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W.P. No. 624-90-01, 02, 03, 04

CONT. No. 94-53

STR. SITE No. 18-20

HWY. No. Q.E.W.

LOCATION Q.E.W. of 18 Mile Creek

No. of PAGES -

OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT. _____

REMARKS: For additional information
see Cont. 94-53 in storage



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FILE No. _____ DATE _____

REMARKS m To Yard George Allan 416-
m To Field Office - Norm Metcalfe
416-582-3486

Borehole Log QEW 92-1

COMPUTER "A"

92 SERIES	91 SERIES
QEW 92-1	18MC-BH1
QEW 92-2	18MC-BH2
QEW 92-3	18MC-BH3
QEW 92-4	18MC-BH4
QEW 92-5	18MC-BH5
QEW 92-6	18MC-BH5A
QEW 92-7	18MC-BH6
QEW 92-8	18MC-BH7
QEW 92-9	18MC-BH8
	18MC-BH9

FOUNDATION INVESTIGATION REPORT

CONTRACT NO. 94-53



Ministry of
Transportation

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DESCRIPTION

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Note: For purposes of the contract, this report supersedes all other Foundation Reports prepared by, or for the Ministry in connection with the above mentioned projects.

EXPLANATION OF TERMS USED IN REPORT

2

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

FOUNDATION INVESTIGATION REPORT

For

Q.E.W. Crossing at 18 Mile Creek

W.P. 624-90-01 Westbound Lane - Site No. 18-20

W.P. 624-90-02 Eastbound Lane - Site No. 18-20

W.P. 624-90-03 South Service Rd. - Site No. 18-375

W.P. 624-90-04 North Service Rd. - Site No. 18-374

District 4, Burlington

INTRODUCTION

This report summarizes the information obtained from a foundation investigation carried out at the above mentioned site where three span four bridge structures are proposed to carry the existing Q.E.W. and South and North Service Roads Crossing at 18 Mile Creek.

The field works for the foundation investigation were carried out at the above mentioned site during the period of December 2 to December 20, 1991 and May 11 to May 29, 1992. Ten boreholes (BH 91-1 to BH 91-9 inclusive, plus BH 91-5A) were advanced and sampled between December 2 and December 20, 1991.

Additional nine boreholes (BH 92-1 to BH 92-9) were advanced and sampled as part of this project between May 11 and May 29, 1992. These boreholes extended down to depths between 14.2 m and 30.5 m below the existing ground surface.

Total of nineteen (19) boreholes were drilled for four bridge structures. Among them, eleven (11) boreholes are located within the Q.E.W. eastbound and westbound lanes, while four (4) boreholes are situated within South Service Road structure and North Service Road structure, respectively. The information from these boreholes is utilized in this report.

This report contains factual information obtained from these investigations pertaining to structure foundations, approach embankments and related earthworks for the Q.E.W. bridge structures, eastbound and westbound lanes, as shown on Dwg. No. 6249001/02-A and B,*for the South Service Rd. as shown on Dwg. No. 6249003-A,* and for the North Service Road as shown on Dwg. No. 6249004-A.*

SITE DESCRIPTION AND GEOLOGY

The site is located on the existing alignment of Q.E.W. where it crosses the Eighteen Mile Creek in the Town of Lincoln, Regional Municipality of Niagara. The proposed structures are located approximately 2.5 km east of Jordan Harbour. The topography in the area is gently undulating with a valley. Land use in the vicinity of the site is primarily agricultural known as the Niagara Fruit Belt.

Physiographically, the site is located in the "Iroquois Plain" region (Ref: Chapman and Putnam, 1984). The general area was inundated by the Pleistocene Lake Iroquois. As the lake level receded much below the present level of Lake Ontario, the Eighteen Mile Creek cut a valley through the till. Underlying the glacial deposit is the red Queenston Shale from which the till's reddish colour is derived. Later, the rise in the Lake Ontario water level to approximately its present level, drowned the outlet of the creek and created a lagoon and marsh separated from the lake by a barrier beach. Water flow is to the north into Lake Ontario.

SUBSURFACE CONDITIONS

The subsoil conditions are generally consistent across the site. The Q.E.W. crosses the Eighteen Mile Creek at this location. The road embankment fill of the existing Q.E.W. consists of bedding sand, mainly clayey silt and some crushed stone as much as 13.6 m in the middle of valley.

Underlying the fill is a layer of organics which was encountered at all borehole locations except at one borehole location (BH 92-7). The thickness of this layer ranges from 1.1 m at BH 91-1 to 5.6 m at BH 91-2.

*Drawing Nos. 2A, 2B, 2C and 2D (Sheets 151, 152, 153 and 154) of the Contract Drawings.

Underneath this layer, clayey silt with some sand and trace of gravel was encountered. The thickness of this layer ranges from 6.1 m at BH 91-9 to 18.3 m at 92-7. A thin layer of silty sand and gravel was found at 6 borehole locations (BH's 91-2, 91-3, 91-5, 91-5A, 91-6, and 92-2) in between the organic material and clayey silt with a maximum thickness of about 1.2 m at BH 92-7.

Cohesive glacial till was encountered underneath the clayey silt at all boreholes locations. This material can be described as a heterogeneous mixture of clayey silt, sand and gravel. The maximum thickness of this deposit was found to be about 5.2 m at BH 92-9. This layer is underlain by shale and siltstone bedrock. A thin layer of non-cohesive glacial till, which can be described as a heterogeneous mixture of silt, sand and gravel, was found with a thickness of 2.4 m at BH 91-9.

Sound bedrock was proven in 14 borehole locations by obtaining up to 2.7 m of NQ rock cores. The bedrock surface ranges from an elevation of 56.4 m at BH 92-9 to an elevation of 60.0 m at BH 91-4 which corresponds to 29.0 m and 23.0 m below the existing ground surface, respectively. The upper portion of bedrock was slightly weathered for a maximum 1.2 m at BH 92-8 below the rock surface. The sound bedrock surface ranges from an elevation of 56.4 m at BH 92-9 to an elevation of 59.3 m at BH 91-4 which corresponds to 29.0 m and 23.7 m below the existing ground surface. The bedrock is known to be "SHALE and interbedded SILTSTONE of the Queenston Formation".

The boundaries between the various soil types, in situ and laboratory test results are shown on the attached Record of Borehole Sheets in the Appendix. The locations and elevations of the boreholes, along with a profile and sections, are shown on Dwg. No. 624901/02-A and B,* 6249003-A* and 6249004-A*.

A detailed description of the subsurface conditions encountered is given below.

Embankment Fill

The embankment fill consists of bedding sand, mainly clayey silt and some crushed

*Drawings Nos. 2A, 2B, 2C and 2D (Sheets 151, 152, 153 and 154) of the Contract Drawings.

stone. The thickness of this layer was found to range from 4.4 m at BH 92-7 to 13.6 m at BH's 91-6 and 92-9.

Atterberg Limit Tests were performed on clayey silt samples and the results are plotted on Figure 1 and summarized as follows:

<u>Property</u>	<u>Range (%)</u>
Natural Moisture Content (w)	8.5 - 24.5
Liquid Limit (w_L)	16.5 - 36.0
Plastic Limit (w_p)	13.0 - 17.5
Plasticity Index (I_p)	3.0 - 19.0

From the Plasticity Chart, it is evident that the layer can be classified as a clayey silt to silt, some sand and gravel with low plasticity (CL or CL-ML).

Grain Size Distribution tests were carried out on this fill material. Figure 2 in the Appendix shows the results in an envelope form. In this stratum, the "N" values range from 0 to over 31 blows/0.3 m indicating the consistency of this deposit described as very soft to hard. Some silty sand layers were found within this clayey silt fill as shown on Figure 3.

Organic Clayey Silt to Silty Clay, Some Sand

This deposit was encountered beneath the existing embankment fill in all boreholes except BH No's 91-4 and 92-7 which were on or near the edge of the valley. The thickness of this deposit ranges from 1.1 m at BH 91-1 to 5.6 m at BH 91-2 and this deposit gradually peters out near the valley's edge.

The material, as sampled, was highly organic with organic pieces generally visible, and well-decayed pieces of roots and wood were not uncommon. Occasional samples were fibres. Some sand and occasional gravel were noted as well as occasional sand seams.

Atterberg Limit tests were performed on these samples and the results are plotted on Figure 4 and summarized as follows:

<u>Index Property</u>	<u>Range (%)</u>
Natural Moisture Content (w)	19.0 - 70.0
Liquid Limit (w_L)	17.0 - 68.0
Plastic Limit (w_p)	14.0 - 45.0
Plasticity Index (I_p)	3.0 - 23.0

From the plasticity chart, it is evident that the layer can be classified as an organic clayey silt to silty clay with low to high plasticity (OL.OI and OH).

Grain Size Distribution tests were carried out on these materials. Figure 5 in the Appendix shows the results in an envelope form.

Undrained Shear Strength of the soil was determined by in situ vane tests and by laboratory tests, namely unconfined compression tests. The results are plotted on Figure 6 and the Record of Borehole log sheets in the Appendix and summarized as follows:

<u>Undrained Shear Strength</u>	<u>Cu (kPa)</u>	<u>Sensitivity</u>
In-Situ Vane Tests	15 - >115	1 - 6
Unconfined Compression Tests	28 - 98	

As shown on Figure 6, the vane strengths measured within organic layer varied from 15 kPa to greater than 115 kPa, indicating soft to very stiff consistency. This layer has a sensitivity varying from 1 to 6 based on the measured undisturbed and remoulded vane strengths. This would indicate that the organic clayey silt to silty clay is generally sensitive.

An oedometer test was carried out to investigate the consolidation characteristics of the organic clayey silt to silty clay. The sample tested is

considered representative of the organic deposit was selected from a Shelby tube sample obtained at about an elevation of 69 m in BH 91-8. The result of the consolidation test is shown on Figure 7. The preconsolidation pressure is estimated to be about 330 kPa, indicating an overconsolidation ratio of about 1.25 relative to the existing effective overburden stress. The compression index (C_c) was determined to be about 0.213.

Silty Sand With Gravel

This deposit was found at five (5) borehole locations underlying the organic stratum (BH 91-2, 91-3, 91-5, 91-5A and 92-7). The thickness of this layer ranges from 0.5 m at BH 91-3 to 1.1 m at BH's 91-5, 91-5A and 92-7. Figure 3 in the Appendix shows the result of Grain Size Distribution test.

In this stratum, the "N" values ranged from 9 to 22 blows/0.3 m indicating a state of compaction described as loose to compact.

Clayey Silt With Sand

This deposit was encountered in all boreholes, either beneath the organic clayey silt to silty clay or the silty sand deposit, and appeared to represent the original material into which the Creek Valley had been carved. Hence, the deposit varied in thickness from 18.3 m at BH 92-7 near the edge of the valley to a minimum of 6.1 m at BH 91-9 near the centre of the valley.

Atterberg Limit tests were performed on these samples and the results are plotted on Figure 8 and summarized as follows:

<u>Index Property</u>	<u>Range (%)</u>
Natural Moisture Content (w)	13.0 - 20.5
Liquid Limit (w_L)	19.0 - 32.0
Plastic Limit (w_p)	14.0 - 17.0
Plasticity Index (I_p)	4.0 - 15.0

From the plasticity chart, it is evident that the layer can be classified as an inorganic clayey silt, some sand with low plasticity (CL or CL-ML).

Grain Size Distribution tests were carried out on these materials. Figure 9 in the Appendix shows the results in an envelope form.

Undrained shear strength of the soil was obtained by in-situ vane tests and by laboratory unconfined compression tests. The results are plotted on Figure 6 and the Record of Borehole log sheets in the Appendix and summarized as follows:

<u>Undrained Shear Strength</u>	<u>Cu (kPa)</u>	<u>Sensitivity</u>
In-situ Vane Tests	61 - >115	1 - 3
Unconfined Compression Tests	69 - 285	

The field vane strengths obtained in this stratum varied from 61 kPa to greater than 115 kPa indicating a stiff to hard consistency. The sensitivity of this deposit varies from 1 to about 3 indicating this material being normal.

Heterogeneous Mixture of Clayey Silt, Sand and Gravel (Cohesive Glacial Till)

This stratum was encountered underneath the clayey silt layer and immediately above the bedrock. The thickness of this layer ranges from 0.7 m at BH 91-4 to 5.2 m at BH 92-9.

Atterberg Limit tests were performed on these samples and the results are plotted on Figure 10 and summarized as follows:

<u>Property</u>	<u>Range (%)</u>
Natural Moisture Content (w)	7.0 - 13.0
Liquid Limit (w_L)	17.0 - 24.0
Plastic Limit (w_p)	12.0 - 14.0
Plasticity Index (I_p)	5.0 - 10.0

From the plasticity chart, it is evident that this deposit can be classified as a heterogeneous mixture of clayey silt, sand and gravel with low plasticity (CL or CL-ML).

Grain Size Distribution tests were carried out on the cohesive glacial till material. Figure 11 in the Appendix shows the results. An increasing frequency of fragments of weathered shale was encountered within the lower portion of this till.

In this stratum, the "N" value range from 30 to over 100 blows/0.3 m indicating the consistency of this deposit as hard.

Heterogeneous Mixture of Silt, Sand and Gravel (Non-Cohesive Glacial Till)

This layer was encountered between clayey silt and cohesive glacial till at a borehole location. The thickness of this layer was found to be about 2.3 m at BH 91-9.

A Grain Size Distribution test was carried out on this material as shown on Figure 12. This layer is basically non-cohesive. In this stratum, the "N" value is about 27 blows/0.3 m indicating a state of compaction described as compact.

Bedrock

Bedrock was cored in fourteen (14) boreholes by obtaining up to 2.7 m of NQ rock at BH 92-8. The top of the bedrock ranged from elevation 56.4 m to 60.0 m which correspond to 29.0 m and 23.0 m below the existing ground surface, respectively. The upper 0 to 1.2 m is in a slightly weathered state. The top of the sound bedrock ranged from 56.4 m to 59.3 m.

The bedrock is a red shale with interbedded green siltstone (approximately 85% shale, 15% siltstone) of the Queenston Formation. Detailed description of the rock is attached in the Appendix entitled "Rock Core Description".

The Core Recovery (CR) and Rock Quality Designation (RQD) values were determined in-situ and also in the laboratory to evaluate the competence and integrity of the rock. The Core Recoveries (CR) range between 73 and 100 percent and Rock Quality Designation (RQD) values range from 7 to 69 percent. Based on these results, the rock can be classified as weak to very weak and slightly to unweathered.

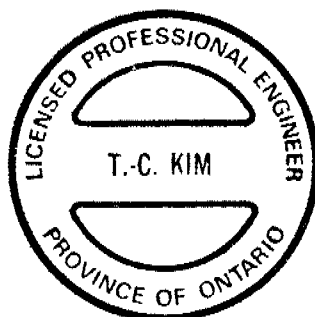
GROUNDWATER CONDITIONS

Groundwater conditions were observed by measurement of water levels in the open boreholes. The groundwater level was found to be at approximate elevation between 63.7 m at BH 92-7 and 74.6 at BH 91-4 which correspond to depths of 21.5 m and 8.4 m below the existing ground surface. However, it is likely that the groundwater level was the same as the creek level and is subject to seasonal fluctuations.

MISCELLANEOUS

The initial fieldwork for this investigation was carried out during the period of December 2 to December 20, 1991 under the supervision of R. Ng, Trainee Engineer and Tae C. Kim, Sr. Foundation Engineer. The equipment was owned and operated by Master Soil Investigation Ltd., Toronto. Additional fieldwork for this investigation was carried out during the period of May 11 to May 29, 1992 under the supervision of M. Iampietro, Student Engineer, and Tae C. Kim, Sr. Foundation Engineer. The equipment was owned and operated by Malone's Soil Samples Co. Ltd., Toronto.

This report was written by Tae C. Kim, Senior Foundation Engineer and reviewed by M. Devata, Chief Foundation Engineer.

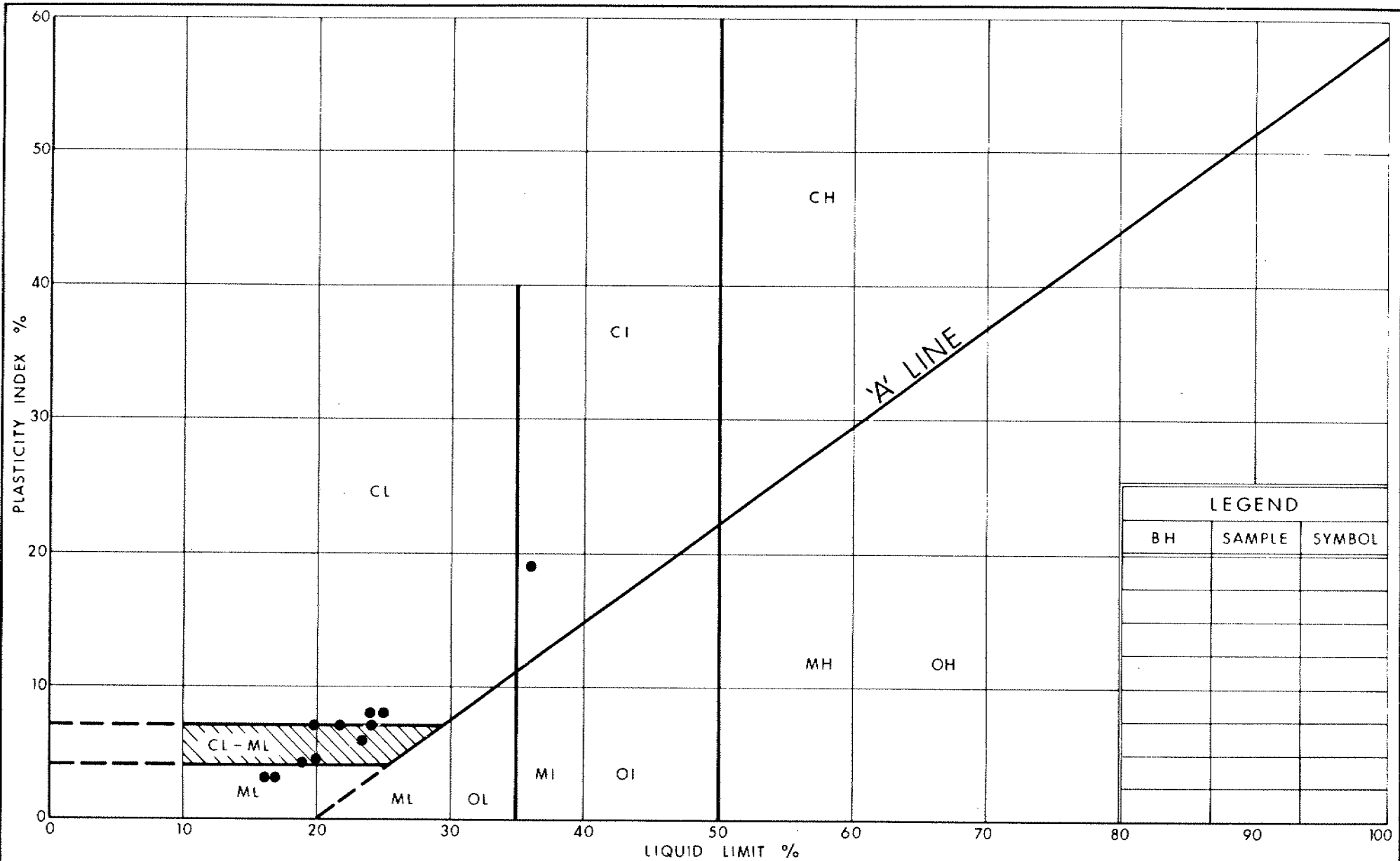


Tae C. Kim
Tae C. Kim, P. Eng.
Sr. Foundation Engineer



D. Dundas
D. Dundas, P. Eng.
Chief Foundation Engineer
(Acting)

APPENDIX



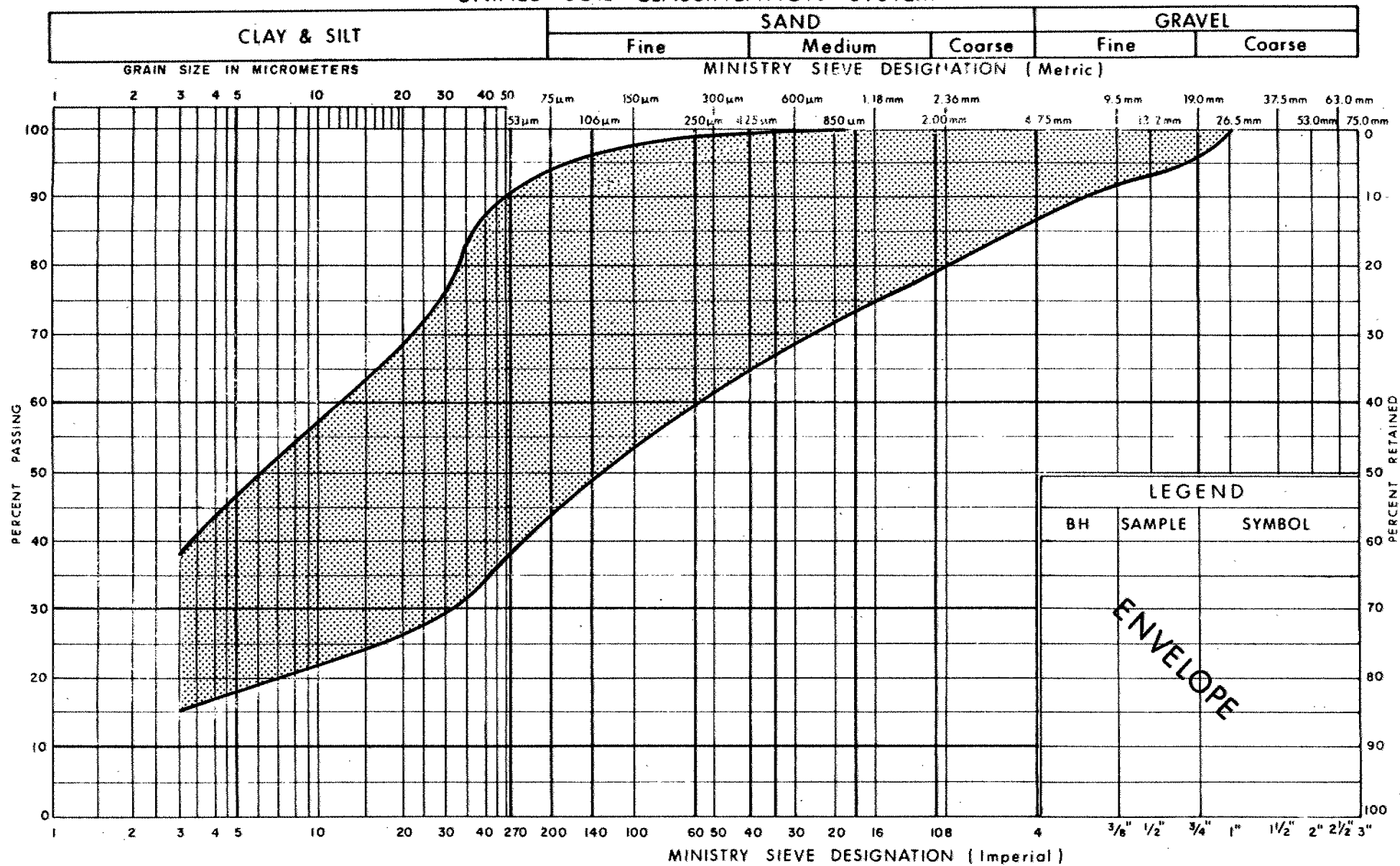
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PLASTICITY CHART CLAYEY SILT TO SILT (Fill)

FIG No 1

W P 624-90-01/02

UNIFIED SOIL CLASSIFICATION SYSTEM

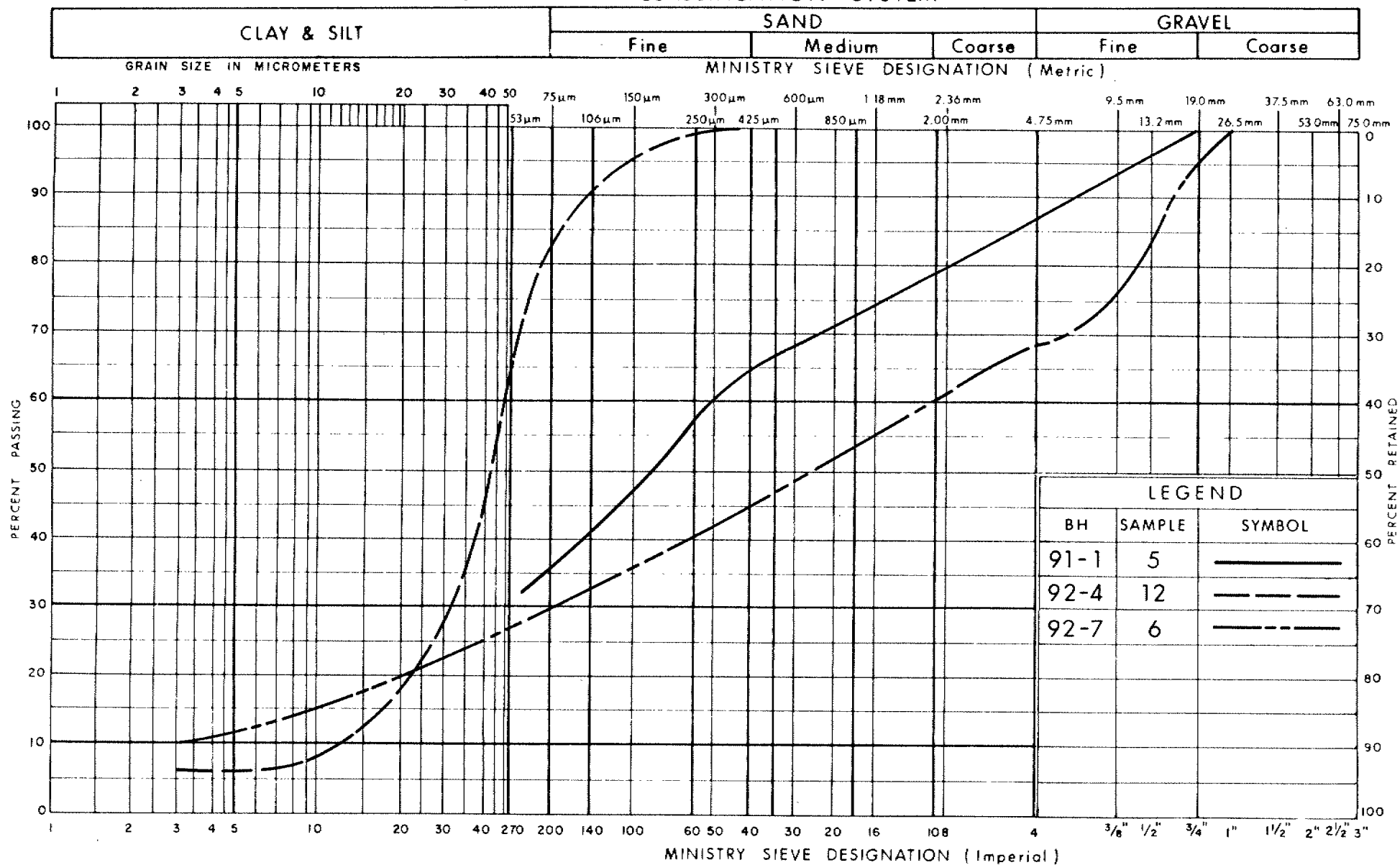

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 GRAIN SIZE DISTRIBUTION
CLAYEY SILT TO SILT
(Fill)

FIG No 2

W P 624-90-01/02

UNIFIED SOIL CLASSIFICATION SYSTEM

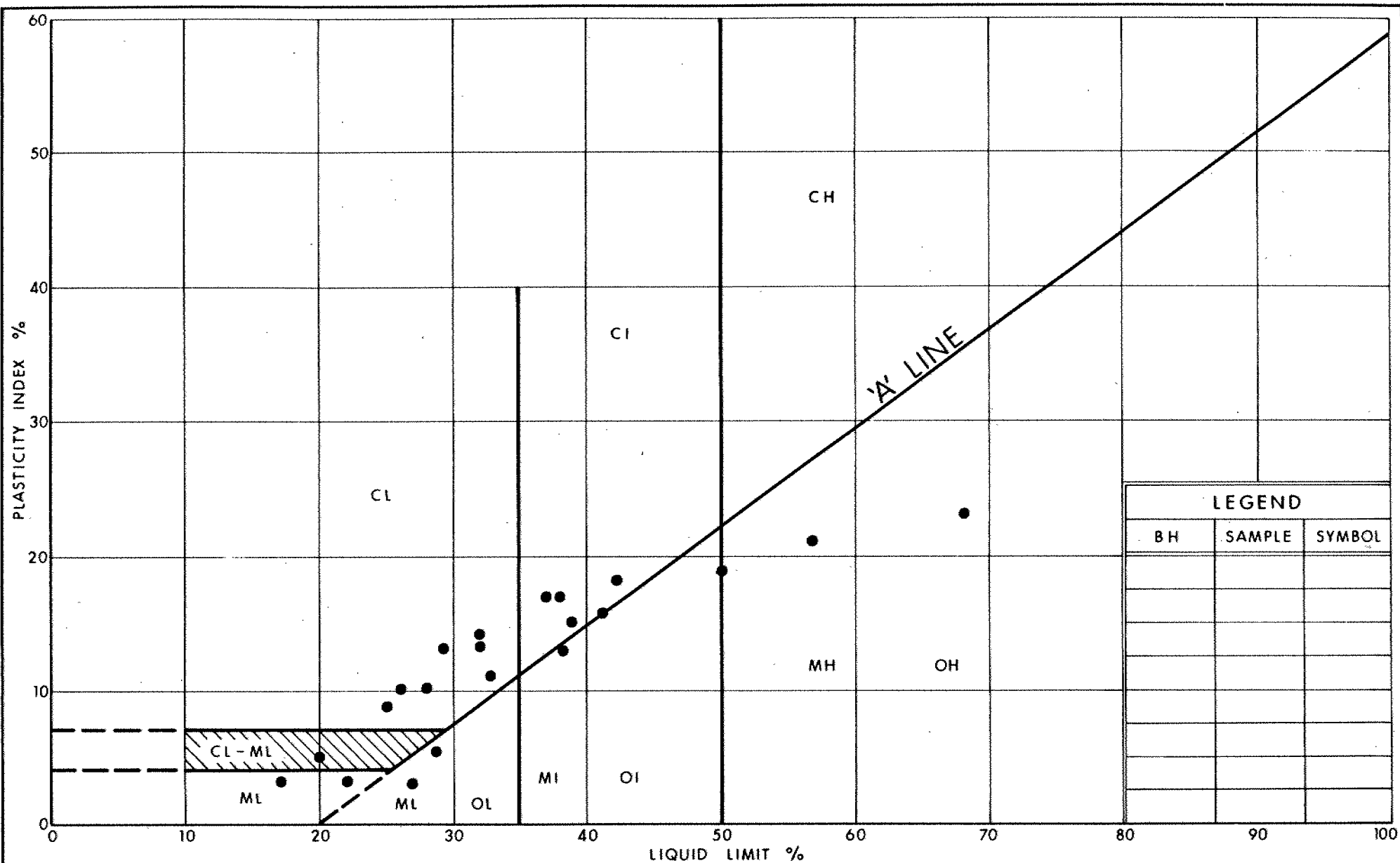


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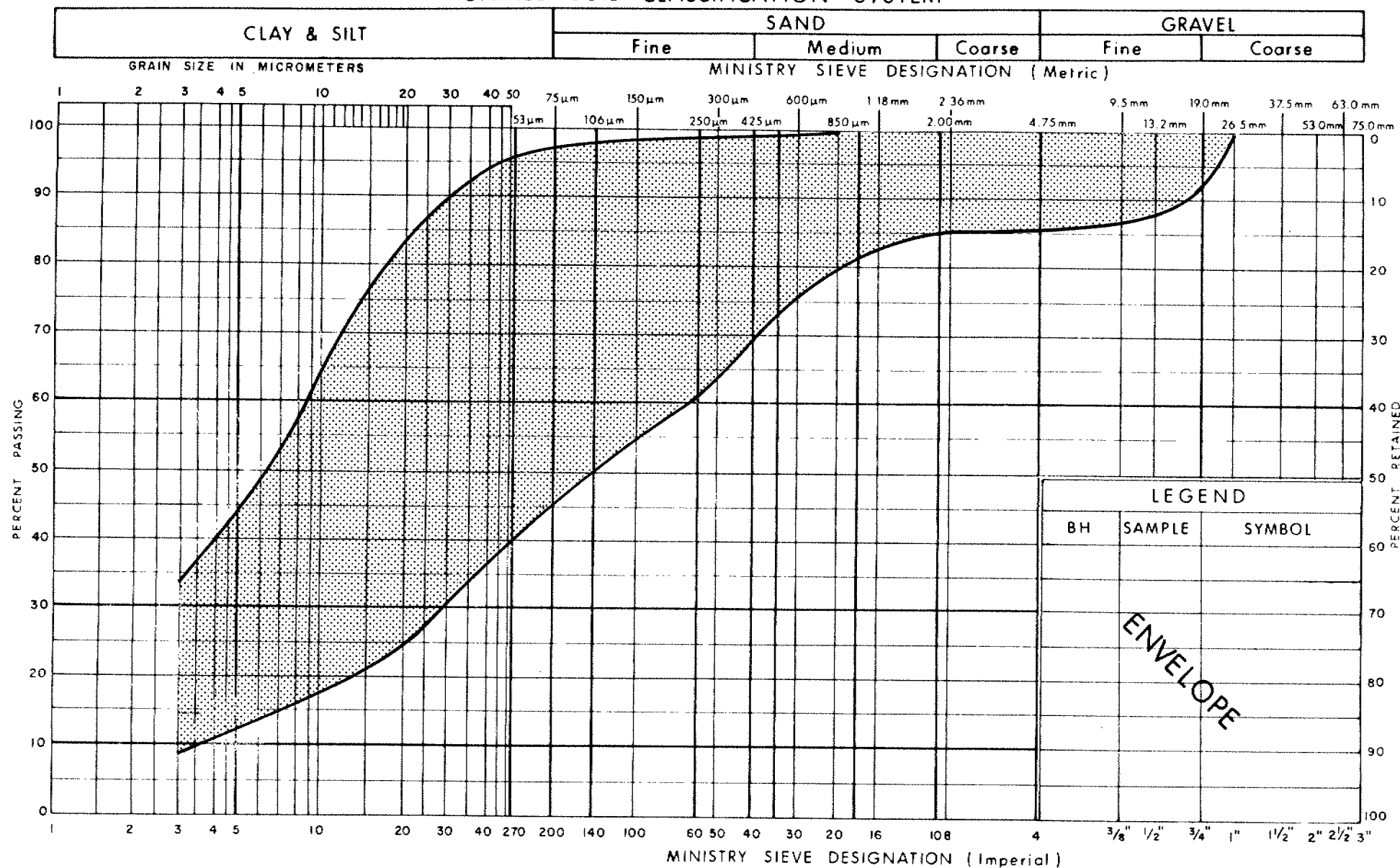
GRAIN SIZE DISTRIBUTION SILTY SAND TO SANDY SILT

FIG No 3

W P 624-90-01/02



UNIFIED SOIL CLASSIFICATION SYSTEM

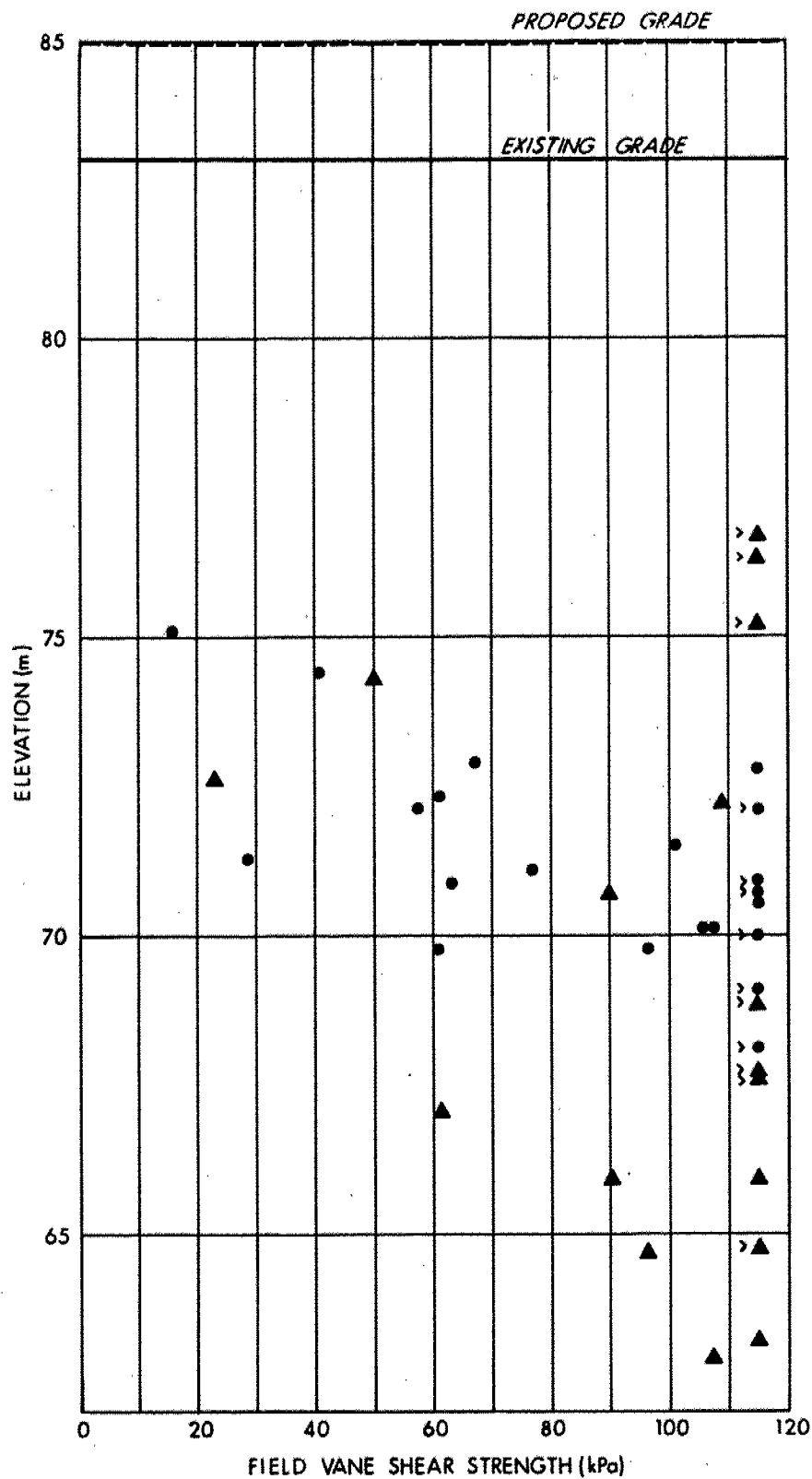


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GRAIN SIZE DISTRIBUTION ORGANIC CLAYEY SILT TO SILTY CLAY

FIG No 5

W P 624-90-01/02



PROFILE OF FIELD VANE TESTS
ORGANIC CLAYEY SILT TO SILTY CLAY

- ORGANIC CLAYEY SILT TO SILTY CLAY
- ▲ CLAYEY SILT

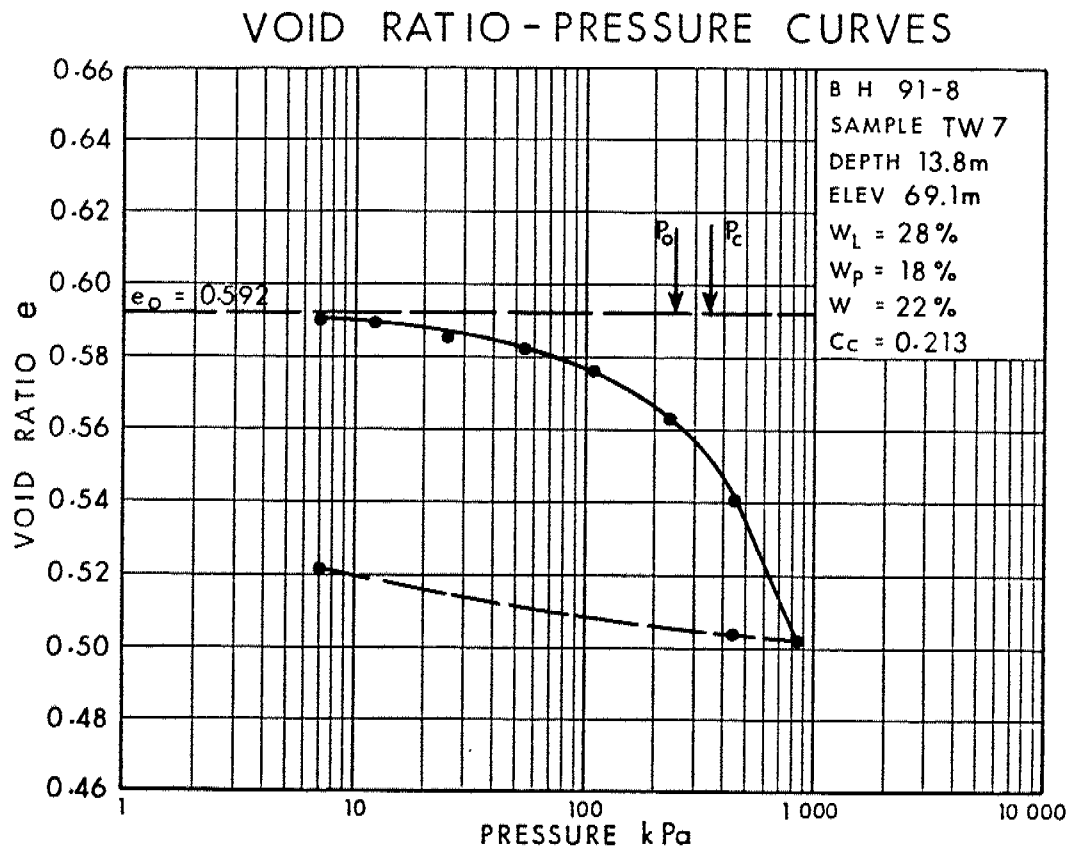
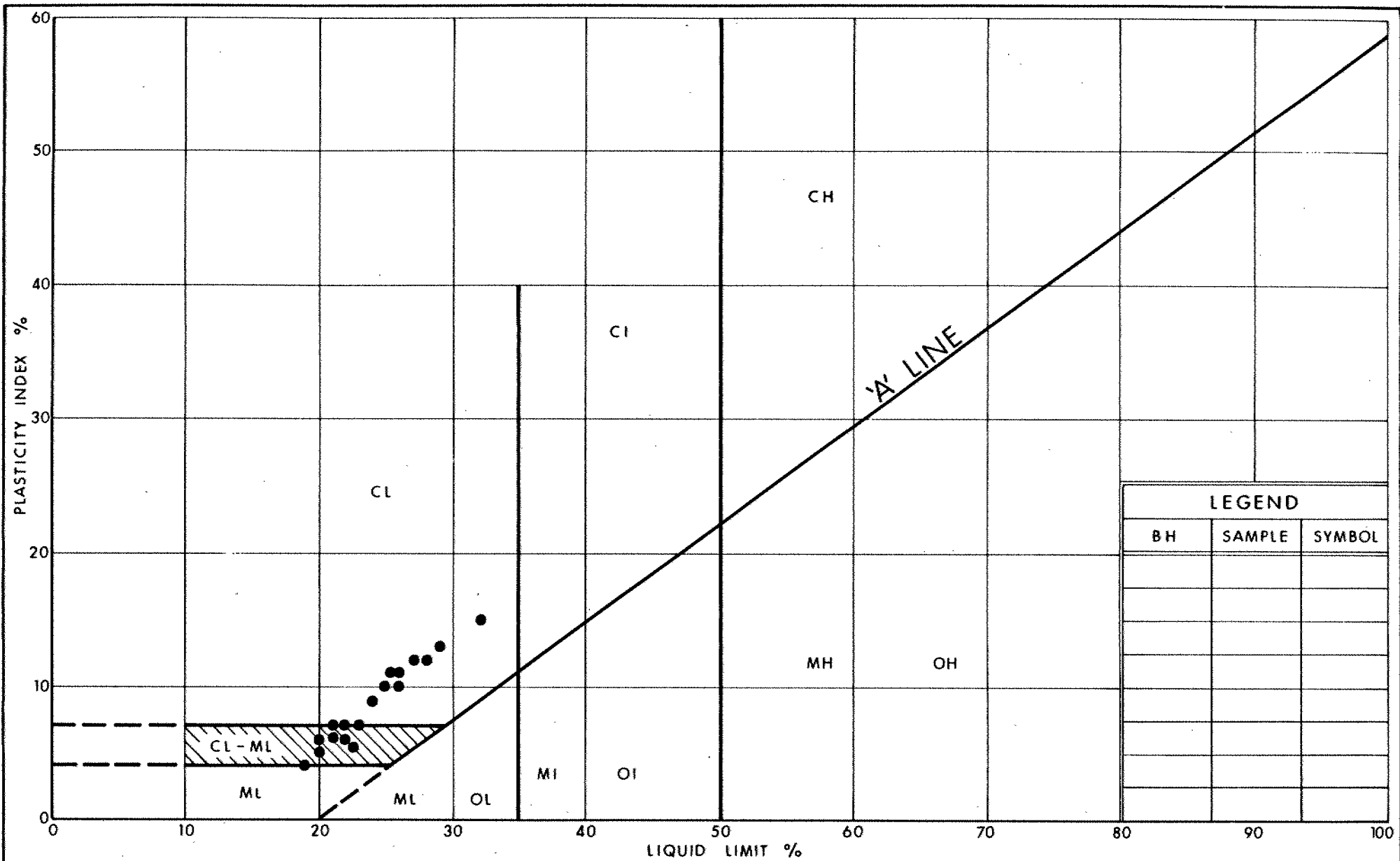


Fig 7

WP 624-90-01/02



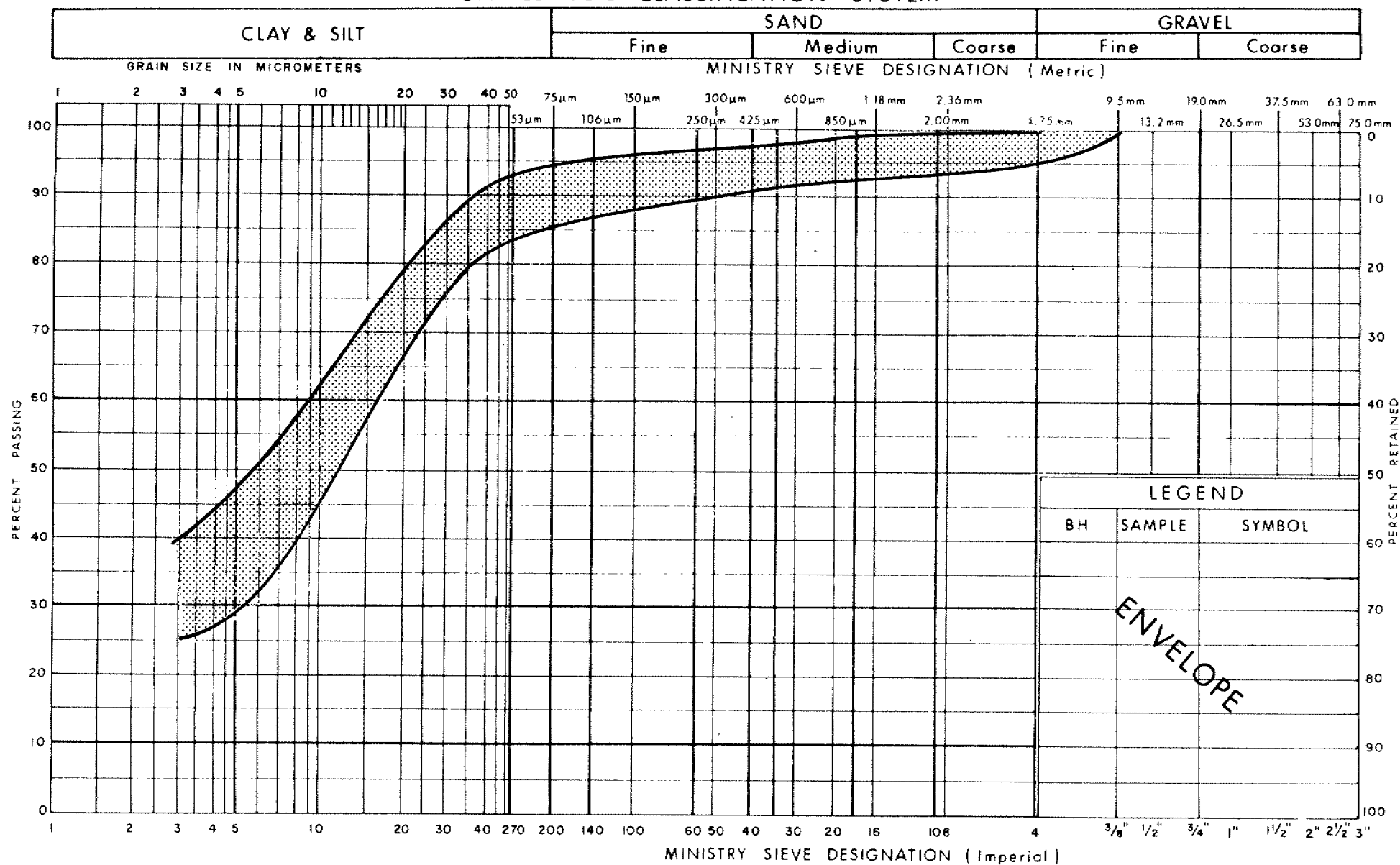
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PLASTICITY CHART
CLAYEY SILT
WITH SOME SAND AND TRACE OF GRAVEL

FIG No 8

W P 624-90-01/02

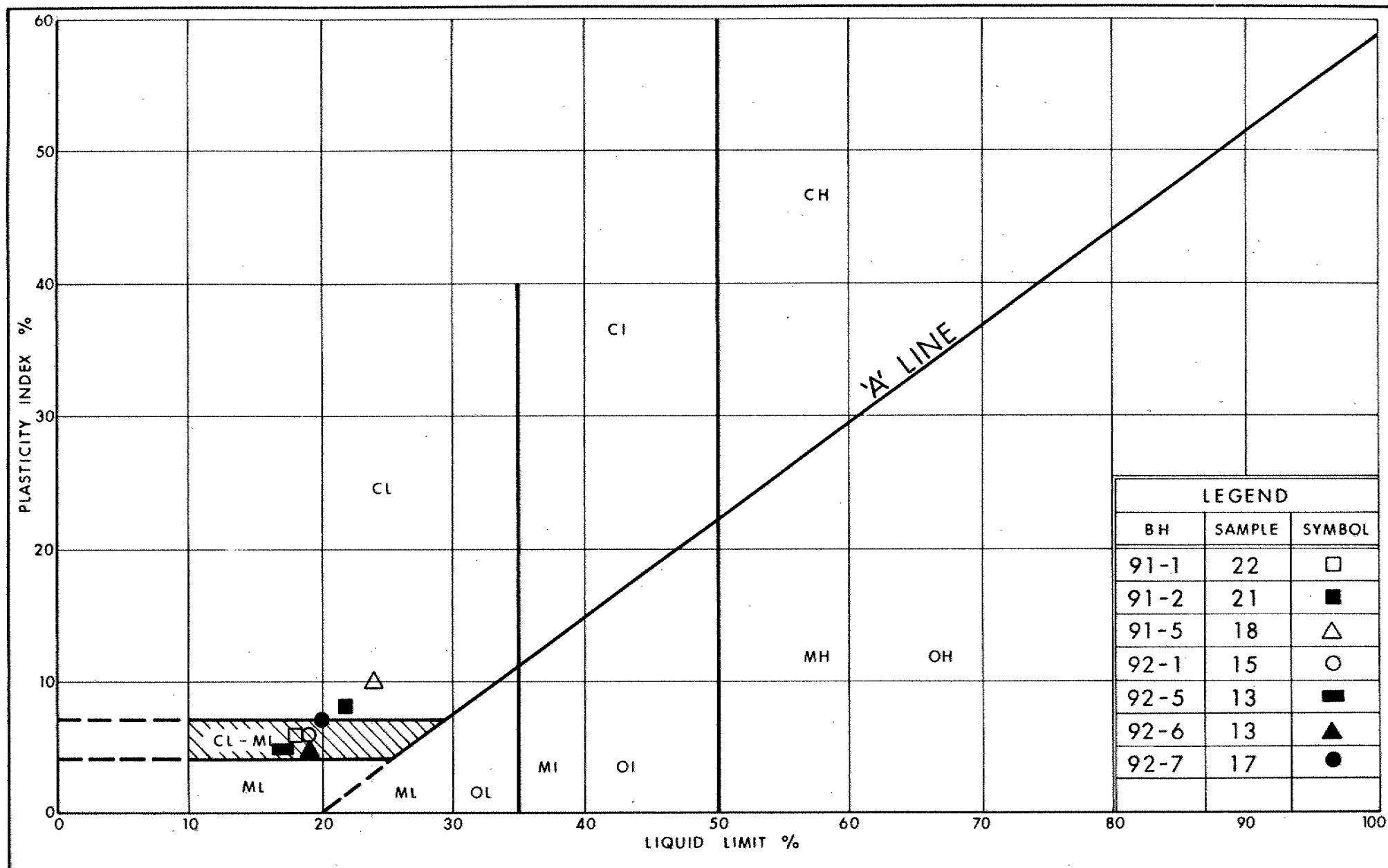
UNIFIED SOIL CLASSIFICATION SYSTEM


 Ministry of
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GRAIN SIZE DISTRIBUTION
 CLAYEY SILT
 WITH SOME SAND AND TRACE OF GRAVEL

