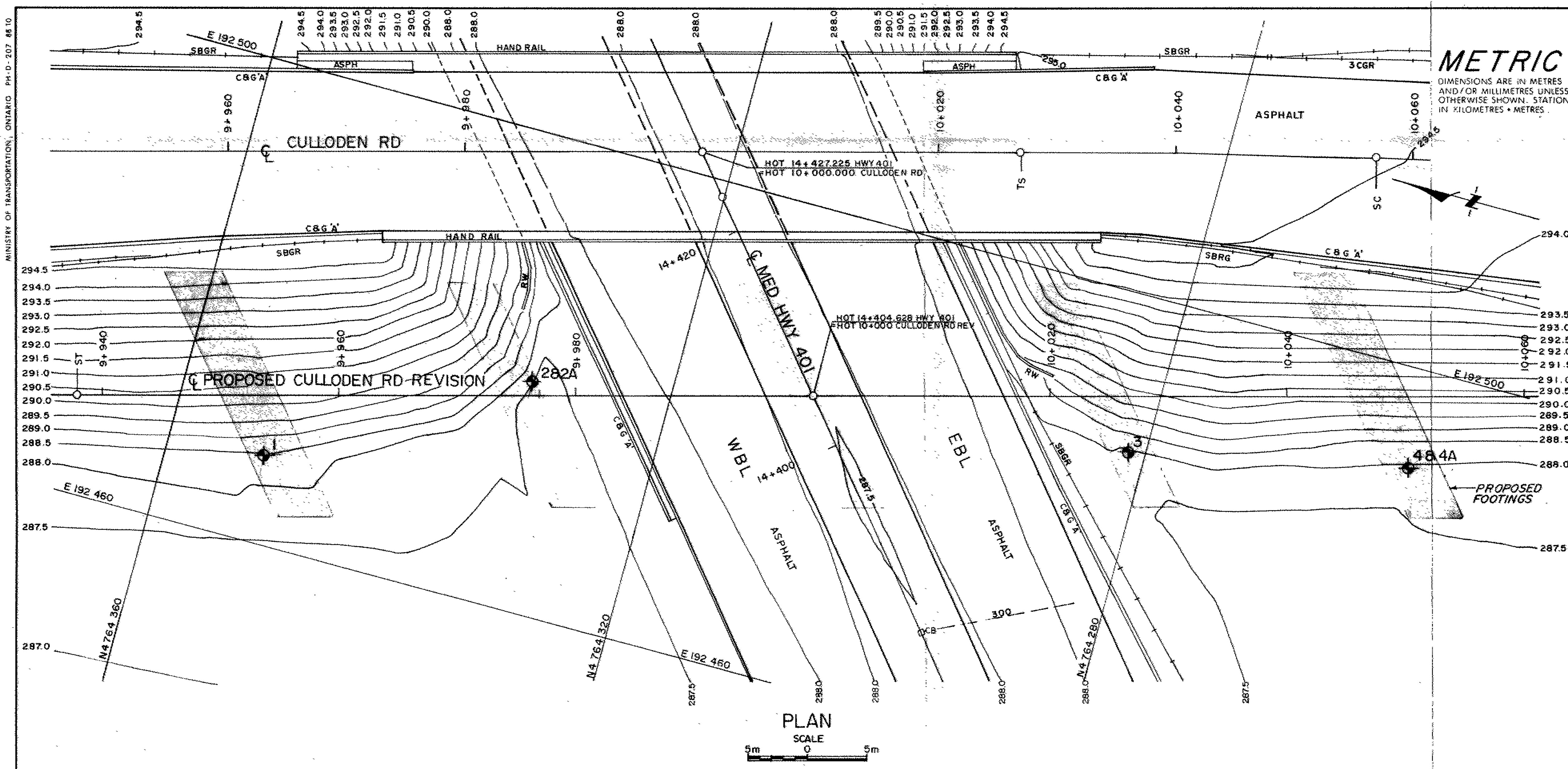
CULLODEN RD NEW UNDERPASS
(2.7 km West of Hwy (9))