FIG No 9

W P 624-90-01/02



Ministry of
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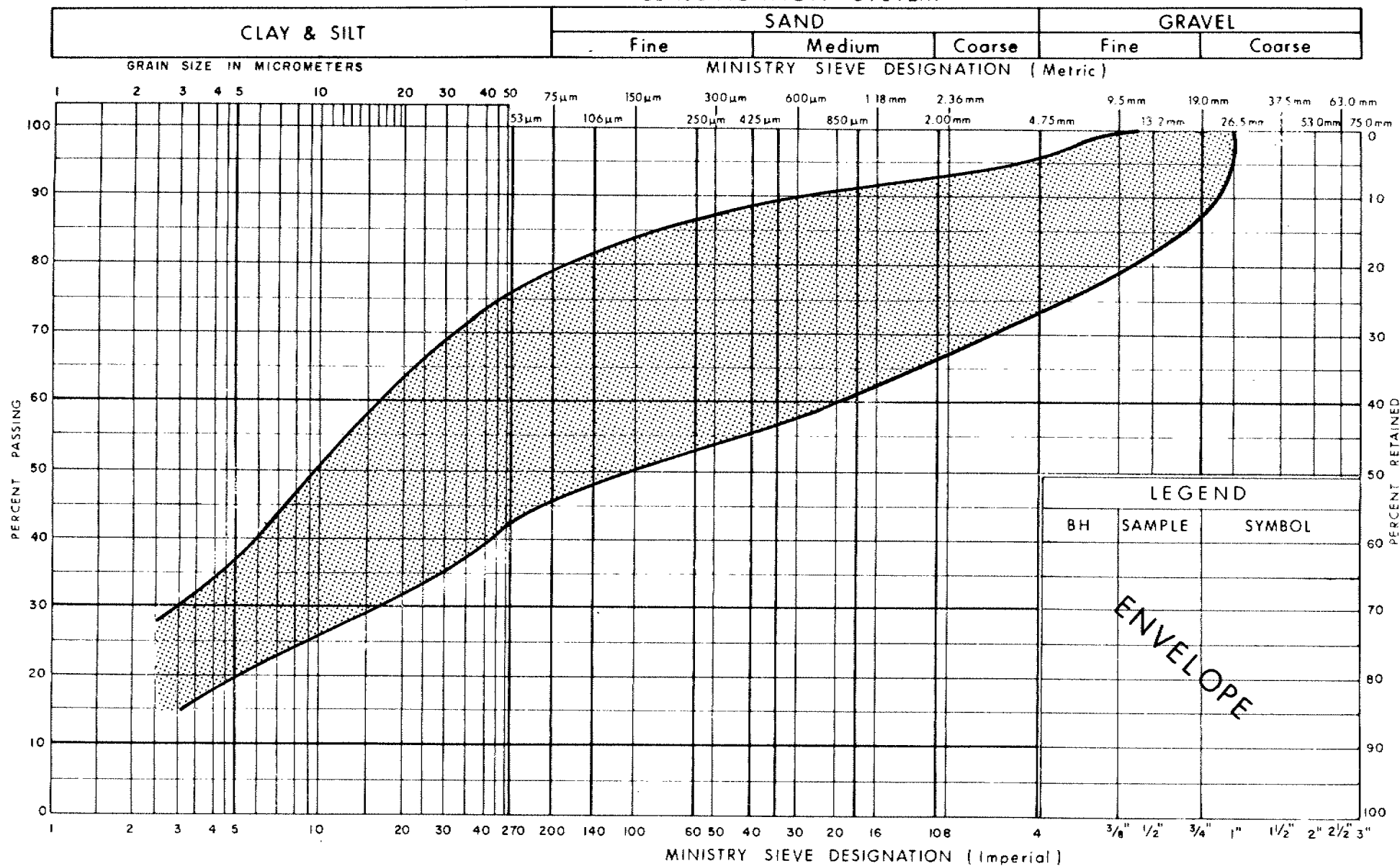
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PLASTICITY CHART
HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND & GRAVEL
 (COHESIVE GLACIAL TILL)

FIG No 10

W P 624-90-01/02

UNIFIED SOIL CLASSIFICATION SYSTEM



Ontario

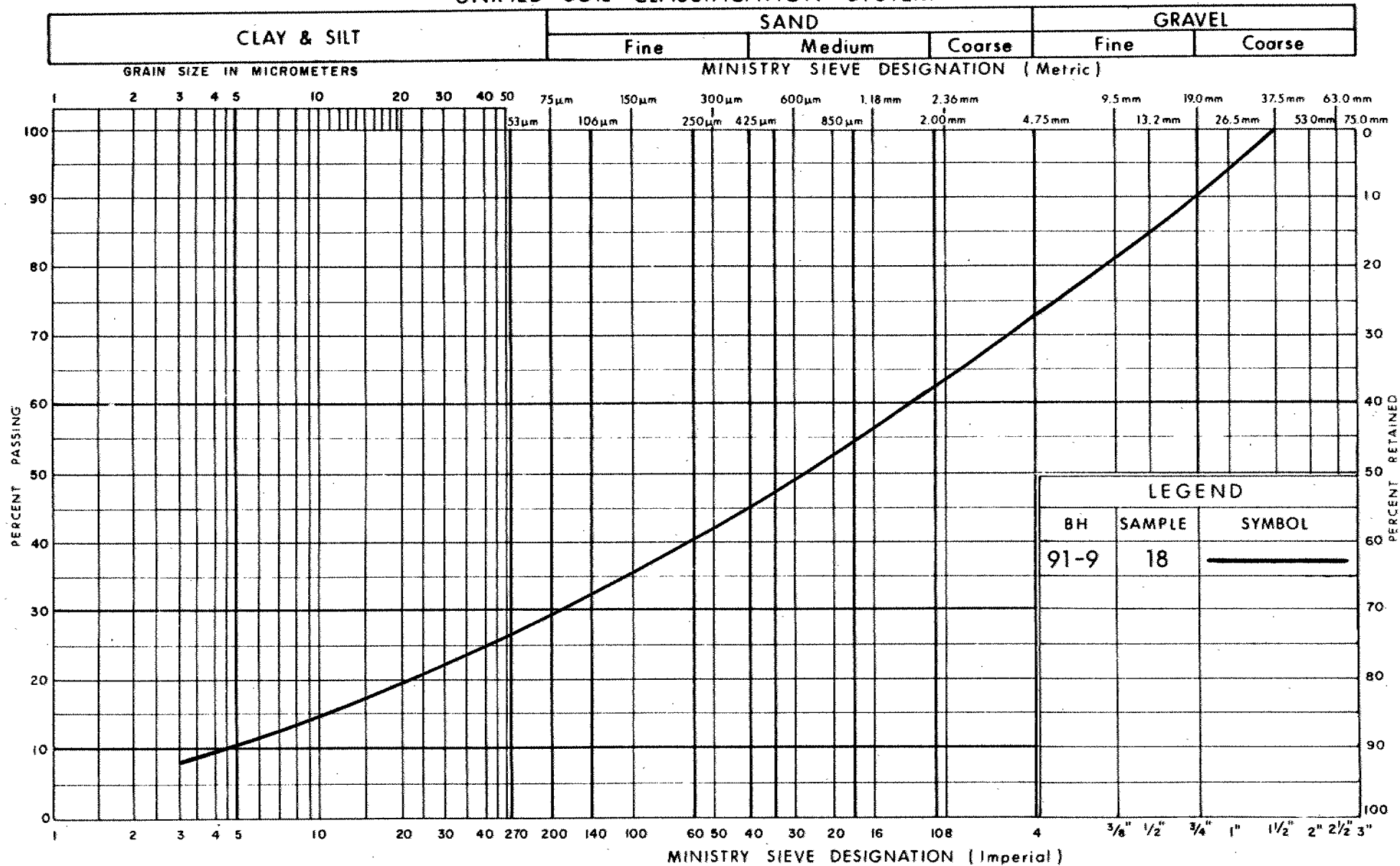
Ministry of
Transportation

GRAIN SIZE DISTRIBUTION
HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND & GRAVEL
 (COHESIVE GLACIAL TILL)

FIG No 11

W P 624 - 90-01/02

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation

GRAIN SIZE DISTRIBUTION
HETEROGENEOUS MIXTURE OF SILT, SAND & GRAVEL
 (NON-COHESIVE GLACIAL TILL)

FIG No 12

W P 624-90-01/02

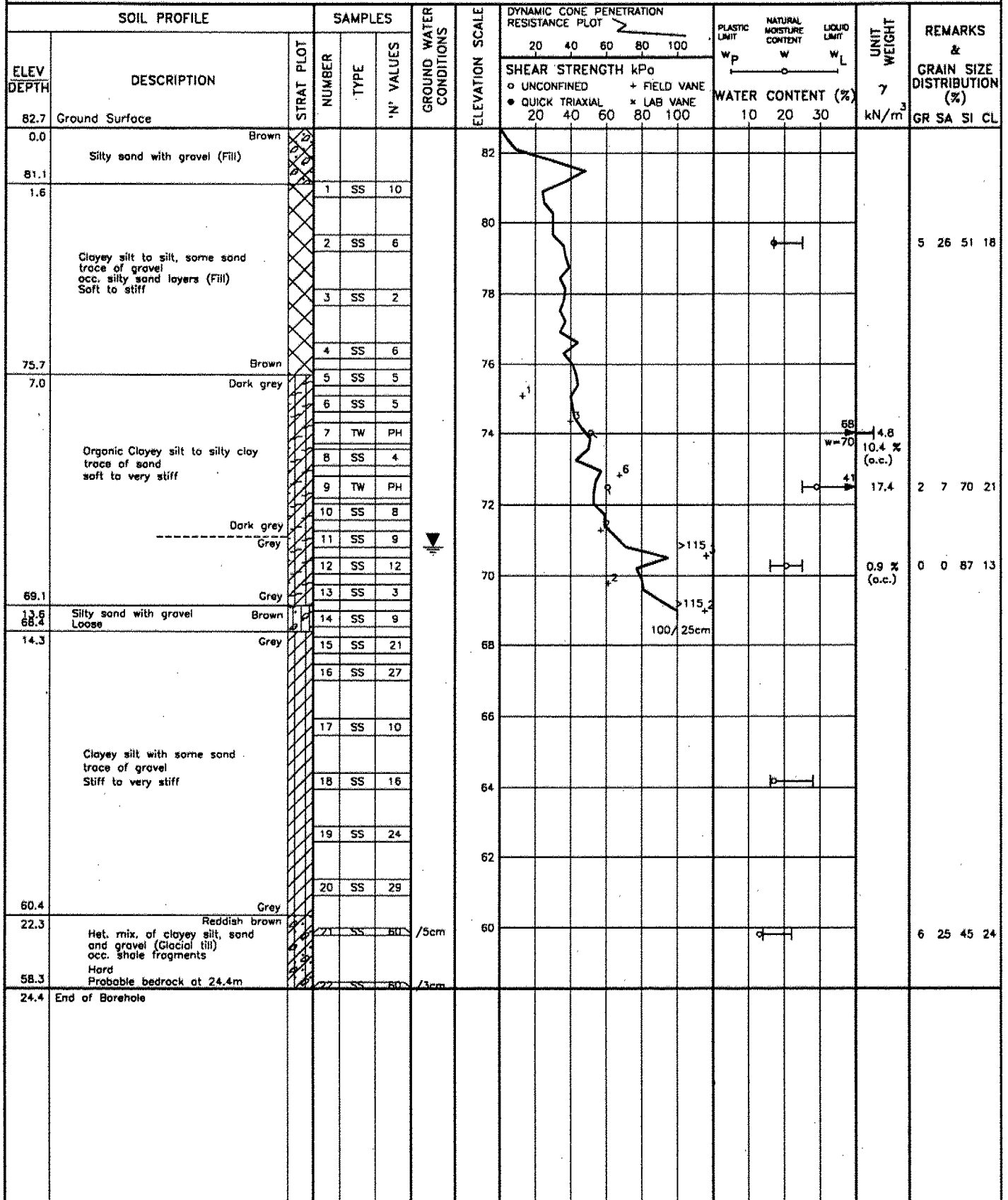
RECORD OF BOREHOLE No 91-1 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4782 027.9 E 317 883.7 ORIGINATED BY T.C.K.
 DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Cone Tests, Vane Tests, NQ Rock Core COMPILED BY R.N.
 DATUM Geodetic DATE Dec. 5 & 9, 1991 CHECKED BY T.C.K.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT		NATURAL MOISTURE CONTENT		LIQUID LIMIT		UNIT WEIGHT 7 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	W _p	W	W _p	W	W _L	W		
85.2	Ground Surface																
0.0	Sand and gravel (Fill)	Brown															
0.6	Granular 'A' (Fill)	Grey															
83.7		Grey															
1.5		Brown	1	SS	14												
			2	SS	21												
			3	SS	15												
	Clayey silt to silt, some sand and trace of gravel, occ. silty sand layers (Fill) Firm to very stiff		4	SS	19												1 35 43 21
			5	SS	26												13 51 (36)
	Silty sand layer Compact		6	SS	6												
			7	SS	10												
75.1			8	SS	9												
10.1			9	SS	7												
	Crushed Stone with sand (Fill) Loose to compact		10	SS	0												
			11	SS	7												
70.1		Brown	12	SS	10												
15.1	Organic clayey silt, some sand and gravel Very stiff	Grey	13	SS	16											2.2 % (a.c.)	15 7 72 6
69.0			14	SS	18												
16.2			15	SS	22												
			16	TW	PH											21.4	1 4 76 19
	Clayey silt with some sand trace of gravel Very stiff to hard		17	SS	32												1 10 65 24
			18	SS	27												
			19	SS	24												
			20	TW	PH												
60.1		Grey	21	SS	35												
25.1	Het. mixture of clayey silt, sand and gravel (Glacial till) occ. shale fragments	Reddish Brown	22	SS	101												26 29 35 10
58.4	Hard	Reddish brown	23	SS	109												
26.8	Queenston shale bedrock	Red	24	SS	60												
56.9			25	RC	REC	77%											RQD 23%
28.3	End of Borehole																

RECORD OF BOREHOLE No 91-2 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4782 009.5 E 317 869.7 ORIGINATED BY T.C.K.
DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Cone Tests, Vane Tests COMPILED BY R.N.
DATUM Geodetic DATE Dec. 13 & 16, 1991 CHECKED BY T.C.K.



RECORD OF BOREHOLE No 91-3 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4782 010.1 E 317 884.9 ORIGINATED BY T.C.K.
 DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Cone Tests, Vane Tests, NQ Rock Core COMPILED BY R.N.
 DATUM Geodetic DATE Dec. 16 & 17, 1991 CHECKED BY T.C.K.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT 7 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100					
82.8	Ground Surface													
0.0														
81.3	Silty sand with gravel (Fill)	Brown												
1.5			1	SS	19									
			2	SS	6									
	Clayey silt to silt some sand occ. silty sand layers (Fill) Soft to very stiff		3	SS	6									
			4	SS	9									
75.6		Brown	5	SS	0									
7.2		Dark grey	6	SS	15									
		Dark grey	7	SS	10									
		Grey	8	TW	PH									
	Organic Clayey silt to silty clay some sand Stiff to very stiff		9	SS	13									
			10	SS	11									
			11	SS	16									
70.8		Grey	12	SS	11									
12.0	Silty sand with gravel, compact	Brown	13	SS	22									
12.5		Grey												
			14	SS	31									
			15	SS	24									
	Clayey silt with some sand trace of gravel Very stiff to hard		16	SS	21									
			17	SS	31									
			18	SS	25									
60.5		Grey												
22.3	Reddish brown Het. mix. of clayey silt, sand and gravel (Glacial Till) occ. shale fragments		19	SS	50	/15cm								
58.4	Hard	Reddish brown												
24.4	weathered sound	Red												
	Queenston shale bedrock		20	RC	REC	88%								RQD 17%
56.0			21	RC	REC	83%								RQD 69%
26.8	End of Borehole													

RECORD OF BOREHOLE No 91-4 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4781 970.3 E 317 876.4 ORIGINATED BY T.C.K.
 DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Cone Tests, Vane Tests, NQ Rock Core COMPILED BY R.N.
 DATUM Geodetic DATE Dec. 10 & 11, 1991 CHECKED BY T.C.K.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT 7 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100					
83.0	Ground Surface													
0.0	Silty sand with gravel (Fill)													
81.3			1	SS	13									
1.7			2	SS	5									
	Clayey silt to silt, some sand, trace of gravel Occ. silty sand layers (Fill) Soft to stiff		3	SS	5									
			4	SS	0									
			5	SS	0									
72.9			6	SS	4									
10.1	Sand and gravel with crushed stone (Fill) Compact		7	SS	20									
71.0		Brown												
12.0		Grey	8	TW	PH									
			9	SS	22									
			10	SS	25									
	Clayey silt, some sand, trace of gravel Very stiff		11	SS	18									
			12	SS	29									
			13	SS	28									
60.7		Grey												
22.3	Het. mix of clayey silt, sand and Reddish gravel, occ. shale (Glacial Till)	Brown	14	SS	60									
60.0		Red												
23.0		weathered	15	RC	REC									
58.6	Queenston shale bedrock	sound			85%									RQD 19%
24.4	End of Borehole													

RECORD OF BOREHOLE No 91-5 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4781 971.0 E 317 892.1 ORIGINATED BY T.C.K.
 DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Cone Tests, Vane Tests, NQ Rock Core COMPILED BY R.N.
 DATUM Geodetic DATE Dec. 10 & 11, 1991 CHECKED BY T.C.K.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100					
82.9	Ground Surface													
0.0	Silty sand (Fill) Silty sand layer Loose Clayey silt to silt, some sand, trace of gravel (Fill) Occ. silty sand layers Firm to stiff	Brown	1	SS	6		82							
81.5			2	SS	4		80							
1.4			3	SS	5		78							
			4	SS	10		76							
			5	SS	5		74							
72.8			6	SS	8		72							
10.1	Organic Clayey Silt to Silty Clay trace of sand Soft to stiff	Grey	7	SS	8		70							
69.7			8	SS	0		68							
13.2			9	TW	PH		66							
68.6	Silty sand with gravel Clayey silt with some sand, trace of gravel Stiff to very stiff	Brown	10	SS	17		64							
14.3			11	TW	PH		62							
			12	SS	15		60							
			13	SS	42		58							
			14	SS	23									
			15	SS	21									
			16	SS	28									
			17	TW	PH									
60.6	Het. mix. of clayey silt, sand and gravel (Glacial Till) occ. shale fragments Hard	Brown	18	SS	60	/8cm								
58.5			19	SS	60	/15cm								
24.4	Queenston shale bedrock	Red	20	RC	REC 91%									
57.0														
25.9	End of Borehole													

RECORD OF BOREHOLE No 91-5A 1 OF 1 METRIC

W.P. B24-90-01/02/03/04 LOCATION Co-ord. N 4781 989.2 E 317 892.1 ORIGINATED BY T.C.K.
 DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Vane Tests COMPILED BY R.N.
 DATUM Geodetic DATE Dec. 12, 1991 CHECKED BY T.C.K.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	W _p	W	W _L		
82.9	Ground Surface																
0.0																	
81.4	Silty sand (Fill)																
1.5																	
	Clayey silt to silt, some sand trace of gravel Occ. silty sand layers (Fill)																
72.6		Brown	1	SS	10												
10.3		Grey	2	SS	11												
	Organic clayey silt to silty clay some sand, trace of gravel Stiff to very stiff		3	TW	PH												
69.5			4	SS	8												
13.4			5	TW	PH												
68.4	Silty sand with gravel Compact		6	SS	15												
14.5			7	SS	26												
	Clayey silt with some sand trace of gravel Very stiff to hard		8	SS	21												
			9	TW	PH												
			10	SS	13												
			11	SS	21												
64.2			12	SS	37												
18.7	End of Borehole																

RECORD OF BOREHOLE No 91-6 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4781 952.3 E 317 899.1 ORIGINATED BY T.C.K.
 DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Cone Tests, Vane Tests, NQ Rock Core COMPILED BY R.N.
 DATUM Geodetic DATE Dec. 2 & 4, 1991 CHECKED BY T.C.K.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								20 40 60 80 100							

85.3	Ground Surface													
84.7	Granular 'A' (Fill)	Grey												
0.6		Brown												
	Clayey silt to silt, some sand trace of gravel Occ. silty sand layers (Fill) Very stiff		1	SS	18									
			2	SS	25									
			3	SS	29									
				4	SS	31								
				5	SS	16								
76.8														
8.5	Crushed stone or subgrade material (Fill) Compact to very dense		6	SS	17									
			7	SS	8									
			8	SS	50 /4cm									
73.4														
11.9	Clayey silt to silt, trace of sand (Fill) Stiff to very stiff		9	SS	20									0 4 62 34
71.7		Brown	10	SS	14									
13.6	Organic clayey silt to silty clay some sand, trace of gravel Very stiff	Grey	11	SS	13									
			12	SS	12									3 48 34 15
69.1														
16.2				13	SS	54								0 5 70 25
				14	TW	PH								
	Clayey silt, trace of sand and gravel, occ. silt layers Very stiff to hard		15	SS	35									
			16	SS	34									
			17	TW	PH									
			18	SS	22									
61.4			Grey											
23.9	Reddish brown		19	SS	60 /15cm									
			20	SS	60 /8cm									
57.9	Hard	Reddish brown												
27.4	Queenston shale bedrock	Red	22	RC	REC 98%									RQD 9%
56.6														
28.7	End of Borehole													

RECORD OF BOREHOLE No 91-7 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4782 013.2 E 317 803.7 ORIGINATED BY I.K.
 DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Vane Tests COMPILED BY R.N.
 DATUM Geodetic DATE Dec. 18, 1991 CHECKED BY I.C.K.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
82.8	Ground Surface																
0.0																	
	Clayey silt to silt, some sand trace of gravel acc. silty sand layers (Fill) Firm to Stiff		1	SS	5												
			2	SS	10												
			3	SS	7												
73.0		Brown	4	SS	15												
9.8		Grey	5	SS	14												
	Organic clayey silt to silty clay trace of sand Stiff to Very Stiff		6	SS	19												
			7	SS	16												
69.4			8	SS	12												
13.4	Clayey silt with some sand																
68.6	Stiff																
14.2	End of Borehole																

RECORD OF BOREHOLE No 91-8 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4781 994.2 E 317 903.7 ORIGINATED BY T.C.K.
 DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Vane Tests COMPILED BY R.N.
 DATUM Geodetic DATE Dec. 20, 1991 CHECKED BY T.C.K.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
82.9	Ground Surface																
82.8	Granular "A"																
82.3	Brown																
			1	SS	13												
			2	SS	5												
			3	SS	3												
			4	SS	4												
			5	TW	PH												
71.2																	
			6	TW	PH												
			7	TW	PH												
			8	SS	38												
66.7																	
16.2																	
65.7			9	SS	59												
17.2	End of Borehole																

RECORD OF BOREHOLE No 91-9

1 OF 1

METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4781 971.0 E 317 932.1 ORIGINATED BY T.C.K.
DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Cone Tests, Vane Tests COMPILED BY R.N.
DATUM Geodetic DATE Dec. 12 & 13, 1991 CHECKED BY T.C.K.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100		
82.5	Ground Surface													
0.0	Silty sand (Fill)													
81.1														
1.4			1	SS	5									
			2	SS	15									
			3	SS	2									
	Clayey silt to silt, some sand, trace of gravel occ. silty sand layers (Fill) Soft to Stiff		4	SS	1									
			5	SS	3									
			6	TW	PM									
			7	SS	2									
71.6		Brown	8	SS	10									
10.8		Grey												
	Organic clayey silt to silty clay some sand Stiff to Very Stiff		9	SS	12									
			10	TW	PH									
68.2			11	SS	11									
14.3			12	TW	PH									
	Clayey silt, some sand, trace of gravel Compact to Dense		13	SS	30									
			14	SS	24									
			15	SS	35									
			16	SS	0									
			17	SS	27									
62.1		Grey												
20.4		Brown												
	Het. mix. of silt, sand and gravel (Glacial Till) Compact		18	SS	27									
59.8			19	SS	75	/15cm								
22.7	End of Borehole													
	Het. mix. of clay silt, sand and gravel occ. shale fragments (Glacial Till)													

RECORD OF BOREHOLE No 92-1 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4782 027.8 E 317 844.3 ORIGINATED BY MI
DIST 4 HWY QEW BOREHOLE TYPE HS Auger, Vane Tests, NQ Rock Core COMPILED BY MI
DATUM Gedeotic DATE May 15, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT 7 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
85.0	Ground Surface																
0.0																	
			1	SS	19		84										
			2	SS	19		82										
	Clayey Silt to Silt, some sand and trace of gravel occ. silty sand layers (Fill) Firm to Very Stiff		3	SS	14		80										
			4	SS	12		78										13 41 28 18
			5	SS	7		76										
			6	SS	7		74										
73.3		Brown	7	SS	7												
11.7		D.Grey	8	SS	5		72										
	Organic Clayey Silt to Silty Clay trace of sand Firm to Stiff		9	TW	PH												
69.9		D.Grey	10	SS	5		70										
15.1		Grey	11	SS	15		68										
			12	SS	20		66										
	Silty Sand		13	SS	21		64										
	Clayey Silt, some sand, trace of gravel occ. silty sand layers Stiff to Very Stiff		14	SS	15		62										
61.5		Grey	15	SS	100		60										
23.5		Reddish Brown	16	SS	100		58										
59.0	Het. Mixture of Clayey Silt, Sand and Gravel occ. shale fragments Hard (Glacial Till)	Reddish Brown	17	RC	REC 97%												24 20 41 15
26.0	Queenston Shale	Red															
57.5	Bedrock																RQD 25%
27.5	End of Borehole																

RECORD OF BOREHOLE No 92-2 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4782 028.6 E 317 865.3 ORIGINATED BY MI
 DIST 4 HWY QEW BOREHOLE TYPE HS Auger, Vane Tests, NQ Rock Core COMPILED BY MI
 DATUM Gedeckle DATE May 19, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
85.0	Ground Surface																
0.0																	
			1	SS	10		84										
			2	SS	13		82										
			3	SS	14		80										
			4	SS	14		78										
			5	SS	8		76										
			6	SS	7		74										
74.8			7	SS	9		72										
10.1	Sand and Gravel with crushed stone (Fill)	Brown	8	SS	4		70										
73.3			9	SS	4		68										
11.7		D.Grey	10	TW	PH		66										
			11	SS	4		64										
			12	SS	8		62										
			13	SS	13		60										
69.2		D.Grey	14	TW	PH		58										
15.8		Grey	15	SS	8		56										
			16	SS	33		54										
			17	SS	100		52										
60.4		Grey	18	RC	REC		50										
24.6	Hel. Mixture Clayey Silt, Reddish Brown Sand and Gravel (Glacial Till) occ. Shale Fragments, Hard	Reddish Brown					48										
58.0		Weathered Sound					46										
26.0	Queenston Shale Bedrock						44										
57.3							42										
27.7	End of Borehole						40										

RECORD OF BOREHOLE No 92-3 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4782 030.1 E 317 904.3 ORIGINATED BY MI
 DIST 4 HWY QEW BOREHOLE TYPE HS Auger, Vane Tests, NO Rock Core COMPILED BY MI
 DATUM Gedectic DATE May 13, 1992 to May 14, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT 7 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
85.3	Ground Surface													
0.0														
			1	SS	25		84							
	Silty Sand		2	SS	22		82							
			3	SS	26		80							
	Silty Sand		4	SS	12		78							
	Clayey Silt to Silt, some sand, trace of gravel occ. silty sand layers (Fill)		5	SS	6		76							
75.2	Firm to Very Stiff	Brown	6	SS	7		74							
10.1	Organic Clayey Silt to Silty Clay trace of sand	D.Grey	7	SS	3		72							
74.0	Soft	Grey	8	TW	PH		70							
11.3			9	SS	20		68							
			10	SS	13		66							
			11	SS	13		64							
			12	SS	9		62							
	Clayey Silt, with sand, trace of gravel		13	SS	10		60							
	Very Stiff		14	SS	16		58							
			15	SS	19		56							
60.7		Grey					54							
24.6	Reddish Brown		16	SS	100	/25cm	52							
	Het. Mixture of Clayey Silt, Sand and Gravel occ. shale fragments (Glacial Till)		17	SS	100	/18cm	50							
57.7	Hard	Reddish Brown					48							
27.6	weathered sound	Red	18	RC	REC	100%	46							
56.2	Queenston Shale Bedrock						44							
29.1	End of Borehole						42							

RECORD OF BOREHOLE No 92-4 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-urd. N 4781 992.0 E 317 850.7 ORIGINATED BY MI
 DIST 4 HWY QEW BOREHOLE TYPE HS Auger, Vane Tests, NQ Rock Core COMPILED BY MI
 DATUM Gedeotic DATE May 27, 1992 to May 28, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
83.4	Ground Surface																
0.0																	
			1	SS	3		82										
			2	SS	1		80										
			3	SS	2		78										
			4	SS	1		76										
			5	SS	1												
74.8			6	SS	7		74										
8.6			7	TW	PH		72										
73.6			8	SS	21		70										
9.8			9	SS	7		68										
			10	SS	7		66										
			11	SS	10		64										
			12	SS	10		62										
61.8			13	SS	115		60										
21.6			14	SS	100		58										
58.9			15	RC	REC 84%												
24.5																	
57.3																	
26.1																	

RECORD OF BOREHOLE No 92-5 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4781 988.3 E 317 910.9 ORIGINATED BY MI
DIST 4 HWY QEW BOREHOLE TYPE HS Auger, Vane Tests, NQ Rock Core COMPILED BY MI
DATUM Cedectic DATE May 26, 1992 to May 27, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
83.4	Ground Surface																
0.0	Granular "A" (Fill)																
81.9																	
1.5			1	SS	9		82										
			2	SS	16		80										
			3	SS	7		78										
			4	SS	7		76										
	Clayey Silt to Silt, some sand and gravel, occ. silty sand layers (Fill)		5	SS	1		74										
	Soft to Very Soft		6	SS	1		72										
			7	SS	2		70										
71.7			8	SS	10		68										
11.7	Organic Clayey Silt to Silty Clay some sand Stiff to Very Stiff	Brown D.Grey	9	TW	PH		66										
68.3			10	SS	15		64										
15.1			11	TW	PH		62										
	Clayey Silt, with some sand, trace of gravel Stiff to Very Stiff	D.Grey Grey	12	SS	12		60										
61.1			13	SS	91		58										
22.3	Het. Mixture of Clayey Silt, Sand and Gravel, occ. shale fragments (Glacial Till) Hard	Reddish Brown	14	SS	100												
58.2			15	RC	REC 92%												
25.2	Queenston Shale Bedrock	Red															
56.7																	
26.7	End of Borehole																

RECORD OF BOREHOLE No 92-6

1 OF 1

IMPERIAL

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4781 971.4 E 317 914.5 ORIGINATED BY MI
DIST 4 HWY QEW BOREHOLE TYPE HS Auger, Vane Tests, NQ Rock Core COMPILED BY MI
DATUM Gedeotic DATE May 28, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT 7 pcf	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
82.9	Ground Surface																
0.0	Sandy Silt (Fill) Compact		1	SS	10		82										
80.2			2	SS	4		80										
2.7			3	SS	5		78										
	Clayey Silt to Silt, some sand, trace of gravel occ. silty sand layers (Fill) Firm		4	SS	5		76										
			5	SS	4		74										
72.8			6	SS	4		72										
10.1	Brown Organic Clayey Silt to Silty Clay traces of sand Stiff		7	SS	8		70										
71.2	D.Grey Grey		8	SS	4		68										
11.7			9	SS	44		66										
	Clayey Silt, with some sand, trace of gravel Firm to Hard		10	SS	22		64										
			11	SS	16		62										
61.4	Grey		12	SS	30		60										
21.5	Reddish Brown		13	SS	100	/28cm	58										
58.4	Het. Mixture of Clayey Silt, Sand and Gravel occ. shale fragments (Glacial Till) Hard		14	SS	100	/13cm											
24.5	Red		15	RC	REC 100%												
56.8	Queenston Shale Bedrock																
26.0	End of Borehole																

RECORD OF BOREHOLE No 92-7 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N4781 950.4 E 317 861.3 ORIGINATED BY MI
DIST 4 HWY QEW BOREHOLE TYPE HS Auger, Vane Tests, NQ Rock Core COMPILED BY MI
DATUM Gedecitic DATE May 11, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT 7 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
85.2	Ground Surface																
0.0	Clayey Silt to Silt, some sand and trace of gravel occ. silty sand layers (Fill) Stiff to Very Stiff		1	SS	18		84							o	H		11 44 30 15
			2	SS	20												
			3	SS	17												
			4	SS	23		82										
80.8			5	SS	11												
4.4	Silty Sand, some gravel, trace of clay Compact	Brown	6	SS	18		80							o	H		31 39 23 7
79.6		Grey	7	SS	11												
5.6			8	SS	11		78										
			9	SS	7		76										
			10	SS	9		74										
	Clayey Silt some sand, trace of gravel Stiff to Very Stiff		11	SS	10		72										
			12	SS	5		70										
			13	SS	11		68										
			14	SS	11		66										
			15	SS	10		64										
			16	SS	15		62										
61.3		Grey	17	SS	100		60							o	H		25 23 38 14
23.9	Reddish Brown Het. Mixture of Clayey Silt, Sand and Gravel occ. shale fragments (Glacial Till) Hard	Reddish Brown	18	SS	100		58										
59.1		Red	19	RC	REC 89%												RQD 44%
26.1	Queenston Shale Bedrock		20	RC	REC 100%												RQD 0%
57.6																	
27.8	End of Borehole																
	• Water level not stabilized																

RECORD OF BOREHOLE No 92-8

1 OF 1

METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N4781 951.1 E 317 881.3 ORIGINATED BY MI
DIST 4 HWY QEW BOREHOLE TYPE HS Auger, NQ Rock Core COMPILED BY MI
DATUM Gedectic DATE May 20, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT 7 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
85.2	Ground Surface													
0.0	Clayey Silt to Silt some sand and gravel occ. silty sand to sandy silt layers (Fill) Stiff		1	SS	11		84							
			2	SS	13		82							
			3	SS	14		80							4 30 44 22
			4	SS	11		78							
76.6			5	SS	10		76							
8.6	Sand and Gravel with crushed stone (Fill)		6	SS	16		74							
75.1	Compact Brown		7	SS	4		72							
10.1	Organic Clayey Silt to Silty Clay some sand D.Grey		8	SS	22		70							1 21 58 20
73.9	Firm Grey		9	SS	19		68							
11.3	Silty Sand		10	SS	63		66							
			11	SS	19		64							
	Clayey Silt, some sand, trace of gravel occ. silty sand layers Stiff to Very Stiff		12	SS	15		62							
			13	SS	14		60							
61.3	Grey		14	SS	78		58							
23.9	Reddish Brown Het. Mixture of Clayey Silt, Sand and Gravel occ. shale fragments (Glacial Till)		15	SS	100	/25cm								
58.8	Hard Reddish Brown		16	SS	100	/13cm								
26.4	Red Queenston Shale Bedrock		17	RC	REC 73%									RQD 68%
56.1														
29.1	End of Borehole													

RECORD OF BOREHOLE No 92-9

1 OF 1

METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4781 952.6 E 317 921.2 ORIGINATED BY MI
DIST 4 HWY QEW BOREHOLE TYPE HS, NO Core COMPILED BY MI
DATUM Cedectic DATE May 12, 1992 to May 13, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
85.4	Ground Surface																
0.0			1	SS	11		84										
			2	SS	14		82										
	Sandy Silt		3	SS	15		80										
			4	SS	10		78										
	Silty Sand		5	SS	13		76										
	Clayey Silt to Silt, some sand, trace of gravel occ. sandy silt to silty sand layers		6	SS	9		74										
	Stiff to Very Stiff		7	SS	9		72										
	(Fill)		8	SS	8		70										
71.8	Brown		9	SS	9		68										
13.6	Organic Clayey Silt to Silty Clay trace of sand		10	SS	7		66										
	Firm to Very Stiff		11	TW	PH		64										
69.2	D.Grey		12	SS	3		62										
16.2	Grey		13	SS	9		60										
			14	SS	14		58										
	Clayey Silt, some sand, trace of gravel		15	SS	14		56										
	Stiff to Very Stiff		16	SS	11		54										
61.6	Grey		17	SS	86		52										
23.8	Reddish Brown		18	SS	100	/23cm	50										
	Het. Mixture of Clayey Silt, Sand and Gravel, occ. shale fragments		19	SS	100	/10cm	48										
	(Glacial Till)		20	RC	REC	97%	46										
56.4	Reddish Brown						44										
29.0	Red						42										
54.9	Queenston Shale Bedrock						40										
30.5	End of Borehole						38										

+³, x⁵. Numbers refer to
Sensitivity

20
15-5 (%) STRAIN AT FAILURE
10

ROCK CORE DESCRIPTION
WP 624-90-01/02/03/04

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CORE RECOVERY					CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
91-1	25	26.82-28.35	77	23	26.82-28.35	SHALE , greyish red, with interbedded greenish grey SILTSTONE (7%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 27.89-28.12 m); fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
91-3	19	24.38-25.91	88	17	24.38-26.82	SHALE , greyish red, with interbedded greenish grey SILTSTONE (14%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 24.38-24.71 m); fractures moderately close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
	20	25.91-26.82	83	69		
91-4	15	23.01-24.38	85	19	23.01-24.38	SHALE , greyish red, with interbedded greenish grey SILTSTONE (7%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 23.01-23.72 m); fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
91-5	20	24.38-25.93	91	23	24.38-25.93	SHALE , greyish red, with interbedded greenish grey SILTSTONE (8%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
91-6	22	27.43-28.68	98	9	27.43-28.68	SHALE , greyish red, with interbedded greenish grey SILTSTONE (14%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 27.43-27.51 m); fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

(NOTE: Depths are approximated where core recovery is less than 100%)

Logged by: DAW, Soils and Aggregates Section

ROCK CORE DESCRIPTION
WP 624-90-01/02/03/04

Page 1 of 2

CORE RECOVERY					CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
92-1	17	25.98-27.51	97	25	25.98-27.51	SHALE , greyish red, with interbedded greenish grey SILTSTONE (5%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-2	18	26.19-27.71	93	7	26.19-27.71	SHALE , greyish red, with interbedded greenish grey SILTSTONE (5%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-3	18	27.61-29.13	100	50	27.61-29.13	SHALE , greyish red, with interbedded greenish grey SILTSTONE (15%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 27.61-28.04 m); fractures moderate to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-4	15	24.54-26.06	84	27	24.54-26.06	SHALE , greyish red, with interbedded greenish grey SILTSTONE (6%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 24.54-24.66 m); fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-5	15	25.15-26.67	92	18	25.15-26.67	SHALE , greyish red, with interbedded greenish grey SILTSTONE (7%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

(NOTE: Depths are approximated where core recovery is less than 100%)

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ROCK CORE DESCRIPTION
WP 624-90-01/02/03/04

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CORE RECOVERY					CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
92-6	15	24.51-26.04	100	45	24.51-26.04	SHALE, greyish red, with interbedded greenish grey SILTSTONE (7%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-7	19	26.11-27.03	89	44	26.11-27.64	SHALE, greyish red, with interbedded greenish grey SILTSTONE (8%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
	20	27.03-27.64	100	0		
92-8	17	27.56-29.08	73	68	27.56-29.08	SHALE, greyish red, with interbedded greenish grey SILTSTONE (13%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-9	20	29.06-30.58	97	43	29.06-30.58	SHALE, greyish red, with interbedded greenish grey SILTSTONE (8%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to very close spaced, flat to near vertical, planar to undulating, smooth.

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

(NOTE: Depths are approximated where core recovery is less than 100%)

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Ministry
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Transportation

FOUNDATION DESIGN SECTION

**foundation
investigation and
design report**

ENGINEERING MATERIALS OFFICE
FOUNDATION DESIGN SECTION

CONT 94-53

WP 624-90-01/02 DIST 4

HWY Q.E.W. STR SITE 18-20

Q.E.W. Crossing at 18 Mile Creek
Westbound and Eastbound Lanes

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FOUNDATION INVESTIGATION REPORT
For
Q.E.W. Crossing at 18 Mile Creek
W.P. 624-90-01 Westbound Lane
W.P. 624-90-02 Eastbound Lane
Site No. 18-20
District 4, Burlington

INTRODUCTION

This report summarizes the information obtained from a foundation investigation carried out at the above mentioned site where three span four bridge structures are proposed to carry the existing Q.E.W. and South and North Service Roads Crossing at 18 Mile Creek.

The field works for the foundation investigation were carried out at the above mentioned site during the period of December 2 to December 20, 1991 and May 11 to May 29, 1992. Ten boreholes (BH 91-1 to BH 91-9 inclusive, plus BH 91-5A) for the proposed original large twin culverts (5.9 m X 5.9 m X 137 m) were advanced and sampled between December 2 and December 20, 1991 to replace the existing twin culverts.

It should be noted that the original design scheme was found to be not environmentally viable. Therefore, a new proposal brought forth to replace the existing culverts with four (4) bridge structures. Additional nine boreholes (BH 92-1 to BH 92-9) were advanced and sampled as part of this project between May 11 and May 29, 1992. These boreholes extended down to depths between 14.2 m and 30.5 m below the existing ground surface.

Total of nineteen (19) boreholes were drilled for four bridge structures. Among them, eleven (11) boreholes are located within the Q.E.W. eastbound and westbound lanes, while four (4) boreholes are situated within South Service Road structure and North Service Road structure, respectively. The information from these boreholes is utilized in this report.

This report contains factual information obtained from these investigations pertaining to structure foundations, approach embankments and related earthworks for the Q.E.W. bridge structures, eastbound and westbound lanes, as shown on Dwg. No. 6249001/02-A and B.

SITE DESCRIPTION AND GEOLOGY

The site is located on the existing alignment of Q.E.W. where it crosses the Eighteen Mile Creek in the Town of Lincoln, Regional Municipality of Niagara. The proposed structures are located approximately 2.5 km east of Jordan Harbour. The topography in the area is gently undulating with a valley. Land use in the vicinity of the site is primarily agricultural known as the Niagara Fruit Belt.

Physiographically, the site is located in the "Iroquois Plain" region (Ref: Chapman and Putnam, 1984). The general area was inundated by the Pleistocene Lake Iroquois. As the lake level receded much below the present level of Lake Ontario, the Eighteen Mile Creek cut a valley through the till. Underlying the glacial deposit is the red Queenston Shale from which the till's reddish colour is derived. Later, the rise in the Lake Ontario water level to approximately its present level, drowned the outlet of the creek and created a lagoon and marsh separated from the lake by a barrier beach. Water flow is to the north into Lake Ontario.

SUBSURFACE CONDITIONS

The subsoil conditions are generally consistent across the site. The Q.E.W. crosses the Eighteen Mile Creek at this location. The road embankment fill of the existing Q.E.W. consists of bedding sand, mainly clayey silt and some crushed stone as much as 13.6 m in the middle of valley.

Underlying the fill is a layer of organics which was encountered at all borehole locations except at one borehole location (BH 92-7). The thickness of this layer ranges from 1.1 m at BH 91-1 to 5.6 m at BH 91-2.

Underneath this layer, clayey silt with some sand and trace of gravel was encountered. The thickness of this layer ranges from 6.1 m at BH 91-9 to 18.3 m at 92-7. A thin layer of silty sand and gravel was found at 6 borehole locations (BH's 91-2, 91-3, 91-5, 91-5A, 91-6, and 92-2) in between the organic material and clayey silt with a maximum thickness of about 1.2 m at BH 92-7.

Cohesive glacial till was encountered underneath the clayey silt at all boreholes locations. This material can be described as a heterogeneous mixture of clayey silt, sand and gravel. The maximum thickness of this deposit was found to be about 5.2 m at BH 92-9. This layer is underlain by shale and siltstone bedrock. A thin layer of non-cohesive glacial till, which can be described as a heterogeneous mixture of silt, sand and gravel, was found with a thickness of 2.4 m at BH 91-9.

Sound bedrock was proven in 14 borehole locations by obtaining up to 2.7 m of NQ rock cores. The bedrock surface ranges from an elevation of 56.4 m at BH 92-9 to an elevation of 60.0 m at BH 91-4 which corresponds to 29.0 m and 23.0 m below the existing ground surface, respectively. The upper portion of bedrock was slightly weathered for a maximum 1.2 m at BH 92-8 below the rock surface. The sound bedrock surface ranges from an elevation of 56.4 m at BH 92-9 to an elevation of 59.3 m at BH 91-4 which corresponds to 29.0 m and 23.7 m below the existing ground surface. The bedrock is known to be "SHALE and interbedded SILTSTONE of the Queenston Formation".

The boundaries between the various soil types, in situ and laboratory test results are shown on the attached Record of Borehole Sheets in the Appendix. The locations and elevations of the boreholes, along with a profile and sections, are shown on Dwg. No. 624901/02-A and B.

A detailed description of the subsurface conditions encountered is given below.

Embankment Fill

The embankment fill consists of bedding sand, mainly clayey silt and some crushed

stone. The thickness of this layer was found to range from 4.4 m at BH 92-7 to 13.6 m at BH's 91-6 and 92-9.

Atterberg Limit Tests were performed on clayey silt samples and the results are plotted on Figure 1 and summarized as follows:

<u>Property</u>	<u>Range (%)</u>
Natural Moisture Content (w)	8.5 - 24.5
Liquid Limit (w_L)	16.5 - 36.0
Plastic Limit (w_p)	13.0 - 17.5
Plasticity Index (I_p)	3.0 - 19.0

From the Plasticity Chart, it is evident that the layer can be classified as a clayey silt to silt, some sand and gravel with low plasticity (CL or CL-ML).

Grain Size Distribution tests were carried out on this fill material. Figure 2 in the Appendix shows the results in an envelope form. In this stratum, the "N" values range from 0 to over 31 blows/0.3 m indicating the consistency of this deposit described as very soft to hard. Some silty sand layers were found within this clayey silt fill as shown on Figure 3.

Organic Clayey Silt to Silty Clay, Some Sand

This deposit was encountered beneath the existing embankment fill in all boreholes except BH No's 91-4 and 92-7 which were on or near the edge of the valley. The thickness of this deposit ranges from 1.1 m at BH 91-1 to 5.6 m at BH 91-2 and this deposit gradually peters out near the valley's edge.

The material, as sampled, was highly organic with organic pieces generally visible, and well-decayed pieces of roots and wood were not uncommon. Occasional samples were fibres. Some sand and occasional gravel were noted as well as occasional sand seams.

Atterberg Limit tests were performed on these samples and the results are plotted on Figure 4 and summarized as follows:

<u>Index Property</u>	<u>Range (%)</u>
Natural Moisture Content (w)	19.0 - 70.0
Liquid Limit (w_L)	17.0 - 68.0
Plastic Limit (w_p)	14.0 - 45.0
Plasticity Index (I_p)	3.0 - 23.0

From the plasticity chart, it is evident that the layer can be classified as an organic clayey silt to silty clay with low to high plasticity (OL.OI and OH).

Grain Size Distribution tests were carried out on these materials. Figure 5 in the Appendix shows the results in an envelope form.

Undrained Shear Strength of the soil was determined by in situ vane tests and by laboratory tests, namely unconfined compression tests. The results are plotted on Figure 6 and the Record of Borehole log sheets in the Appendix and summarized as follows:

<u>Undrained Shear Strength</u>	<u>Cu (kPa)</u>	<u>Sensitivity</u>
In-Situ Vane Tests	15 - >115	1 - 6
Unconfined Compression Tests	28 - 98	

As shown on Figure 6, the vane strengths measured within organic layer varied from 15 kPa to greater than 115 kPa, indicating soft to very stiff consistency. This layer has a sensitivity varying from 1 to 6 based on the measured undisturbed and remoulded vane strengths. This would indicate that the organic clayey silt to silty clay is generally sensitive.

An oedometer test was carried out to investigate the consolidation characteristics of the organic clayey silt to silty clay. The sample tested is

considered representative of the organic deposit was selected from a Shelby tube sample obtained at about an elevation of 69 m in BH 91-8. The result of the consolidation test is shown on Figure 7. The preconsolidation pressure is estimated to be about 330 kPa, indicating an overconsolidation ratio of about 1.25 relative to the existing effective overburden stress. The compression index (C_c) was determined to be about 0.213.

Silty Sand With Gravel

This deposit was found at five (5) borehole locations underlying the organic stratum (BH 91-2, 91-3, 91-5, 91-5A and 92-7). The thickness of this layer ranges from 0.5 m at BH 91-3 to 1.1 m at BH's 91-5, 91-5A and 92-7. Figure 3 in the Appendix shows the result of Grain Size Distribution test.

In this stratum, the "N" values ranged from 9 to 22 blows/0.3 m indicating a state of compaction described as loose to compact.

Clayey Silt With Sand

This deposit was encountered in all boreholes, either beneath the organic clayey silt to silty clay or the silty sand deposit, and appeared to represent the original material into which the Creek Valley had been carved. Hence, the deposit varied in thickness from 18.3 m at BH 92-7 near the edge of the valley to a minimum of 6.1 m at BH 91-9 near the centre of the valley.

Atterberg Limit tests were performed on these samples and the results are plotted on Figure 8 and summarized as follows:

<u>Index Property</u>	<u>Range (%)</u>
Natural Moisture Content (w)	13.0 - 20.5
Liquid Limit (w_L)	19.0 - 32.0
Plastic Limit (w_p)	14.0 - 17.0
Plasticity Index (I_p)	4.0 - 15.0

From the plasticity chart, it is evident that the layer can be classified as an inorganic clayey silt, some sand with low plasticity (CL or CL-ML).

Grain Size Distribution tests were carried out on these materials. Figure 9 in the Appendix shows the results in an envelope form.

Undrained shear strength of the soil was obtained by in-situ vane tests and by laboratory unconfined compression tests. The results are plotted on Figure 6 and the Record of Borehole log sheets in the Appendix and summarized as follows:

<u>Undrained Shear Strength</u>	<u>Cu (kPa)</u>	<u>Sensitivity</u>
In-situ Vane Tests	61 - >115	1 - 3
Unconfined Compression Tests	69 - 285	

The field vane strengths obtained in this stratum varied from 61 kPa to greater than 115 kPa indicating a stiff to hard consistency. The sensitivity of this deposit varies from 1 to about 3 indicating this material being normal.

Heterogeneous Mixture of Clayey Silt, Sand and Gravel (Cohesive Glacial Till)

This stratum was encountered underneath the clayey silt layer and immediately above the bedrock. The thickness of this layer ranges from 0.7 m at BH 91-4 to 5.2 m at BH 92-9.

Atterberg Limit tests were performed on these samples and the results are plotted on Figure 10 and summarized as follows:

<u>Property</u>	<u>Range (%)</u>
Natural Moisture Content (w)	7.0 - 13.0
Liquid Limit (w_L)	17.0 - 24.0
Plastic Limit (w_p)	12.0 - 14.0
Plasticity Index (I_p)	5.0 - 10.0

From the plasticity chart, it is evident that this deposit can be classified as a heterogeneous mixture of clayey silt, sand and gravel with low plasticity (CL or CL-ML).

Grain Size Distribution tests were carried out on the cohesive glacial till material. Figure 11 in the Appendix shows the results. An increasing frequency of fragments of weathered shale was encountered within the lower portion of this till.

In this stratum, the "N" value range from 30 to over 100 blows/0.3 m indicating the consistency of this deposit as hard.

Heterogeneous Mixture of Silt, Sand and Gravel (Non-Cohesive Glacial Till)

This layer was encountered between clayey silt and cohesive glacial till at a borehole location. The thickness of this layer was found to be about 2.3 m at BH 91-9.

A Grain Size Distribution test was carried out on this material as shown on Figure 12. This layer is basically non-cohesive. In this stratum, the "N" value is about 27 blows/0.3 m indicating a state of compaction described as compact.

Bedrock

Bedrock was cored in fourteen (14) boreholes by obtaining up to 2.7 m of NQ rock at BH 92-8. The top of the bedrock ranged from elevation 56.4 m to 60.0 m which correspond to 29.0 m and 23.0 m below the existing ground surface, respectively. The upper 0 to 1.2 m is in a slightly weathered state. The top of the sound bedrock ranged from 56.4 m to 59.3 m.

The bedrock is a red shale with interbedded green siltstone (approximately 85% shale, 15% siltstone) of the Queenston Formation. Detailed description of the rock is attached in the Appendix entitled "Rock Core Description".

The Core Recovery (CR) and Rock Quality Designation (RQD) values were determined in-situ and also in the laboratory to evaluate the competence and integrity of the rock. The Core Recoveries (CR) range between 73 and 100 percent and Rock Quality Designation (RQD) values range from 7 to 69 percent. Based on these results, the rock can be classified as weak to very weak and slightly to unweathered.

GROUNDWATER CONDITIONS

Groundwater conditions were observed by measurement of water levels in the open boreholes. The groundwater level was found to be at approximate elevation between 63.7 m at BH 92-7 and 74.6 at BH 91-4 which correspond to depths of 21.5 m and 8.4 m below the existing ground surface. However, it is likely that the groundwater level was the same as the creek level and is subject to seasonal fluctuations.

DISCUSSION AND RECOMMENDATIONS

The recommendations in this report apply to the bridge structures and related approaches.

It is proposed to construct four (4) three span bridge structures (19 m x 22 m x 19 m) which will replace the existing twin concrete culverts along the Q.E.W. crossing the Eighteen Mile Creek. It is understood that an increase in grade for the Q.E.W. embankment will be required to avoid some snow accumulation within the Q.E.W. during the winter season due to the ditch effect on the highway. This would involve the additional placement and compaction of up to 1.7 m fill for the permanent approach along the Q.E.W. to the same level with the existing South and North Service Roads.

Recommendations pertaining to the foundations of the two new bridges for the Q.E.W. eastbound and westbound lanes and related earth works are summarized as follows.

Structure Foundations

East and West Abutments

In view of the low shear strength and compressibility of the organic clayey silt to silt clay and the extensive clayey silt layers, conventional spread footing shallow foundations are not applicable at this site. It is recommended that the abutment may be supported on end-bearing steel "H" piles, equipped with reinforced tips in order to facilitate pile penetration through the basal glacial till and driven to sound bedrock.

In consideration of no additional load application underneath the pile cap at the both abutments, the following design parameters are suggested for the purpose of the O.H.B.D.C..

<u>Pile Type</u>	<u>Factored Axial Capacity at U.L.S</u>	<u>Axial Capacity at S.L.S. Type II</u>
HP 310 x 79	1150 kN	900 kN
HP 310 x 110	1600 kN	1150 kN

Pile tip elevations for estimating the pile lengths are given below.

<u>Structure</u>	<u>East Abutment(Elevation)</u>	<u>West Abutment(Elevation)</u>
Q.E.W. Eastbound and Westbound lanes	57.3 m - 58.3 m	58.7 m - 59.0 m

Battered piles should be installed, where required, to resist lateral load on abutments.

In view of the extreme denseness of the glacial till stratum located immediately above the bedrock, some piles may not penetrate this dense stratum. The pile should be equipped with standard MTO tip reinforcement. In such a case, the pile capacity should be controlled in the field using current MTO pile driving standards. However, attempts should be made in all cases to drive the piles to the bedrock surface. It should also be noted that the pile driving be controlled by maximum capacity of piles.

During pile driving, the steel "H" pile should be set to a termination of 8 blows for the last 12 millimetres of penetration using a hammer transferring about 60 kilojoules of energy per blow to the pile.

Provision should be made to restrike all piles to confirm the set after adjacent piles have been driven. Piles that do not meet the design set criteria on the first restrike would require additional restriking. A minimum of 48 hour should be allowed before restriking a pile.

In order to enhance pile driving, the fill material immediately below pile caps, should not contain particle sizes greater than 75 mm.

Alternatively, caisson foundations can be considered for the both abutments. Details for caissons will be discussed in Pier Foundations.

East and West Piers

In consideration of the existence of weak and compressible organic clayey silt to silty clay and extensive clayey silt layers, conventional spread shallow foundations are not applicable for the piers at this site. It should be noted that during the construction, to avoid the problems associated with excavation through embankment toward longitudinal direction, it is recommended that the structural loading at the piers be transferred to the underlying sound bedrock by means of bored cast-in-place caissons installed through the embankment and overburden.

The caisson should have a minimum length to diameter ratio of 3 within the bedrock and should be socketed at least 0.5 metre into the sound shale bedrock. The caissons may be design using an end bearing factored capacity at Ultimate Limit States of 3500 kilopascals. Serviceability Limit States is not relevant to caissons founded on bedrock since the stresses required to produce detrimental settlements will be larger the value given for the factored bearing capacity at ULS.

The following caisson bottom elevations are suggested for estimating the caisson length.

<u>Structure</u>	<u>East Pier (Elevation)</u>	<u>West Pier (Elevation)</u>
Q.E.W. Eastbound and Westbound lanes	57.6 m - 58.0 m	57.8 m - 58.8 m

Caissons should be a minimum diameter of 900 mm to allow for both the clean out

of any basal debris and final evaluation of the rock surface in order to confirm the above-stated capacities.

Groundwater infiltration may have to be controlled by using drilling mud coupled with telescoping liners or other methods. However, regardless of the method used, during withdrawal of the innermost liner, it is recommended that, while pouring, a positive head of concrete should be maintained at all times to prevent intrusion of the surrounding soils, groundwater and/or bentonite slurry.

The proposed method of caisson installation be in accordance OPSS 903.07.03 and subject to review by this office.

It should be noted that to avoid the need for deep excavation of the existing embankment and frost protection, caisson cap for the piers should be placed immediately below the bridge decks.

Other Considerations

Lateral Earth Pressures

Free draining material such as Granular "A" or Granular "B" is recommended as an appropriate backfill material to prevent hydrostatic pressure build-up on the abutment walls. Design parameters of the soil are given below for the purpose of the O.H.B.D.C.

	Granular "A"	Granular "B"
Angle of Internal Friction (ϕ)	35 ⁰	30 ⁰
Unit Weight (kN/m ³), γ	22.8	21.2
Coefficient of Active Earth Pressure (Ka)	0.27	0.33
Coefficient of Earth Pressure at Rest (Ko)	0.43	0.5

The earth pressure coefficient at rest is to be used when the design of abutment walls are rigid and unyielding.

Dewatering

No major dewatering difficulties are anticipated for footing excavation in consideration of lower groundwater levels and the relatively low permeability of the clayey silt fill. However, if localized seepage or surface water to accumulates in excavations, it can be controlled by perimeter ditches and pumping from corner sumps.

Frost Protection

The pile caps should be placed so as to have a minimum earth cover of 1.2 m to allow for frost protection.

Settlement of Approach Embankments

Based on currently available information, it is our understanding that the proposed grade of the roadway at the approach embankments will be raised by up to 1.7 m. Consequently, the additional fill will act as a surcharge and induce settlement within the underlying organic clayey silt to silty clay.

To minimize settlement, total embankment loading should not exceed the preconsolidation pressure, σ'_p , of the organic clayey silt to silty clay. Based on the results of the consolidation test and our previous experience with similar organic deposits, it is estimated that σ'_p is about 330 kPa. Since the field vane shear strengths were found to be reasonably constant with this deposit, it is anticipated that σ'_p would not vary significantly with depth. Accordingly, the organic clayey silt to silty clay at mid-level of the stratum is considered to be preconsolidated by about 66 kPa in excess of the existing effective overburden stress. Assuming that the unit weight of compacted granular

fill is about 21 kN/m^3 , 1.7 m of such fill would correspond to a surcharge of 36 kPa. As such, the proposed additional embankment loading will not result in stresses higher than σ'_p . Based on the compression index, C_c , obtained from the consolidation test, the magnitude of settlement of the approach embankment will be modest, being in the order of 40 mm. Consideration should be given to placing and compacting the additional fill well in advance of bridge construction to allow some settlement to take place prior to final road paving.

Stability of Approach Embankment

The stability analyses were carried out based on a minimum design underdrained shear strength of 50 kPa for the organic clayey silt to silty clay, as established by field vane tests. Since no additional fill will be placed on the South and North Service Road, the existing slope will be stable in the transverse direction.

However, since additional earth fill of 1.7 m will be placed within Q.E.W. Lanes and the existing embankment fill of about 11 m will be cut down to creek level, stability analyses were carried out to evaluate the overall stability of the approach fill in the longitudinal direction and also the internal stability of the fills were examined. Based on the "Total Stress" analyses, the forward slope for the Q.E.W. structures and North and South Service Road Structures will require a 3 m wide mid-height beam with a 2H to 1V side slope to meet a minimum factor of safety of 1.3 as shown on Figure 13.

Construction Consideration

Prior to raising the existing embankment, topsoil, organics and other foreign materials should be removed from the fill placement area. Such locations, should be excavated and backfilled with an approved, compacted fill material. Clean earth fill at suitable water contents should be used as embankment fill.

The additional fill should be placed in thin layers and compacted as per MTO standards. The fill should be keyed into the pre-existing slope in accordance

with current MTO standards and practice.

Excavations for abutments, pile-caps construction may be carried out in temporary open cuts with side slopes maintained at gradients not steeper than 1.5H:1V through the clayey silt fill. All excavations should be carried out according to the guidelines contained in the latest edition of the Ontario Occupational Health and Safety Act. To prevent softening of the exposed clayey silt fill, it is recommended that Granular "A" material be placed on the excavation base to provide protection to the founding stratum as soon as the base of the excavation has been inspected.

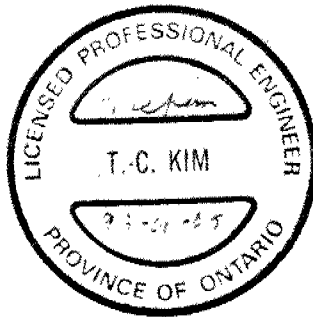
Excavation cut of the forward slope toward 18 Mile Creek should be delayed until the four bridge structures are completed in order to avoid expensive roadway protection scheme such as very high temporary shoring system.

For erosion protection purposes, the embankment forward slopes should be covered with a layer of topsoil and properly seeded in order to enhance adequate vegetation cover. Suitable protection measures should also be provided to the creek banks adjacent the abutments. Such measures may include appropriately sized rip-rap underlain by suitable granular filter.

MISCELLANEOUS

The initial fieldwork for this investigation was carried out during the period of December 2 to December 20, 1991 under the supervision of R. Ng, Trainee Engineer and Tae C. Kim, Sr. Foundation Engineer. The equipment was owned and operated by Master Soil Investigation Ltd., Toronto. Additional fieldwork for this investigation was carried out during the period of May 11 to May 29, 1992 under the supervision of M. Iampietro, Student Engineer, and Tae C. Kim, Sr. Foundation Engineer. The equipment was owned and operated by Malone's Soil Samples Co. Ltd., Toronto.

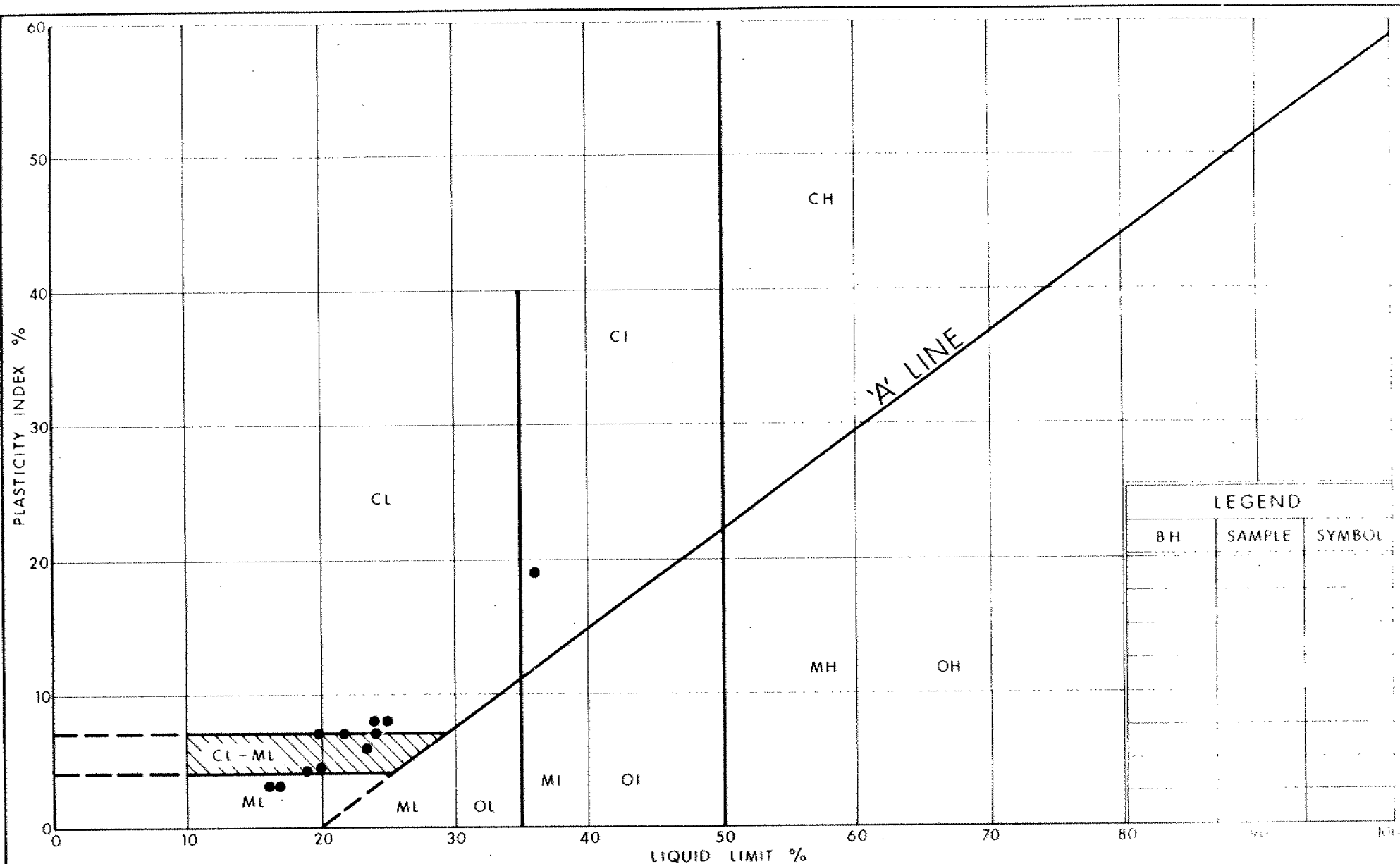
This report was written by Tae C. Kim, Senior Foundation Engineer and reviewed by M. Devata, Chief Foundation Engineer.



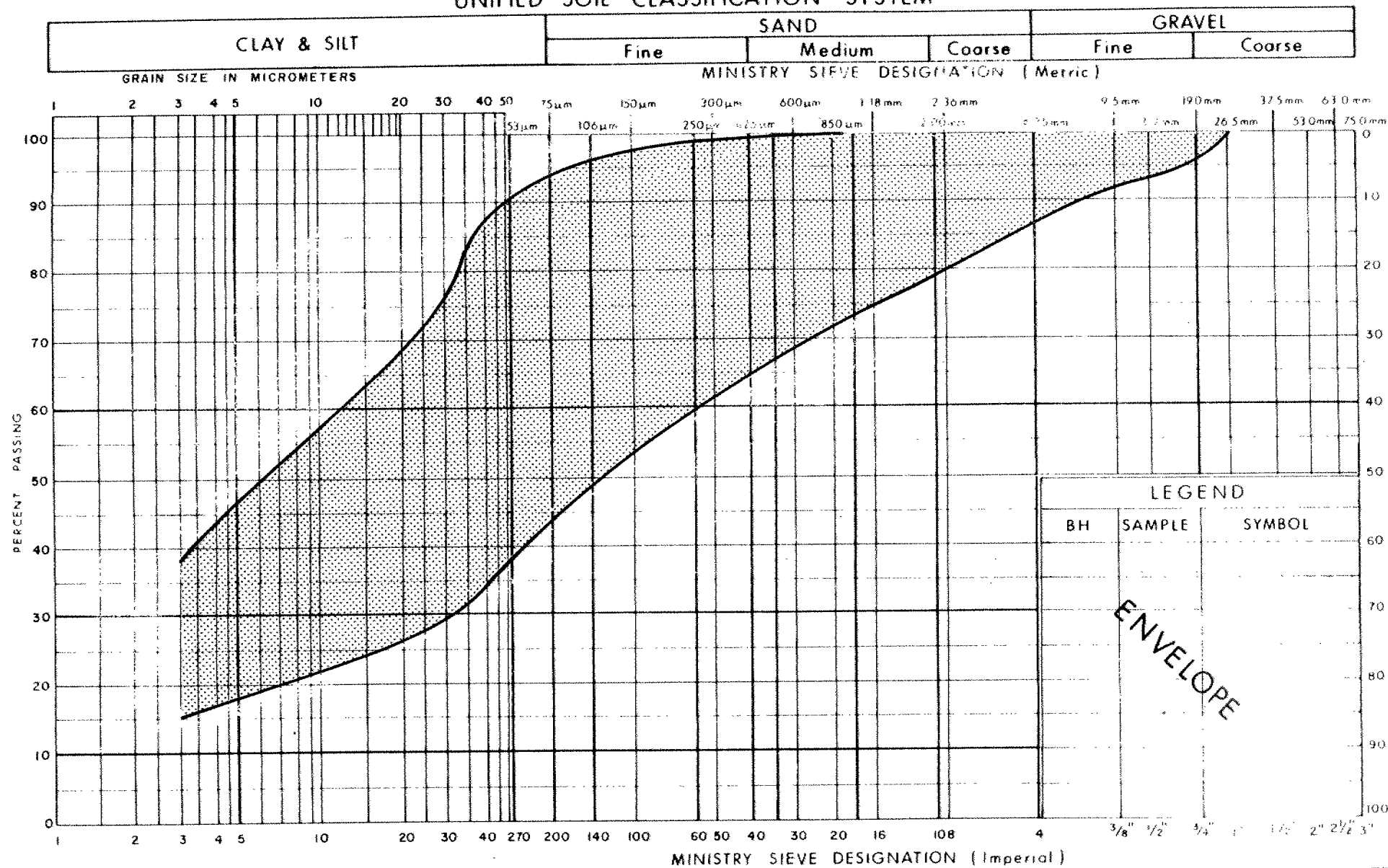
Tae C. Kim
Tae C. Kim, P. Eng.
Sr. Foundation Engineer

M. Devata
M. Devata, P. Eng.
Chief Foundation Engineer

APPENDIX



UNIFIED SOIL CLASSIFICATION SYSTEM



Ontario

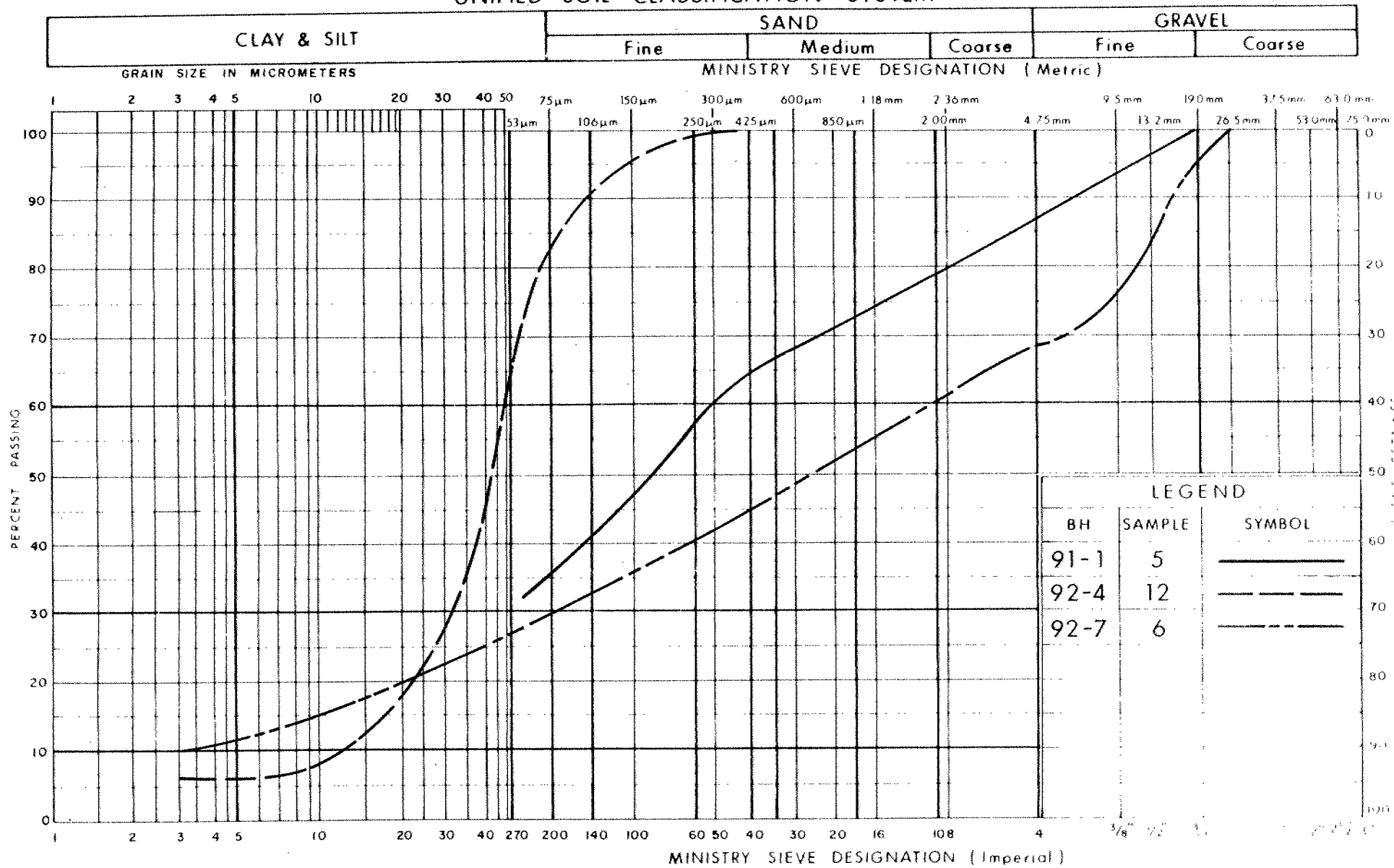
Ministry of
Transportation

GRAIN SIZE DISTRIBUTION
CLAYEY SILT TO SILT
(Fill)

FIG No 2

W P 624-90-01/02

UNIFIED SOIL CLASSIFICATION SYSTEM



Ontario

Ministry of
TransportationGRAIN SIZE DISTRIBUTION
SILTY SAND TO SANDY SILT

FIG No.

W P 624-90-01/02



ORGANIC CLAYEY SILT TO SILTY CLAY

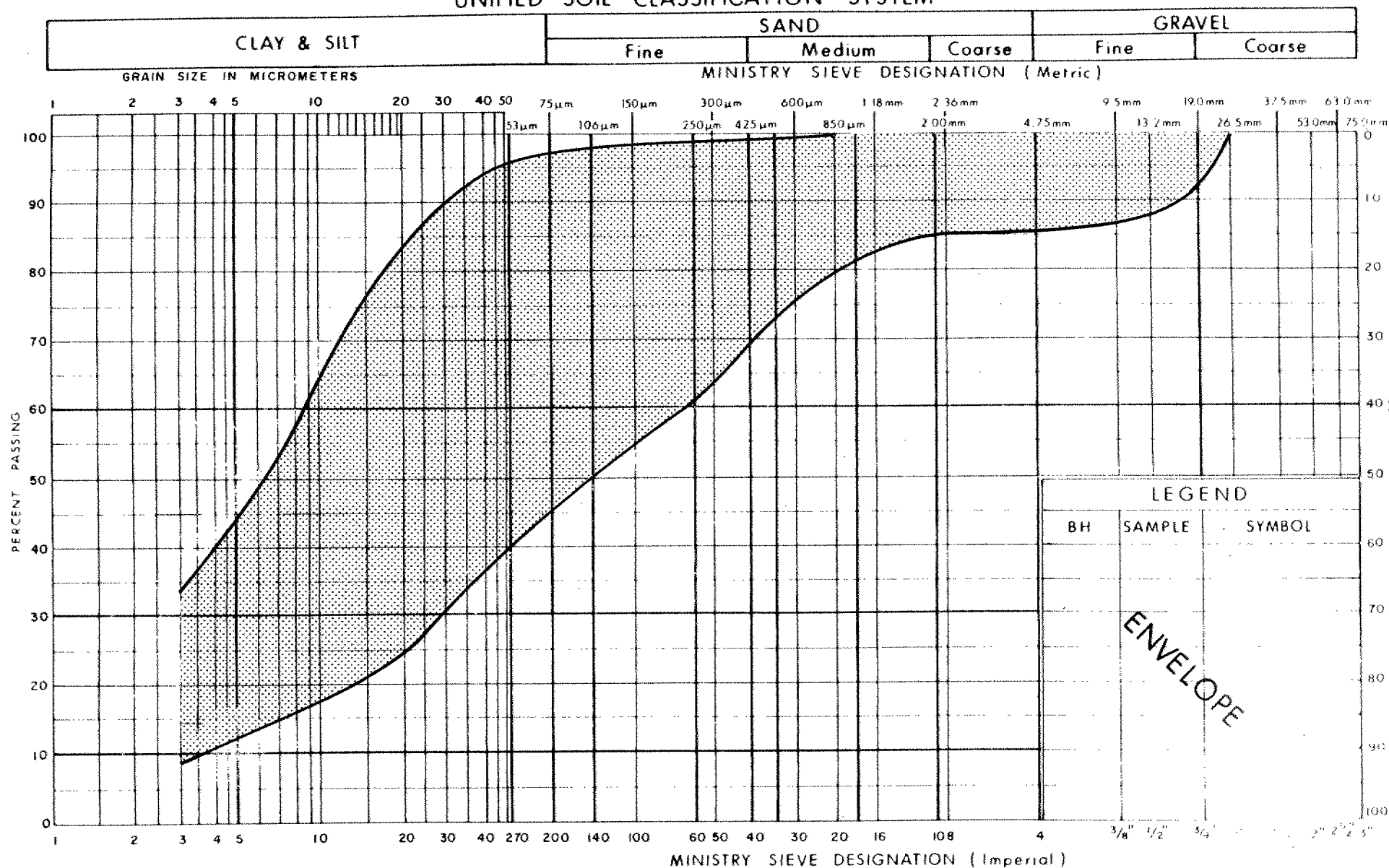
FIG No 4

WP 624-90-01/02



Ministry of
Transportation

UNIFIED SOIL CLASSIFICATION SYSTEM



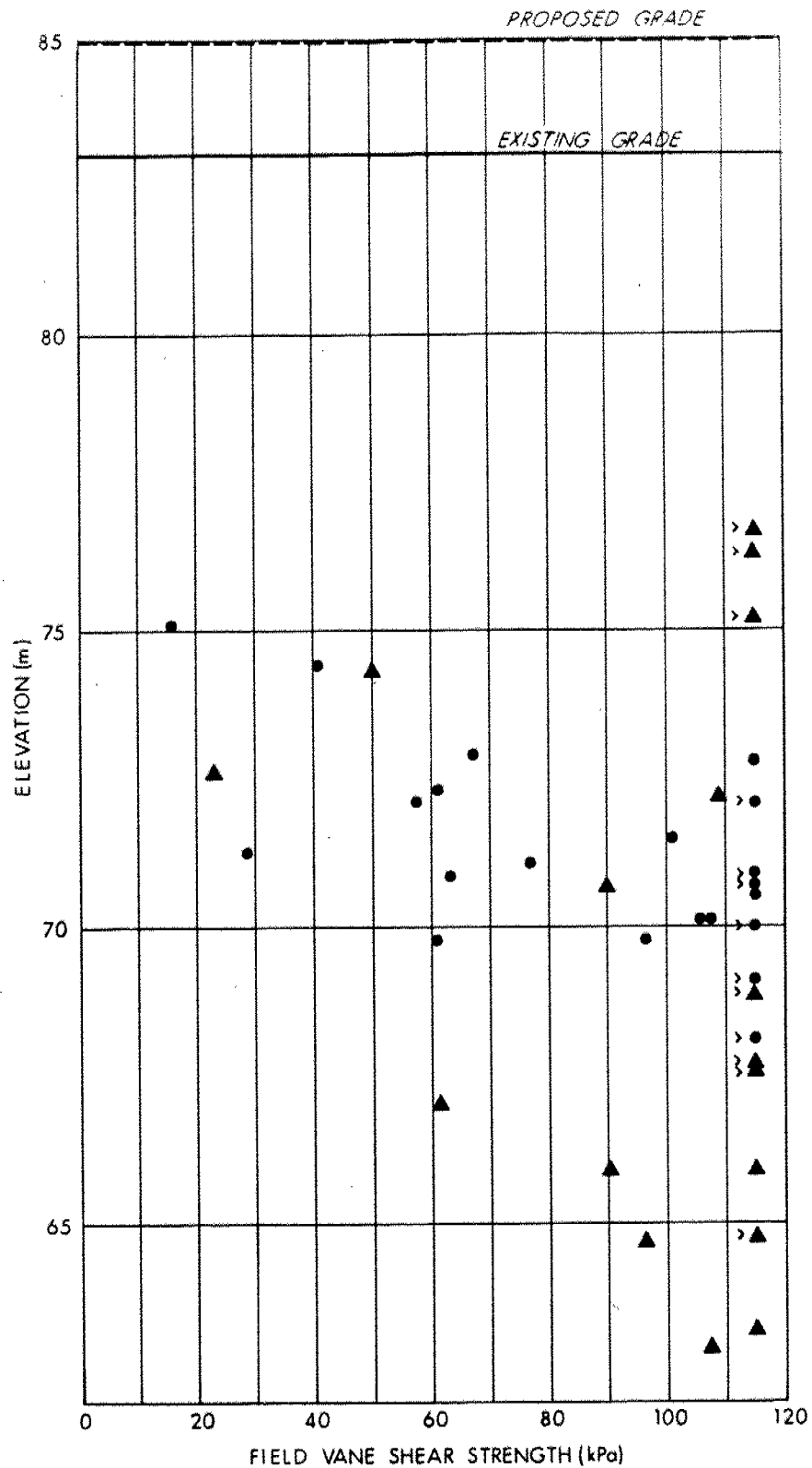
Ontario

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Transportation

GRAIN SIZE DISTRIBUTION ORGANIC CLAYEY SILT TO SILTY CLAY

FIG No 5

W P 624-90 01/02



PROFILE OF FIELD VANE TESTS
ORGANIC CLAYEY SILT TO SILTY CLAY

- ORGANIC CLAYEY SILT TO SILTY CLAY
- ▲ CLAYEY SILT

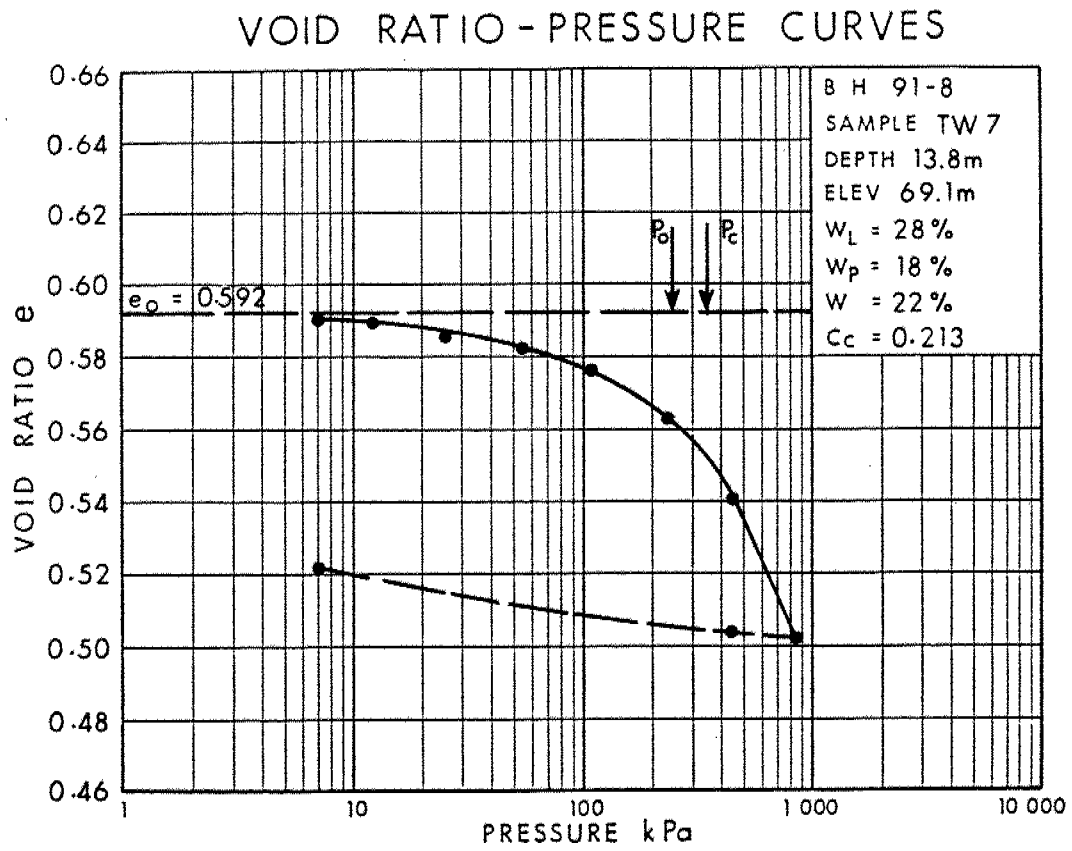


Fig 7

WP 624-90-01/02

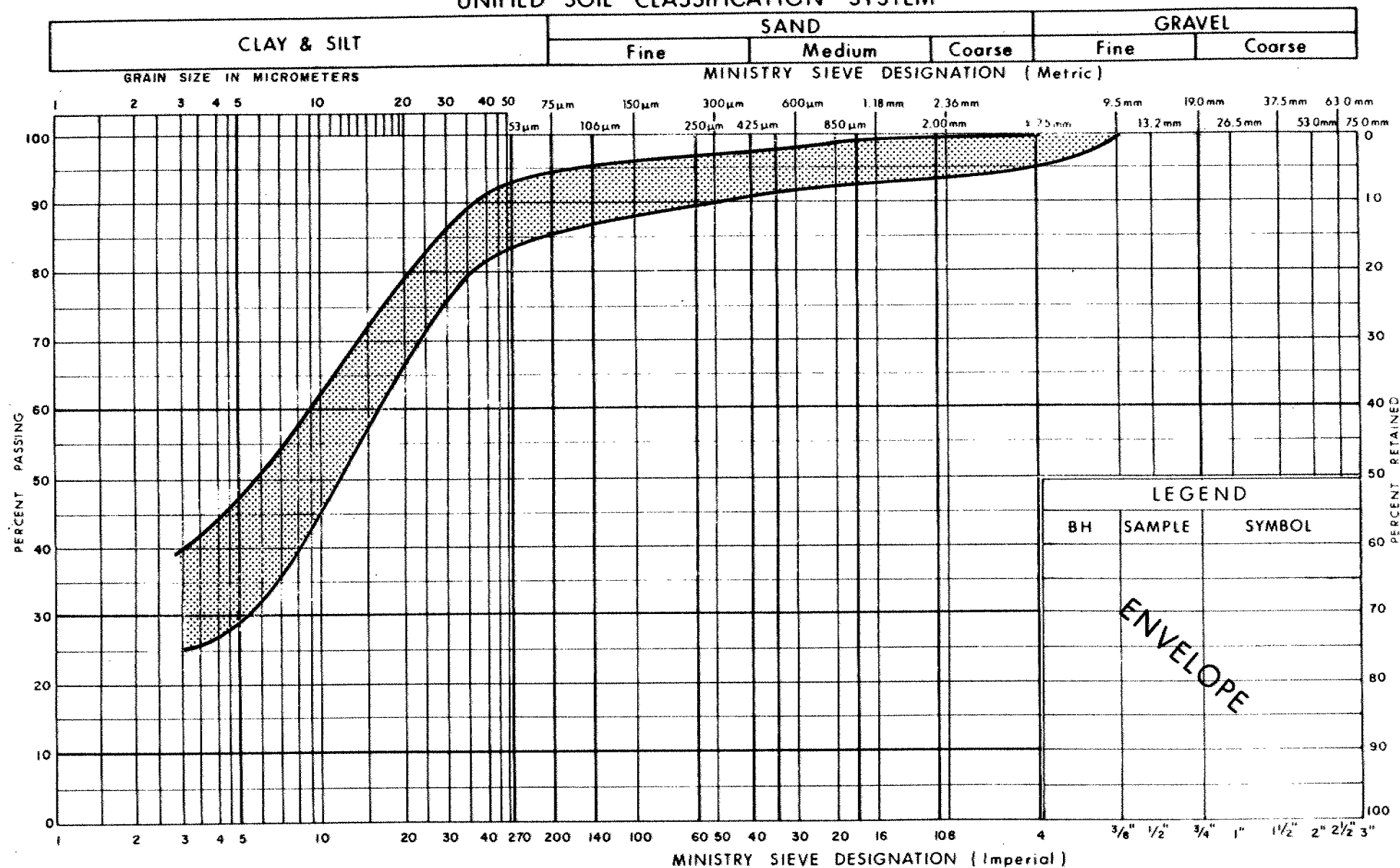


PLASTICITY CHART
CLAYEY SILT
WITH SOME SAND AND TRACE OF GRAVEL

FIG No 8

W P 624 - 90 - 01/02

UNIFIED SOIL CLASSIFICATION SYSTEM



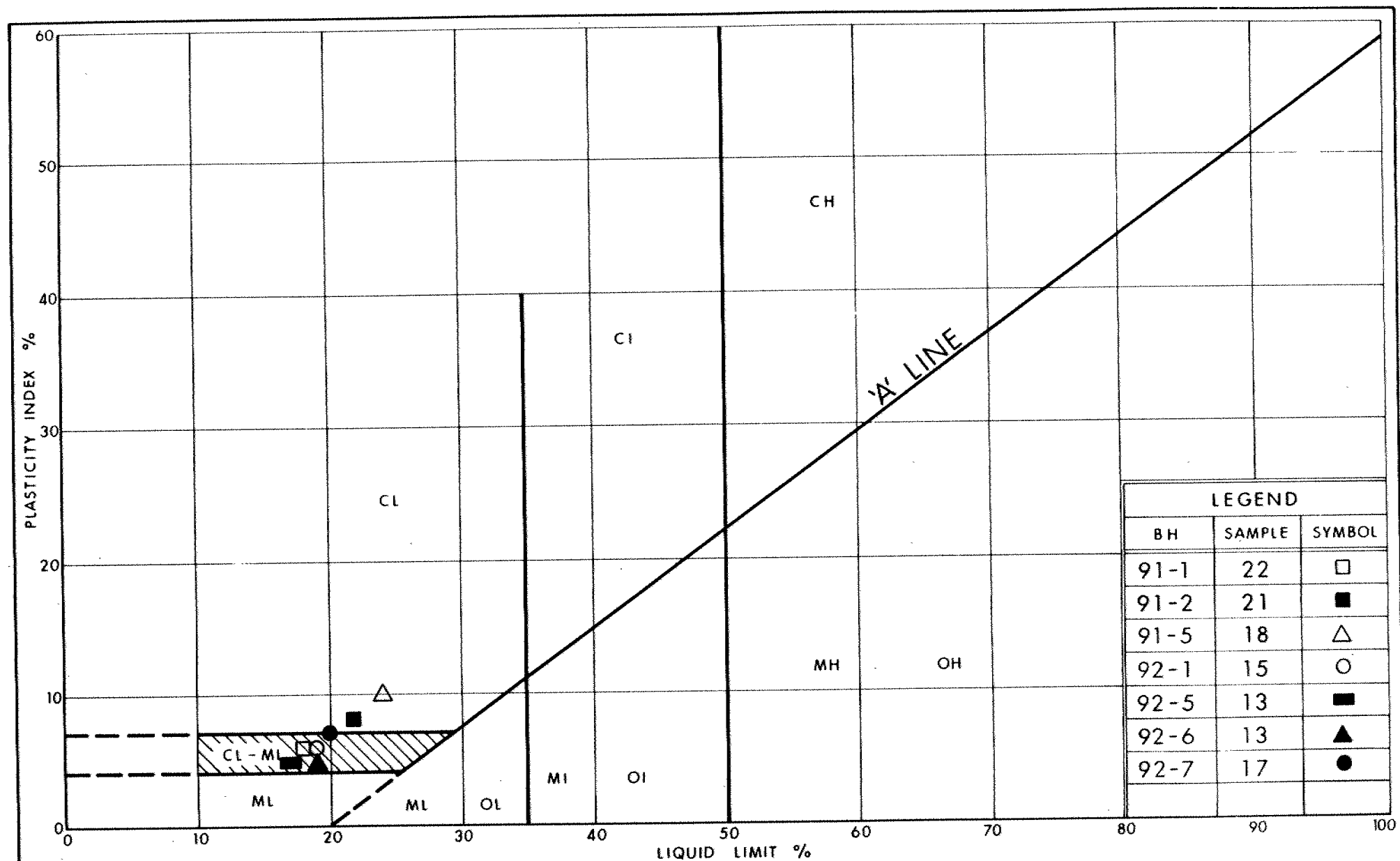
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GRAIN SIZE DISTRIBUTION
CLAYEY SILT
WITH SOME SAND AND TRACE OF GRAVEL

FIG No 9

W P 624-90-01/02



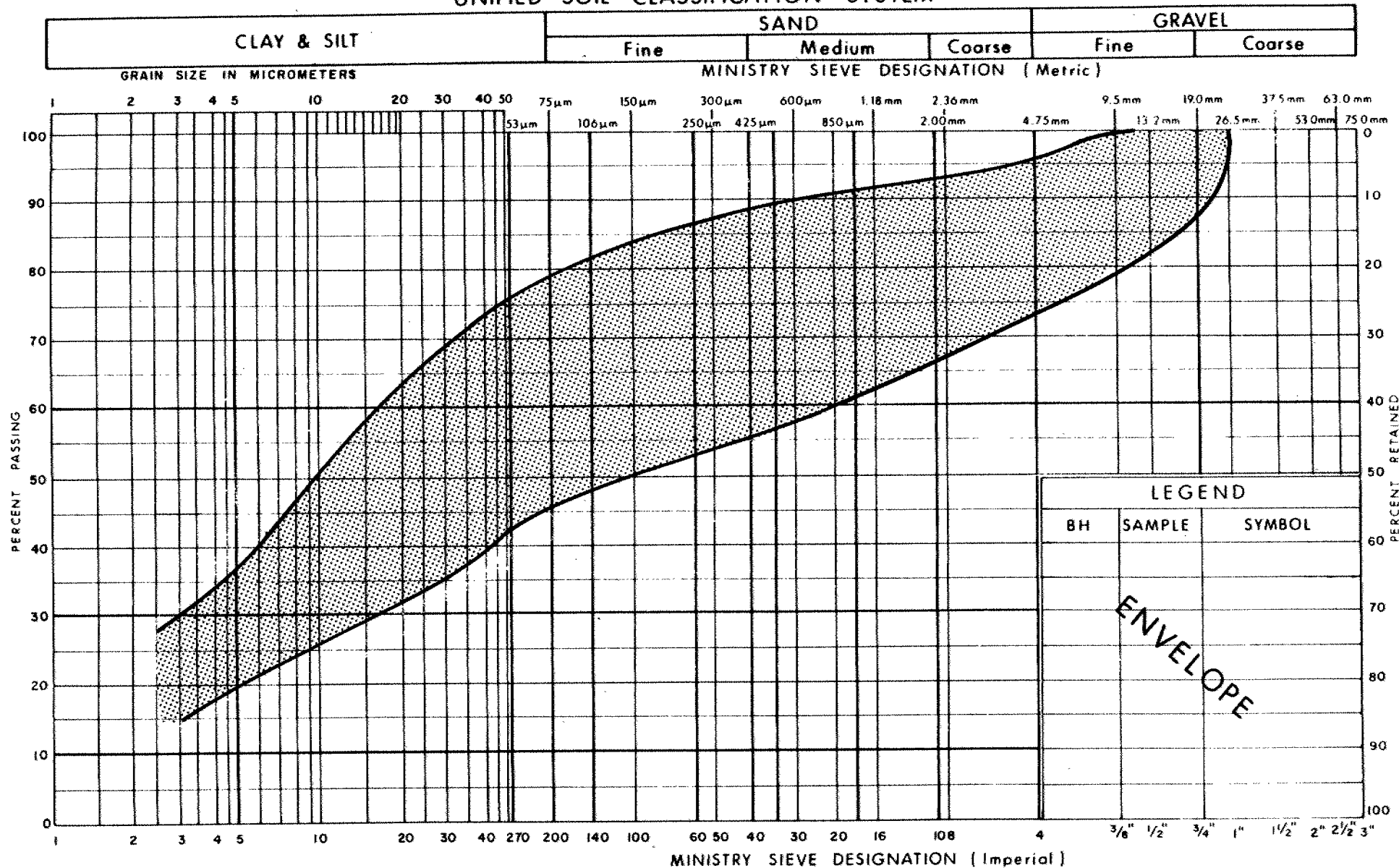
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Transportation

PLASTICITY CHART
HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND & GRAVEL
 (COHESIVE GLACIAL TILL)

FIG No 10

W P 624-90-01/02

UNIFIED SOIL CLASSIFICATION SYSTEM



Ontario

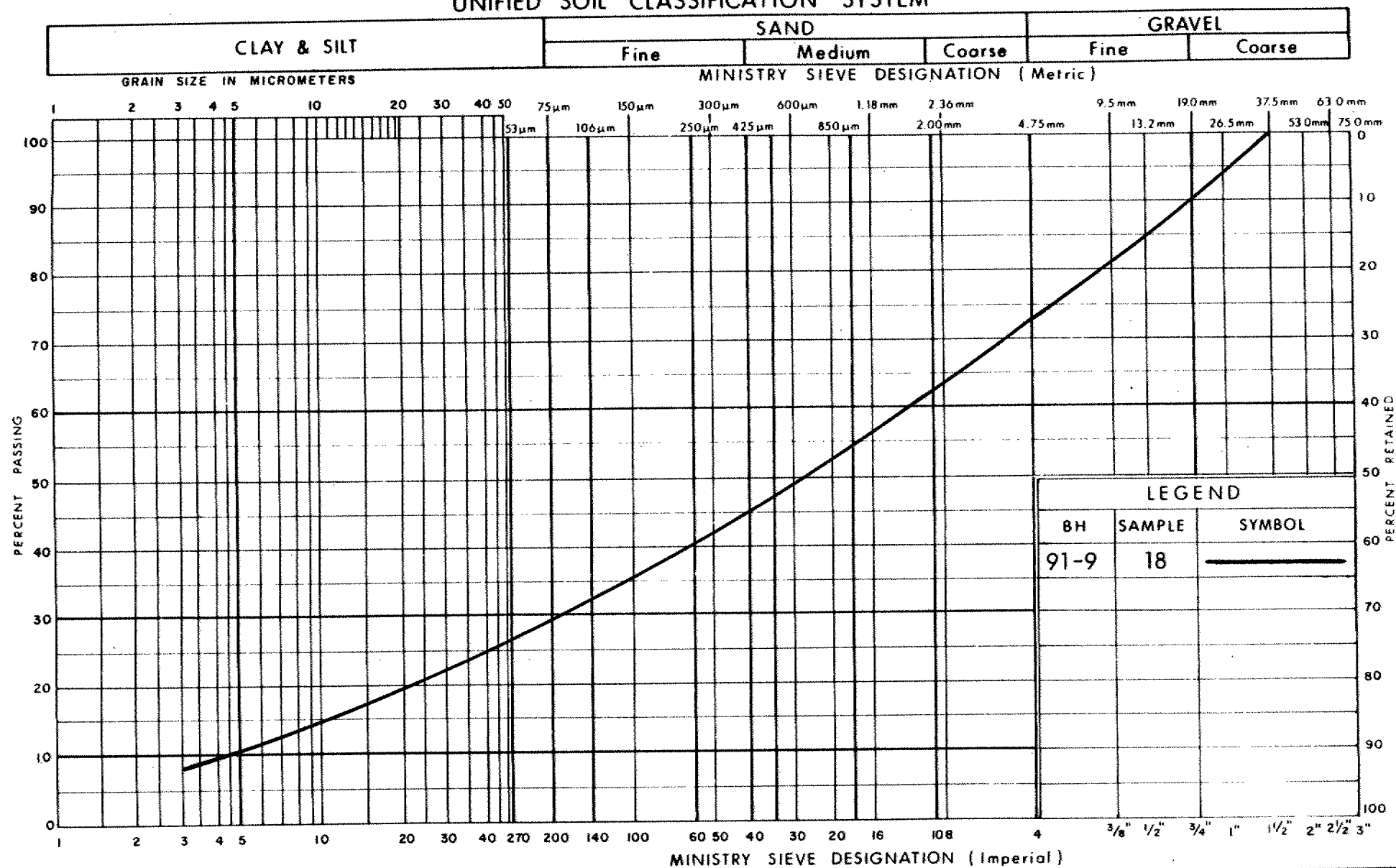
Ministry of
Transportation

GRAIN SIZE DISTRIBUTION
HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND & GRAVEL
 (COHESIVE GLACIAL TILL)

FIG No 11

W P 624-90-01/02

UNIFIED SOIL CLASSIFICATION SYSTEM



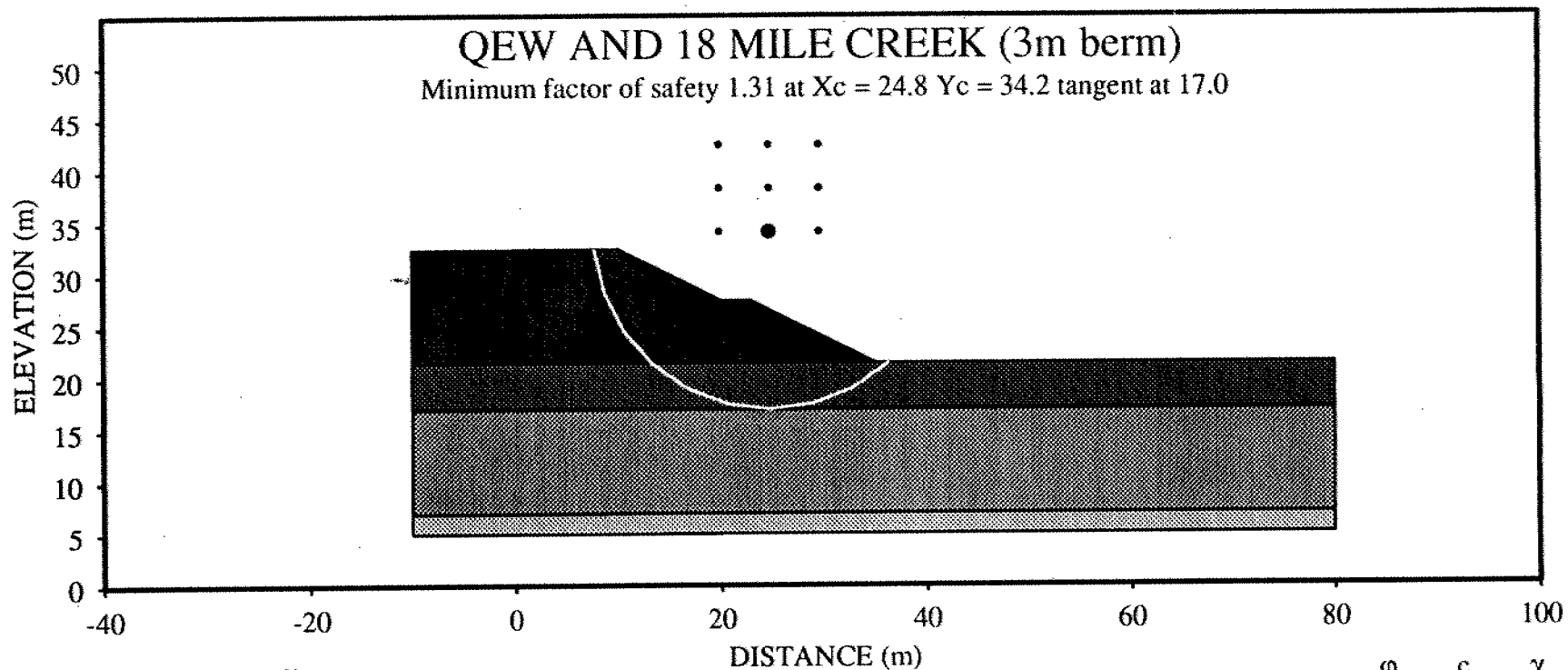
Ontario

Ministry of
Transportation

GRAIN SIZE DISTRIBUTION
HETEROGENEOUS MIXTURE OF SILT, SAND & GRAVEL
(NON-COHESIVE GLACIAL TILL)

FIG No 12

W P 624-90-01/02



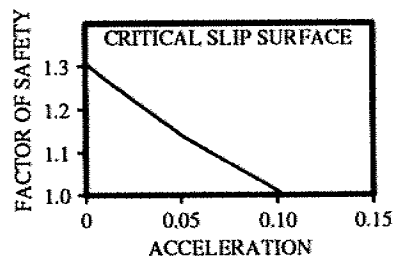
ϕ	c	γ
--------	---	----------

30.0	0.0	21.0	CLAYEY SILT (FILL)
------	-----	------	--------------------

0.0	50.0	18.0	ORGANIC SILT
-----	------	------	--------------

CRITICAL ACCELERATIONS

0.090	0.105	0.165
0.087	0.100	0.173
0.097	0.104	0.204



ϕ	c	γ
--------	---	----------

0.0	92.0	21.3	CLAYEY SILT
-----	------	------	-------------

35.0	0.1	22.0	COHESIVE TILL
------	-----	------	---------------

FACTORS OF SAFETY

1.362	1.348	1.496
1.332	1.311	1.498
1.348	1.308	1.588

WP 624-90-01/02

Fig 13

RECORD OF BOREHOLE No 91-1

1 OF 1

METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4782 027.9 E 317 883.7 ORIGINATED BY T.C.K.
DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Cone Tests, Vane Tests, NQ Rock Core COMPILED BY R.N.
DATUM Geodetic DATE Dec. 5 & 9, 1991 CHECKED BY T.C.K.