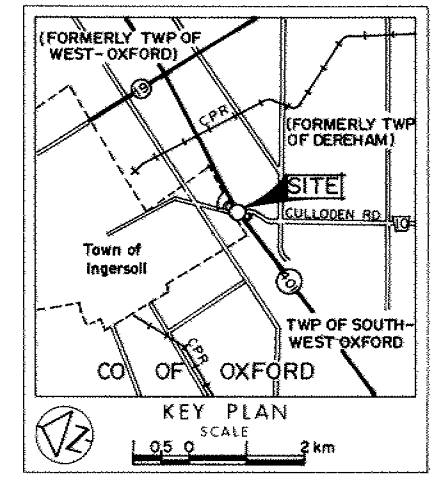
BORE HOLE LOCATIONS & SOIL STRATA

SHEET

PETO MacCALLUM LTD.

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

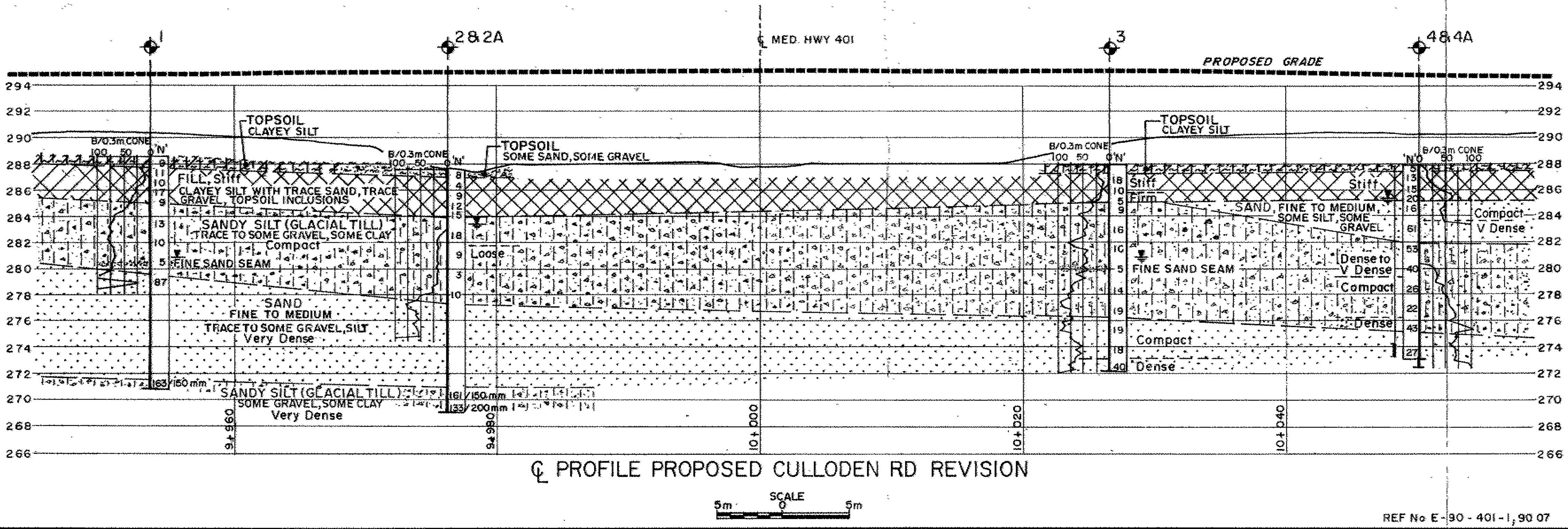




LEGEND

- 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 Aug 1990
- PIEZOMETER

No	ELEVATION	CO-ORDINATES NORTH	EAST
1	288.46	4764 351.8	192 467.5
2	287.55	4764 331.5	192 479.3
3	287.85	4764 281.4	192 486.8
4	287.86	4764 258.4	192 491.6



REF No E-90-401-1, 90 07

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 40P2-46

HWY No 401			DIST 2-LONDON
SUBM'D PC	CHECKED	DATE 1990 09	SITE 23-208
DRAWN K.C.	CHECKED	APPROVED	DWG 4798904-A