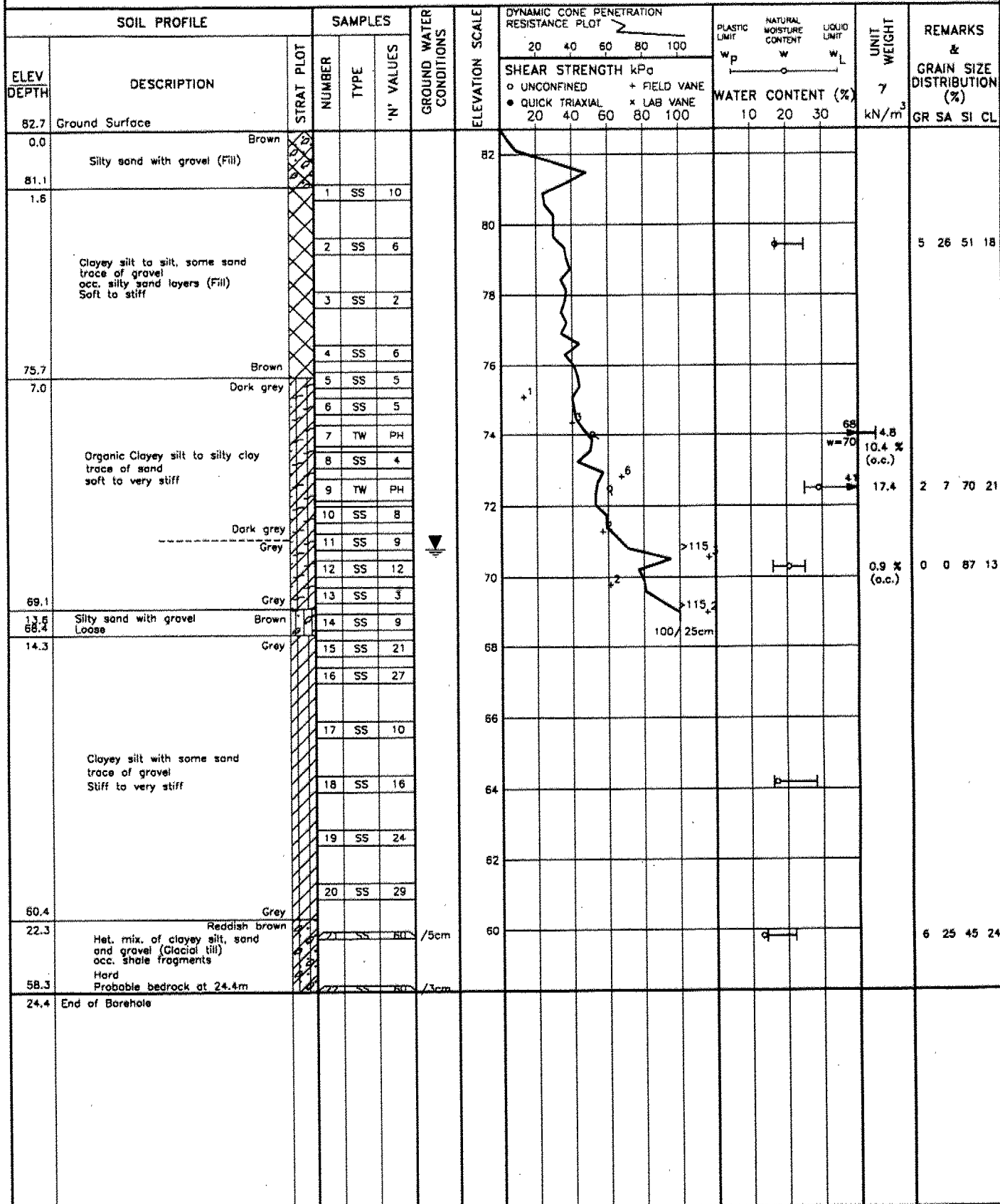
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100					
85.2	Ground Surface													
0.0	Sand and gravel (Fill)	Brown												
0.6	Granular 'A' (Fill)	Grey												
83.7		Grey												
1.5		Brown	1	SS	14									
			2	SS	21									
			3	SS	15									
	Clayey silt to silt, some sand and trace of gravel, acc. silty sand layers (Fill) Firm to very stiff		4	SS	19									
			5	SS	26									
	Silty sand layer Compact		6	SS	6									
			7	SS	10									
75.1			8	SS	9									
10.1			9	SS	7									
	Crushed Stone with sand (Fill) Loose to compact		10	SS	0									
			11	SS	7									
70.1		Brown	12	SS	10									
15.1	Organic clayey silt, some sand and gravel Very stiff	Grey	13	SS	16									
69.0			14	SS	18									
16.2			15	SS	22									
			16	TW	PH									
	Clayey silt with some sand trace of gravel Very stiff to hard		17	SS	32									
			18	SS	27									
			19	SS	24									
			20	TW	PH									
60.1		Grey	21	SS	35									
25.1	Reddish Brown Het. mixture of clayey silt, sand and gravel (Glacial till) acc. shale fragments		22	SS	101									
58.4	Hard	Reddish brown	23	SS	109									
26.8	Queenston shale bedrock	Red	24	SS	60									
56.9			25	RC	REC	77%								
28.3	End of Borehole													

RECORD OF BOREHOLE No 91-2

1 OF 1

METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4782 009.5 E 317 869.7 ORIGINATED BY T.C.K.
DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Cone Tests, Vane Tests COMPILED BY R.N.
DATUM Geodetic DATE Dec. 13 & 16, 1991 CHECKED BY T.C.K.



RECORD OF BOREHOLE No 91-3 1 of 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4782 010.1 E 317 884.9 ORIGINATED BY T.C.K.
 DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Cone Tests, Vane Tests, NQ Rock Core COMPILED BY R.N.
 DATUM Geodetic DATE Dec. 15 & 17, 1991 CHECKED BY T.C.K.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT		UNIT WEIGHT 7 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	W _p W W _L	WATER CONTENT (%)		
82.8	Ground Surface												
0.0	Silty sand with gravel (Fill)	Brown					82						
81.3													
1.5			1	SS	19								
			2	SS	6								
	Clayey silt to silt some sand occ. silty sand layers (Fill) Soft to very stiff		3	SS	6								
			4	SS	9								
75.6		Brown	5	SS	0								
7.2		Dark grey	6	SS	15							3.2 % (o.c.)	0 10 67 23
		Dark grey	7	SS	10								
		Grey	8	1W	PH							19.9	0 8 69 23
	Organic Clayey silt to silty clay some sand Stiff to very stiff		9	SS	13								
			10	SS	11							1.0 % (o.c.)	0 12 66 22
			11	SS	16								
70.8		Grey	12	SS	11								
12.0	Silty sand with gravel, compact	Brown	13	SS	22								
12.5		Grey											
			14	SS	31								
			15	SS	24								
	Clayey silt with some sand trace of gravel Very stiff to hard		16	SS	21								
			17	SS	31								
			18	SS	25								
60.5		Grey											
22.3	Reddish brown Het. mix. of clayey silt, sand and gravel (Glacial Till) acc. shale fragments		19	SS	50	/15cm							
58.4	Hard	Reddish brown											
24.4	Queenston shale bedrock	weathered sound	20	RC	REC	88%							RQD 17%
56.0			21	RC	REC	83%							RQD 69%
26.8	End of Borehole												

RECORD OF BOREHOLE No 91-4 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4781 970.3 E 317 876.4 ORIGINATED BY T.C.K.
 DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Cone Tests, Vane Tests, NQ Rock Core COMPILED BY R.N.
 DATUM Geodetic DATE Dec. 10 & 11, 1991 CHECKED BY T.C.K.

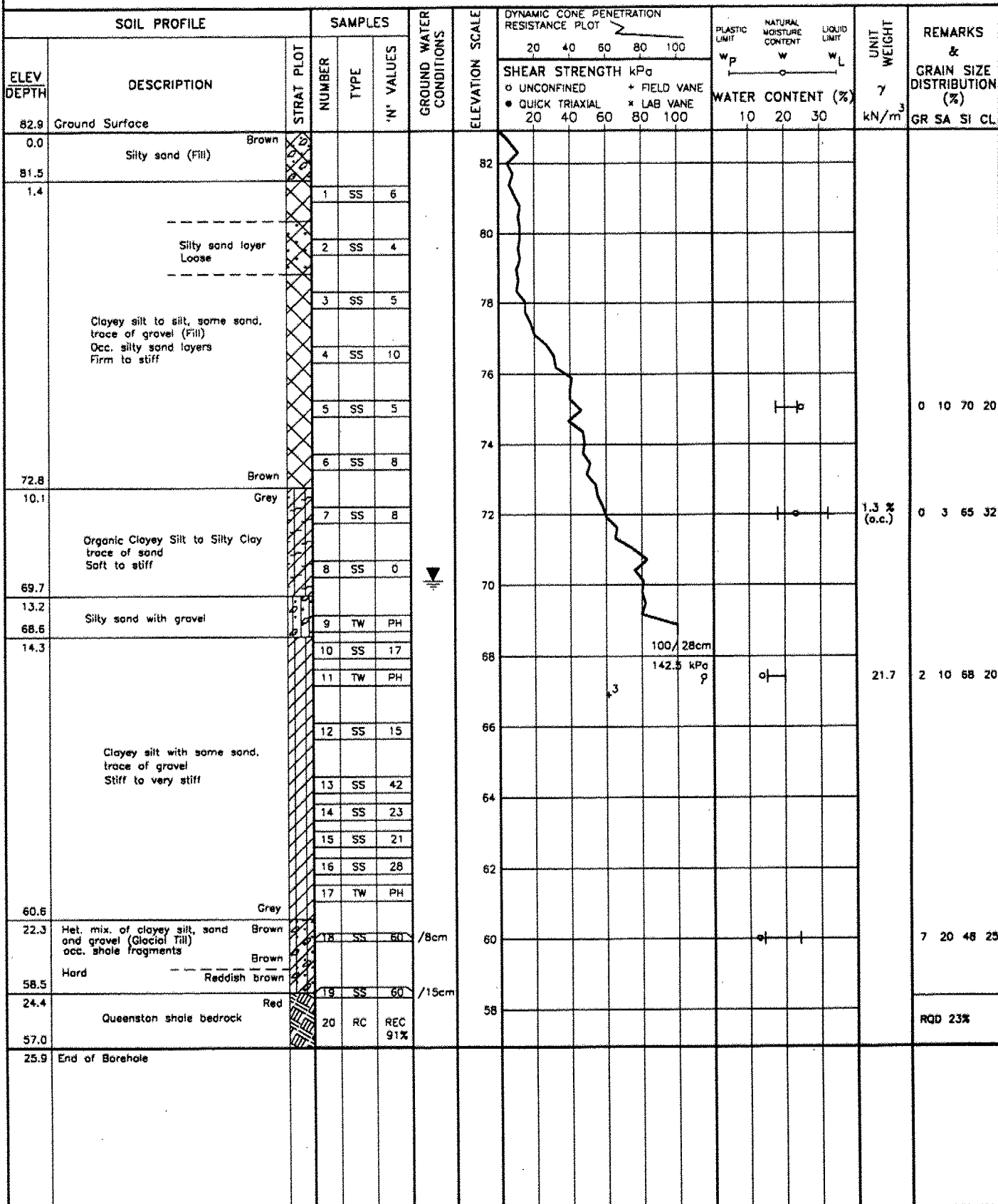
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT 7 kn/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100					
83.0	Ground Surface													
0.0	Silty sand with gravel (Fill)	[Pattern]												
81.3			1	SS	13									
1.7			2	SS	5									
			3	SS	5									
			4	SS	0									
			5	SS	0									
72.9	Clayey silt to silt, some sand, trace of gravel Occ. silty sand layers (Fill) Soft to stiff	[Pattern]	6	SS	4									
10.1			7	SS	20									
71.0			8	TW	PH									
12.0	Sand and gravel with crushed stone (Fill) Compact Brown Grey	[Pattern]	9	SS	22									
			10	SS	25									
			11	SS	19									
			12	SS	29									
			13	SS	28									
60.7	Het. mix of clayey silt, sand and Reddish gravel, occ. shale (Glacial Till) Brown Red	[Pattern]	14	SS	60	/15cm								
23.0			15	RC	REC 85%									
58.6	Queenston shale bedrock weathered sound	[Pattern]												
24.4	End of Borehole													

RECORD OF BOREHOLE No 91-5

1 OF 1

METRIC

W.P. 824-90-01/02/03/04 LOCATION Co-ord. N 4781 971.0 E 317 892.1 ORIGINATED BY T.C.K.
DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Cone Tests, Vane Tests, NQ Rock Core COMPILED BY R.N.
DATUM Geodetic DATE Dec. 10 & 11, 1991 CHECKED BY T.C.K.



+3, x5: Numbers refer to Sensitivity
20
15-5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 91-5A 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4781 969.2 E 317 892.1 ORIGINATED BY T.C.K.
 DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Vane Tests COMPILED BY R.N.
 DATUM Geodetic DATE Dec. 12, 1991 CHECKED BY T.C.K.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT 7 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)		
								20 40 60 80 100							10 20 30		
82.9	Ground Surface																
0.0	Silty sand (Fill)						82										
81.4																	
1.5																	
	Clayey silt to silt, some sand trace of gravel Occ. silty sand layers (Fill)						80										
72.6		Brown	1	SS	10												
10.3	Organic clayey silt to silty clay some sand, trace of gravel Stiff to very stiff	Grey	2	SS	11												
			3	TW	PH												
			4	SS	8												
69.5			5	TW	PH												
13.4	Silty sand with gravel Compact		6	SS	15												
68.4			7	SS	26												
14.5	Clayey silt with some sand trace of gravel Very stiff to hard		8	SS	21												
			9	TW	PH												
			10	SS	13												
			11	SS	21												
64.2			12	SS	37												
18.7			End of Borehole														

RECORD OF BOREHOLE No 91-6

1 OF 1

METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4781 952.3 E 317 899.1 ORIGINATED BY T.C.K.
DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Cone Tests, Vane Tests, NQ Rock Core COMPILED BY R.N.
DATUM Geodetic DATE Dec. 2 & 4, 1991 CHECKED BY T.C.K.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100					
85.3	Ground Surface													
84.7	Granular 'A' (Fill)	Grey												
0.6		Brown												
			1	SS	18									
			2	SS	25									
	Clayey silt to silt, some sand trace of gravel Occ. silty sand layers (Fill) Very stiff		3	SS	29									
	Granular 'A' Dense		4	SS	31									
			5	SS	16									
76.8			6	SS	17									
8.5			7	SS	8									
	Crushed stone or subgrade material (Fill) Compact to very dense		8	SS	50 /4cm									
73.4			9	SS	20									
11.9	Clayey silt to silt, trace of sand (Fill) Stiff to very stiff	Brown	10	SS	14									0 4 62 34
13.6		Grey	11	SS	13									
	Organic clayey silt to silty clay some sand, trace of gravel Very stiff		12	SS	12									3 48 34 15
69.1			13	SS	54									
16.2			14	TW	PH									0 5 70 25
			15	SS	35									
	Clayey silt, trace of sand and gravel, occ. silt layers Very stiff to hard		16	SS	34									
			17	TW	PH									
			18	SS	22									
61.4		Grey	19	SS	60 /15cm									
23.9		Reddish brown	20	SS	60 /8cm									
	Het. mix. of clayey silt, sand and gravel (Glacial Till) occ. shale fragments		21	SS	60 /10cm									
57.9		Reddish brown weathered sound	22	RC	REC 98%									
27.4	Queenston shale bedrock	Red												RQD 9%
56.6														
28.7	End of Borehole													

+3, x5: Numbers refer to
Sensitivity

20
15-25 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 91-7

1 OF 1

METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4782 013.2 E 317 903.7 ORIGINATED BY T.K.
DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Vane Tests COMPILED BY R.N.
DATUM Geodetic DATE Dec. 18, 1991 CHECKED BY T.C.K.

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	20	40	60	80						100
62.8	Ground Surface																
0.0	Clayey silt to silt, some sand trace of gravel occ. silty sand layers (Fill) Firm to Stiff Organic clayey silt to silty clay trace of sand Stiff to Very Stiff Clayey silt with some sand Stiff		1	SS	5												
			2	SS	10												
73.0			3	SS	7												
9.8			4	SS	15												
			5	SS	14												
			6	SS	19												
			7	SS	16												
69.4			8	SS	12												
13.4 68.6	End of Borehole																

RECORD OF BOREHOLE No 91-8 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4781 994.2 E 317 903.7 ORIGINATED BY T.C.K.
 DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Vane Tests COMPILED BY R.N.
 DATUM Geodetic DATE Dec. 20, 1991 CHECKED BY T.C.K.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT 7 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL * LAB VANE	WATER CONTENT (%)					
82.9	Ground Surface.													
82.8	Granular 'A'													
82.3	Brown													
			1	SS	13									
			2	SS	5									
	Clayey silt to silt, some sand and gravel Occ. silty sand layers (Fill) Soft to Stiff		3	SS	3									
			4	SS	4									
			5	TW	PH									
71.2	Brown Grey		6	TW	PH									
11.7	Silty sand		7	TW	PH									
	Organic clayey silt to silty clay some sand occ. silty sand layers Stiff to Hard		8	SS	38									
66.7			9	SS	59									
16.2	Silt with some sand and gravel Very Dense													
65.7														
17.2	End of Borehole													

RECORD OF BOREHOLE No 91-9 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord: N 4781 971.0 E 317 932.1 ORIGINATED BY T.C.K.
 DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Cone Tests, Vane Tests COMPILED BY R.N.
 DATUM Geodetic DATE Dec. 12 & 13, 1991 CHECKED BY T.C.K.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa									
								20 40 60 80 100									
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%) 10 20 30					
82.5	Ground Surface																
0.0	Silty sand (Fill)						82										
81.1																	
1.4			1	SS	5												
			2	SS	15												
			3	SS	2												
			4	SS	1												
			5	SS	3												
			6	TW	PM												
71.6	Clayey silt to silt, some sand, trace of gravel occ. silty sand layers (Fill) Soft to Stiff		7	SS	2												
			8	SS	10												
			9	SS	12												
			10	TW	PH												
			11	SS	11												
			12	TW	PH												
			13	SS	30												
			14	SS	24												
68.2	Organic clayey silt to silty clay some sand Stiff to Very Stiff		15	SS	35												
			16	SS	0												
			17	SS	27												
			18	SS	27												
			19	SS	75	/15cm											
			20	SS	27												
			21	SS	27												
			22	SS	27												
62.1	Het. mix. of silt, sand and gravel (Glacial Till) Compact		23	SS	27												
			24	SS	27												
			25	SS	27												
			26	SS	27												
			27	SS	27												
			28	SS	27												
			29	SS	27												
			30	SS	27												
59.8	Het. mix. of clay silt, sand and gravel occ. shale fragments (Glacial Till)		31	SS	27												
			32	SS	27												
			33	SS	27												
			34	SS	27												
			35	SS	27												
			36	SS	27												
			37	SS	27												
			38	SS	27												
22.7	End of Borehole																

RECORD OF BOREHOLE No 92-2

1 OF 1

METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4782 028.6 E 317 865.3 ORIGINATED BY MI
DIST 4 HWY QEW BOREHOLE TYPE HS Auger, Vane Tests, NO Rock Core COMPILED BY MI
DATUM Gedectic DATE May 19, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
85.0	Ground Surface																
0.0	Clayey Silt to Silt, some sand and trace of gravel occ. silty sand layers (Fill) Firm to Stiff		1	SS	10		84										
			2	SS	13		82										
			3	SS	14		80										
			4	SS	14		78										
			5	SS	8		76										
			6	SS	7		74										
74.9	Sand and Gravel with crushed stone (Fill) Brown		7	SS	9		72										
73.3			8	SS	4		70										
11.7	Organic Clayey Silt to Silty Clay trace of sand Very Stiff D.Grey		9	SS	4		68										
			10	TW	PH		66										
			11	SS	4		64										
			12	SS	8		62										
69.2	Clayey Silt, some sand and trace of gravel Stiff Grey		13	SS	13		60										
15.8			14	TW	PH		58										
			15	SS	8		56										
			16	SS	33		54										
60.4	Het. Mixture Clayey Silt, Reddish Brown Sand and Gravel (Glacial Till) occ. Shale Fragments, Hard Grey		17	SS	100		52										
24.6			18	RC	REC 93%		50										
59.0	Queenston Shale Bedrock Reddish Brown Weathered -- Red Sound						48										
26.0							46										
57.3	End of Borehole						44										
27.7							42										

+3, x5: Numbers refer to
Sensitivity

20
15-5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 92-3

1 OF 1

METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4782 030.1 E 317 904.3 ORIGINATED BY MI
DIST 4 HWY QEW BOREHOLE TYPE H5 Auger, Vane Tests, NQ Rock Core COMPILED BY MI
DATUM Geodetic DATE May 13, 1992 to May 14, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
85.3	Ground Surface																
0.0																	
			1	SS	25		84										
			2	SS	22		82										
	Silty Sand		3	SS	26		80										
			4	SS	12		78										
	Silty Sand		5	SS	6		76										
	Clayey Silt to Silt, some sand, trace of gravel occ. silty sand layers (Fill)		6	SS	7		74										
75.2	Firm to Very Stiff	Brown	7	SS	3		72										
10.1	Organic Clayey Silt to Silty Clay trace of sand	D.Grey	8	TW	PH		70										
74.0	Soft	Grey	9	SS	20		68										
11.3			10	SS	13		66										
			11	SS	13		64										
			12	SS	9		62										
	Clayey Silt, with sand, trace of gravel		13	SS	10		60										
	Very Stiff		14	SS	16		58										
			15	SS	19		56										
60.7		Grey	16	SS	100	/25cm	54										
24.6	Het. Mixture of Clayey Silt, Sand and Gravel occ. shale fragments (Glacial Till)	Reddish Brown	17	SS	100	/18cm	52										
57.7	Hard	Reddish Brown	18	RC	REC	100%	50										
27.6	Queenston Shale Bedrock	weathered sound Red					48										
56.2							46										
29.1	End of Borehole						44										

+3, x5: Numbers refer to
Sensitivity

20
15-25 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 92-4

1 OF 1

METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-urd. N 4781 992.0 E 317 850.7 ORIGINATED BY MI
DIST 4 HWY QEW BOREHOLE TYPE HS Auger, Vane Tests, NQ Rock Core COMPILED BY MI
DATUM Gedecic DATE May 27, 1992 to May 28, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
83.4	Ground Surface																
0.0																	
			1	SS	3												
			2	SS	1												
	Clayey Silt to Silt, some sand, trace of gravel, occ. silty sand layers (Fill)		3	SS	2												
			4	SS	1												
	Very Soft to Soft		5	SS	1												
74.8	Brownish Grey																
8.6	Organic Clayey Silt to Silty Clay		6	SS	7												
73.6	trace sand, Firm		7	TW	PH												
9.8			8	SS	21												
			9	SS	7												
			10	SS	7												
	Clayey Silt, some sand, trace of gravel, occ. sandy silt layers Firm to Very Stiff		11	SS	10												
			12	SS	10												
	Sandy Silt																
61.8	Grey																
21.6	Reddish Brown		13	SS	115	/25cm											
58.9	Het. Mixture Clayey Silt, Sand and Gravel, occ. shale fragments (Glacial Till) Hard		14	SS	100	/10cm											
24.5	Queenston Shale Bedrock		15	RC	REC 84%												
57.3																	
26.1	End of Borehole																

RECORD OF BOREHOLE No 92-5 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4781 988.3 E 317 910.9 ORIGINATED BY MI
DIST 4 HWY QEW BOREHOLE TYPE HS Auger, Vane Tests, NQ Rock Core COMPILED BY MI
DATUM Gedeotic DATE May 26, 1992 to May 27, 1992 CHECKED BY TCK

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT 7 KN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES		20 40 60 80 100	20 40 60 80 100	W _p	W	W _L		
83.4	Ground Surface												
0.0	Granular "A" (Fill)												
81.9			1	SS	9								
1.5			2	SS	16								
			3	SS	7								
			4	SS	7								
	Clayey Silt to Silt, some sand and gravel, occ. silty sand layers (Fill)		5	SS	1								
	Soft to Very Soft		6	SS	1								
			7	SS	2								
71.7		Brown											
11.7		D.Grey	8	SS	10								
	Organic Clayey Silt to Silty Clay some sand		9	TW	PH								
	Stiff to Very Stiff												
68.3		D.Grey	10	SS	15								
15.1		Grey											
			11	TW	PH								
	Clayey Silt, with some sand, trace of gravel												
	Stiff to Very Stiff		12	SS	12								
61.1		Grey											
22.3		Reddish Brown	13	SS	91								
	Het. Mixture of Clayey Silt, Sand and Gravel, occ. shale fragments (Glacial Till) Hard		14	SS	100	/13cm							
58.2		Reddish Brown											
25.2	Queenston Shale Bedrock	Red	15	RC	REC 92%								
56.7													
26.7	End of Borehole												

+3, x5: Numbers refer to
Sensitivity

20
15-5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 92-6 1 OF 1 IMPERIAL

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4781 971.4 E 317 914.5 ORIGINATED BY MI
DIST 4 HWY QEW BOREHOLE TYPE HS Auger, Vane Tests, NQ Rock Core COMPILED BY MI
DATUM Gedeotic DATE May 28, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100					
82.9	Ground Surface													
0.0	Sandy Silt (Fill) Compact		1	SS	10		82							
80.2							80							
2.7	Clayey Silt to Silt, some sand, trace of gravel occ. silty sand layers (Fill) Firm		2	SS	4		78							
			3	SS	5		76							
			4	SS	5		74							
			5	SS	4									
			6	SS	4									
72.8	Brown						72							
10.1	Organic Clayey Silt to Silty Clay traces of sand Stiff D.Grey		7	SS	8								42 4.4% (O.C.)	0 8 67 25
71.2	Grey		8	SS	4		70							
11.7			9	SS	44		68							
	Clayey Silt, with some sand, trace of gravel Firm to Hard		10	SS	22		66							
			11	SS	16		64							
							62							
61.4	Grey		12	SS	30		60							4 18 57 21
21.5	Reddish Brown		13	SS	100	/28cm	58							
58.4	Het. Mixture of Clayey Silt, Sand and Gravel occ. shale fragments (Glacial Till) Hard Reddish Brown		14	SS	100	/13cm								
24.5	Queenston Shale Bedrock Red		15	RC	REC 100%									RQD 45%
56.9														
26.0	End of Borehole													

RECORD OF BOREHOLE No 92-7 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N4781 950.4 E 317 861.3 ORIGINATED BY MI
DIST 4 HWY QEW BOREHOLE TYPE HS Auger, Vane Tests, NQ Rock Core COMPILED BY MI
DATUM Cedectic DATE May 11, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)			
								20	40							60	80	100
85.2	Ground Surface																	
0.0	Clayey Silt to Silt, some sand and trace of gravel occ. silty sand layers (Fill) Stiff to Very Stiff		1	SS	18													
			2	SS	20													
			3	SS	17													
			4	SS	23													
80.8			5	SS	11													
4.4	Silty Sand, some gravel, trace of clay Compact	Brown	6	SS	18													
79.6																		
5.6	Clayey Silt some sand, trace of gravel Stiff to Very Stiff	Grey	7	SS	11													
			8	SS	11													
			9	SS	7													
			10	SS	9													
			11	SS	10													
			12	SS	5													
			13	SS	11													
			14	SS	11													
			15	SS	10													
			16	SS	15													
61.3				Grey														
23.9			Reddish Brown Het. Mixture of Clayey Silt, Sand and Gravel occ. shale fragments (Glacial Till) Hard		17	SS	100											
59.1				Reddish Brown	18	SS	100											
26.1			Queenston Shale Bedrock	Red	19	RC	REC 89%											
57.6			20	RC	REC 100%													
27.8	End of Borehole																	
	• Water level not stabilized																	

RECORD OF BOREHOLE No 92-8

1 OF 1

METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N4781 951.1 E 317 881.3 ORIGINATED BY MI
DIST 4 HWY QEW BOREHOLE TYPE HS Auger, NQ Rock Core COMPILED BY MI
DATUM Gedectic DATE May 20, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								20 40 60 80 100							
85.2	Ground Surface														
0.0	Clayey Silt to Silt some sand and gravel occ. silty sand to sandy silt layers (Fill) Stiff		1	SS	11		84							4 30 44 22	
			2	SS	13		82								
			3	SS	14		80								
			4	SS	11		78								
			5	SS	10		76								
76.6															
8.6	Sand and Gravel with crushed stone (Fill)		6	SS	16		76							1 21 58 20	
75.1	Compact Brown														
10.1	Organic Clayey Silt to Silty Clay some sand		7	SS	4		74								
73.9	Firm D.Grey		8	SS	22		72								
11.3	Grey		9	SS	19		70								
	Silty Sand		10	SS	63		68								
			11	SS	19		66								
			12	SS	15		64								
	Clayey Silt, some sand, trace of gravel occ. silty sand layers Stiff to Very Stiff		13	SS	14		62								
61.3		Grey					60								
23.9		Reddish Brown	14	SS	78		58								
	Het. Mixture of Clayey Silt, Sand and Gravel occ. shale fragments (Glacial Till)														
58.8		Hard Reddish Brown	15	SS	100	/25cm									
26.4	Red														
		weathered	16	SS	100	/13cm									
	Queenston Shale Bedrock														
56.1		sound	17	RC	REC 73%									RQD 68%	
29.1	End of Borehole														

+3, x5: Numbers refer to
Sensitivity

20
15-5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 92-9

1 OF 1

METRIC

W.P. 824-90-01/02/03/04 LOCATION Co-ord. N 4781 952.6 E 317 921.2 ORIGINATED BY MI
DIST 4 HWY QEW BOREHOLE TYPE HS, NQ Core COMPILED BY MI
DATUM Cedectic DATE May 12, 1992 to May 13, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT		UNIT WEIGHT 7 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	W _P W W _L	WATER CONTENT (%) 10 20 30			
85.4	Ground Surface												
0.0			1	SS	11		84						
			2	SS	14		82						
	Sandy Silt		3	SS	15		80						
			4	SS	10		78						
	Silty Sand		5	SS	13		76						
	Clayey Silt to Silt, some sand, trace of gravel occ. sandy silt to silty sand layers Stiff to Very Stiff (Fill)		6	SS	9		74						
			7	SS	9		72						
71.8	Brown		8	SS	8		70						
13.6	D.Grey		9	SS	9		68						
	Organic Clayey Silt to Silty Clay trace of sand Firm to Very Stiff		10	SS	7		66						
69.2	D.Grey		11	TW	PH		64						
16.2	Grey		12	SS	3		62						
			13	SS	9		60						
			14	SS	14		58						
	Clayey Silt, some sand, trace of gravel Stiff to Very Stiff		15	SS	14		56						
61.6	Grey		16	SS	11		54						
23.8	Reddish Brown		17	SS	86		52						
	Het. Mixture of Clayey Silt, Sand and Gravel, occ. shale fragments (Glacial Till) Hard		18	SS	100	/23cm	50						
56.4	Reddish Brown		19	SS	100	/10cm	48						
29.0	Red		20	RC	REC	97%	46						
54.9	Queenston Shale Bedrock						44						
							42						

+3, x5: Numbers refer to Sensitivity
20
15-25 (%) STRAIN AT FAILURE
10

RQD 43%

ROCK CORE DESCRIPTION

WP 624-90-01/02/03/04

Page 1 of 1

CORE RECOVERY					CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
91-1	25	26.82-28.35	77	23	26.82-28.35	SHALE, greyish red, with interbedded greenish grey SILTSTONE (7%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 27.89-28.12 m); fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
91-3	19	24.38-25.91	88	17	24.38-26.82	SHALE, greyish red, with interbedded greenish grey SILTSTONE (14%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 24.38-24.71 m); fractures moderately close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
	20	25.91-26.82	83	69		
91-4	15	23.01-24.38	85	19	23.01-24.38	SHALE, greyish red, with interbedded greenish grey SILTSTONE (7%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 23.01-23.72 m); fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
91-5	20	24.38-25.93	91	23	24.38-25.93	SHALE, greyish red, with interbedded greenish grey SILTSTONE (8%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
91-6	22	27.43-28.68	98	9	27.43-28.68	SHALE, greyish red, with interbedded greenish grey SILTSTONE (14%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 27.43-27.51 m); fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

(NOTE: Depths are approximated where core recovery is less than 100%)

Logged by: DAW, Soils and Aggregates Section

ROCK CORE DESCRIPTION **WP 624-90-01/02/03/04**

Page 1 of 2

CORE RECOVERY					CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
92-1	17	25.98-27.51	97	25	25.98-27.51	SHALE, greyish red, with interbedded greenish grey SILTSTONE (5%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-2	18	26.19-27.71	93	7	26.19-27.71	SHALE, greyish red, with interbedded greenish grey SILTSTONE (5%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-3	18	27.61-29.13	100	50	27.61-29.13	SHALE, greyish red, with interbedded greenish grey SILTSTONE (15%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 27.61-28.04 m); fractures moderate to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-4	15	24.54-26.06	84	27	24.54-26.06	SHALE, greyish red, with interbedded greenish grey SILTSTONE (6%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 24.54-24.66 m); fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-5	15	25.15-26.67	92	18	25.15-26.67	SHALE, greyish red, with interbedded greenish grey SILTSTONE (7%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

(NOTE: Depths are approximated where core recovery is less than 100%)

Logged by: DAW, Soils and Aggregates Section

ROCK CORE DESCRIPTION **WP 624-90-01/02/03/04**

Page 2 of 2

CORE RECOVERY					CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
92-6	15	24.51-26.04	100	45	24.51-26.04	SHALE, greyish red, with interbedded greenish grey SILTSTONE (7%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-7	19	26.11-27.03	89	44	26.11-27.64	SHALE, greyish red, with interbedded greenish grey SILTSTONE (8%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
	20	27.03-27.64	100	0		
92-8	17	27.56-29.08	73	68	27.56-29.08	SHALE, greyish red, with interbedded greenish grey SILTSTONE (13%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-9	20	29.06-30.58	97	43	29.06-30.58	SHALE, greyish red, with interbedded greenish grey SILTSTONE (8%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to very close spaced, flat to near vertical, planar to undulating, smooth.

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

(NOTE: Depths are approximated where core recovery is less than 100%)

Logged by: DAW, Soils and Aggregates Section

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

MECHANICAL PROPERTIES OF SOIL

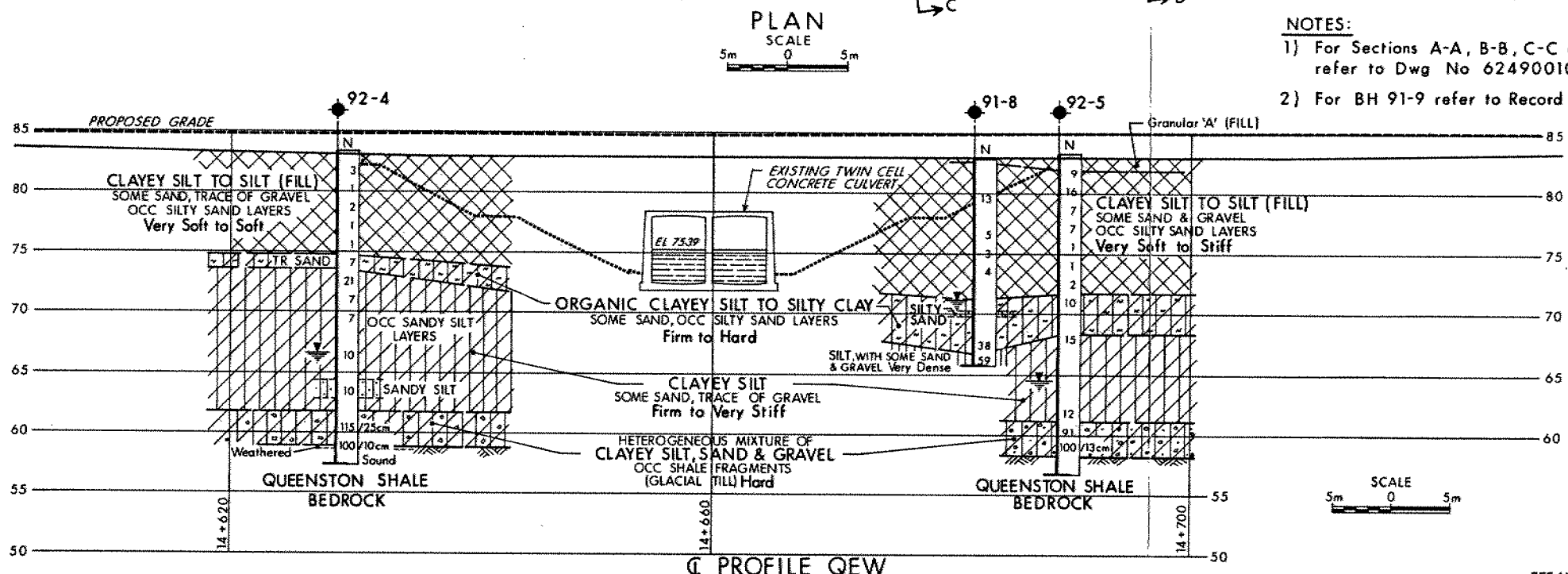
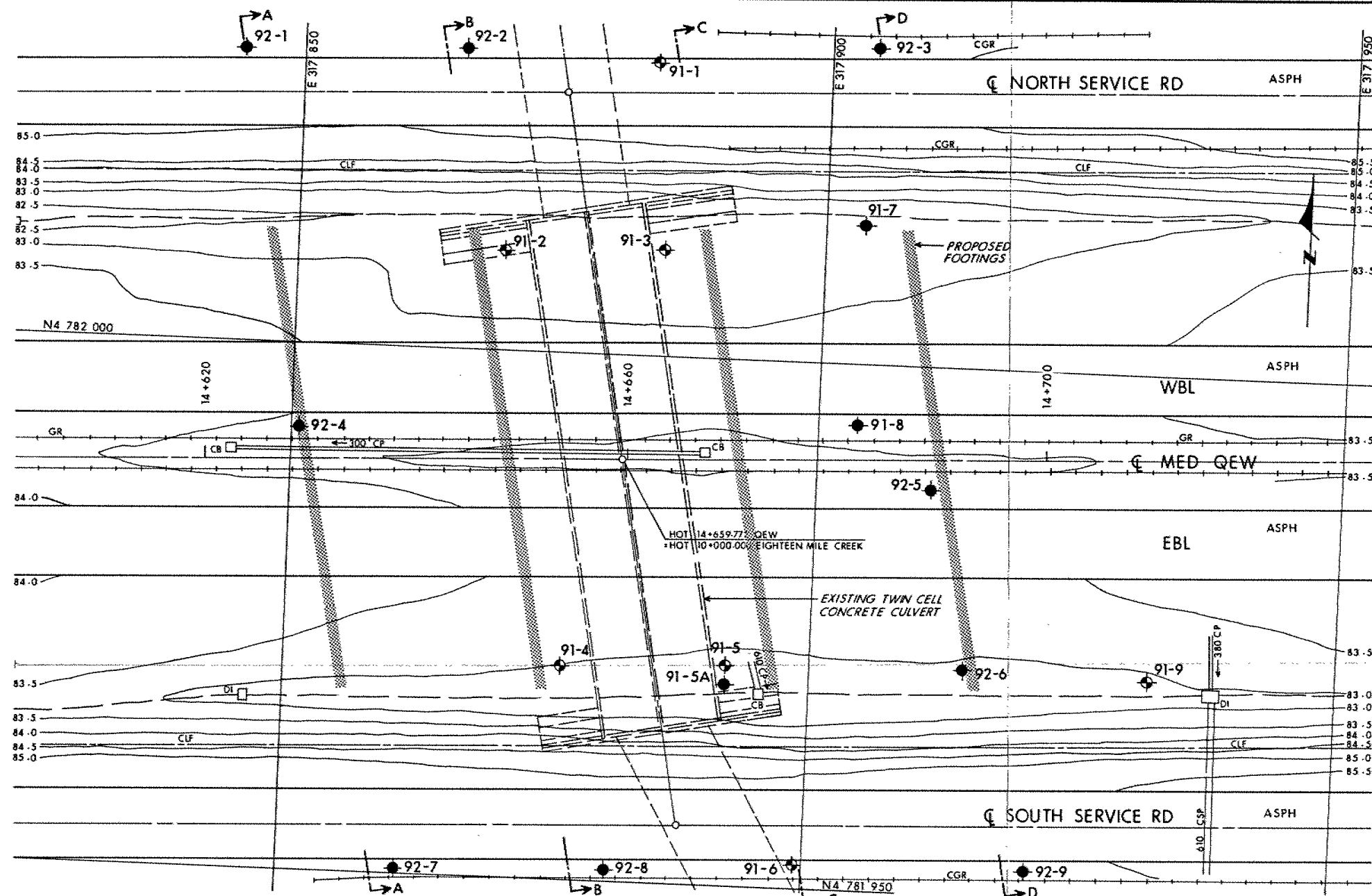
m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
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 = $\frac{c_u}{\tau_r}$

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

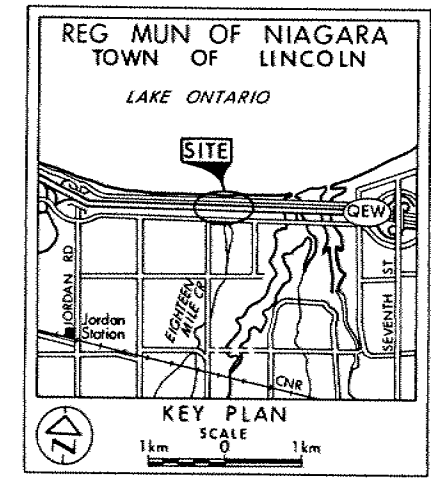
PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	e_{min}	1, %	VOID RATIO IN DENSEST STATE
γ_s	KN/m^3	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m^3	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	KN/m^3	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m^3	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	KN/m^3	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m^3	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m^3/s	RATE OF DISCHARGE
γ_d	KN/m^3	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
γ_{sat}	KN/m^3	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL	e_{max}	1, %	VOID RATIO IN LOOSEST STATE	j	KN/m^2	SEEPAGE FORCE
γ'	KN/m^3	UNIT WEIGHT OF SUBMERGED SOIL						



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

CONT No
WP No 624-90-01/02
EIGHTEEN MILE CREEK
(GEW WBL & EBL)
BORE HOLE LOCATIONS & SOIL STRATA



- 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
1991 12 and 1992 05

No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
91-1	85.2	4 782 027.9	317 883.7
91-2	82.7	4 782 009.5	317 869.7
91-3	82.8	4 782 010.1	317 884.9
91-4	83.0	4 781 970.3	317 876.4
91-5	82.9	4 781 971.0	317 892.1
91-5A	82.9	4 781 969.2	317 892.1
91-6	85.3	4 781 952.3	317 899.1
91-7	82.8	4 782 013.2	317 903.7
91-8	82.9	4 781 994.2	317 903.7
91-9	82.5	4 781 971.0	317 932.1
92-1	85.0	4 782 027.8	317 844.3
92-2	85.0	4 782 028.6	317 865.3
92-3	85.3	4 782 030.1	317 904.3
92-4	83.4	4 781 992.0	317 850.7
92-5	83.4	4 781 988.3	317 910.9
92-6	82.9	4 781 971.4	317 914.5
92-7	85.2	4 781 950.4	317 861.3
92-8	85.2	4 781 951.1	317 881.3
92-9	85.4	4 781 952.6	317 921.2

- NOTES:**
- For Sections A-A, B-B, C-C and D-D refer to Dwg No 624900102-B
 - For BH 91-9 refer to Record of Borehole Sheet

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 GC 2.01 of OPS Gen Cond.

REV	DATE	BY	DESCRIPTION

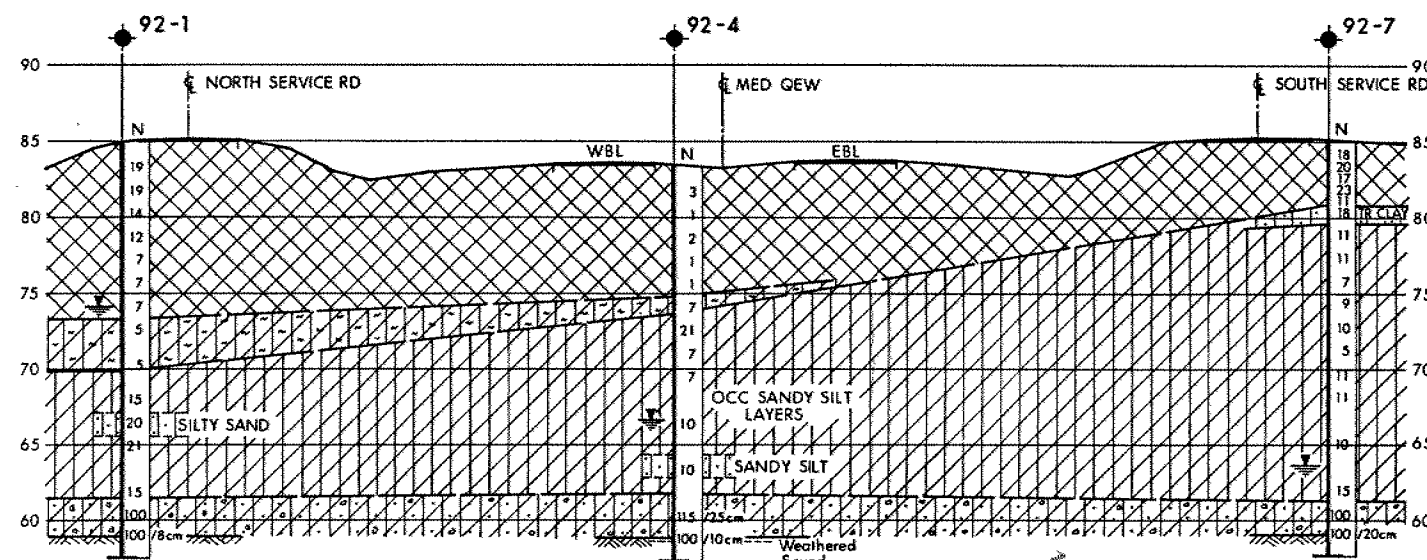
Geocres No 30M3-194

HWY No GEW	DIST 4
SUBMD TCK CHECKED 7/94	DATE 1992 12 18
DRAWN DT CHECKED 7/94	APPROVED
	SITE 18-20
	DWG 624900102-A

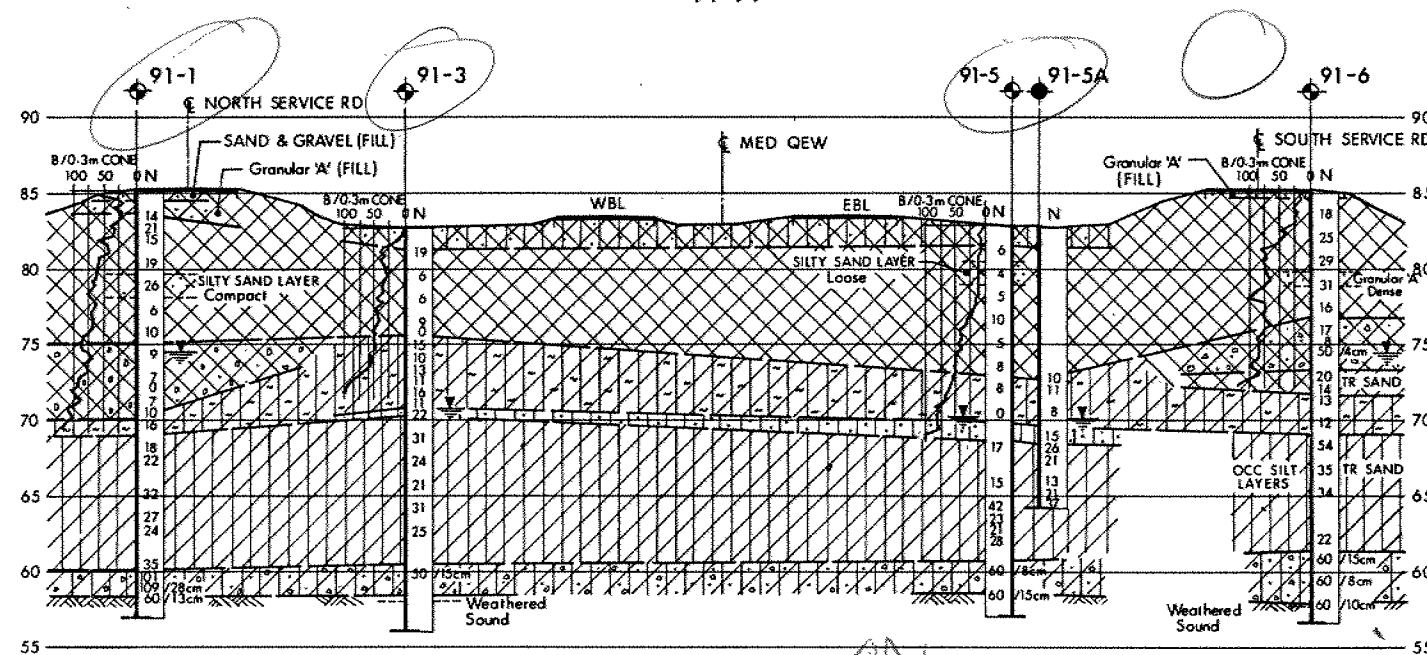
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETRES + METRES.

CONT No
WP No 624-90-01/02
EIGHTEEN MILE CREEK
(GEW WBL & EBL)
BORE HOLE LOCATIONS & SOIL STRATA

SHEET



A-A WEST ABUT



B-B WEST PIEN

SECTIONS
SCALE
5m 0 5m

LEGEND	No	ELEVATION	CO-ORDINATES NORTH	EAST
● Bore Hole	91-1	85.2	4 782 027.9	317 883.7
⊕ Dynamic Cone Penetration Test (Cone)	91-2	82.7	4 782 009.5	317 869.7
⊕ Bore Hole & Cone	91-3	82.8	4 782 010.1	317 884.9
N Blows/0.3m (Std Pen Test, 475 J/blow)	91-4	83.0	4 781 970.3	317 876.4
CONE Blows/0.3m (60° Cone, 475 J/blow)	91-5	82.9	4 781 971.0	317 892.1
WL at time of investigation 1991 12 and 1992 05	91-5A	82.9	4 781 969.2	317 892.1
	91-6	85.3	4 781 952.3	317 899.1
	91-7	82.8	4 782 013.2	317 903.7
	91-8	82.9	4 781 994.2	317 903.7
	91-9	82.5	4 781 971.0	317 932.1
	92-1	85.0	4 782 027.8	317 844.3
	92-2	85.0	4 782 028.6	317 865.3
	92-3	85.3	4 782 030.1	317 904.3
	92-4	83.4	4 781 992.0	317 850.7
	92-5	83.4	4 781 988.3	317 910.9
	92-6	82.9	4 781 971.4	317 914.5
	92-7	85.2	4 781 950.4	317 861.3
	92-8	85.2	4 781 951.1	317 881.3
	92-9	85.4	4 781 952.6	317 921.2

SOIL STRATIGRAPHY LEGEND

	SILTY SAND (FILL)
	CLAYEY SILT TO SILT (FILL) SOME SAND, TRACE OF GRAVEL OCC SILTY SAND TO SANDY SILT LAYERS Very Soft to Very Stiff
	CRUSHED STONE (FILL) WITH SAND Loose to Very Dense
	SILTY SAND SOME /WITH GRAVEL Loose to Compact

	ORGANIC CLAYEY SILT TO SILTY CLAY TRACE/SOME SAND, TRACE GRAVEL Soft to Very Stiff
	CLAYEY SILT SOME /WITH SAND, TRACE GRAVEL OCC SILTY SAND LAYERS Firm to Hard
	HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND & GRAVEL OCC SHALE FRAGMENTS (GLACIAL TILL) Hard
	QUEENSTON SHALE BEDROCK

NOTE

For Plan and Profile
refer to Dwg. No 624900102-A

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 2.01 of OPS Gen Cond

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DRAWN DT [CHECKED] APPROVED	DWG 624900102-B	

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FOUNDATION DESIGN SECTION

**foundation
investigation and
design report**

ENGINEERING MATERIALS OFFICE
FOUNDATION DESIGN SECTION

CONT. 94-53

WP 624-90-03 DIST 4

HWY Q.E.W. STR SITE 18-20

Q.E.W. Crossing at 18 Mile Creek
South Service Road

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FOUNDATION INVESTIGATION REPORT
For
Q.E.W. Crossing at 18 Mile Creek
W.P. 624-90-03 South Service Road
Site No. 18-20
District 4, Burlington

INTRODUCTION

This report summarizes the information obtained from a foundation investigation carried out at the above mentioned site where a three span bridge structure is proposed to carry the existing Q.E.W. South Service Road Crossing at 18 Mile Creek.

The field works for the foundation investigation were carried out at the above mentioned site during the period of December 2 to December 20, 1991 and May 11 to May 29, 1992. Ten boreholes (BH 91-1 to BH 91-9 inclusive, plus BH 91-5A) for the proposed original large twin culverts (5.9 m X 5.9 m X 137 m) were advanced and sampled between December 2 and December 20, 1991 to replace the existing twin culverts.

It should be noted that the original design scheme was found to be not environmentally viable. Therefore, a new proposal brought forth to replace the existing culverts with four (4) bridge structures. Additional nine boreholes (BH 92-1 to BH 92-9) were advanced and sampled as part of this project between May 11 and May 29, 1992. These boreholes extended down to depths between 14.2 m and 30.5 m below the existing ground surface.

Total of nineteen (19) boreholes were drilled for four bridge structures. Among them, eleven (11) boreholes are located within the Q.E.W. eastbound and westbound lanes, while four (4) boreholes are situated within South Service Road structure and North Service Road structure, respectively. The information from these boreholes is utilized in this report.

This report contains factual information obtained from these investigations

pertaining to structure foundations, approach embankments and related earthworks for the South Service Road bridge structures as shown on Dwg. No. 6249003-A and Dwg. 6249001/02-A and B in Report No. W.P. 624-90-01/02.

SITE DESCRIPTION AND GEOLOGY

The site is located on the existing alignment of Q.E.W. where it crosses the Eighteen Mile Creek in the Town of Lincoln, Regional Municipality of Niagara. The proposed structure is located approximately 2.5 km east of Jordan Harbour. The topography in the area is gently undulating with a valley. Land use in the vicinity of the site is primarily agricultural known as the Niagara Fruit Belt.

Physiographically, the site is located in the "Iroquois Plain" region (Ref: Chapman and Putnam, 1984). The general area was inundated by the Pleistocene Lake Iroquois. As the lake level receded much below the present level of Lake Ontario, the Eighteen Mile Creek cut a valley through the till. Underlying the glacial deposit is the red Queenston Shale from which the till's reddish colour is derived. Later, the rise in the Lake Ontario water level to approximately its present level, drowned the outlet of the creek and created a lagoon and marsh separated from the lake by a barrier beach. Water flow is to the north into Lake Ontario.

SUBSURFACE CONDITIONS

The subsoil conditions are generally consistent across the site. The Q.E.W. crosses the Eighteen Mile Creek at this location. The road embankment fill of the existing Q.E.W. consists of bedding sand, mainly clayey silt and some crushed stone as much as 13.6 m in the middle of valley.

Underlying the fill is a layer of organics which was encountered at all borehole locations except at one borehole location (BH 92-7). The thickness of this layer ranges from 1.1 m at BH 91-1 to 5.6 m at BH 91-2.

Underneath this layer, clayey silt with some sand and trace of gravel was

encountered. The thickness of this layer ranges from 6.1 m at BH 91-9 to 18.3 m at 92-7. A thin layer of silty sand and gravel was found at 6 borehole locations (BH's 91-2, 91-3, 91-5, 91-5A, 91-6, and 92-2) in between the organic material and clayey silt with a maximum thickness of about 1.2 m at BH 92-7.

Cohesive glacial till was encountered underneath the clayey silt at all boreholes locations. This material can be described as a heterogeneous mixture of clayey silt, sand and gravel. The maximum thickness of this deposit was found to be about 5.2 m at BH 92-9. This layer is underlain by shale and siltstone bedrock. A thin layer of non-cohesive glacial till, which can be described as a heterogeneous mixture of silt, sand and gravel, was found with a thickness of 2.4 m at BH 91-9.

Sound bedrock was proven in 14 borehole locations by obtaining up to 2.7 m of NQ rock cores. The bedrock surface ranges from an elevation of 56.4 m at BH 92-9 to an elevation of 60.0 m at BH 91-4 which corresponds to 29.0 m and 23.0 m below the existing ground surface, respectively. The upper portion of bedrock was slightly weathered for a maximum 1.2 m at BH 92-8 below the rock surface. The sound bedrock surface ranges from an elevation of 56.4 m at BH 92-9 to an elevation of 59.3 m at BH 91-4 which corresponds to 29.0 m and 23.7 m below the existing ground surface. The bedrock is known to be "SHALE and interbedded SILTSTONE of the Queenston Formation".

The boundaries between the various soil types, in situ and laboratory test results are shown on the attached Record of Borehole Sheets in the Appendix. The locations and elevations of the boreholes, along with a profile and sections, are shown on Dwg. No. 6249003-A and Dwg. No. 6249001/02-A and B in Report W.P. 624-90-01/02.

A detailed description of the subsurface conditions encountered is given below.

Embankment Fill

The embankment fill consists of bedding sand, mainly clayey silt and some crushed

stone. The thickness of this layer was found to range from 4.4 m at BH 92-7 to 13.6 m at BH's 91-6 and 92-9.

Atterberg Limit Tests were performed on clayey silt samples and the results are plotted on Figure 1 and summarized as follows:

<u>Property</u>	<u>Range (%)</u>
Natural Moisture Content (w)	8.5 - 24.5
Liquid Limit (w_L)	16.5 - 36.0
Plastic Limit (w_p)	13.0 - 17.5
Plasticity Index (I_p)	3.0 - 19.0

From the Plasticity Chart, it is evident that the layer can be classified as a clayey silt to silt, some sand and gravel with low plasticity (CL or CL-ML).

Grain Size Distribution tests were carried out on this fill material. Figure 2 in the Appendix shows the results in an envelope form. In this stratum, the "N" values range from 0 to over 31 blows/0.3 m indicating the consistency of this deposit described as very soft to hard. Some silty sand layers were found within this clayey silt fill as shown on Figure 3.

Organic Clayey Silt to Silty Clay, Some Sand

This deposit was encountered beneath the existing embankment fill in all boreholes except BH No's 91-4 and 92-7 which were on or near the edge of the valley. The thickness of this deposit ranges from 1.1 m at BH 91-1 to 5.6 m at BH 91-2 and this deposit gradually peters out near the valley's edge.

The material, as sampled, was highly organic with organic pieces generally visible, and well-decayed pieces of roots and wood were not uncommon. Occasional samples were fibres. Some sand and occasional gravel were noted as well as occasional sand seams.

Atterberg Limit tests were performed on these samples and the results are plotted on Figure 4 and summarized as follows:

<u>Index Property</u>	<u>Range (%)</u>
Natural Moisture Content (w)	19.0 - 70.0
Liquid Limit (w_L)	17.0 - 68.0
Plastic Limit (w_p)	14.0 - 45.0
Plasticity Index (I_p)	3.0 - 23.0

From the plasticity chart, it is evident that the layer can be classified as an organic clayey silt to silty clay with low to high plasticity (OL.OI and OH).

Grain Size Distribution tests were carried out on these materials. Figure 5 in the Appendix shows the results in an envelope form.

Undrained Shear Strength of the soil was determined by in situ vane tests and by laboratory tests, namely unconfined compression tests. The results are plotted on Figure 6 and the Record of Borehole log sheets in the Appendix and summarized as follows:

<u>Undrained Shear Strength</u>	<u>Cu (kPa)</u>	<u>Sensitivity</u>
In-Situ Vane Tests	15 - >115	1 - 6
Unconfined Compression Tests	28 - 98	

As shown on Figure 6, the vane strengths measured within organic layer varied from 15 kPa to greater than 115 kPa, indicating soft to very stiff consistency. This layer has a sensitivity varying from 1 to 6 based on the measured undisturbed and remoulded vane strengths. This would indicate that the organic clayey silt to silty clay is generally sensitive.

An oedometer test was carried out to investigate the consolidation characteristics of the organic clayey silt to silty clay. The sample tested is

considered representative of the organic deposit was selected from a Shelby tube sample obtained at about an elevation of 69 m in BH 91-8. The result of the consolidation test is shown on Figure 7. The preconsolidation pressure is estimated to be about 330 kPa, indicating an overconsolidation ratio of about 1.25 relative to the existing effective overburden stress. The compression index (C_c) was determined to be about 0.213.

Silty Sand With Gravel

This deposit was found at five (5) borehole locations underlying the organic stratum (BH 91-2, 91-3, 91-5, 91-5A and 92-7). The thickness of this layer ranges from 0.5 m at BH 91-3 to 1.1 m at BH's 91-5, 91-5A and 92-7. Figure 3 in the Appendix shows the result of Grain Size Distribution test.

In this stratum, the "N" values ranged from 9 to 22 blows/0.3 m indicating a state of compaction described as loose to compact.

Clayey Silt With Sand

This deposit was encountered in all boreholes, either beneath the organic clayey silt to silty clay or the silty sand deposit, and appeared to represent the original material into which the Creek Valley had been carved. Hence, the deposit varied in thickness from 18.3 m at BH 92-7 near the edge of the valley to a minimum of 6.1 m at BH 91-9 near the centre of the valley.

Atterberg Limit tests were performed on these samples and the results are plotted on Figure 8 and summarized as follows:

<u>Index Property</u>	<u>Range (%)</u>
Natural Moisture Content (w)	13.0 - 20.5
Liquid Limit (w_L)	19.0 - 32.0
Plastic Limit (w_p)	14.0 - 17.0
Plasticity Index (I_p)	4.0 - 15.0

From the plasticity chart, it is evident that the layer can be classified as an inorganic clayey silt, some sand with low plasticity (CL or CL-ML).

Grain Size Distribution tests were carried out on these materials. Figure 9 in the Appendix shows the results in an envelope form.

Undrained shear strength of the soil was obtained by in-situ vane tests and by laboratory unconfined compression tests. The results are plotted on Figure 6 and the Record of Borehole log sheets in the Appendix and summarized as follows:

<u>Undrained Shear Strength</u>	<u>Cu (kPa)</u>	<u>Sensitivity</u>
In-situ Vane Tests	61 - >115	1 - 3
Unconfined Compression Tests	69 - 285	

The field vane strengths obtained in this stratum varied from 61 kPa to greater than 115 kPa indicating a stiff to hard consistency. The sensitivity of this deposit varies from 1 to about 3 indicating this material being normal.

Heterogeneous Mixture of Clayey Silt, Sand and Gravel (Cohesive Glacial Till)

This stratum was encountered underneath the clayey silt layer and immediately above the bedrock. The thickness of this layer ranges from 0.7 m at BH 91-4 to 5.2 m at BH 92-9.

Atterberg Limit tests were performed on these samples and the results are plotted on Figure 10 and summarized as follows:

<u>Property</u>	<u>Range (%)</u>
Natural Moisture Content (w)	7.0 - 13.0
Liquid Limit (w_L)	17.0 - 24.0
Plastic Limit (w_p)	12.0 - 14.0
Plasticity Index (I_p)	5.0 - 10.0

From the plasticity chart, it is evident that this deposit can be classified as a heterogeneous mixture of clayey silt, sand and gravel with low plasticity (CL or CL-ML).

Grain Size Distribution tests were carried out on the cohesive glacial till material. Figure 11 in the Appendix shows the results. An increasing frequency of fragments of weathered shale was encountered within the lower portion of this till.

In this stratum, the "N" value range from 30 to over 100 blows/0.3 m indicating the consistency of this deposit as hard.

Heterogeneous Mixture of Silt, Sand and Gravel (Non-Cohesive Glacial Till)

This layer was encountered between clayey silt and cohesive glacial till at a borehole location. The thickness of this layer was found to be about 2.3 m at BH 91-9.

A Grain Size Distribution test was carried out on this material as shown on Figure 12. This layer is basically non-cohesive. In this stratum, the "N" value is about 27 blows/0.3 m indicating a state of compaction described as compact.

Bedrock

Bedrock was cored in fourteen (14) boreholes by obtaining up to 2.7 m of NQ rock at BH 92-8. The top of the bedrock ranged from elevation 56.4 m to 60.0 m which correspond to 29.0 m and 23.0 m below the existing ground surface, respectively. The upper 0 to 1.2 m is in a slightly weathered state. The top of the sound bedrock ranged from 56.4 m to 59.3 m.

The bedrock is a red shale with interbedded green siltstone (approximately 85% shale, 15% siltstone) of the Queenston Formation. Detailed description of the rock is attached in the Appendix entitled "Rock Core Description".

The Core Recovery (CR) and Rock Quality Designation (RQD) values were determined in-situ and also in the laboratory to evaluate the competence and integrity of the rock. The Core Recoveries (CR) range between 73 and 100 percent and Rock Quality Designation (RQD) values range from 7 to 69 percent. Based on these results, the rock can be classified as weak to very weak and slightly to unweathered.

GROUNDWATER CONDITIONS

Groundwater conditions were observed by measurement of water levels in the open boreholes. The groundwater level was found to be at approximate elevation between 63.7 m at BH 92-7 and 74.6 at BH 91-4 which correspond to depths of 21.5 m and 8.4 m below the existing ground surface. However, it is likely that the groundwater level was the same as the creek level and is subject to seasonal fluctuations.

DISCUSSION AND RECOMMENDATIONS

The recommendations in this report apply to the bridge structure and related approaches.

It is proposed to construct a three span bridge structure (19 m x 22 m x 19 m) which will replace the existing twin concrete culverts along the South Service Rd. crossing the Eighteen Mile Creek. It is understood that an increase in grade for the Q.E.W. embankment will be required to avoid some snow accumulation within the Q.E.W. during the winter season due to the ditch effect on the highway. This would involve the additional placement and compaction of up to 1.7 m fill for the permanent approach along the Q.E.W. to the same level with the existing South and North Service Roads. No additional fill material will be placed on the South Service Road.

Recommendations pertaining to the foundations of a new bridge for the South Service Road and related earth works are summarized as follows.

Structure Foundations

East and West Abutments

In view of the low shear strength and compressibility of the organic clayey silt to silt clay and the extensive clayey silt layers, conventional spread footing shallow foundations are not applicable at this site. It is recommended that the abutments may be supported on end-bearing steel "H" piles, equipped with reinforced tips in order to facilitate pile penetration through the basal glacial till and driven to sound bedrock.

In consideration of no additional load application underneath the pile cap at the both abutments, the following design parameters are suggested for the purpose of the O.H.B.D.C..

<u>Pile Type</u>	<u>Factored Axial Capacity at U.L.S</u>	<u>Axial Capacity at S.L.S. Type II</u>
HP 310 x 79	1150 kN	900 kN
HP 310 x 110	1600 kN	1150 kN

Pile tip elevations for estimating the pile lengths are given below.

<u>Structure</u>	<u>East Abutment(Elevation)</u>	<u>West Abutment(Elevation)</u>
Q.E.W. S. Service Rd.	56.4 m - 57.5 m	59.1 m

Battered piles should be installed, where required, to resist lateral load on abutments.

In view of the extreme denseness of the glacial till stratum located immediately above the bedrock, some piles may not penetrate this dense stratum. In such a case, the pile capacity should be controlled in the field using current MTO pile driving standards. However, attempts should be made in all cases to drive the piles to the bedrock surface. It should also be noted that the pile driving be controlled by maximum capacity of piles.

During pile driving, the steel "H" pile should be set to a termination of 8 blows for the last 12 millimetres of penetration using a hammer transferring about 60 kilojoules of energy per blow to the pile.

Provision should be made to restrike all piles to confirm the set after adjacent piles have been driven. Piles that do not meet the design set criteria on the first restrike would require additional restriking. A minimum of 48 hour should be allowed before restriking a pile.

In order to enhance pile driving, the fill material immediately below pile caps, should not contain particle sizes greater than 75 mm.

Alternatively, caisson foundations can be considered for the both abutments. Details for caissons will be discussed in Pier Foundations.

East and West Piers

In consideration of the existence of weak and compressible organic clayey silt to silty clay and extensive clayey silt layers, conventional spread shallow foundations are not applicable for the piers at this site. It should be noted that during the construction, to avoid the problems associated with excavation through embankment toward longitudinal direction , it is recommended that the structural loading at the piers be transferred to the underlying sound bedrock by means of bored cast-in-place caissons installed through the embankment and overburden.

The caisson should have a minimum length to diameter ratio of 3 within the bedrock and should be socketed at least 0.5 metre into the sound shale bedrock. The caissons may be design using an end bearing factored capacity at Ultimate Limit States of 3500 kilopascals. Serviceability Limit States is not relevant to caissons founded on bedrock since the stresses required to produce detrimental settlements will be larger the value given for the factored bearing capacity at ULS.

The following caisson bottom elevations are suggested for estimating the caisson length.

<u>Structure</u>	<u>East Pier (Elevation)</u>	<u>West Pier (Elevation)</u>
Q.E.W. S. Service Rd.	57.3 m	57.1 m

Caissons should be a minimum diameter of 900 mm to allow for both the clean out of any basal debris and final evaluation of the rock surface in order to confirm the above-stated capacities.

Groundwater infiltration may have to be controlled by using drilling mud coupled with telescoping liners or other methods. However, regardless of the method used, during withdrawal of the innermost liner, it is recommended that, while pouring, a positive head of concrete should be maintained at all times to prevent intrusion of the surrounding soils, groundwater and/or bentonite slurry.

The proposed method of caisson installation be in accordance OPSS 903.07.03 and subject to review by this office.

It should be noted that to avoid the need for deep excavation of the existing embankment and frost protection, caisson cap for the piers should be placed immediately below the bridge decks.

Other Considerations

Lateral Earth Pressures

Free draining material such as Granular "A" or Granular "B" is recommended as an appropriate backfill material to prevent hydrostatic pressure build-up on the abutment walls. Design parameters of the soil are given below for the purpose of the O.H.B.D.C.

	Granular "A"	Granular "B"
Angle of Internal Friction (ϕ)	35 ⁰	30 ⁰
Unit Weight (kN/m ³), γ	22.8	21.2
Coefficient of Active Earth Pressure (K_a)	0.27	0.33
Coefficient of Earth Pressure at Rest (K_o)	0.43	0.5

The earth pressure coefficient at rest is to be used when the design of abutment walls are rigid and unyielding.

Dewatering

No major dewatering difficulties are anticipated for footing excavation in consideration of lower groundwater levels and the relatively low permeability of the clayey silt fill. However, if localized seepage or surface water to accumulates in excavations, it can be controlled by perimeter ditches and pumping from corner sumps.

Frost Protection

The pile caps should be placed so as to have a minimum earth cover of 1.2 m to allow for frost protection.

Stability of Approach Embankment

The stability analyses were carried out based on a minimum design underdrained shear strength of 50 kPa for the organic clayey silt to silty clay, as established by field vane tests. Since no additional fill will be placed on the South Service Road, the existing slope will be stable in the transverse direction.

However, since the existing embankment fill of about 11 m will be cut down to creek level, stability analyses were carried out to evaluate the overall stability of the approach fill in the longitudinal direction and also the internal stability of the fills were examined. Based on the stability analyses, the forward slope for the Q.E.W. South Service Road Structure will require a 3 m wide mid-height beam with a 2H to 1V side slope to meet a minimum factor of safety of 1.3 as shown on Figure 13.

Construction Consideration

Excavations for abutments, pile-caps construction may be carried out in temporary open cuts with side slopes maintained at gradients not steeper than 1.5H:1V through the clayey silt fill. All excavations should be carried out according to the guidelines contained in the latest edition of the Ontario Occupational Health and Safety Act. To prevent softening of the exposed clayey silt fill, it is recommended that Granular "A" material be placed on the excavation base to provide protection to the founding stratum as soon as the base of the excavation has been inspected.

Excavation cut of the forward slope toward 18 Mile Creek should be delayed until the four bridge structures are completed in order to avoid expensive roadway protection scheme such as very high temporary shoring system.

For erosion protection purposes, the embankment forward slopes should be covered with a layer of topsoil and properly seeded in order to enhance adequate vegetation cover. Suitable protection measures should also be provided to the creek banks adjacent the abutments. Such measures may include appropriately sized rip-rap underlain by suitable granular filter.

MISCELLANEOUS

The initial fieldwork for this investigation was carried out during the period of December 2 to December 20, 1991 under the supervision of R. Ng, Trainee Engineer and Tae C. Kim, Sr. Foundation Engineer. The equipment was owned and

operated by Master Soil Investigation Ltd., Toronto. Additional fieldwork for this investigation was carried out during the period of May 11 to May 29, 1992 under the supervision of M. Iampietro, Student Engineer, and Tae C. Kim, Sr. Foundation Engineer. The equipment was owned and operated by Malone's Soil Samples Co. Ltd., Toronto.

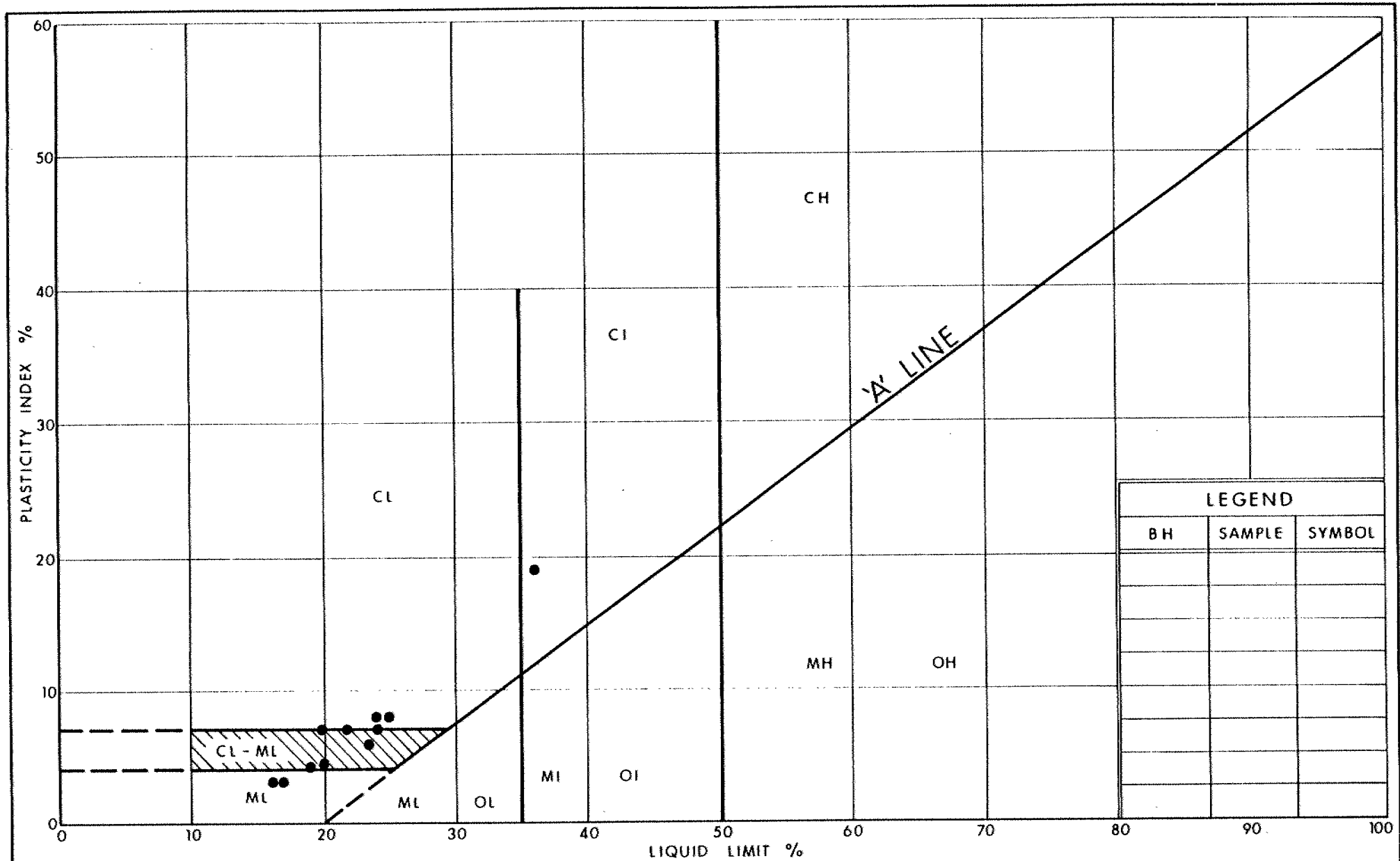
This report was written by Tae C. Kim, Senior Foundation Engineer and reviewed by M. Devata, Chief Foundation Engineer.



Tae C. Kim
Tae C. Kim, P. Eng.
Sr. Foundation Engineer

M. Devata
M. Devata, P. Eng.
Chief Foundation Engineer

APPENDIX



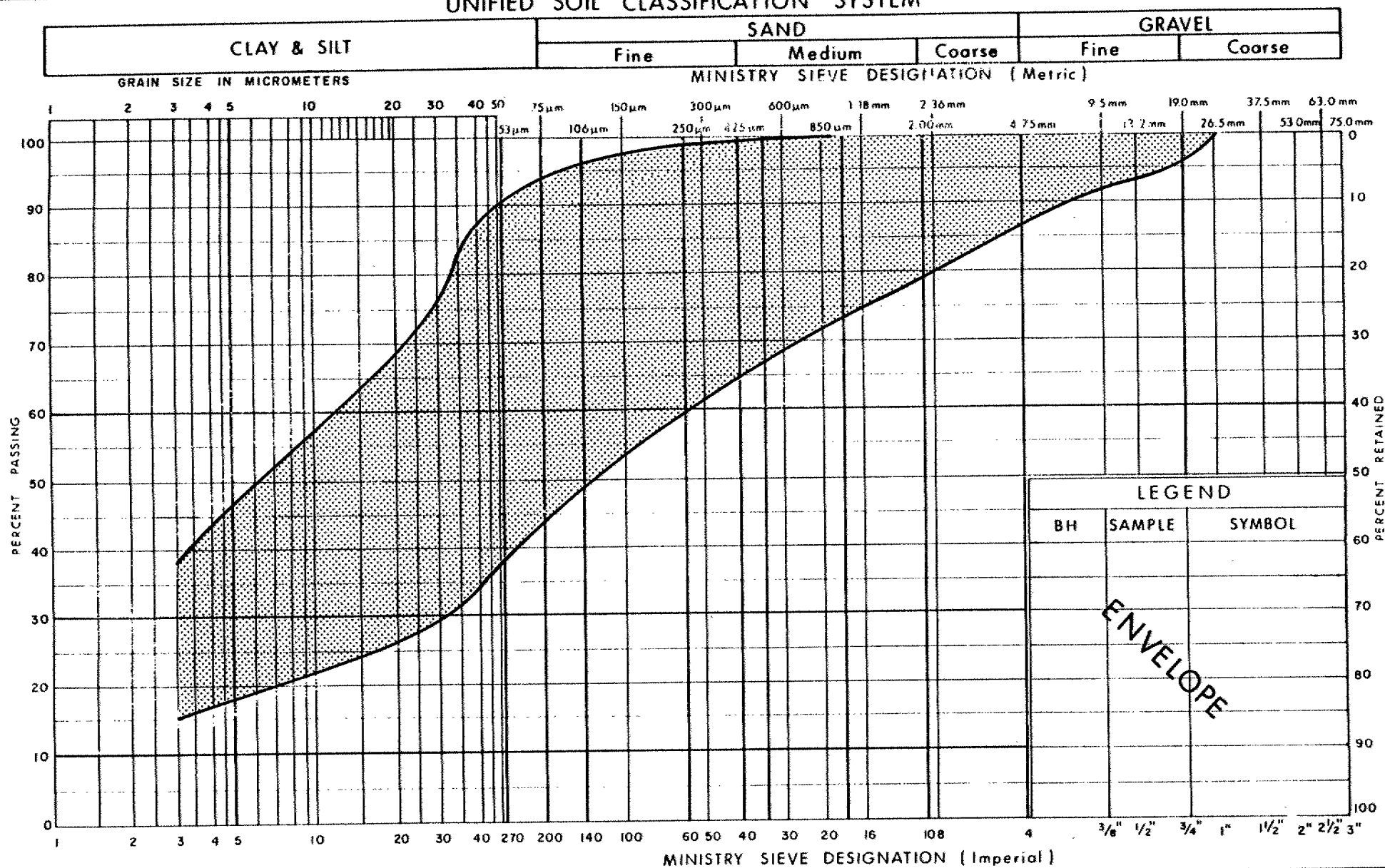
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PLASTICITY CHART CLAYEY SILT TO SILT (Fill)

FIG No 1

W P 624-90-03

UNIFIED SOIL CLASSIFICATION SYSTEM



Ontario

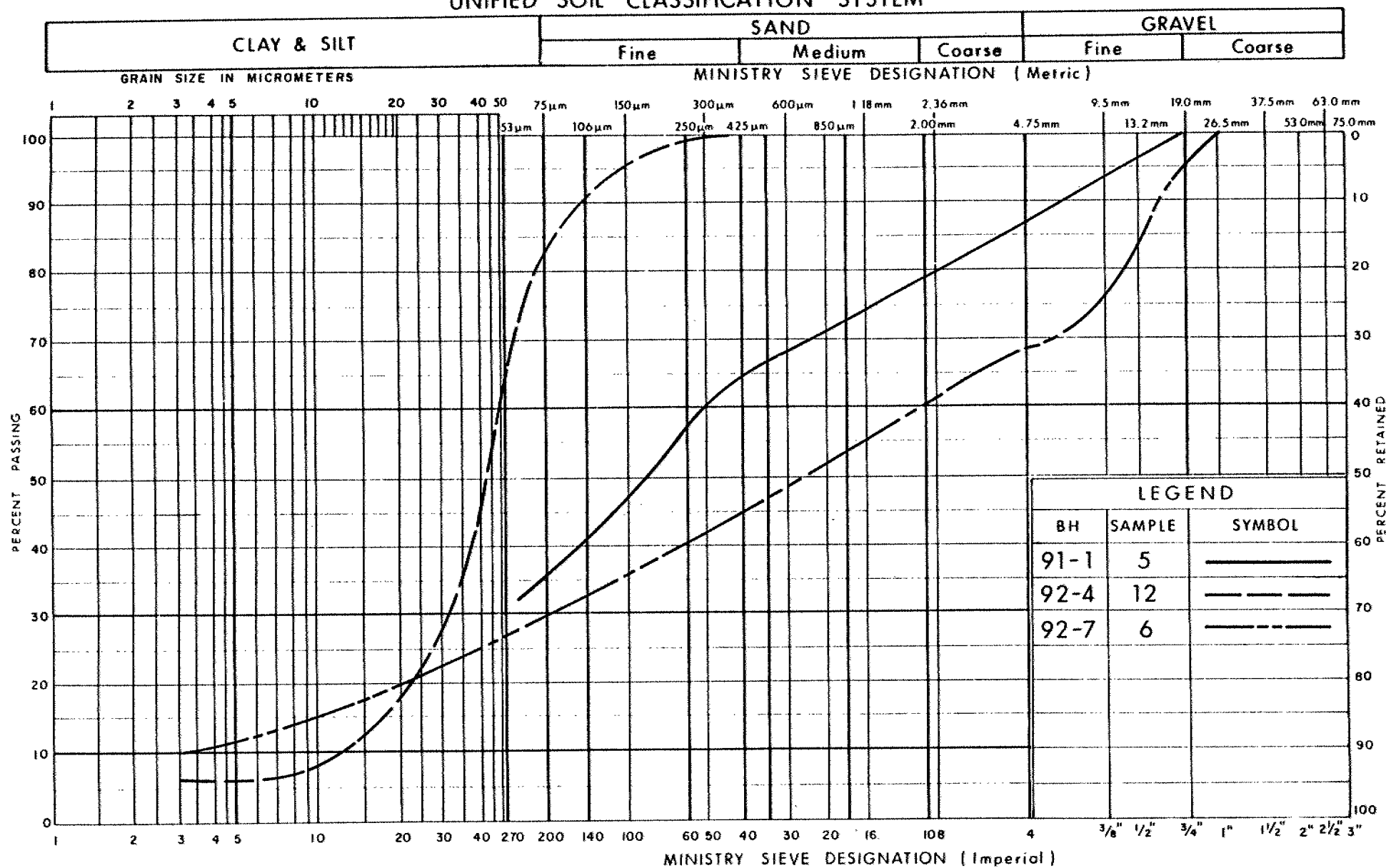
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GRAIN SIZE DISTRIBUTION
CLAYEY SILT TO SILT
(Fill)

FIG No 2

W P 624-90-03

UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION
SILTY SAND TO SANDY SILT

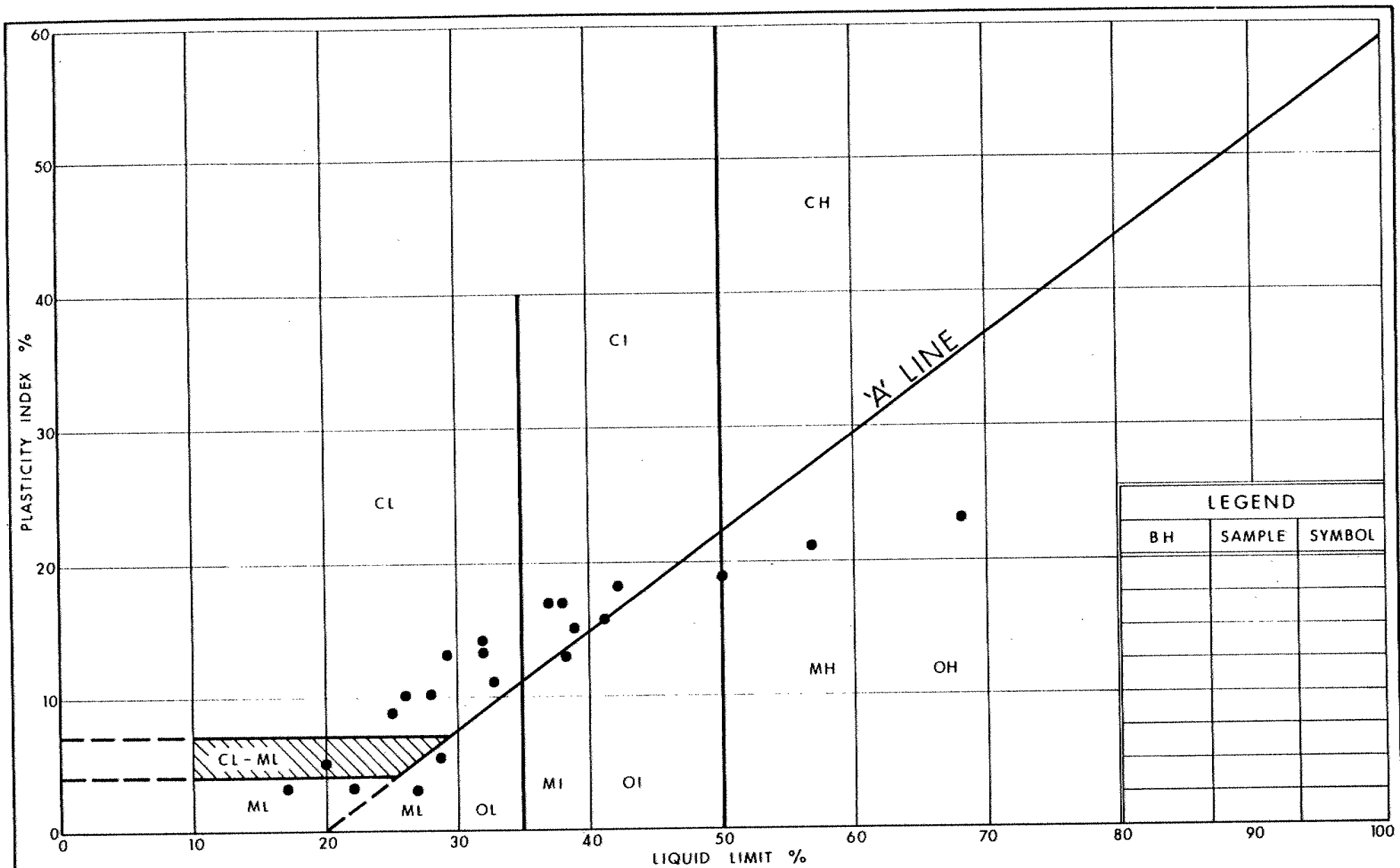
FIG No 3

W P 624-90-03



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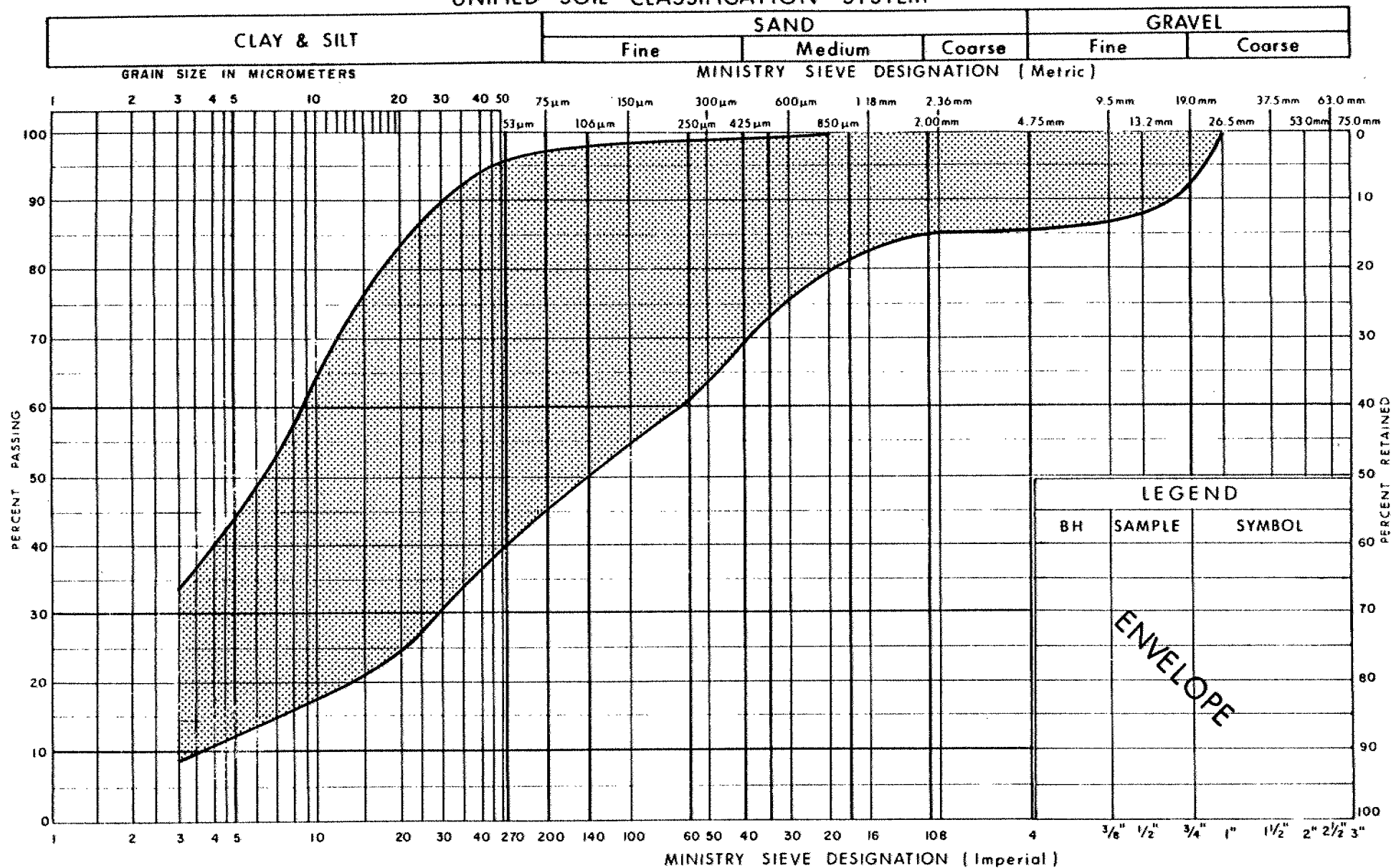
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PLASTICITY CHART
ORGANIC CLAYEY SILT TO SILTY CLAY

FIG No 4

W P 624-90-03

UNIFIED SOIL CLASSIFICATION SYSTEM

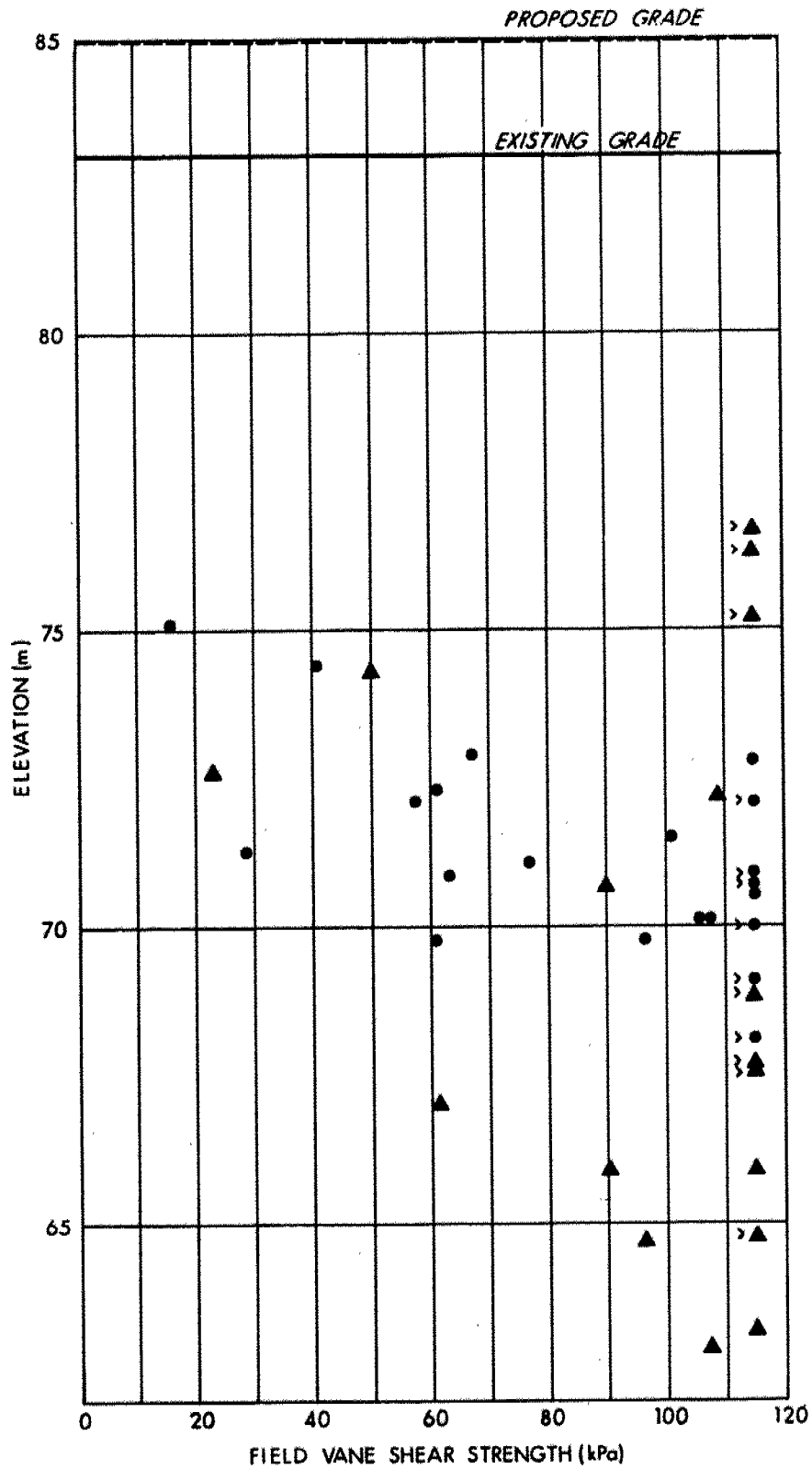


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GRAIN SIZE DISTRIBUTION ORGANIC CLAYEY SILT TO SILTY CLAY

FIG No 5

W P 624-90-03



PROFILE OF FIELD VANE TESTS
ORGANIC CLAYEY SILT TO SILTY CLAY

- ORGANIC CLAYEY SILT TO SILTY CLAY
- ▲ CLAYEY SILT

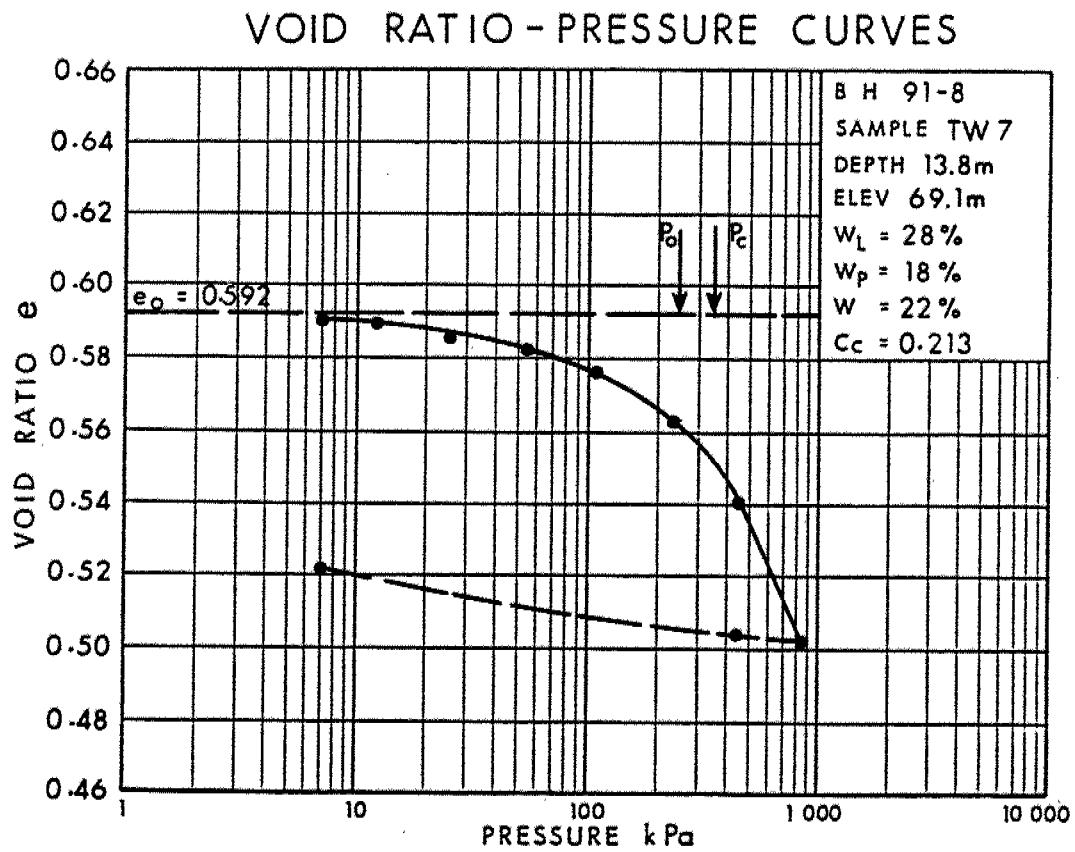
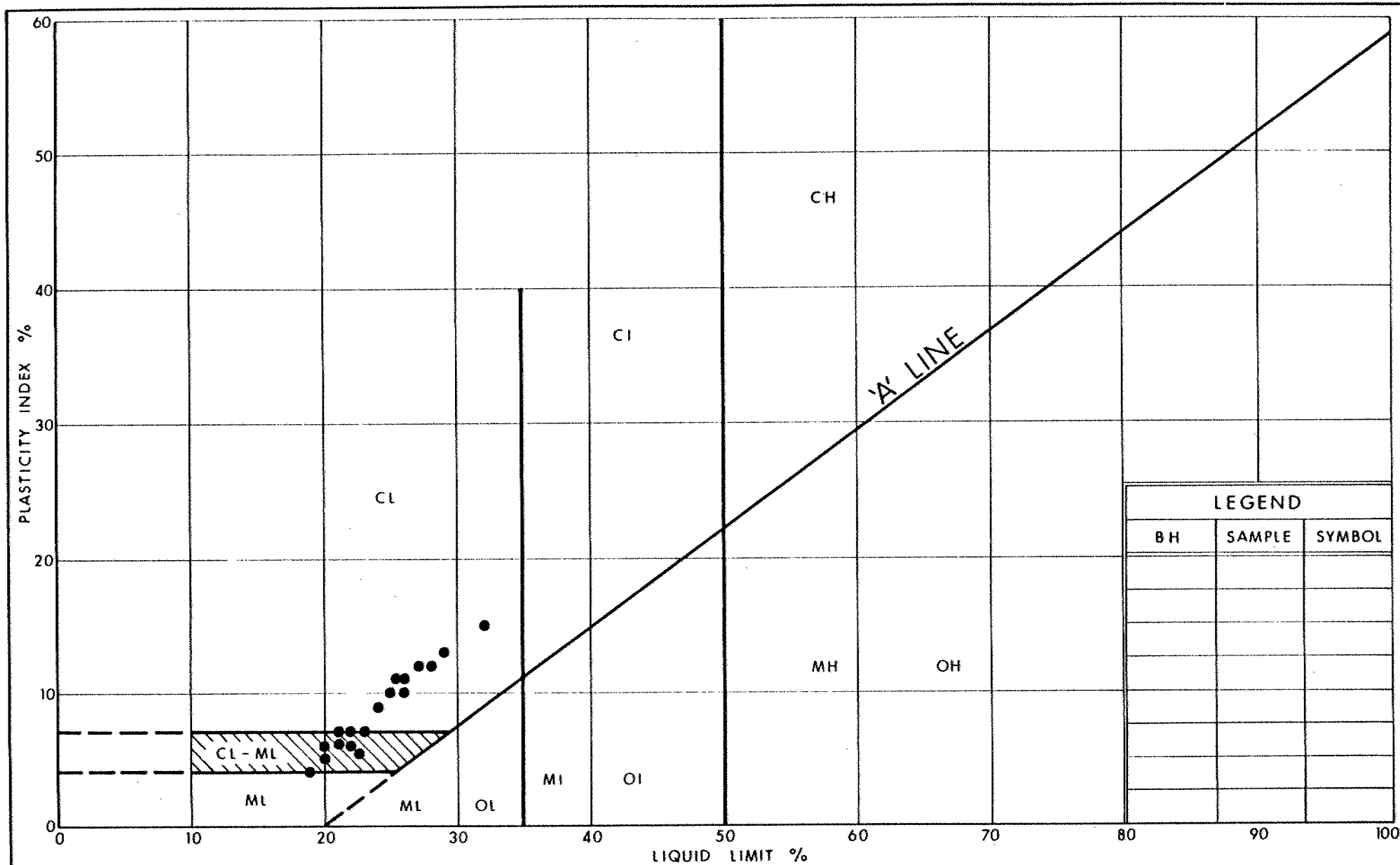


Fig 7

WP 624-90-03

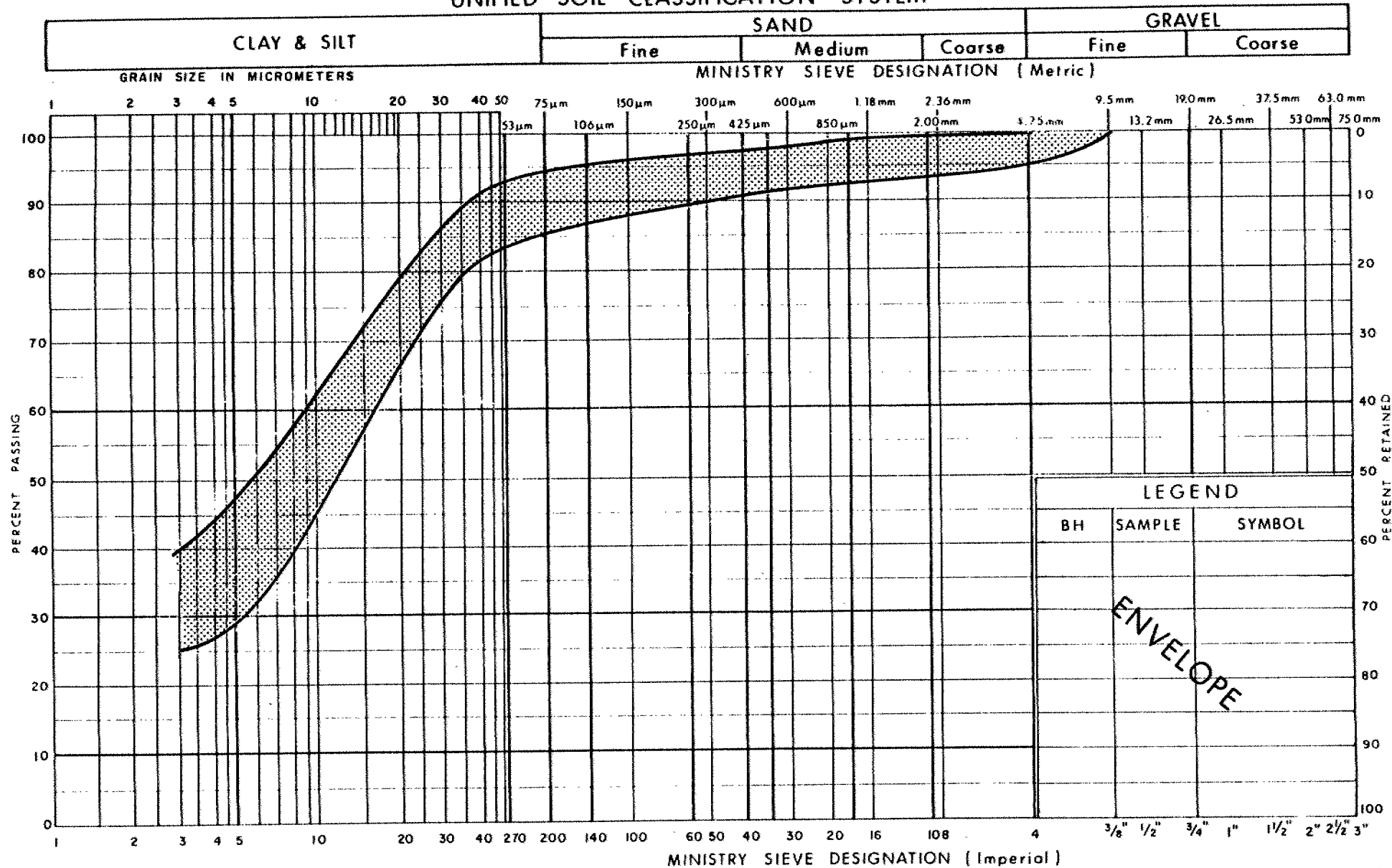
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PLASTICITY CHART
CLAYEY SILT
WITH SOME SAND AND TRACE OF GRAVEL

FIG No 8

W P 624 - 90 - 03

UNIFIED SOIL CLASSIFICATION SYSTEM

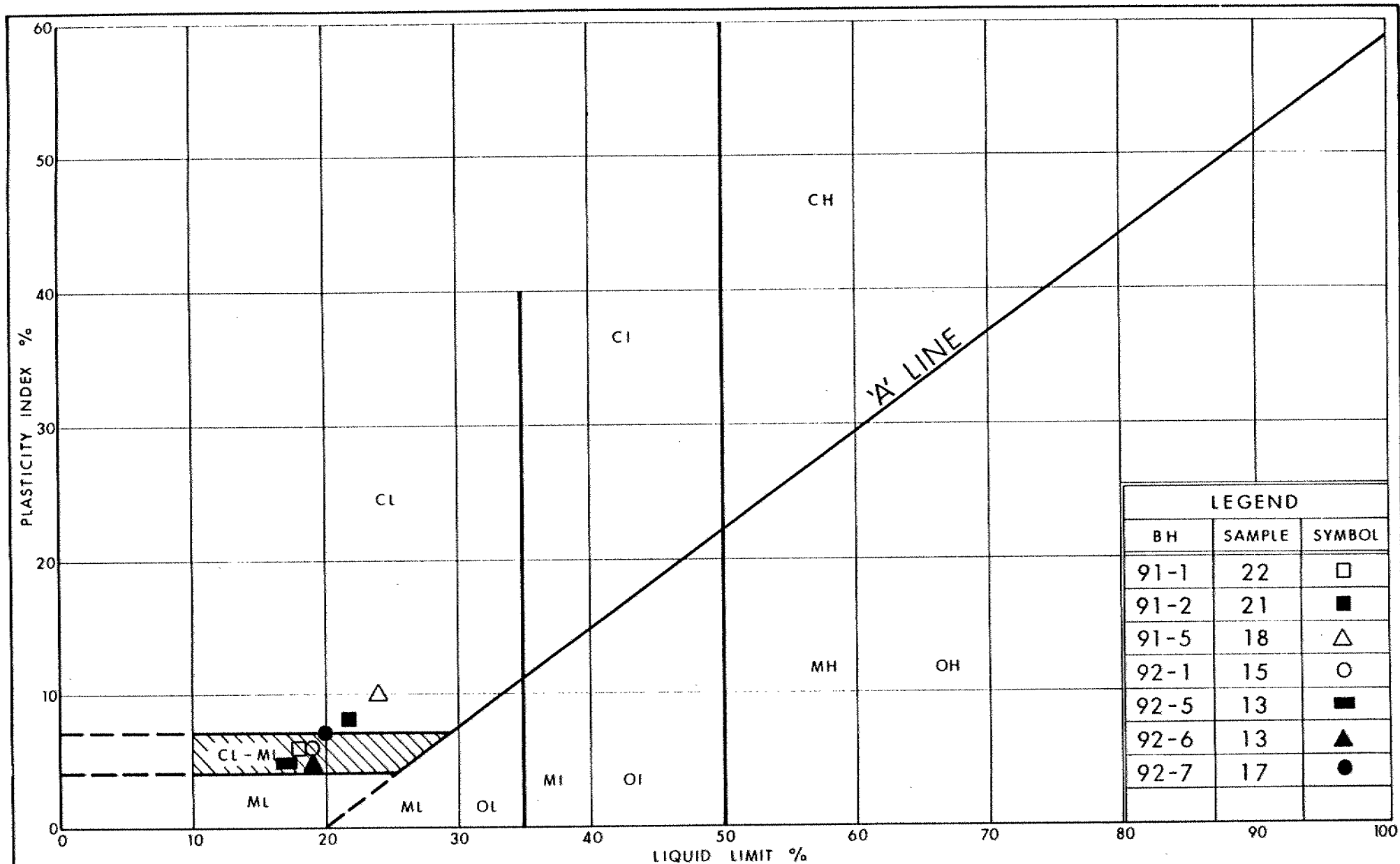


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GRAIN SIZE DISTRIBUTION
CLAYEY SILT
WITH SOME SAND AND TRACE OF GRAVEL

FIG No 9

W P 624-90-03



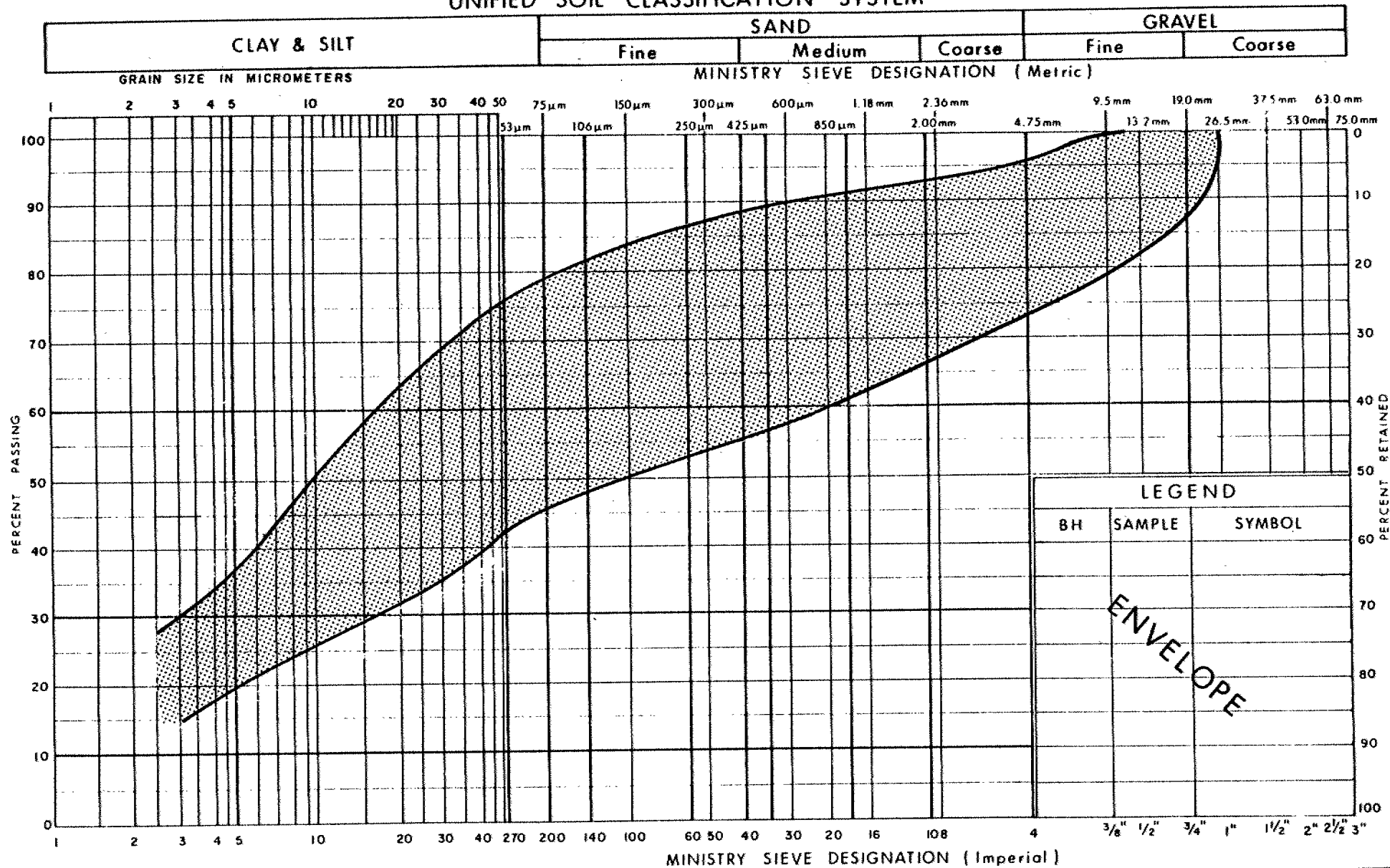
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PLASTICITY CHART
HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND & GRAVEL
 (COHESIVE GLACIAL TILL)

FIG No 10

W P 624-90-03

UNIFIED SOIL CLASSIFICATION SYSTEM



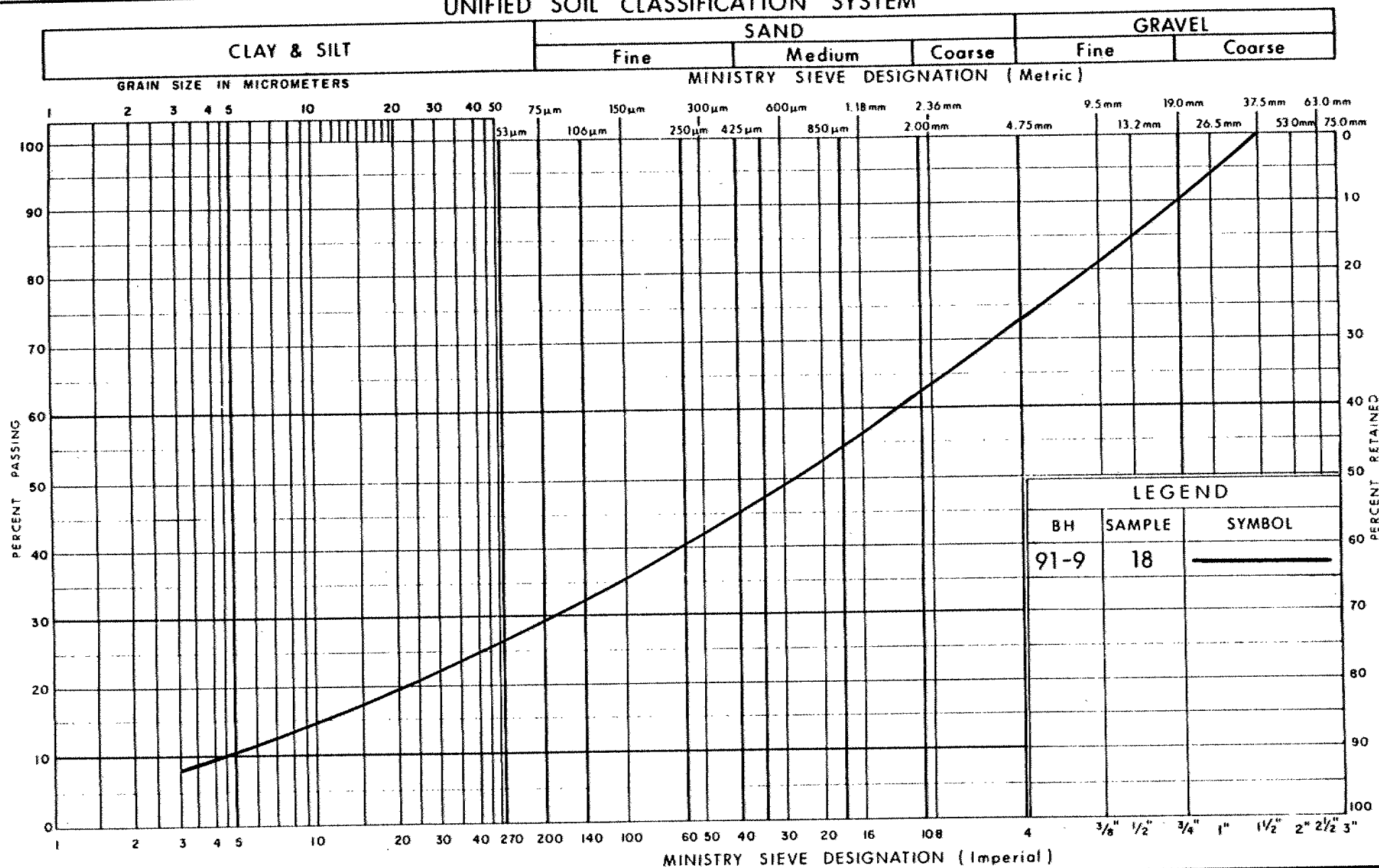
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GRAIN SIZE DISTRIBUTION
HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND & GRAVEL
 (COHESIVE GLACIAL TILL)

FIG No 11

W P 624-90-03

UNIFIED SOIL CLASSIFICATION SYSTEM



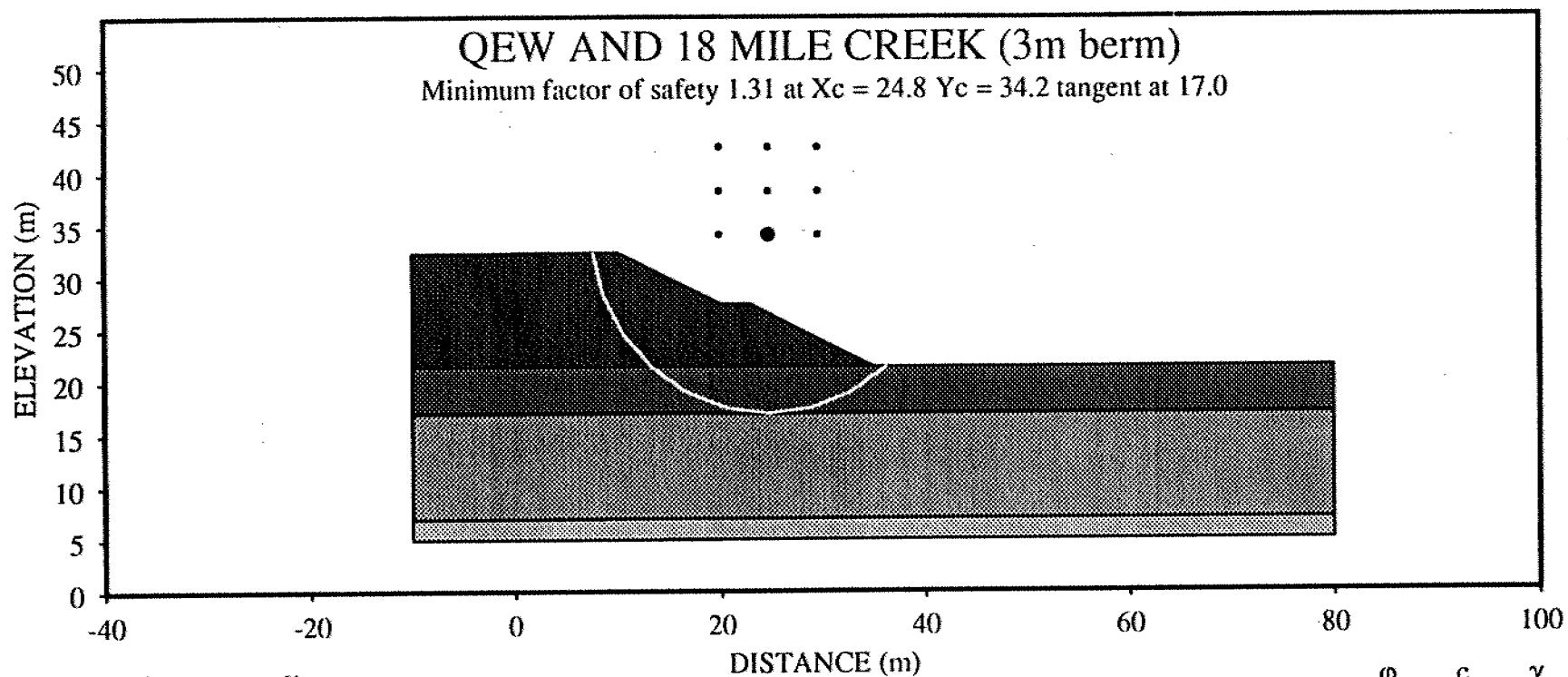
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GRAIN SIZE DISTRIBUTION
HETEROGENEOUS MIXTURE OF SILT, SAND & GRAVEL
 (NON-COHESIVE GLACIAL TILL)

FIG No 12

W P 624-90-03

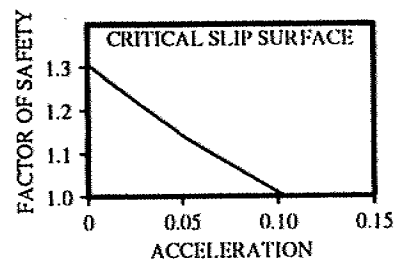


ϕ	c	γ
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30.0	0.0	21.0	CLAYEY SILT (FILL)
0.0	50.0	18.0	ORGANIC SILT

CRITICAL ACCELERATIONS

0.090	0.105	0.165
0.087	0.100	0.173
0.097	0.104	0.204



ϕ	c	γ
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CLAYEY SILT	0.0	92.0	21.3
COHESIVE TILL	35.0	0.1	22.0

FACTORS OF SAFETY

1.362	1.348	1.496
1.332	1.311	1.498
1.348	1.308	1.588

WP 624-90-03

Fig 13

RECORD OF BOREHOLE No 91-6 1 of 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4781 952.3 E 317 899.1 ORIGINATED BY T.C.K.
 DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Cone Tests, Vane Tests, NQ Rock Core COMPILED BY R.N.
 DATUM Geodetic DATE Dec. 2 & 4, 1991 CHECKED BY T.C.K.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT		NATURAL MOISTURE CONTENT		LIQUID LIMIT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	w _p	w	w _p	w	w _L	w		
85.3	Ground Surface																
84.7	Granular 'A' (Fill)	Grey															
0.6		Brown															
			1	SS	18												
			2	SS	25												
	Clayey silt to silt, some sand trace of gravel Occ. silty sand layers (Fill) Very stiff		3	SS	29												
			4	SS	31												
	Granular 'A' Dense		5	SS	16												
76.8																	
8.5			6	SS	17												
	Crushed stone or subgrade material (Fill) Compact to very dense		7	SS	8												
			8	SS	30												
73.4																	
11.9	Clayey silt to silt, trace of sand (Fill)		9	SS	20												
71.7	Stiff to very stiff	Brown	10	SS	14												0 4 62 34
13.6		Grey	11	SS	13												
	Organic clayey silt to silty clay some sand, trace of gravel Very stiff		12	SS	12												3 48 34 15
69.1																	
16.2			13	SS	54												0 5 70 25
			14	TW	PH												
			15	SS	35												
	Clayey silt, trace of sand and gravel, occ. silt layers Very stiff to hard		16	SS	34												
			17	TW	PH												
			18	SS	22												
61.4		Grey															
23.9		Reddish brown	19	SS	60	/15cm											
	Het. mix. of clayey silt, sand and gravel (Glacial Till) occ. shale fragments		20	SS	60	/8cm											
	Hard																
57.9		Reddish brown	21	SS	60	/10cm											
27.4	Queenston shale bedrock	Red	22	RC	REC 98%												RQD 9%
56.6																	
28.7	End of Borehole																

RECORD OF BOREHOLE No 92-7 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N4781 950.4 E 317 861.3 ORIGINATED BY MI
 DIST 4 HWY QEW BOREHOLE TYPE HS Auger, Vane Tests, NQ Rock Core COMPILED BY MI
 DATUM Cedeatic DATE May 11, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					NATURAL MOISTURE CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100	W _P	W	W _L		
85.2	Ground Surface																
0.0	Clayey Silt to Silt, some sand and trace of gravel occ. silty sand layers (Fill) Stiff to Very Stiff		1	SS	18		84							H			11 44 30 15
			2	SS	20												
			3	SS	17												
			4	SS	23		82										
80.8			5	SS	11												
4.4	Silty Sand, some gravel, trace of clay Compact	Brown	6	SS	18		80							H			31 39 23 7
79.6		Grey															
5.6			7	SS	11												
			8	SS	11		78										
			9	SS	7												
			10	SS	9												
	Clayey Silt some sand, trace of gravel Stiff to Very Stiff		11	SS	10		76										
			12	SS	5												
			13	SS	11												
			14	SS	11		74										
			15	SS	10												
			16	SS	15		72										
			17	SS	100												
			18	SS	100		70										
			19	RC	REC 89%												
			20	RC	REC 100%		68										
61.3	Reddish Brown Het. Mixture of Clayey Silt, Sand and Gravel occ. shale fragments (Glacial Till) Hard	Red					66										
23.9							64										
58.1							62										
26.1	Queenston Shale Bedrock						60										
57.6							58										
27.6	End of Borehole																
	* Water level not stabilized																

RECORD OF BOREHOLE No 92-8

1 of 1

METRIC

W.P. 824-90-01/02/03/04 LOCATION Co-ord. N4781 951.1 E 317 881.3 ORIGINATED BY MI
DIST 4 HWY QEW BOREHOLE TYPE HS Auger, NQ Rock Core COMPILED BY MI
DATUM Gedectic DATE May 20, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT 7 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
85.2	Ground Surface													
0.0	Clayey Silt to Silt some sand and gravel occ. silty sand to sandy silt layers (Fill) Stiff		1	SS	11		84							
			2	SS	13		82							
			3	SS	14		80							4 30 44 22
			4	SS	11		78							
76.6			5	SS	10		76							
8.6	Sand and Gravel with crushed stone (Fill)		6	SS	16		74							
75.1	Compact Brown		7	SS	4		72							
10.1	Organic Clayey Silt to Silty Clay some sand		8	SS	22		70							
73.9	Firm D.Grey		9	SS	19		68							
11.3	Grey		10	SS	63		66							
	Silty Sand		11	SS	18		64							
			12	SS	15		62							
	Clayey Silt, some sand, trace of gravel occ. silty sand layers Stiff to Very Stiff		13	SS	14		60							
61.3	Grey		14	SS	78		58							
23.9	Reddish Brown Het. Mixture of Clayey Silt, Sand and Gravel occ. shale fragments (Glacial Till)		15	SS	100	/25cm								
58.8	Hard Reddish Brown		16	SS	100	/13cm								
26.4	Red weathered sound		17	RC	REC 73%									
56.1	Queenston Shale Bedrock													RQD 68%
29.1	End of Borehole													

RECORD OF BOREHOLE No 92-9

1 OF 1

METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4781 952.6 E 317 921.2 ORIGINATED BY MI
DIST 4 HWY QEW BOREHOLE TYPE HS, NO Core COMPILED BY MI
DATUM Gedectic DATE May 12, 1992 to May 13, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT 7 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	W _p W W _L	10 20 30	10 20 30		
85.4	Ground Surface															
0.0			1	SS	11		84									
			2	SS	14		82									
	Sandy Silt		3	SS	15		80									
			4	SS	10		78									
	Silty Sand		5	SS	13		76									
	Clayey Silt to Silt, some sand, trace of gravel occ. sandy silt to silty sand layers Stiff to Very Stiff (Fill)		6	SS	9		74									
			7	SS	9		72									
71.8	Brown		8	SS	8		70									
13.6	D.Grey Organic Clayey Silt to Silty Clay trace of sand Firm to Very Stiff		9	SS	9		68									
69.2	D.Grey		10	SS	7		66									
16.2	Grey		11	TW	PH		64									
			12	SS	3		62									
			13	SS	9		60									
			14	SS	14		58									
	Clayey Silt, some sand, trace of gravel Stiff to Very Stiff		15	SS	14		56									
61.6	Grey		16	SS	11		54									
23.8	Reddish Brown		17	SS	86		52									
	Het. Mixture of Clayey Silt, Sand and Gravel, occ. shale fragments (Glacial Till) Hard		18	SS	100	/23cm	50									
56.4	Reddish Brown		19	SS	100	/10cm	48									
29.0	Red		20	RC	REC	97%	46									
54.9	Queenston Shale Bedrock															
30.5	End of Borehole															

+3, x5: Numbers refer to
Sensitivity 20
15-5 (%) STRAIN AT FAILURE
10

RQD 43%

ROCK CORE DESCRIPTION **WP 624-90-01/02/03/04**

Page 1 of 3

CORE RECOVERY					CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
91-1	25	26.82-28.35	77	23	26.82-28.35	SHALE , greyish red, with interbedded greenish grey SILTSTONE (7%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 27.89-28.12 m); fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
91-3	19	24.38-25.91	88	17	24.38-26.82	SHALE , greyish red, with interbedded greenish grey SILTSTONE (14%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 24.38-24.71 m); fractures moderately close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
	20	25.91-26.82	83	69		
91-4	15	23.01-24.38	85	19	23.01-24.38	SHALE , greyish red, with interbedded greenish grey SILTSTONE (7%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 23.01-23.72 m); fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
91-5	20	24.38-25.93	91	23	24.38-25.93	SHALE , greyish red, with interbedded greenish grey SILTSTONE (8%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
91-6	22	27.43-28.68	98	9	27.43-28.68	SHALE , greyish red, with interbedded greenish grey SILTSTONE (14%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 27.43-27.51 m); fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

(NOTE: Depths are approximated where core recovery is less than 100%)

Logged by: DAW, Soils and Aggregates Section

ROCK CORE DESCRIPTION **WP 624-90-01/02/03/04**

Page 2 of 3

CORE RECOVERY					CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
92-1	17	25.98-27.51	97	25	25.98-27.51	SHALE, greyish red, with interbedded greenish grey SILTSTONE (5%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-2	18	26.19-27.71	93	7	26.19-27.71	SHALE, greyish red, with interbedded greenish grey SILTSTONE (5%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-3	18	27.61-29.13	100	50	27.61-29.13	SHALE, greyish red, with interbedded greenish grey SILTSTONE (15%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 27.61-28.04 m); fractures moderate to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-4	15	24.54-26.06	84	27	24.54-26.06	SHALE, greyish red, with interbedded greenish grey SILTSTONE (6%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 24.54-24.66 m); fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-5	15	25.15-26.67	92	18	25.15-26.67	SHALE, greyish red, with interbedded greenish grey SILTSTONE (7%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

(NOTE: Depths are approximated where core recovery is less than 100%)

Logged by: DAW, Soils and Aggregates Section

ROCK CORE DESCRIPTION **WP 624-90-01/02/03/04**

Page 3 of 3

CORE RECOVERY					CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
92-6	15	24.51-26.04	100	45	24.51-26.04	SHALE, greyish red, with interbedded greenish grey SILTSTONE (7%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-7	19	26.11-27.03	89	44	26.11-27.64	SHALE, greyish red, with interbedded greenish grey SILTSTONE (8%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
	20	27.03-27.64	100	0		
92-8	17	27.56-29.08	73	68	27.56-29.08	SHALE, greyish red, with interbedded greenish grey SILTSTONE (13%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-9	20	29.06-30.58	97	43	29.06-30.58	SHALE, greyish red, with interbedded greenish grey SILTSTONE (8%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to very close spaced, flat to near vertical, planar to undulating, smooth.

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

(NOTE: Depths are approximated where core recovery is less than 100%)

Logged by: DAW, Soils and Aggregates Section

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

MECHANICAL PROPERTIES OF SOIL

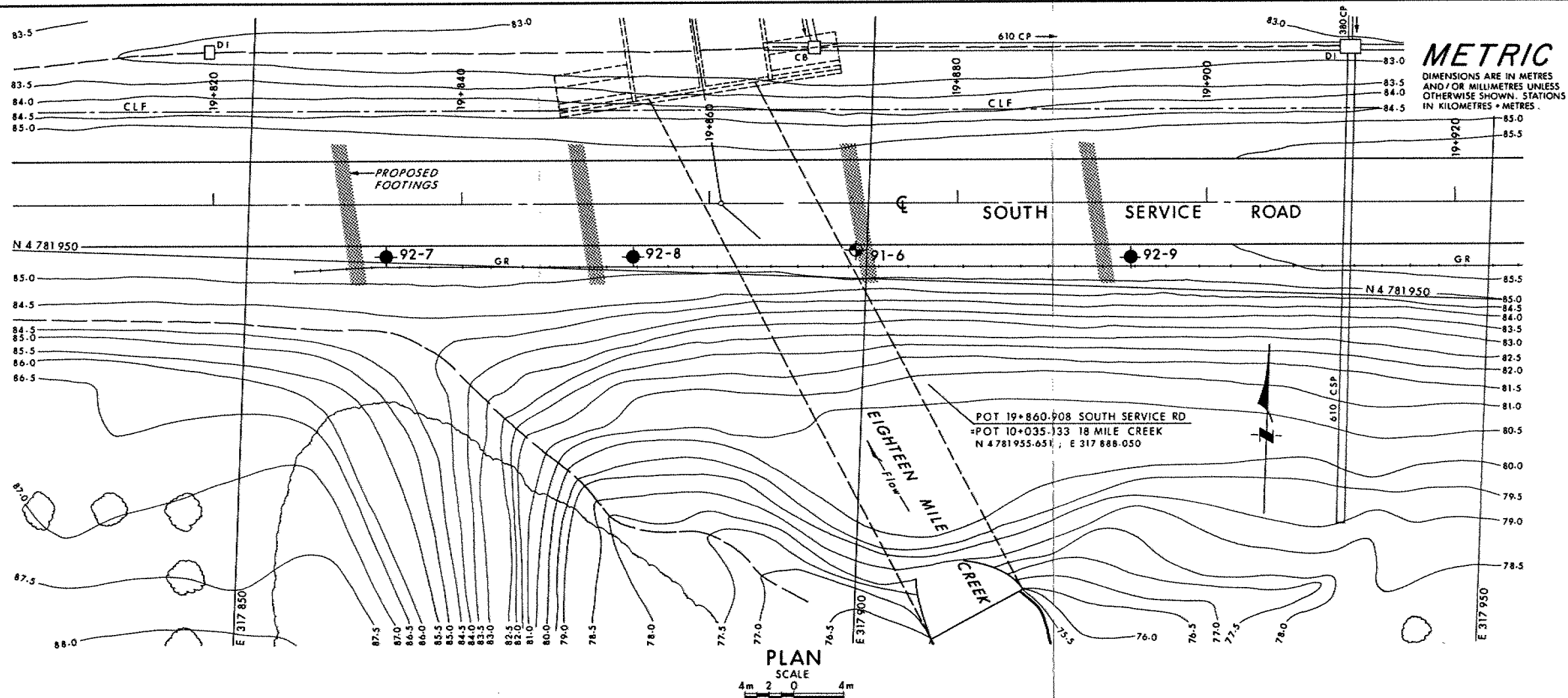
m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
ϕ_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 = $\frac{c_u}{\tau_r}$

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

PHYSICAL PROPERTIES OF SOIL

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

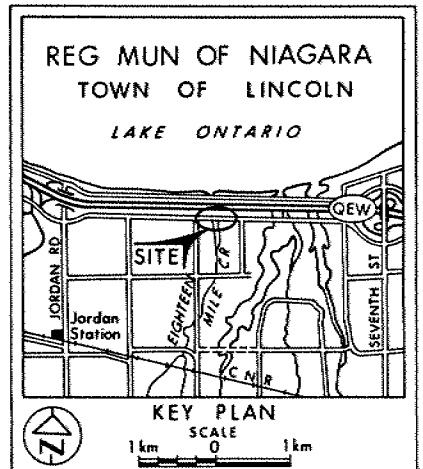


CONT No
WP No 624-90-03

EIGHTEEN MILE CREEK
(SOUTH SERVICE ROAD)
BORE HOLE LOCATIONS & SOIL STRATA



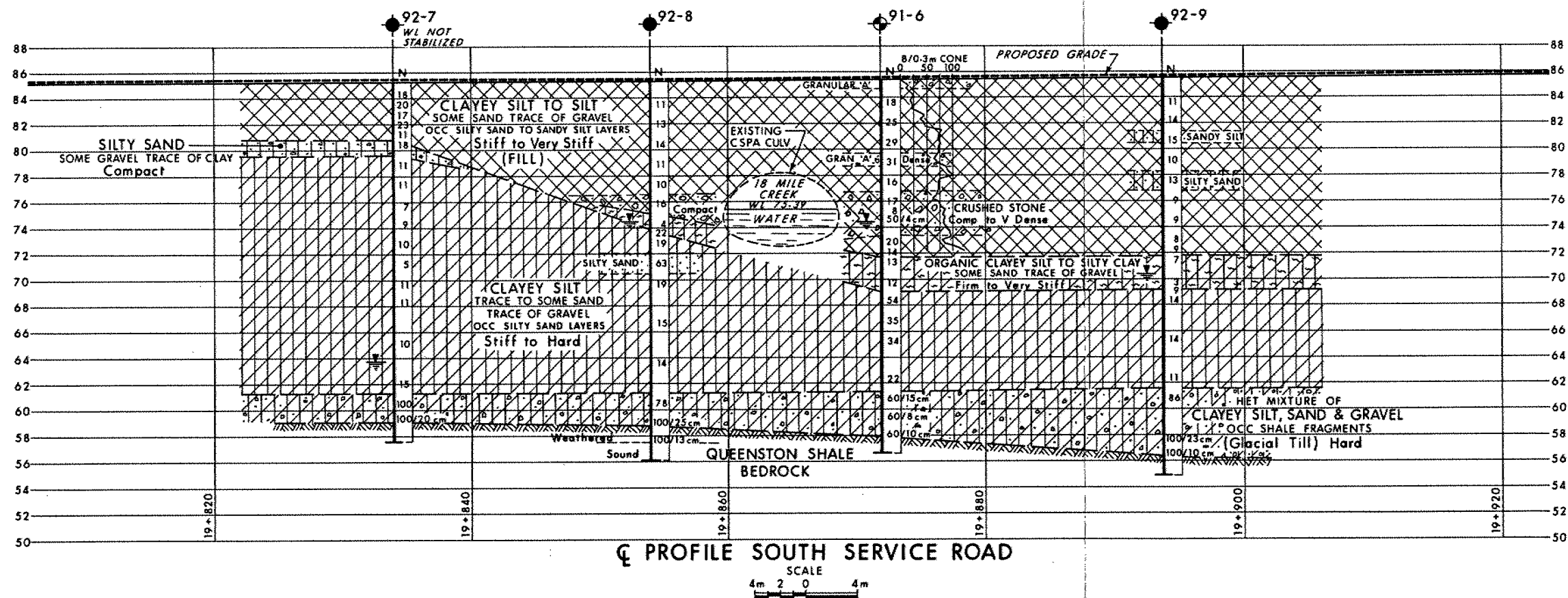
SHEET



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
1991 12 and 1992 05

No	ELEVATION	CO-ORDINATES NORTH	EAST
91-6	85.3	4 781 952.3	317 899.1
92-7	85.2	4 781 950.4	317 861.3
92-8	85.2	4 781 951.1	317 881.3
92-9	85.4	4 781 952.6	317 921.2



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 GC 2.01 of OPS Gen. Cond.

REV	DATE	BY	DESCRIPTION
1			

Geocres No 30M3-196

HWY No QEW / SOUTH SERVICE RD	DIST 4
SUBMD T K	CHECKED 26 DATE 1993 02 26 SITE 18-20
DRAWN CP	CHECKED 26 APPROVED DWG 6249003-A

FILE COPY



Ministry
of
Transportation

Ontario

FOUNDATION DESIGN SECTION

**foundation
investigation and
design report**

ENGINEERING MATERIALS OFFICE
FOUNDATION DESIGN SECTION

CONT. 94-53

WP 624-90-04 DIST 4

HWY Q.E.W. STR SITE 18-20

Q.E.W. Crossing at 18 Mile Creek
North Service Road

DISTRIBUTION

V.F. Boehnke (3)
G. Cautillo
T. Zander (2)
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B. Farago
G.E. Greene
E.A. Joseph
A. Ahmed (Cover Only)
F. Bacchus (Cover Only)
File

FOUNDATION INVESTIGATION REPORT
For
Q.E.W. Crossing at 18 Mile Creek
W.P. 624-90-04 North Service Road
Site No. 18-20
District 4, Burlington

INTRODUCTION

This report summarizes the information obtained from a foundation investigation carried out at the above mentioned site where a three span bridge structure is proposed to carry the existing Q.E.W. North Service Road Crossing at 18 Mile Creek.

The field works for the foundation investigation were carried out at the above mentioned site during the period of December 2 to December 20, 1991 and May 11 to May 29, 1992. Ten boreholes (BH 91-1 to BH 91-9 inclusive, plus BH 91-5A) for the proposed original large twin culverts (5.9 m X 5.9 m X 137 m) were advanced and sampled between December 2 and December 20, 1991 to replace the existing twin culverts.

It should be noted that the original design scheme was found to be not environmentally viable. Therefore, a new proposal brought forth to replace the existing culverts with four (4) bridge structures. Additional nine boreholes (BH 92-1 to BH 92-9) were advanced and sampled as part of this project between May 11 and May 29, 1992. These boreholes extended down to depths between 14.2 m and 30.5 m below the existing ground surface.

Total of nineteen (19) boreholes were drilled for four bridge structures. Among them, eleven (11) boreholes are located within the Q.E.W. eastbound and westbound lanes, while four (4) boreholes are situated within South Service Road structure and North Service Road structure, respectively. The information from these boreholes is utilized in this report.

This report contains factual information obtained from these investigations

pertaining to structure foundations, approach embankments and related earthworks for the North Service Road bridge structure as shown on Dwg. No. 6249004-A and Dwg. 6249001/02-A and B in Report No. W.P. 624-90-01/02.

SITE DESCRIPTION AND GEOLOGY

The site is located on the existing alignment of Q.E.W. where it crosses the Eighteen Mile Creek in the Town of Lincoln, Regional Municipality of Niagara. The proposed structure is located approximately 2.5 km east of Jordan Harbour. The topography in the area is gently undulating with a valley. Land use in the vicinity of the site is primarily agricultural known as the Niagara Fruit Belt.

Physiographically, the site is located in the "Iroquois Plain" region (Ref: Chapman and Putnam, 1984). The general area was inundated by the Pleistocene Lake Iroquois. As the lake level receded much below the present level of Lake Ontario, the Eighteen Mile Creek cut a valley through the till. Underlying the glacial deposit is the red Queenston Shale from which the till's reddish colour is derived. Later, the rise in the Lake Ontario water level to approximately its present level, drowned the outlet of the creek and created a lagoon and marsh separated from the lake by a barrier beach. Water flow is to the north into Lake Ontario.

SUBSURFACE CONDITIONS

The subsoil conditions are generally consistent across the site. The Q.E.W. crosses the Eighteen Mile Creek at this location. The road embankment fill of the existing Q.E.W. consists of bedding sand, mainly clayey silt and some crushed stone as much as 13.6 m in the middle of valley.

Underlying the fill is a layer of organics which was encountered at all borehole locations except at one borehole location (BH 92-7). The thickness of this layer ranges from 1.1 m at BH 91-1 to 5.6 m at BH 91-2.

Underneath this layer, clayey silt with some sand and trace of gravel was

encountered. The thickness of this layer ranges from 6.1 m at BH 91-9 to 18.3 m at 92-7. A thin layer of silty sand and gravel was found at 6 borehole locations (BH's 91-2, 91-3, 91-5, 91-5A, 91-6, and 92-2) in between the organic material and clayey silt with a maximum thickness of about 1.2 m at BH 92-7.

Cohesive glacial till was encountered underneath the clayey silt at all boreholes locations. This material can be described as a heterogeneous mixture of clayey silt, sand and gravel. The maximum thickness of this deposit was found to be about 5.2 m at BH 92-9. This layer is underlain by shale and siltstone bedrock. A thin layer of non-cohesive glacial till, which can be described as a heterogeneous mixture of silt, sand and gravel, was found with a thickness of 2.4 m at BH 91-9.

Sound bedrock was proven in 14 borehole locations by obtaining up to 2.7 m of NQ rock cores. The bedrock surface ranges from an elevation of 56.4 m at BH 92-9 to an elevation of 60.0 m at BH 91-4 which corresponds to 29.0 m and 23.0 m below the existing ground surface, respectively. The upper portion of bedrock was slightly weathered for a maximum 1.2 m at BH 92-8 below the rock surface. The sound bedrock surface ranges from an elevation of 56.4 m at BH 92-9 to an elevation of 59.3 m at BH 91-4 which corresponds to 29.0 m and 23.7 m below the existing ground surface. The bedrock is known to be "SHALE and interbedded SILTSTONE of the Queenston Formation".

The boundaries between the various soil types, in situ and laboratory test results are shown on the attached Record of Borehole Sheets in the Appendix. The locations and elevations of the boreholes, along with a profile and sections, are shown on Dwg. No. 6249004-A and Dwg. No. 6249001/02-A and B in Report W.P. 624-90-01/02.

A detailed description of the subsurface conditions encountered is given below.

Embankment Fill

The embankment fill consists of bedding sand, mainly clayey silt and some crushed

stone. The thickness of this layer was found to range from 4.4 m at BH 92-7 to 13.6 m at BH's 91-6 and 92-9.

Atterberg Limit Tests were performed on clayey silt samples and the results are plotted on Figure 1 and summarized as follows:

<u>Property</u>	<u>Range (%)</u>
Natural Moisture Content (w)	8.5 - 24.5
Liquid Limit (w_L)	16.5 - 36.0
Plastic Limit (w_p)	13.0 - 17.5
Plasticity Index (I_p)	3.0 - 19.0

From the Plasticity Chart, it is evident that the layer can be classified as a clayey silt to silt, some sand and gravel with low plasticity (CL or CL-ML).

Grain Size Distribution tests were carried out on this fill material. Figure 2 in the Appendix shows the results in an envelope form. In this stratum, the "N" values range from 0 to over 31 blows/0.3 m indicating the consistency of this deposit described as very soft to hard. Some silty sand layers were found within this clayey silt fill as shown on Figure 3.

Organic Clayey Silt to Silty Clay, Some Sand

This deposit was encountered beneath the existing embankment fill in all boreholes except BH No's 91-4 and 92-7 which were on or near the edge of the valley. The thickness of this deposit ranges from 1.1 m at BH 91-1 to 5.6 m at BH 91-2 and this deposit gradually peters out near the valley's edge.

The material, as sampled, was highly organic with organic pieces generally visible, and well-decayed pieces of roots and wood were not uncommon. Occasional samples were fibres. Some sand and occasional gravel were noted as well as occasional sand seams.

Atterberg Limit tests were performed on these samples and the results are plotted on Figure 4 and summarized as follows:

<u>Index Property</u>	<u>Range (%)</u>
Natural Moisture Content (w)	19.0 - 70.0
Liquid Limit (w_L)	17.0 - 68.0
Plastic Limit (w_p)	14.0 - 45.0
Plasticity Index (I_p)	3.0 - 23.0

From the plasticity chart, it is evident that the layer can be classified as an organic clayey silt to silty clay with low to high plasticity (OL.OI and OH).

Grain Size Distribution tests were carried out on these materials. Figure 5 in the Appendix shows the results in an envelope form.

Undrained Shear Strength of the soil was determined by in situ vane tests and by laboratory tests, namely unconfined compression tests. The results are plotted on Figure 6 and the Record of Borehole log sheets in the Appendix and summarized as follows:

<u>Undrained Shear Strength</u>	<u>Cu (kPa)</u>	<u>Sensitivity</u>
In-Situ Vane Tests	15 - >115	1 - 6
Unconfined Compression Tests	28 - 98	

As shown on Figure 6, the vane strengths measured within organic layer varied from 15 kPa to greater than 115 kPa, indicating soft to very stiff consistency. This layer has a sensitivity varying from 1 to 6 based on the measured undisturbed and remoulded vane strengths. This would indicate that the organic clayey silt to silty clay is generally sensitive.

An oedometer test was carried out to investigate the consolidation characteristics of the organic clayey silt to silty clay. The sample tested is

considered representative of the organic deposit was selected from a Shelby tube sample obtained at about an elevation of 69 m in BH 91-8. The result of the consolidation test is shown on Figure 7. The preconsolidation pressure is estimated to be about 330 kPa, indicating an overconsolidation ratio of about 1.25 relative to the existing effective overburden stress. The compression index (C_c) was determined to be about 0.213.

Silty Sand With Gravel

This deposit was found at five (5) borehole locations underlying the organic stratum (BH 91-2, 91-3, 91-5, 91-5A and 92-7). The thickness of this layer ranges from 0.5 m at BH 91-3 to 1.1 m at BH's 91-5, 91-5A and 92-7. Figure 3 in the Appendix shows the result of Grain Size Distribution test.

In this stratum, the "N" values ranged from 9 to 22 blows/0.3 m indicating a state of compaction described as loose to compact.

Clayey Silt With Sand

This deposit was encountered in all boreholes, either beneath the organic clayey silt to silty clay or the silty sand deposit, and appeared to represent the original material into which the Creek Valley had been carved. Hence, the deposit varied in thickness from 18.3 m at BH 92-7 near the edge of the valley to a minimum of 6.1 m at BH 91-9 near the centre of the valley.

Atterberg Limit tests were performed on these samples and the results are plotted on Figure 8 and summarized as follows:

<u>Index Property</u>	<u>Range (%)</u>
Natural Moisture Content (w)	13.0 - 20.5
Liquid Limit (w_L)	19.0 - 32.0
Plastic Limit (w_p)	14.0 - 17.0
Plasticity Index (I_p)	4.0 - 15.0

From the plasticity chart, it is evident that the layer can be classified as an inorganic clayey silt, some sand with low plasticity (CL or CL-ML).

Grain Size Distribution tests were carried out on these materials. Figure 9 in the Appendix shows the results in an envelope form.

Undrained shear strength of the soil was obtained by in-situ vane tests and by laboratory unconfined compression tests. The results are plotted on Figure 6 and the Record of Borehole log sheets in the Appendix and summarized as follows:

<u>Undrained Shear Strength</u>	<u>Cu (kPa)</u>	<u>Sensitivity</u>
In-situ Vane Tests	61 - >115	1 - 3
Unconfined Compression Tests	69 - 285	

The field vane strengths obtained in this stratum varied from 61 kPa to greater than 115 kPa indicating a stiff to hard consistency. The sensitivity of this deposit varies from 1 to about 3 indicating this material being normal.

Heterogeneous Mixture of Clayey Silt, Sand and Gravel (Cohesive Glacial Till)

This stratum was encountered underneath the clayey silt layer and immediately above the bedrock. The thickness of this layer ranges from 0.7 m at BH 91-4 to 5.2 m at BH 92-9.

Atterberg Limit tests were performed on these samples and the results are plotted on Figure 10 and summarized as follows:

<u>Property</u>	<u>Range (%)</u>
Natural Moisture Content (w)	7.0 - 13.0
Liquid Limit (w_L)	17.0 - 24.0
Plastic Limit (w_p)	12.0 - 14.0
Plasticity Index (I_p)	5.0 - 10.0

From the plasticity chart, it is evident that this deposit can be classified as a heterogeneous mixture of clayey silt, sand and gravel with low plasticity (CL or CL-ML).

Grain Size Distribution tests were carried out on the cohesive glacial till material. Figure 11 in the Appendix shows the results. An increasing frequency of fragments of weathered shale was encountered within the lower portion of this till.

In this stratum, the "N" value range from 30 to over 100 blows/0.3 m indicating the consistency of this deposit as hard.

Heterogeneous Mixture of Silt, Sand and Gravel (Non-Cohesive Glacial Till)

This layer was encountered between clayey silt and cohesive glacial till at a borehole location. The thickness of this layer was found to be about 2.3 m at BH 91-9.

A Grain Size Distribution test was carried out on this material as shown on Figure 12. This layer is basically non-cohesive. In this stratum, the "N" value is about 27 blows/0.3 m indicating a state of compaction described as compact.

Bedrock

Bedrock was cored in fourteen (14) boreholes by obtaining up to 2.7 m of NQ rock at BH 92-8. The top of the bedrock ranged from elevation 56.4 m to 60.0 m which correspond to 29.0 m and 23.0 m below the existing ground surface, respectively. The upper 0 to 1.2 m is in a slightly weathered state. The top of the sound bedrock ranged from 56.4 m to 59.3 m.

The bedrock is a red shale with interbedded green siltstone (approximately 85% shale, 15% siltstone) of the Queenston Formation. Detailed description of the rock is attached in the Appendix entitled "Rock Core Description".

The Core Recovery (CR) and Rock Quality Designation (RQD) values were determined in-situ and also in the laboratory to evaluate the competence and integrity of the rock. The Core Recoveries (CR) range between 73 and 100 percent and Rock Quality Designation (RQD) values range from 7 to 69 percent. Based on these results, the rock can be classified as weak to very weak and slightly to unweathered.

GROUNDWATER CONDITIONS

Groundwater conditions were observed by measurement of water levels in the open boreholes. The groundwater level was found to be at approximate elevation between 63.7 m at BH 92-7 and 74.6 at BH 91-4 which correspond to depths of 21.5 m and 8.4 m below the existing ground surface. However, it is likely that the groundwater level was the same as the creek level and is subject to seasonal fluctuations.

DISCUSSION AND RECOMMENDATIONS

The recommendations in this report apply to the bridge structure and related approaches.

It is proposed to construct a three span bridge structure (19 m x 22 m x 19 m) which will replace the existing twin concrete culverts along the North Service Rd. crossing the Eighteen Mile Creek. It is understood that an increase in grade for the Q.E.W. embankment will be required to avoid some snow accumulation within the Q.E.W. during the winter season due to the ditch effect on the highway. This would involve the additional placement and compaction of up to 1.7 m fill for the permanent approach along the Q.E.W. to the same level with the existing South and North Service Roads. No additional fill material will be placed on the North Service Road.

*CSP
Culvert
Extension at
NSR*

Recommendations pertaining to the foundations of a new bridge for the North Service Road and related earth works are summarized as follows.

Structure Foundations

East and West Abutments

In view of the low shear strength and compressibility of the organic clayey silt to silt clay and the extensive clayey silt layers, conventional spread footing shallow foundations are not applicable at this site. It is recommended that the abutments may be supported on end-bearing steel "H" piles, equipped with reinforced tips in order to facilitate pile penetration through the basal glacial till and driven to sound bedrock.

In consideration of no additional load application underneath the pile cap at the both abutments, the following design parameters are suggested for the purpose of the O.H.B.D.C..

<u>Pile Type</u>	<u>Factored Axial Capacity at U.L.S</u>	<u>Axial Capacity at S.L.S. Type II</u>
HP 310 x 79	1150 kN	900 kN
HP 310 x 110	1600 kN	1150 kN

Pile tip elevations for estimating the pile lengths are given below.

<u>Structure</u>	<u>East Abutment(Elevation)</u>	<u>West Abutment(Elevation)</u>
Q.E.W. N. Service Rd.	57.3 m	59.0 m

Battered piles should be installed, where required, to resist lateral load on abutments.

In view of the extreme denseness of the glacial till stratum located immediately above the bedrock, some piles may not penetrate this dense stratum. In such a case, the pile capacity should be controlled in the field using current MTO pile driving standards. However, attempts should be made in all cases to drive the piles to the bedrock surface. It should also be noted that the pile driving be controlled by maximum capacity of piles.

During pile driving, the steel "H" pile should be set to a termination of 8 blows for the last 12 millimetres of penetration using a hammer transferring about 60 kilojoules of energy per blow to the pile.

Provision should be made to restrike all piles to confirm the set after adjacent piles have been driven. Piles that do not meet the design set criteria on the first restrike would require additional restriking. A minimum of 48 hour should be allowed before restriking a pile.

In order to enhance pile driving, the fill material immediately below pile caps, should not contain particle sizes greater than 75 mm.

Alternatively, caisson foundations can be considered for the both abutments. Details for caissons will be discussed in Pier Foundations.

East and West Piers

In consideration of the existence of weak and compressible organic clayey silt to silty clay and extensive clayey silt layers, conventional spread shallow foundations are not applicable for the piers at this site. It should be noted that during the construction, to avoid the problems associated with excavation through embankment toward longitudinal direction, it is recommended that the structural loading at the piers be transferred to the underlying sound bedrock by means of bored cast-in-place caissons installed through the embankment and overburden.

The caisson should have a minimum length to diameter ratio of 3 within the bedrock and should be socketed at least 0.5 metre into the sound shale bedrock. The caissons may be design using an end bearing factored capacity at Ultimate Limit States of 3500 kilopascals. Serviceability Limit States is not relevant to caissons founded on bedrock since the stresses required to produce detrimental settlements will be larger the value given for the factored bearing capacity at ULS.

The following caisson bottom elevations are suggested for estimating the caisson length.

<u>Structure</u>	<u>East Pier (Elevation)</u>	<u>West Pier (Elevation)</u>
Q.E.W. N. Service Rd.	57.8 m	58.3 m

Caissons should be a minimum diameter of 900 mm to allow for both the clean out of any basal debris and final evaluation of the rock surface in order to confirm the above-stated capacities.

Groundwater infiltration may have to be controlled by using drilling mud coupled with telescoping liners or other methods. However, regardless of the method used, during withdrawal of the innermost liner, it is recommended that, while pouring, a positive head of concrete should be maintained at all times to prevent intrusion of the surrounding soils, groundwater and/or bentonite slurry.

The proposed method of caisson installation be in accordance OPSS 903.07.03 and subject to review by this office.

It should be noted that to avoid the need for deep excavation of the existing embankment and frost protection, caisson cap for the piers should be placed immediately below the bridge decks.

Other Considerations

Lateral Earth Pressures

Free draining material such as Granular "A" or Granular "B" is recommended as an appropriate backfill material to prevent hydrostatic pressure build-up on the abutment walls. Design parameters of the soil are given below for the purpose of the O.H.B.D.C.

	Granular "A"	Granular "B"
Angle of Internal Friction (ϕ)	35°	30°
Unit Weight (kN/m ³), γ	22.8	21.2
Coefficient of Active Earth Pressure (K_a)	0.27	0.33
Coefficient of Earth Pressure at Rest (K_o)	0.43	0.5

The earth pressure coefficient at rest is to be used when the design of abutment walls are rigid and unyielding.

Dewatering

No major dewatering difficulties are anticipated for footing excavation in consideration of lower groundwater levels and the relatively low permeability of the clayey silt fill. However, if localized seepage or surface water to accumulates in excavations, it can be controlled by perimeter ditches and pumping from corner sumps.

Frost Protection

The pile caps should be placed so as to have a minimum earth cover of 1.2 m to allow for frost protection.

Stability of Approach Embankment

The stability analyses were carried out based on a minimum design underdrained shear strength of 50 kPa for the organic clayey silt to silty clay, as established by field vane tests. Since no additional fill will be placed on the North Service Road, the existing slope will be stable in the transverse direction.

However, since the existing embankment fill of about 11 m will be cut down to creek level, stability analyses were carried out to evaluate the overall stability of the approach fill in the longitudinal direction and also the internal stability of the fills were examined. Based on the stability analyses, the forward slope for the Q.E.W. North Service Road Structure will require a 3 m wide mid-height beam with a 2H to 1V side slope to meet a minimum factor of safety of 1.3 as shown on Figure 13.

Construction Consideration

Excavations for abutments, pile-caps construction may be carried out in temporary open cuts with side slopes maintained at gradients not steeper than 1.5H:1V through the clayey silt fill. All excavations should be carried out according to the guidelines contained in the latest edition of the Ontario Occupational Health and Safety Act. To prevent softening of the exposed clayey silt fill, it is recommended that Granular "A" material be place on the excavation base to provide protection to the founding stratum as soon as the base of the excavation has been inspected.

Excavation cut of the forward slope toward 18 Mile Creek should be delayed until the four bridge structures are completed in order to avoid expensive roadway protection scheme such as very high temporary shoring system.

For erosion protection purposes, the embankment forward slopes should be covered with a layer of topsoil and properly seeded in order to enhance adequate vegetation cover. Suitable protection measures should also be provided to the creek banks adjacent the abutments. Such measures may include appropriately sized rip-rap underlain by suitable granular filter.

MISCELLANEOUS

The initial fieldwork for this investigation was carried out during the period of December 2 to December 20, 1991 under the supervision of R. Ng, Trainee Engineer and Tae C. Kim, Sr. Foundation Engineer. The equipment was owned and

operated by Master Soil Investigation Ltd., Toronto. Additional fieldwork for this investigation was carried out during the period of May 11 to May 29, 1992 under the supervision of M. Iampietro, Student Engineer, and Tae C. Kim, Sr. Foundation Engineer. The equipment was owned and operated by Malone's Soil Samples Co. Ltd., Toronto.

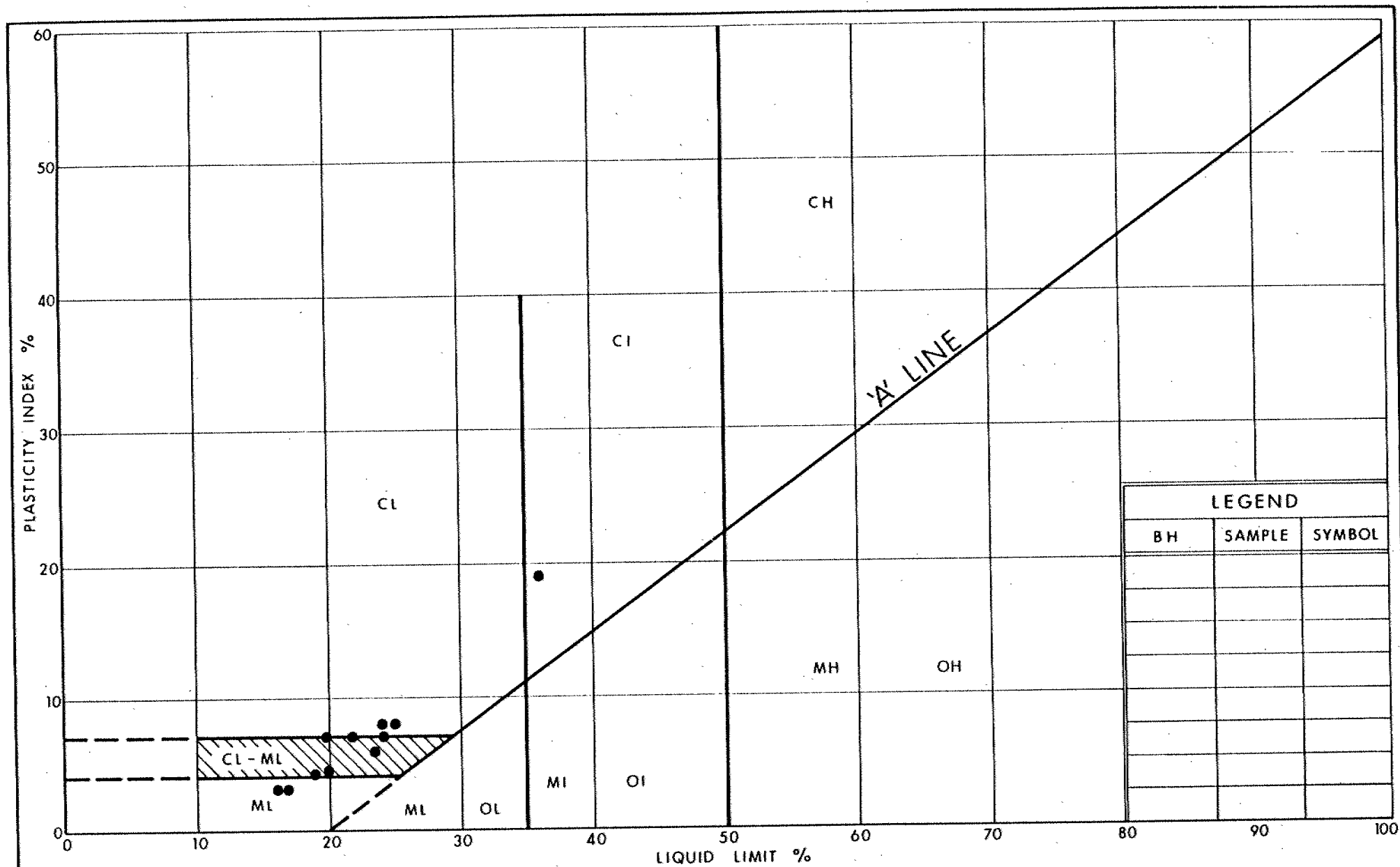
This report was written by Tae C. Kim, Senior Foundation Engineer and reviewed by M. Devata, Chief Foundation Engineer.



Tae C. Kim
Tae C. Kim, P. Eng.
Sr. Foundation Engineer

M. Devata
M. Devata, P. Eng.
Chief Foundation Engineer

APPENDIX



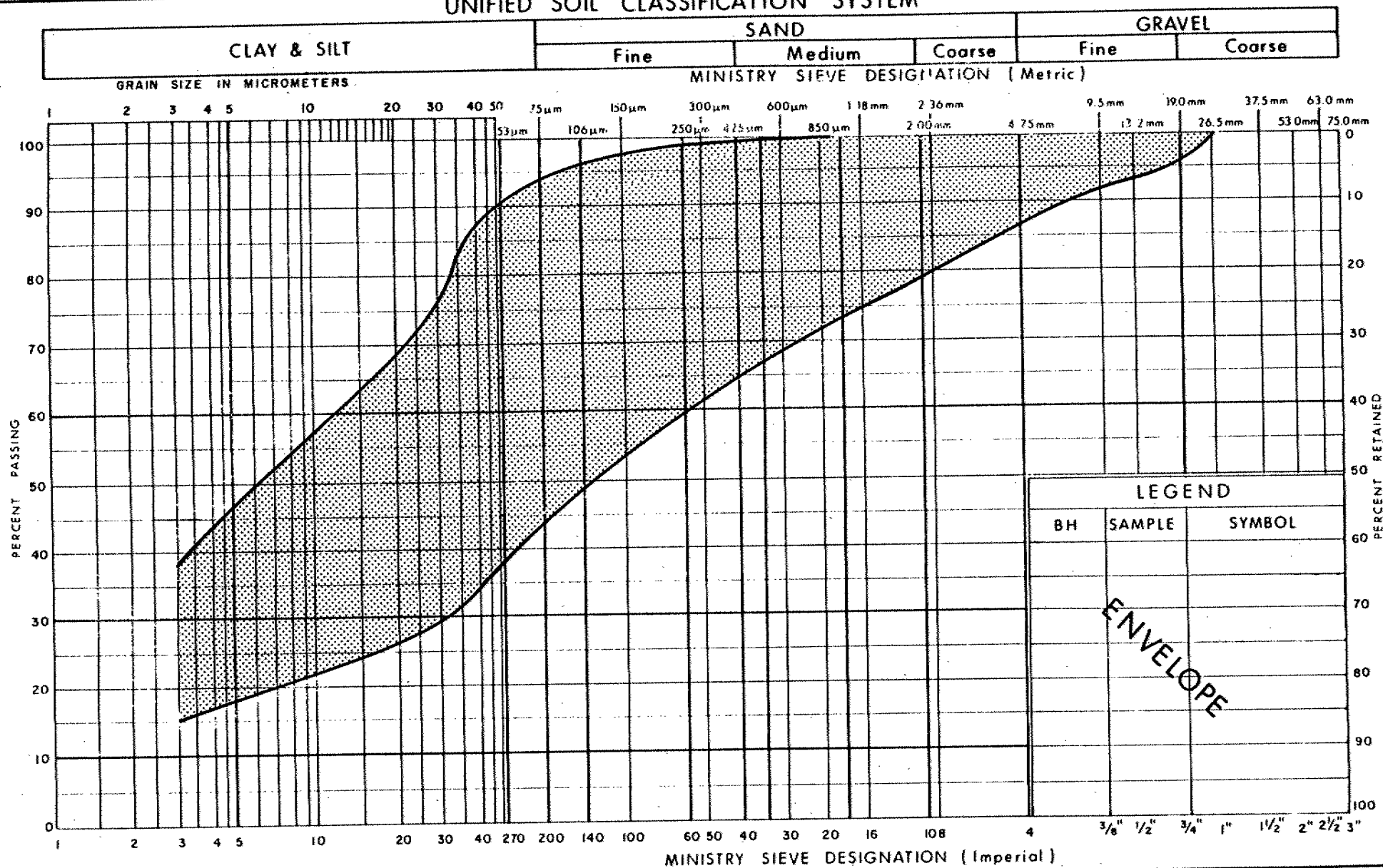
Ministry of
Transportation

PLASTICITY CHART CLAYEY SILT TO SILT (Fill)

FIG No 1

W P 624-90-04

UNIFIED SOIL CLASSIFICATION SYSTEM



Ontario

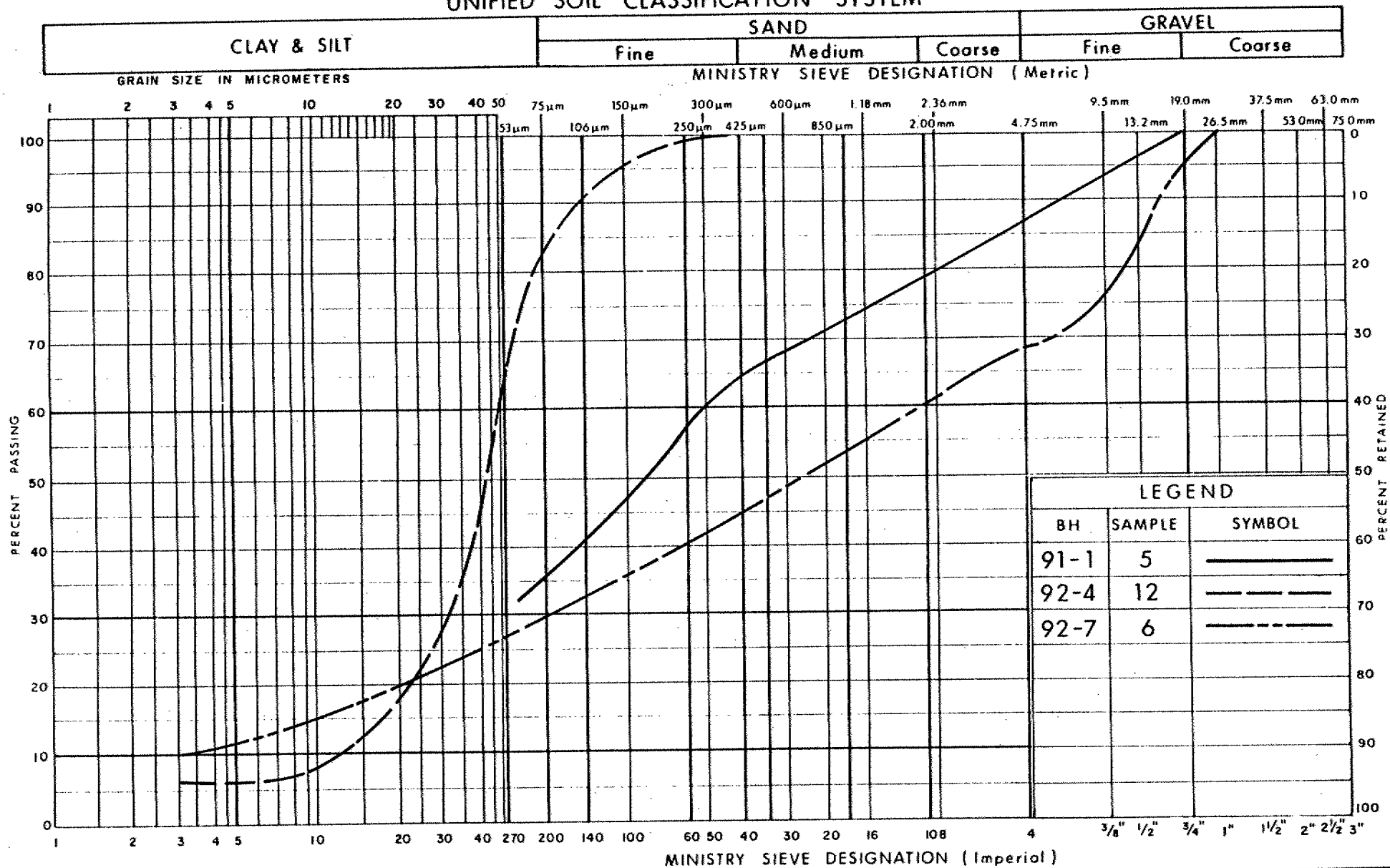
Ministry of
Transportation

GRAIN SIZE DISTRIBUTION
CLAYEY SILT TO SILT
(Fill)

FIG No 2

W P 624-90-04

UNIFIED SOIL CLASSIFICATION SYSTEM

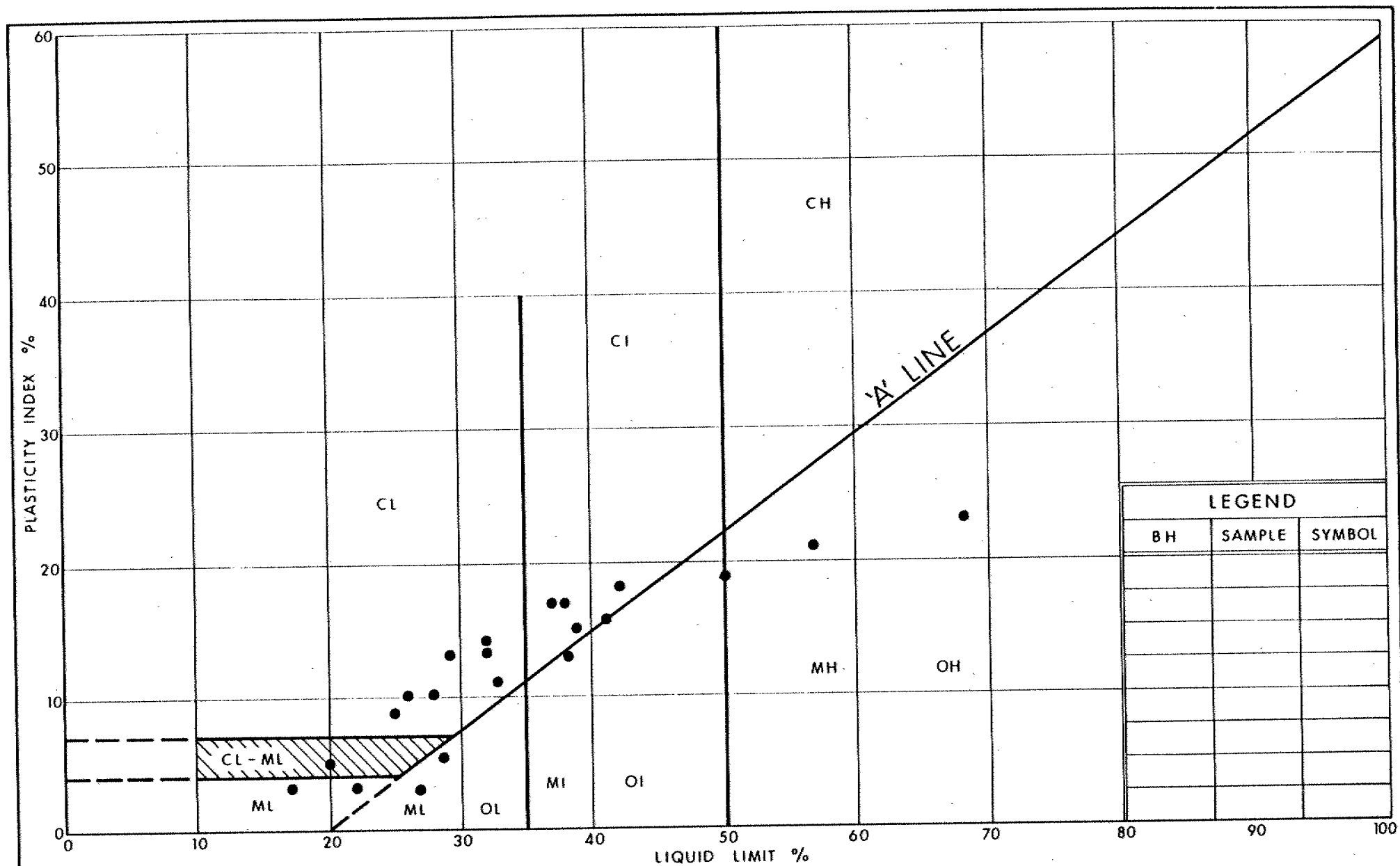


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Transportation

GRAIN SIZE DISTRIBUTION
SILTY SAND TO SANDY SILT

FIG No 3

W P 624-90-04



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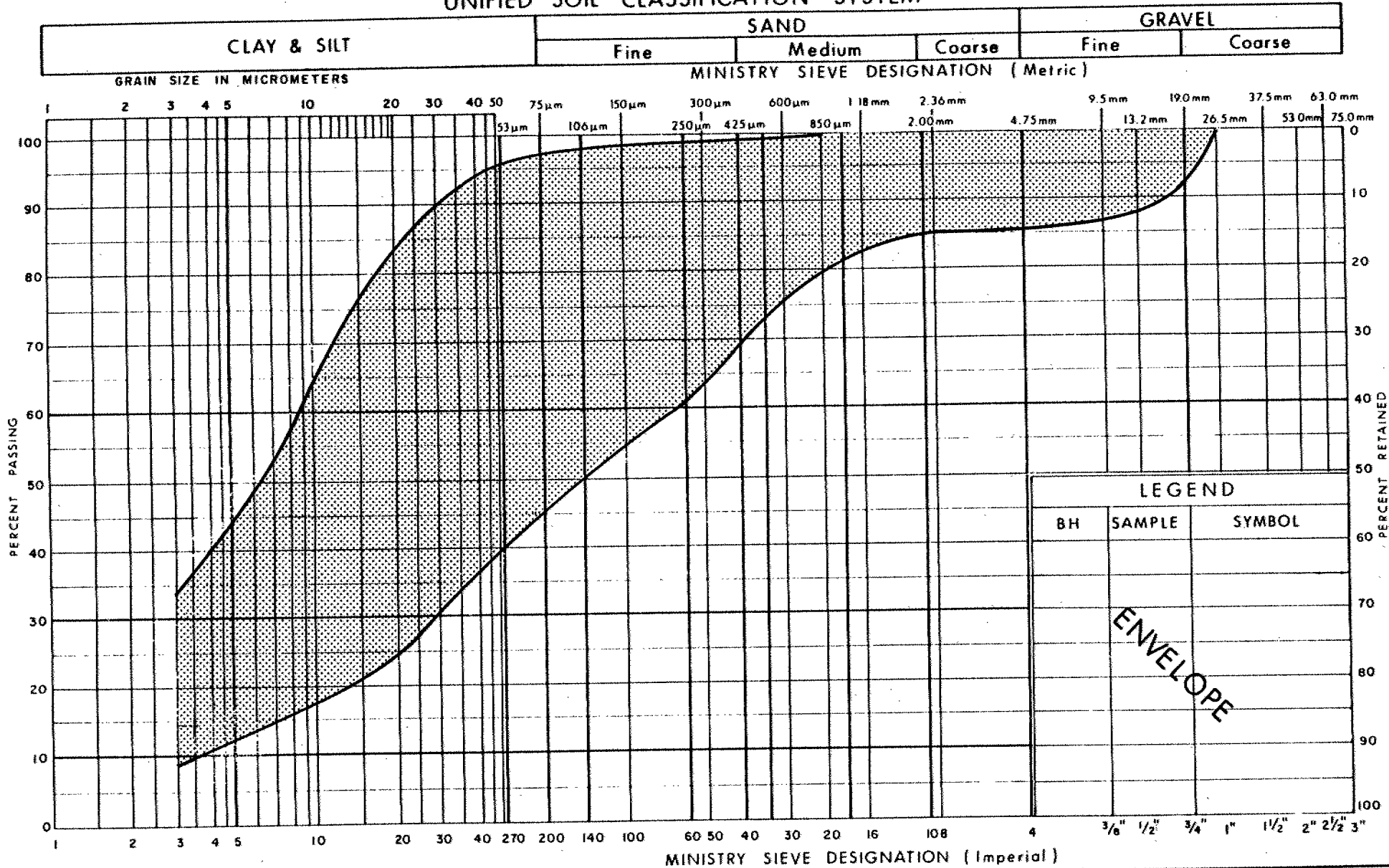
Ontario

PLASTICITY CHART ORGANIC CLAYEY SILT TO SILTY CLAY

FIG No 4

W P 624-90-04

UNIFIED SOIL CLASSIFICATION SYSTEM



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GRAIN SIZE DISTRIBUTION ORGANIC CLAYEY SILT TO SILTY CLAY

FIG No 5

W P 624-90-04

VOID RATIO - PRESSURE CURVES

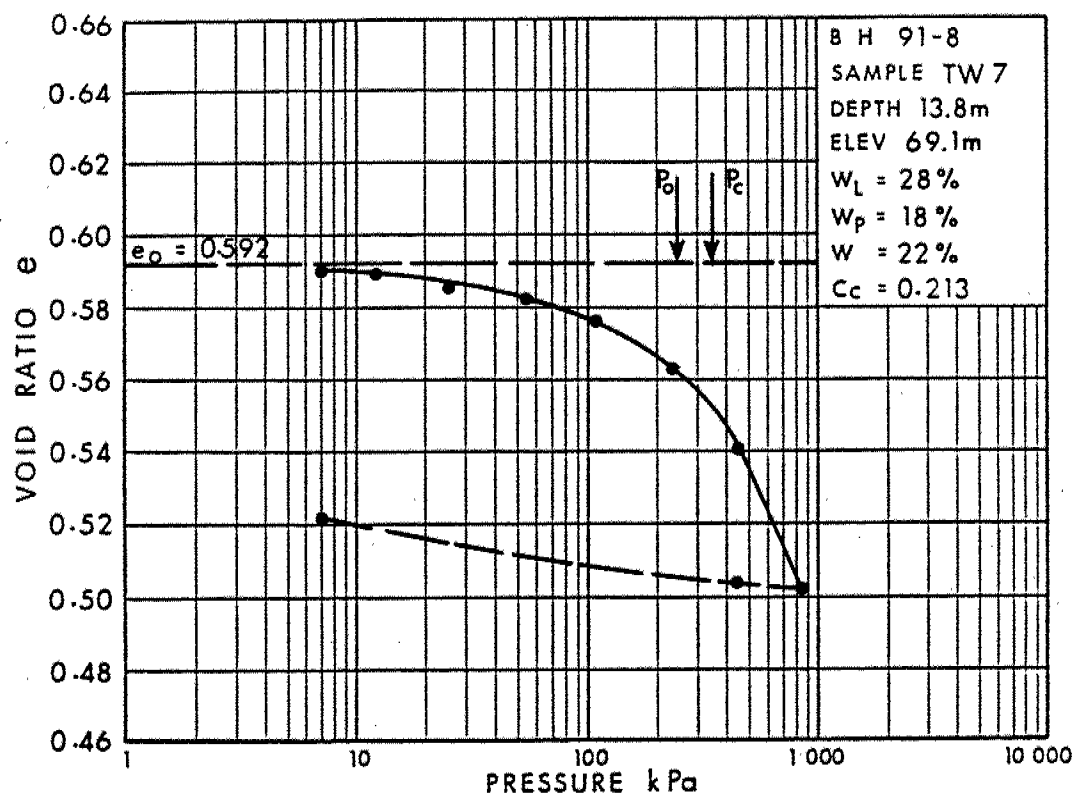
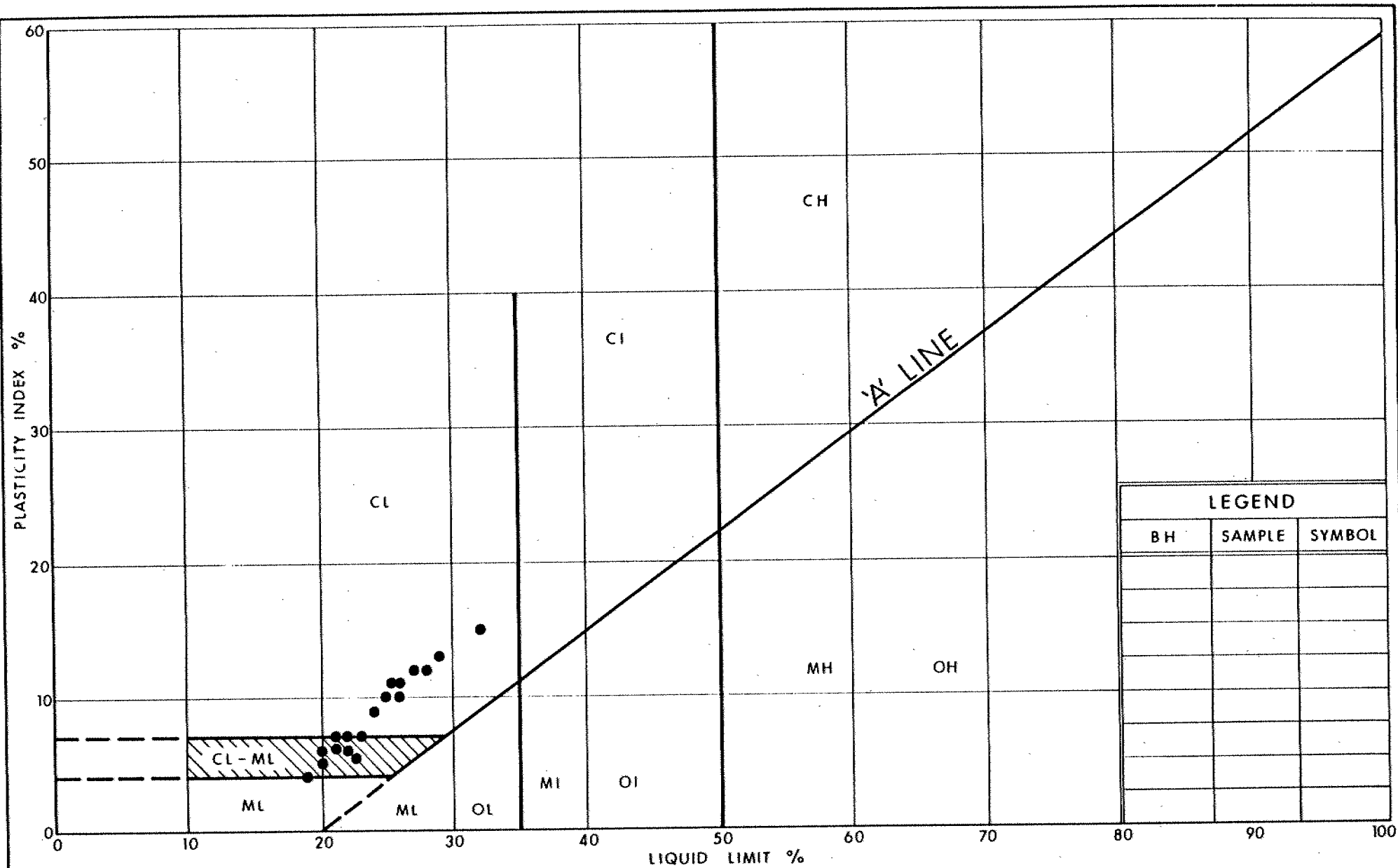


Fig 7

WP 624-90-04



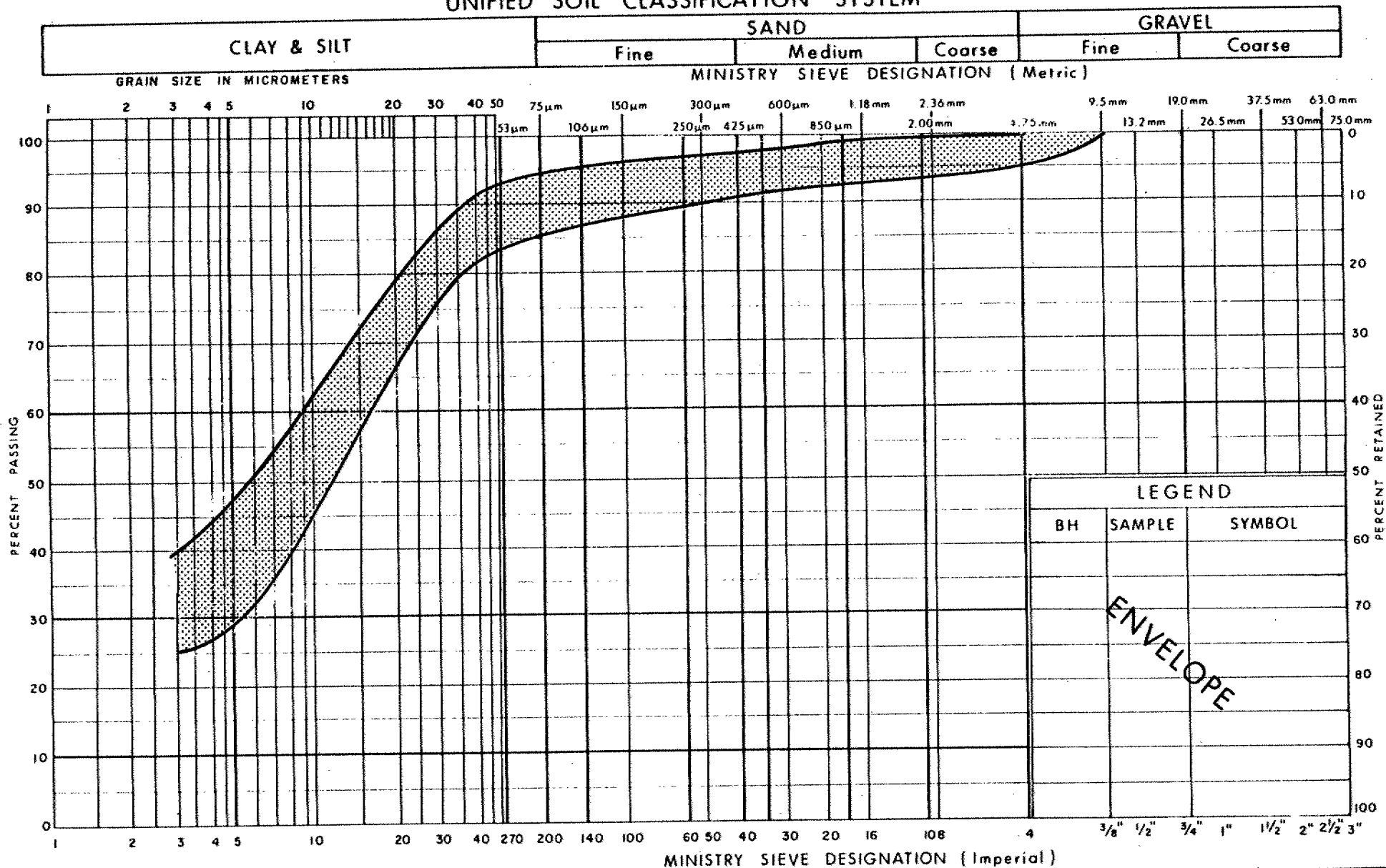
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PLASTICITY CHART
CLAYEY SILT
WITH SOME SAND AND TRACE OF GRAVEL

FIG No 8

W P 624-90-04

UNIFIED SOIL CLASSIFICATION SYSTEM

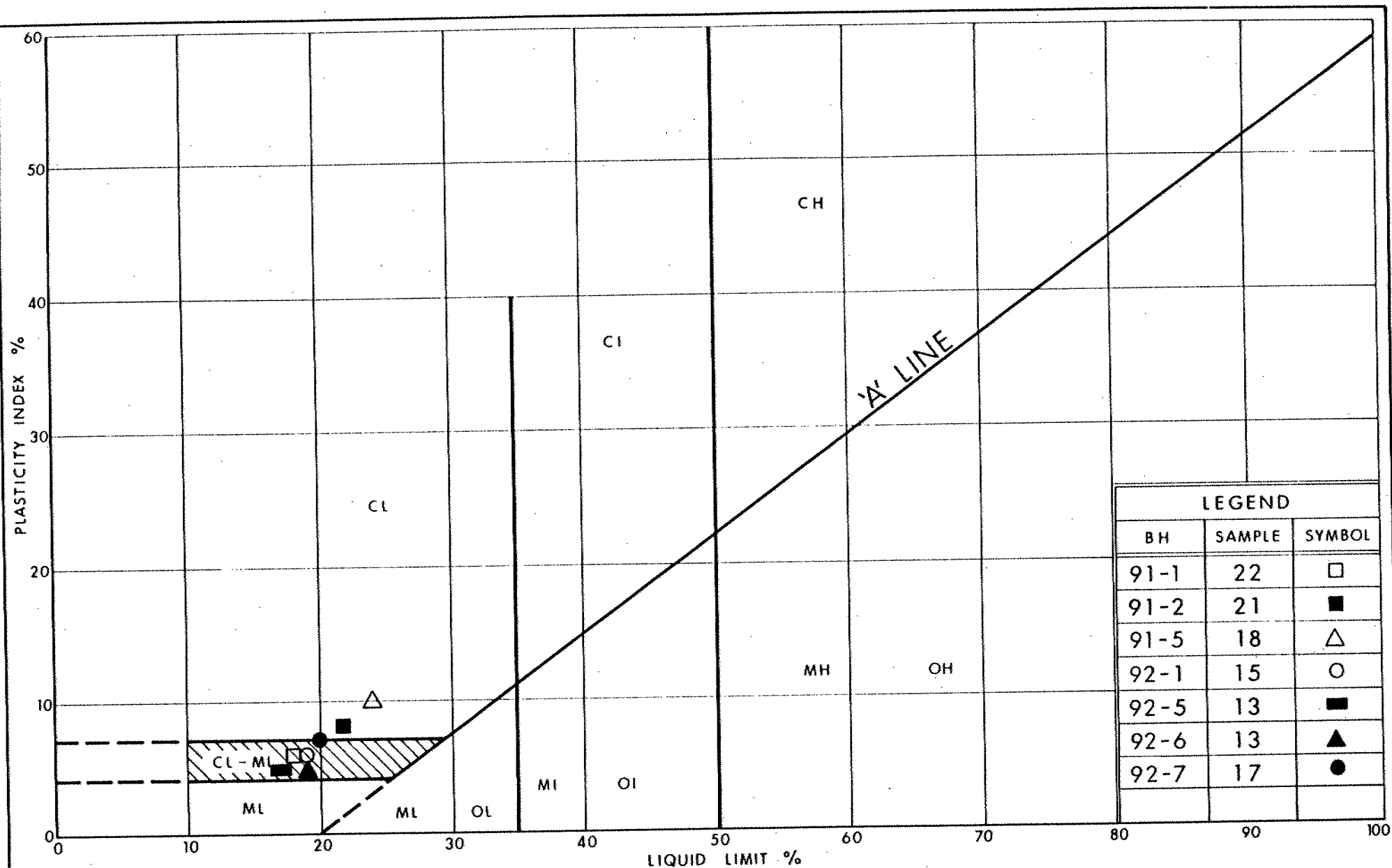


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GRAIN SIZE DISTRIBUTION
CLAYEY SILT
WITH SOME SAND AND TRACE OF GRAVEL

FIG. No 9

W P 624-90-04



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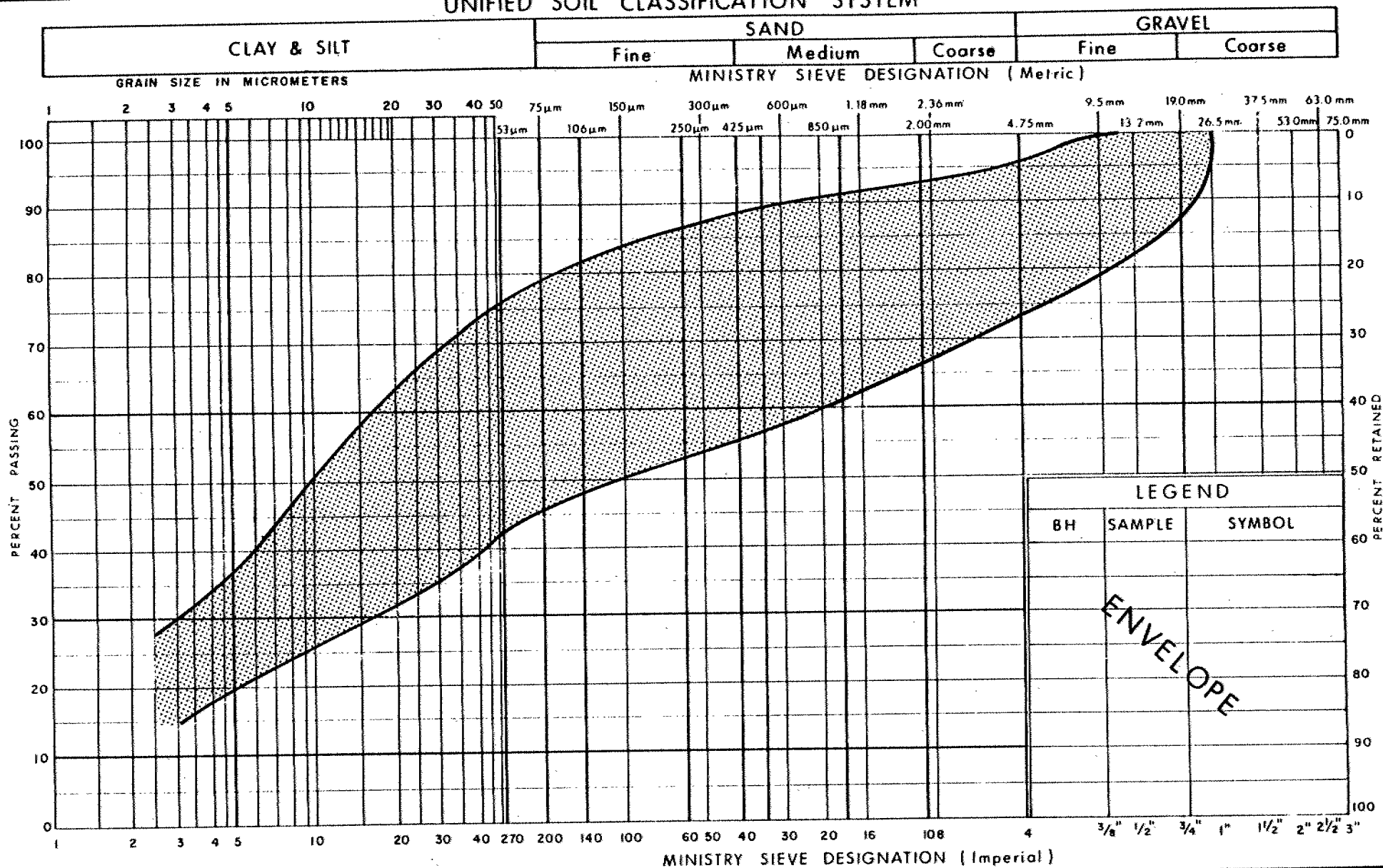
Ontario

PLASTICITY CHART
HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND & GRAVEL
(COHESIVE GLACIAL TILL)

FIG No 10

W P 624-90-04

UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION
HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND & GRAVEL
 (COHESIVE GLACIAL TILL)

FIG No 11

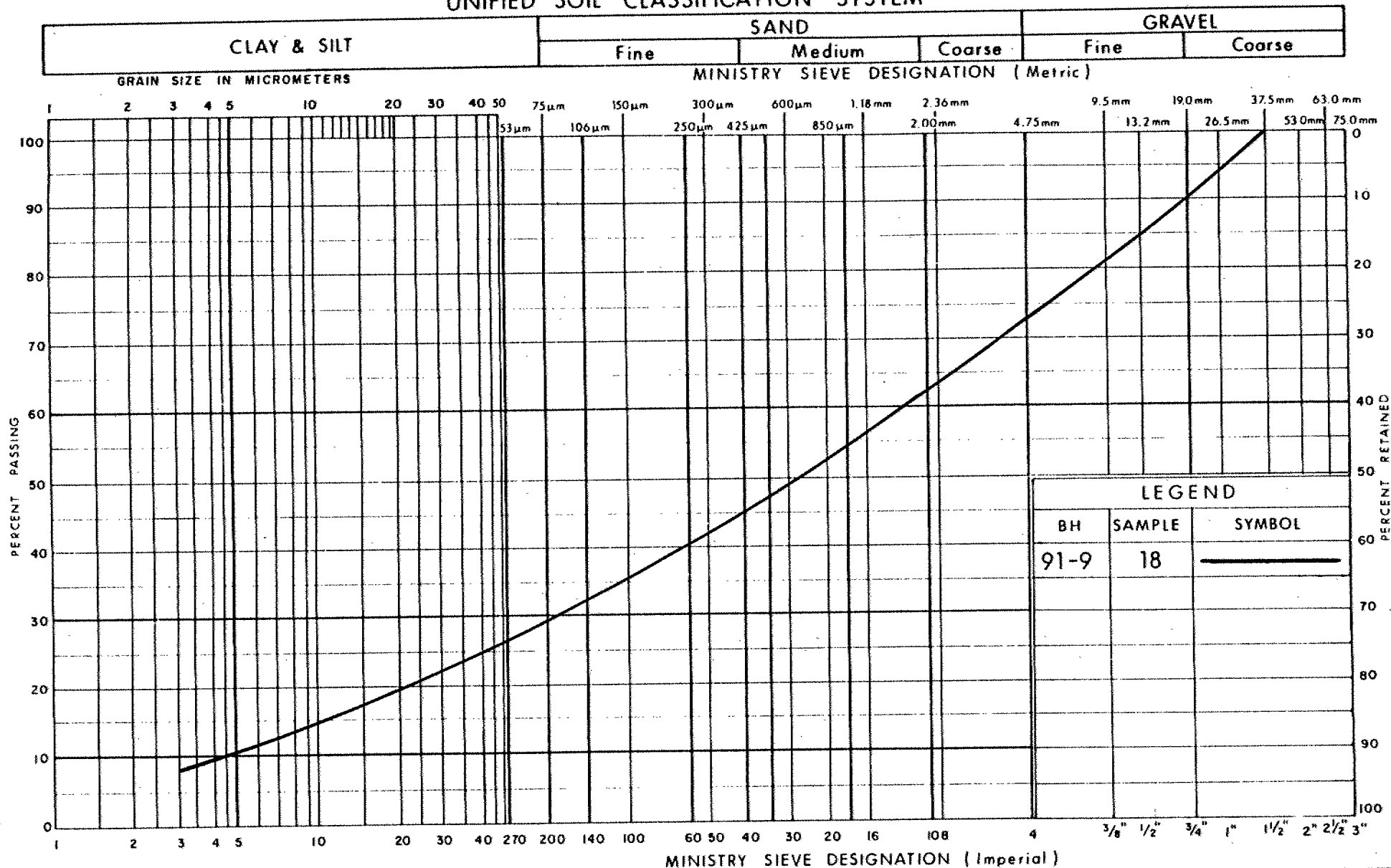
W P 624-90-04



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Transportation

UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION
HETEROGENEOUS MIXTURE OF SILT, SAND & GRAVEL
 (NON-COHESIVE GLACIAL TILL)

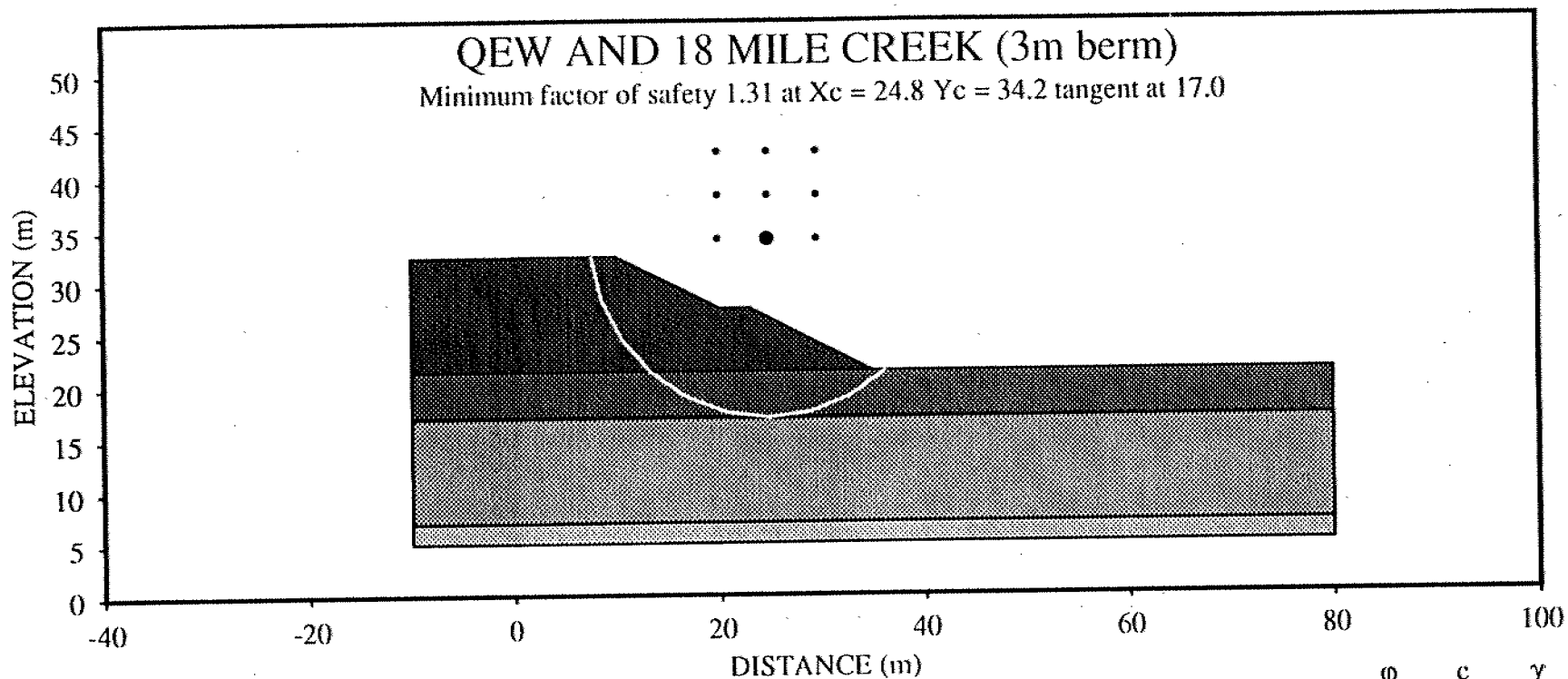
FIG No 12

W P 624-90-04



Ontario

 Ministry of
 Transportation



ϕ c γ

30.0 0.0 21.0

0.0 50.0 18.0

CLAYEY SILT (FILL)

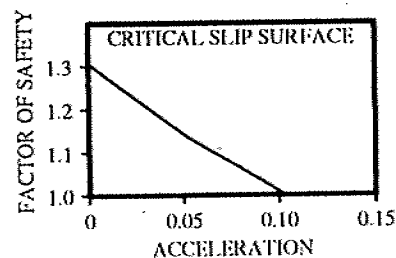
ORGANIC SILT

CRITICAL ACCELERATIONS

0.090 0.105 0.165

0.087 0.100 0.173

0.097 0.104 0.204



ϕ c γ

0.0 92.0 21.3

35.0 0.1 22.0

CLAYEY SILT

COHESIVE TILL

FACTORS OF SAFETY

1.362 1.348 1.496

1.332 1.311 1.498

1.348 **1.308** 1.588

WP 624-90-04

Fig 13

RECORD OF BOREHOLE No 91-1 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4782 027.9 E 317 883.7 ORIGINATED BY T.C.K.
 DIST 4 HWY Q.E.W. BOREHOLE TYPE H.S. Auger, Cone Tests, Vane Tests, NO Rock Core COMPILED BY R.N.
 DATUM Geodetic DATE Dec. 5 & 9, 1991 CHECKED BY T.C.K.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
85.2	Ground Surface																
0.0	Sand and gravel (Fill)	Brown															
0.6	Granular 'A' (Fill)	Grey															
83.7		Grey															
1.5		Brown	1	SS	14												
			2	SS	21												
			3	SS	15												
	Clayey silt to silt, some sand and trace of gravel, occ. silty sand layers (Fill) Firm to very stiff		4	SS	19												
			5	SS	26												
	Silty sand layer Compact		6	SS	6												
			7	SS	10												
75.1			8	SS	9												
10.1			9	SS	7												
	Crushed Stone with sand (Fill) Loose to compact		10	SS	0												
			11	SS	7												
70.1		Brown	12	SS	10												
15.1	Organic clayey silt, some sand and gravel Very stiff	Grey	13	SS	16												
69.0			14	SS	18												
16.2			15	SS	22												
			16	TW	PH												
	Clayey silt with some sand trace of gravel Very stiff to hard		17	SS	32												
			18	SS	27												
			19	SS	24												
			20	TW	PH												
60.1		Grey	21	SS	35												
25.1	Het. mixture of clayey silt, sand and gravel (Glacial till) occ. shale fragments Hard	Reddish Brown	22	SS	101												
58.4		Reddish brown	23	SS	109												
26.8	Queenston shale bedrock	Red	24	SS	60												
56.9			25	RC	REC	77%											
28.3	End of Borehole																

RECORD OF BOREHOLE No 92-1 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4782 027.8 E 317 844.3 ORIGINATED BY MI
 DIST 4 HWY QEW BOREHOLE TYPE HS Auger, Vane Tests, NQ Rock Core COMPILED BY MI
 DATUM Geodetic DATE May 15, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT		NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100								W _p
								SHEAR STRENGTH kPa					WATER CONTENT (%)			
								○ UNCONFINED	+ FIELD VANE							
								● QUICK TRIAXIAL	× LAB VANE							
								20 40 60 80 100		10 20 30						
85.0	Ground Surface													7		GR SA SI CL
0.0																

RECORD OF BOREHOLE No 92-2 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4782 028.6 E 317 865.3 ORIGINATED BY MI
DIST 4 HWY QEW BOREHOLE TYPE HS Auger, Vane Tests, NQ Rock Core COMPILED BY MI
DATUM Geodetic DATE May 19, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100	W _P	W	W _L	
85.0	Ground Surface															
0.0																
			1	SS	10		84									
			2	SS	13		82									
			3	SS	14		80									
			4	SS	14		78									
			5	SS	8		76									
			6	SS	7		74									
74.9			7	SS	9		72									
10.1	Sand and Gravel with crushed stone (Fill)	Brown	8	SS	4		70									
73.3		D.Grey	9	SS	4		68									
11.7			10	TW	PH		66									
			11	SS	4		64									
			12	SS	8		62									
			13	SS	13		60									
69.2		D.Grey	14	TW	PH		58									
15.8		Grey	15	SS	8		56									
			16	SS	33		54									
60.4		Grey	17	SS	100		52									
24.6	Het. Mixture Clayey Silt, Reddish Brown Sand and Gravel (Glacial Till) occ. Shale Fragments, Hard	Reddish Brown Weathered Sound	18	RC	REC 93%		50									
59.0							48									
26.0	Queenston Shale Bedrock						46									
57.3							44									
27.7	End of Borehole						42									

RECORD OF BOREHOLE No 92-3 1 OF 1 METRIC

W.P. 624-90-01/02/03/04 LOCATION Co-ord. N 4782 030.1 E 317 904.3 ORIGINATED BY MI
DIST 4 HWY QEW BOREHOLE TYPE HS Auger, Vane Tests, NQ Rock Core COMPILED BY MI
DATUM Gedectic DATE May 13, 1992 to May 14, 1992 CHECKED BY TCK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
85.3	Ground Surface																
0.0																	
			1	SS	25		84										
	Silty Sand		2	SS	22		82										
			3	SS	26		80										
	Silty Sand		4	SS	12		78										
	Clayey Silt to Silt, some sand, trace of gravel occ. silty sand layers (Fill)		5	SS	6		76										
75.2	Firm to Very Stiff	Brown	6	SS	7		74										
10.1	Organic Clayey Silt to Silty Clay trace of sand	D. Grey	7	SS	3		72										
74.0	Soft	Grey	8	TW	PH		70										
11.3			9	SS	20		68										
			10	SS	13		66										
			11	SS	13		64										
			12	SS	9		62										
	Clayey Silt, with sand, trace of gravel Very Stiff		13	SS	10		60										
			14	SS	16		58										
			15	SS	19		56										
60.7		Grey					54										
24.6	Reddish Brown		16	SS	100	/25cm	52										
	Het. Mixture of Clayey Silt, Sand and Gravel occ. shale fragments (Glacial Till)		17	SS	100	/18cm	50										
57.7	Hard	Reddish Brown					48										
27.6	weathered sound	Red	18	RC	REC	100%	46										
56.2	Queenston Shale Bedrock						44										
29.1	End of Borehole						42										
	* Water Level Not Stabilized						40										

ROCK CORE DESCRIPTION
WP 624-90-01/02/03/04

Page 1 of 3

CORE RECOVERY					CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
91-1	25	26.82-28.35	77	23	26.82-28.35	SHALE, greyish red, with interbedded greenish grey SILTSTONE (7%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 27.89-28.12 m); fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
91-3	19	24.38-25.91	88	17	24.38-26.82	SHALE, greyish red, with interbedded greenish grey SILTSTONE (14%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 24.38-24.71 m); fractures moderately close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
	20	25.91-26.82	83	69		
91-4	15	23.01-24.38	85	19	23.01-24.38	SHALE, greyish red, with interbedded greenish grey SILTSTONE (7%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 23.01-23.72 m); fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
91-5	20	24.38-25.93	91	23	24.38-25.93	SHALE, greyish red, with interbedded greenish grey SILTSTONE (8%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
91-6	22	27.43-28.68	98	9	27.43-28.68	SHALE, greyish red, with interbedded greenish grey SILTSTONE (14%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 27.43-27.51 m); fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

(NOTE: Depths are approximated where core recovery is less than 100%)

Logged by: DAW, Soils and Aggregates Section

ROCK CORE DESCRIPTION
WP 624-90-01/02/03/04

Page 2 of 3

CORE RECOVERY					CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
92-1	17	25.98-27.51	97	25	25.98-27.51	SHALE, greyish red, with interbedded greenish grey SILTSTONE (5%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-2	18	26.19-27.71	93	7	26.19-27.71	SHALE, greyish red, with interbedded greenish grey SILTSTONE (5%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-3	18	27.61-29.13	100	50	27.61-29.13	SHALE, greyish red, with interbedded greenish grey SILTSTONE (15%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 27.61-28.04 m); fractures moderate to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-4	15	24.54-26.06	84	27	24.54-26.06	SHALE, greyish red, with interbedded greenish grey SILTSTONE (6%); very fine grained; weak to very weak; unweathered to slightly weathered (moderately weathered, 24.54-24.66 m); fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-5	15	25.15-26.67	92	18	25.15-26.67	SHALE, greyish red, with interbedded greenish grey SILTSTONE (7%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

(NOTE: Depths are approximated where core recovery is less than 100%)

Logged by: DAW, Soils and Aggregates Section

ROCK CORE DESCRIPTION
WP 624-90-01/02/03/04

Page 3 of 3

CORE RECOVERY					CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
92-6	15	24.51-26.04	100	45	24.51-26.04	SHALE, greyish red, with interbedded greenish grey SILTSTONE (7%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-7	19	26.11-27.03	89	44	26.11-27.64	SHALE, greyish red, with interbedded greenish grey SILTSTONE (8%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
	20	27.03-27.64	100	0		
92-8	17	27.56-29.08	73	68	27.56-29.08	SHALE, greyish red, with interbedded greenish grey SILTSTONE (13%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to extremely close spaced, flat to near vertical, planar to undulating, smooth.
92-9	20	29.06-30.58	97	43	29.06-30.58	SHALE, greyish red, with interbedded greenish grey SILTSTONE (8%); very fine grained; weak to very weak; unweathered to slightly weathered; fractures close to very close spaced, flat to near vertical, planar to undulating, smooth.

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

(NOTE: Depths are approximated where core recovery is less than 100%)

Logged by: DAW, Soils and Aggregates Section

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

MECHANICAL PROPERTIES OF SOIL

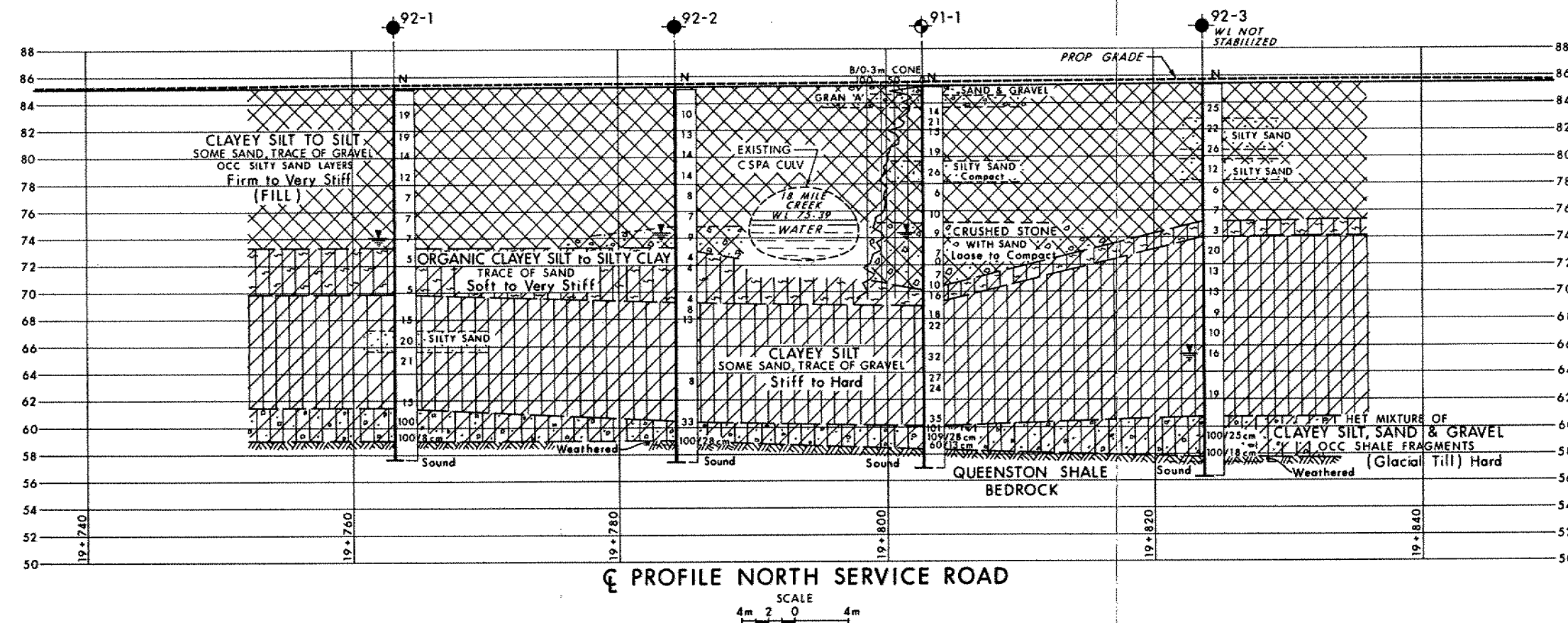
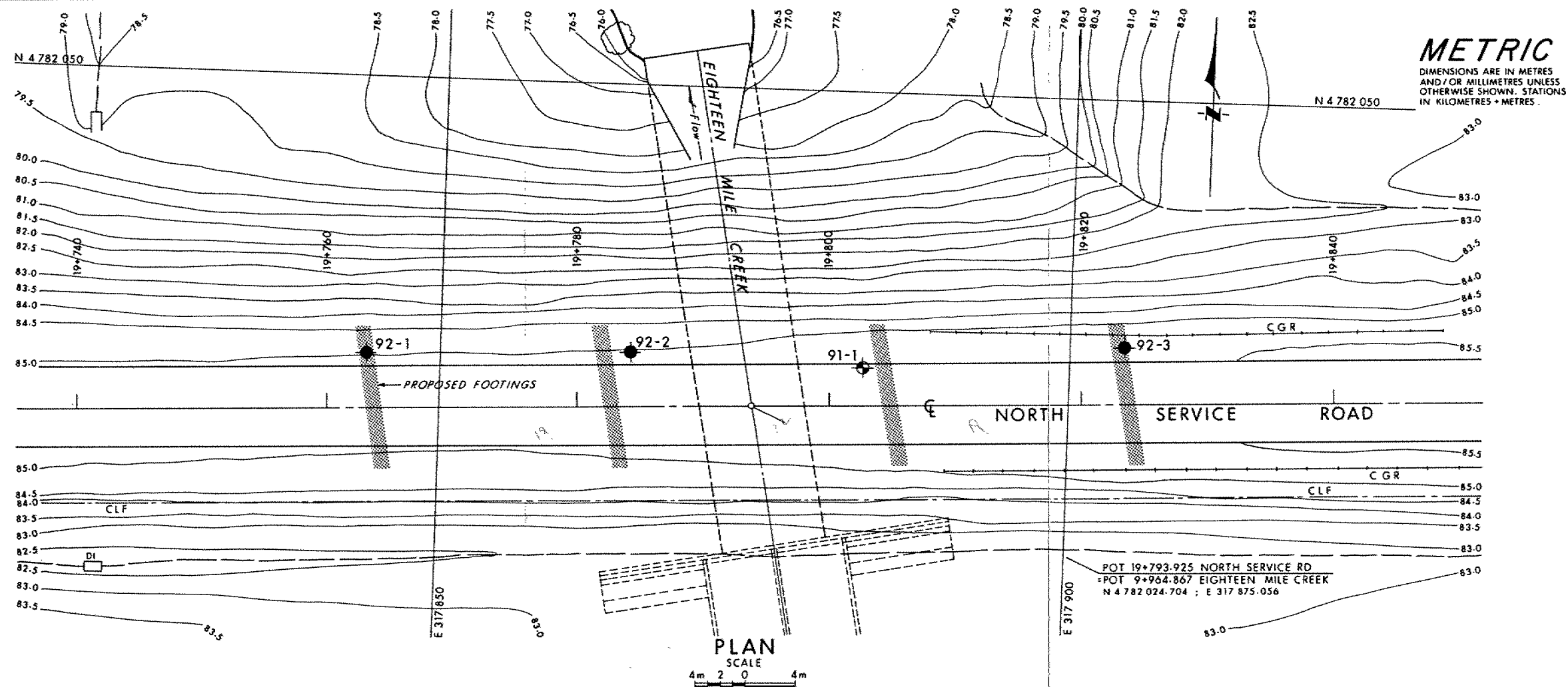
m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_a	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

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

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	e_{\min}	1, %	VOID RATIO IN DENSEST STATE
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{\max} - e}{e_{\max} - e_{\min}}$
ρ_w	kg/m^3	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kN/m^3	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m^3	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	kN/m^3	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m^3	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m^3/s	RATE OF DISCHARGE
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL	e_{\max}	1, %	VOID RATIO IN LOOSEST STATE	j	kN/m^2	SEEPAGE FORCE
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL						

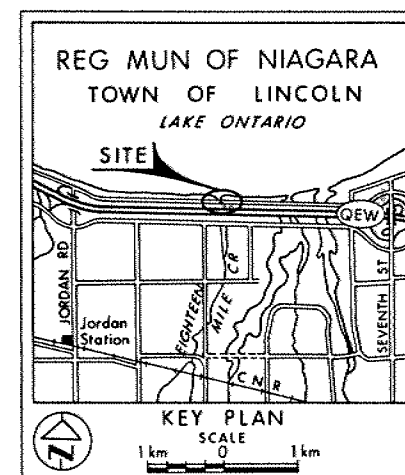


CONT No
WP No 624-90-04

EIGHTEEN MILE CREEK
(NORTH SERVICE ROAD)
BORE HOLE LOCATIONS & SOIL STRATA



SHEET



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
1991 '12 and 1992 '05

No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
91-1	85.2	4 782 027.9	317 883.7
92-1	85.0	4 782 027.8	317 844.3
92-2	85.0	4 782 028.6	317 865.3
92-3	85.3	4 782 030.1	317 904.3

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 GC 2.01 of GPS Gen. Cond.

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Geocres No 30M3-197

HWY No QEW / NORTH SERVICE RD	DIST 4
SUBNO T.K. CHECKED 7/94 DATE 1993 03 17	SITE 18-20
DRAWN C.K. CHECKED 7/94 DATE 1993 03 17	DWG 6249004-A

REF No E-138-QEW-7; 1986 09



Ontario

memorandum

MINISTRY OF TRANSPORTATION
Structural Engineering
1201 Wilson Avenue
Atrium Tower, 4th Floor
Downsview, Ontario, M3M 1J8
Telephone: 235-5505

DATE: August 21, 1995

TO: D. Simington, Construction Office
D. Dundas, Foundation Design Section

RE: Contract 94-53, 18 Mile Creek Structures

For your information, attached please find a copy of Hatch's Project Report detailing their assessment/findings for the recent movement noticed at the east abutment at the above structure.

Please let us know if you require any clarification on the findings.

K. Pilgrim
Area Engineer - Structures
for:
V. F. Boehnke
Head, Structural Engineering

KP:dd





HATCH ASSOCIATES LTD.

HATCH

2800 Speakman Drive, Sheridan Science and Technology Park
Mississauga, Ontario, Canada L5K 2R7 Tel. (905) 855-7600 Fax (905) 855-8270

August 14, 1995

Mr. Ken Wong, P.Eng.
Central Region - Structural Section
Ministry of Transportation
Atrium Tower, 4th Floor
1201 Wilson Avenue
Downsview, ON

Dear Mr. Wong:

**Re: QEW - Eighteen Mile Creek EB Lanes Bridge
Contract 94-53/East Abutment Movement**

Attached herewith please find two copies of the final report.

We have reviewed the draft report dated July 31, 1995, submitted to you on August 2, 1995, for accuracy of the information as made available to us and noted on site. At the meeting of August 4, 1995, some observations in the contractors geotechnical reports were challenged for accuracy which we could not confirm and therefore we are not justified to alter in our report. However, conclusions were added which in our option reflect the consensus reached at the meeting and are compatible with our appraisal of the situation.

Recommendations on the measures to alleviate any adverse effect of the unplanned movement will follow under separate cover.

For clarifications on this report kindly contact the undersigned.

Yours very truly,

for C.A. Laborde-Basto

CAL-B:rb
Attachment
Ref CO58814.002

cc: J.J. Feberwee (letter only)
G.A. Smith (letter only)

August 9, 1995

**MINISTRY OF TRANSPORTATION
EIGHTEEN MILE CREEK BRIDGE****DISTRIBUTION**

K. Wong	- MTO
T. Gregor	- HA
C. Laborde-Basto	- HA

MOVEMENT OF THE EAST ABUTMENT**1.0 BACKGROUND**

Hatch was requested by the Ministry of Transportation (MTO) to assess the condition/adequacy of the east abutment for the QEW eastbound lanes following reports of unplanned movement. The assessment was based on the following documentation supplied by MTO:

- ▶ Letter to Geotec Contracting Ltd. from Mountainview Geotechnical Ltd. on July 11, 1995
- ▶ MTO Memorandum to N.Bot from Pavements and Foundations Section dated July 17, 1995
- ▶ Letter to MTO, S. Ahluwalin, from Stephens & Rankin Inc. dated July 13, 1995
- ▶ Letter To MTO, D. Simmington from Stephens & Rankin Inc. dated July 20, 1995
- ▶ Letter to Geotec Contracting Ltd. from Mountainview Geotechnical Ltd., dated July 20, 1995.

In addition, Messrs. C. Laborde-Basto and T. Gregor visited the site on July 27, 1995 to meet Mr. D. Simmington of MTO and Mr. W. Snow of Stephens & Rankin the contractor.

2.0 SITE VISIT OBSERVATIONS

From the site visit the following observations were noted by inspection and from conversation with the two people named above:

- ▶ Granular material was placed behind the abutment to a height of about 1.4 m above the underside of the headwall on July 6, 1995.

- ▶ Granular material was excavated out to approximate level of underside headwall and stacked behind the sheetpiling after major movement of the abutment.
- ▶ Top of sheetpiling behind abutment was trimmed to elevation ± 82 and some anchor heads were visible. Toe of sheetpiling at elevation ± 70 (B. Snow).
- ▶ The contractor stated that no visible signs of movement were detected in the sheetpiling.
- ▶ D. Simmington said that sheetpiling behind abutments was to remain permanently.
- ▶ Forward movement of the abutment headwall along the north sheetpiling waler was measurable from mortar markings as ± 100 mm.
- ▶ The waler against the top of the headwall had been welded to the sheetpiling but the welds burnt out by the contractor about July 24, 1995.
- ▶ The top of the headwall under the waler at the north sheetpiling wall had broken out a piece about 150 mm wide by about 300 mm deep. Length along the wall was not visible.
- ▶ No signs of cracking were visible in the headwall.
- ▶ The contractor suspected movement in the abutment on July 12 and ordered the survey on July 13.
- ▶ The contractor's statement (letter of July 20) that the headwall "... is leaning towards the west at the top by approximately 10 to 15 mm ..." was not based on a previously surveyed reference point(s) (D. Simmington).
- ▶ Forward slope fill remained as placed roughly to elevation 81.
- ▶ The amount of forward slope does not provide any meaningful support to an unrestrained cantilevering abutment.
- ▶ No indications of settlement of the backfill behind the headwall or of separations cracks between fill and sheetpiling or headwall were noticed after the major movement between July 6 and July 7.
- ▶ Inclinometer readings on July 26 continued to show little or no change from before.

- ▶ D. Simmington informed that the water table in the embankment is high enough to maintain water visible in the road side ditches behind the west abutment all the time.
- ▶ Settlement of the repaved QEW surface behind the north sheetpiling wall required padding twice since repaving.
- ▶ Site records (MTO) show that it rained July 5 and July 7 around 10:30 a.m. No rain for at least one week before July 5.
- ▶ D. Simmington said that french drains between abutments and existing culvert continued to drain water.
- ▶ In an excavation about 2 m deep between the east abutment headwall and the service road bridge abutment it was apparent that the moisture content in the road fill was high.

3.0 METHODOLOGY OF ASSESSMENT

- ▶ Review available data from reports and from observations and correlate with inclinometer readings and site observations.
- ▶ From the sequence of events and data reported rationalize the most probable mechanisms which can explain the wall movement.
- ▶ Develop probable loading distributions on the abutment and correlate calculated deflections with survey data.
- ▶ Assess probable stress conditions in the piles in the current deflected condition under the action of the design loading resulting from proceeding with construction.
- ▶ Summarize the most likely stress conditions in the piles in accordance with OHBDC'83 and comment on the risk and other conditions which may influence the reliability of the abutment lifespan.

4.0 ASSESSMENT

Study of inclinometer readings in A3 and A4 show reasonable correlation with each other and with the expected displacement of the forward slope under the reported saturated soil conditions encountered before July 6. Inclinometers show the depth of the soil displacement zone being from surface to about elevation 71.0 m. It is likely that the actual extent of the soil displacement zone is not as deep as shown since influence of the inclinometer casing stiffness tends to exaggerate depth of the zone. However, since stiffness of an H-pile is larger than that of the casing, the pile movement zone will be at least as deep as shown by the inclinometer readings.

Excavation for the forward slope starting from the north end with a cut face up to 5 m deep (MTO memorandum to N. Bot of July 17, 1995) indicates that, notwithstanding the reported saturated condition of the soil, it still had enough cohesive strength to transfer some loading to the abutment piles. This may be a reason why no visible settlement of the soil nor of cracks between abutment and sheetpiling was noticed. It is possible that some forward movement of the abutment took place at this time too.

It is very likely that the combination of poor embankment soil, rainy weather conditions (started July 5) and excavation for the forward slope led to full earth and hydrostatic pressures in the embankment developing and being resisted mostly by the sheetpile wall. It is also conceivable that with the saturated soil depth to approximately elevation 71 (Mountainview Geotechnical report of July 20, page 3) the embedment of the sheetpiling may not have been enough to prevent deflection of the sheetpile wall. This deflection below the anchor level towards the abutment shifted forward the 5 m wide soil block resulting in the large displacements observed.

Based on this likely scenario, the most probable loading distribution acting on the abutment piles can be simulated by a trapezoidal shape. Another possibility is that loading on the piles is proportioned to the amount of movement of the surrounding soil. These loading distributions (see Fig. 1) were assumed to act on the abutment piles between elevations 71 and 81.5. In each case, the intensity of loading was prorated for deflections in the abutment consistent with the survey measurements (110 mm). Pile support conditions were kept the same as in the original design below elevation 71.

Computer plots of the pile analysis are attached to this report and constitute the basis for the conclusions discussed next.

5.0

CONCLUSION

The stresses in the piles obtained from the analysis were added to the maximum stresses in the piles calculated for the ULS conditions in the original design analysis. Group of charts 1, 2 and 3 shows stress levels for the various assumed load distributions. The analyses demonstrate that the shape of assumed load distribution does not have a pronounced effect on the value of stresses in the piles.

The loading diagrams assumed were conservatively taken to level 71. It is recognized by correlating with the inclinometer readings that a loading cut-off higher than 71 would be truer. However, the unknown influence of the inclinometer casing stiffness and the variability in soil parameters are enough not to warrant further analytical refinement.

The calculated stresses in the piles are within the code requirements but leaving no reserve in the pile flexural capacity to accommodate any unplanned subsequent movements of the abutment.

Although our analysis shows satisfactory stress levels in the piles we are very much concerned about the following aspects:

- ▶ What will happen if the sheetpiling or the soil anchors fail with time?
- ▶ The slope in the front of the abutment appears to be unstable. The abutment was designed to resist the pressure of granular backfill acting only on the headwall. However, it can not and was not intended to provide global stability of the slope on a slip plane below the headwall as the soil can flow between the H-piles. This can produce additional loading of the piles. Additional measures have to therefore be taken since the granular backfill, still to be placed, will increase pressure differential between the front and back of the abutment.

In conclusion, we recommend minimum measures the following:

- ▶ Provide and maintain permanent drainage of the abutment backfill for improved shear strength of the soil surrounding abutment piles.
- ▶ Increase the stability of abutment by reducing the forward slope and by using high permeability fill.

- ▶ Backfilling and/or loading of the backfill must not take place under the present free cantilevering abutment condition.
- ▶ Ensure the long term stability of the sheetpiling behind the abutments and the durability of the ground anchors.
- ▶ Ensure no load shedding to the abutments under the eastbound QEW during construction of the structure for the westbound QEW.
- ▶ Protect the toe of the forward slopes from erosion or sluffing under high water flooding.


Tomas Gregor, P.Eng.

TG:bk

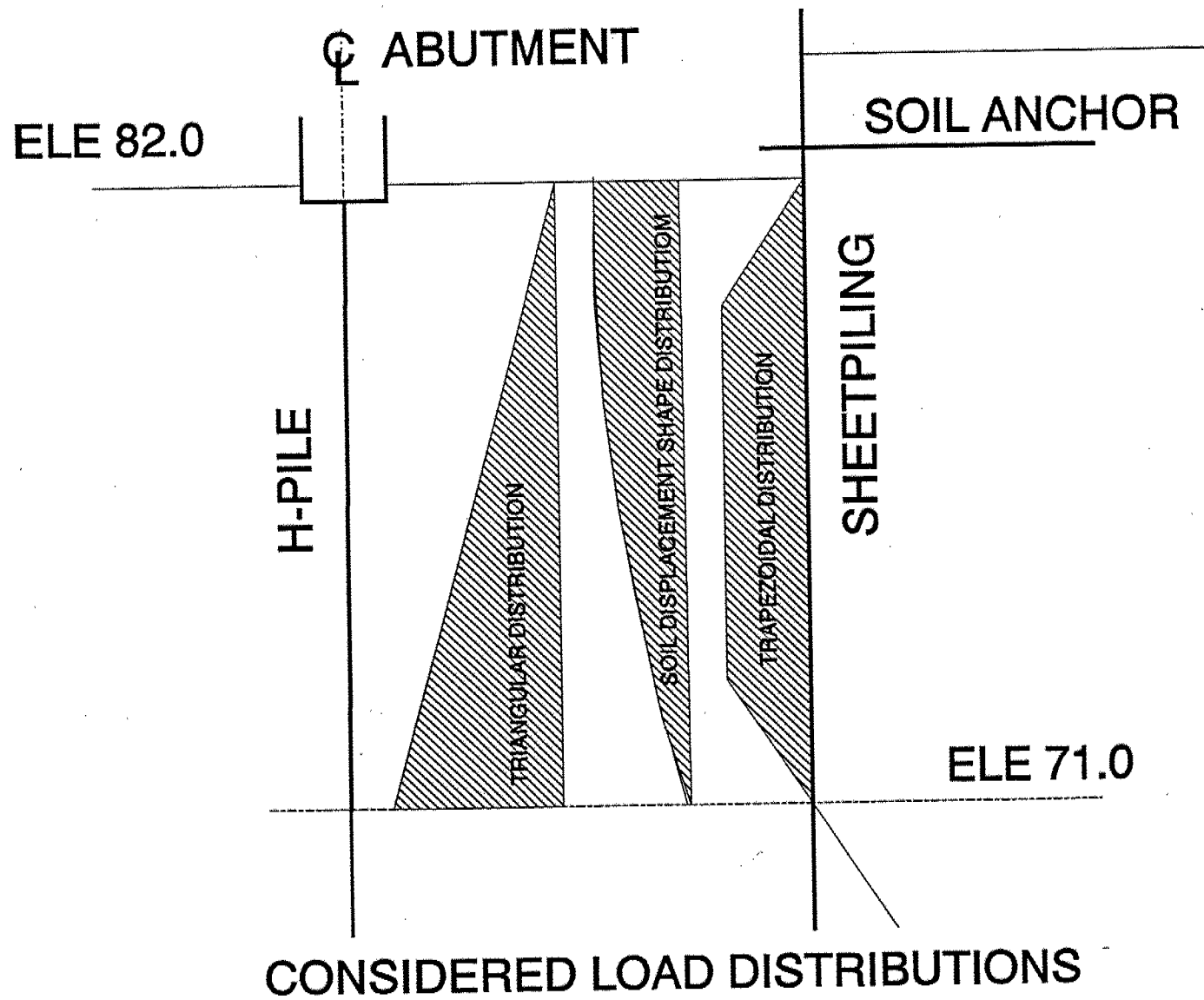


Figure 1.

Maximum Compression Stresses in Piles Soil Displacement Load Distribution

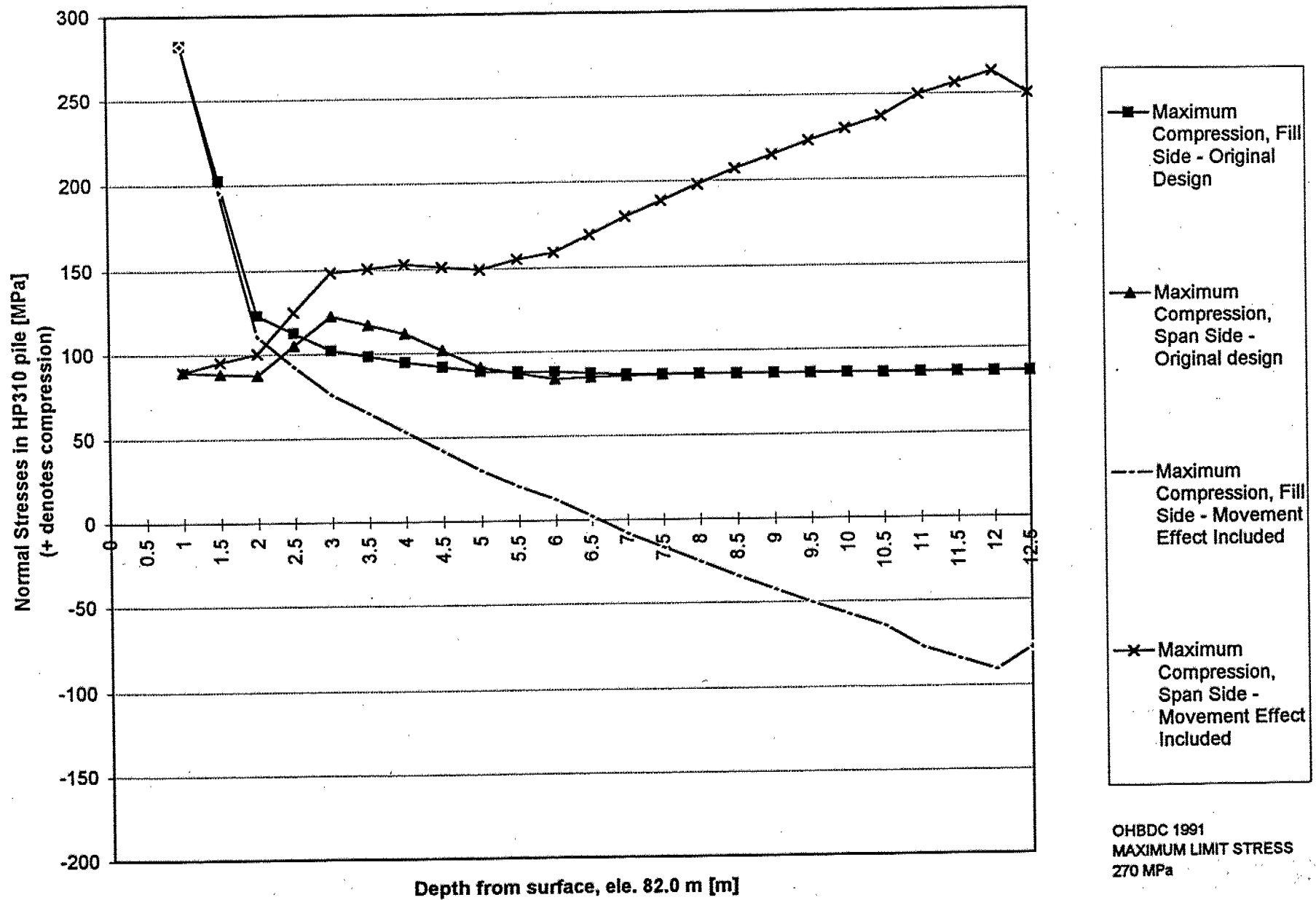
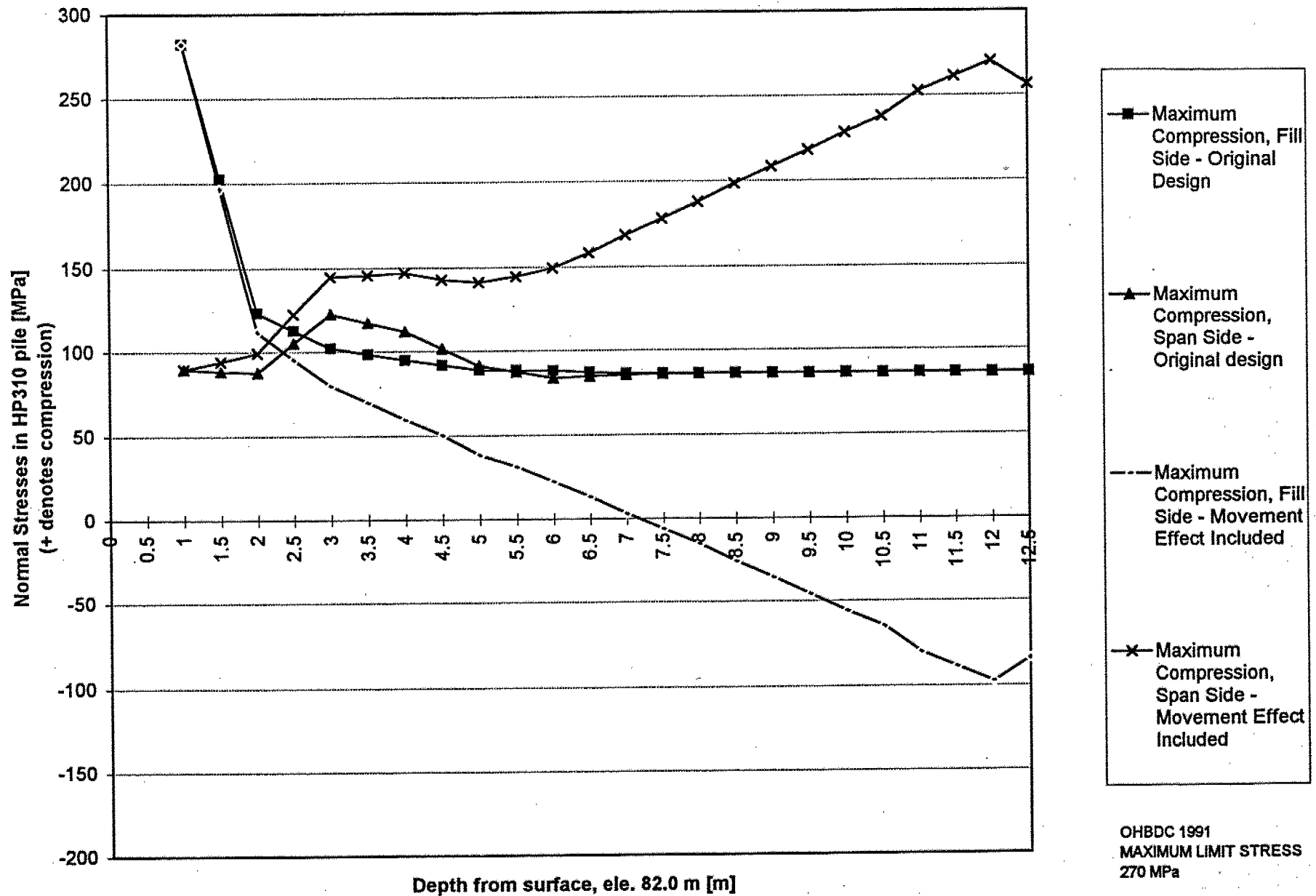


CHART 1

OHBC 1991
MAXIMUM LIMIT STRESS
270 MPa

Maximum Compression Stresses in Piles Trapezoidal Load Distribution



Maximum Compression Stresses in Piles Triangular Load Distribution

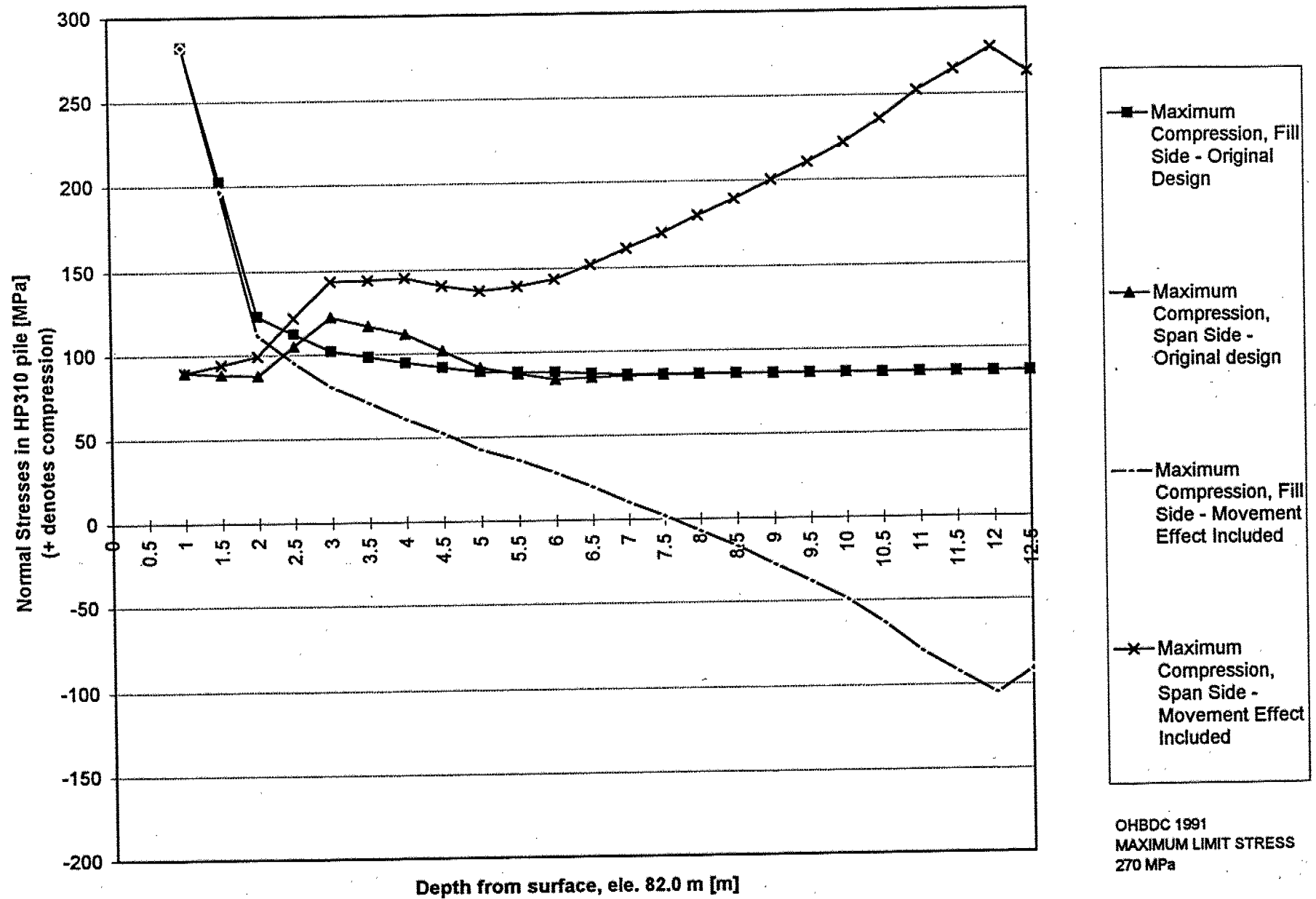
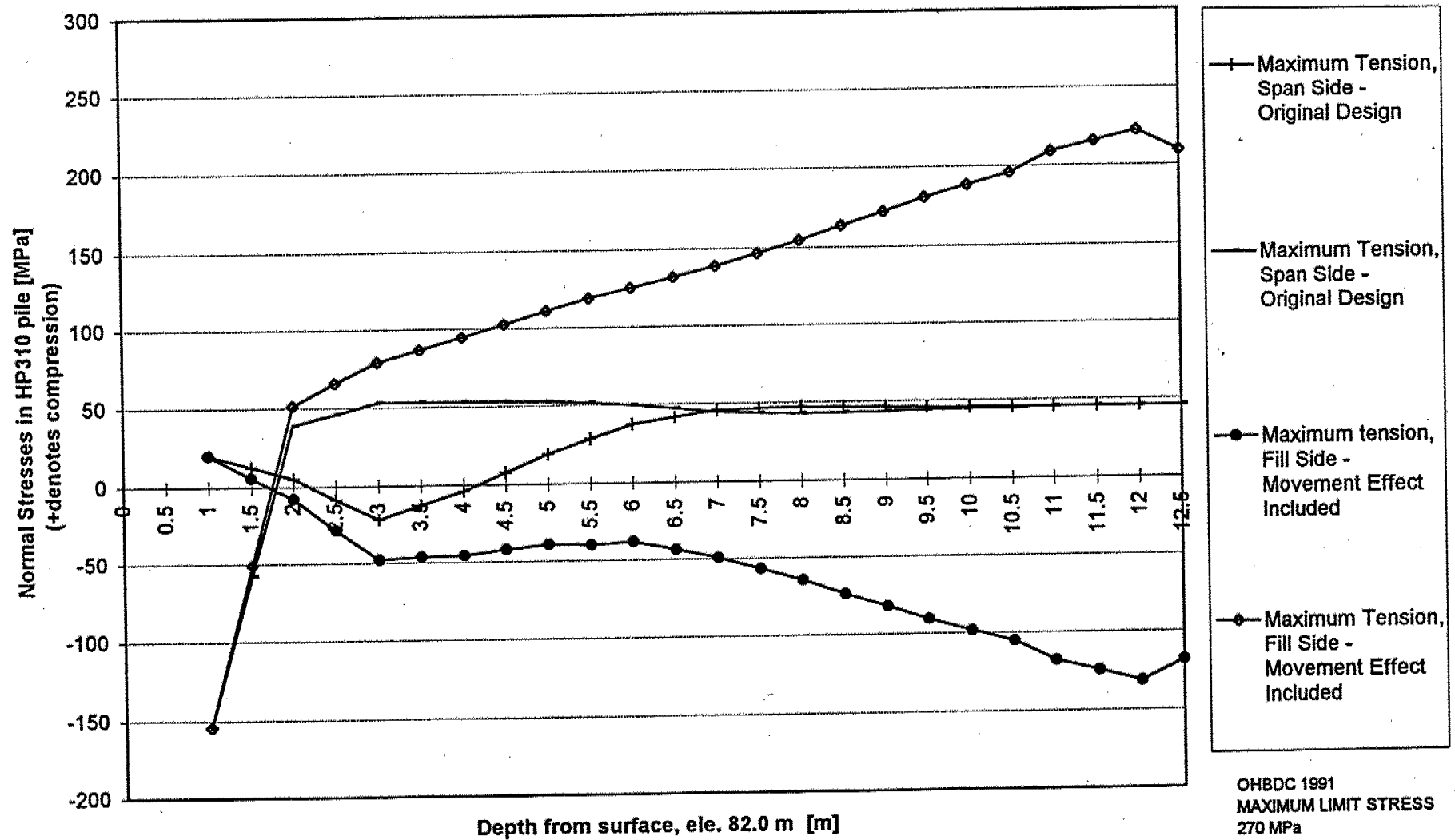


CHART 1

OHBC 1991
MAXIMUM LIMIT STRESS
270 MPa

Maximum Tensile Stresses in Piles Soil Displacement Load Distribution



Maximum Tensile Stresses in Piles Triangular Load Distribution

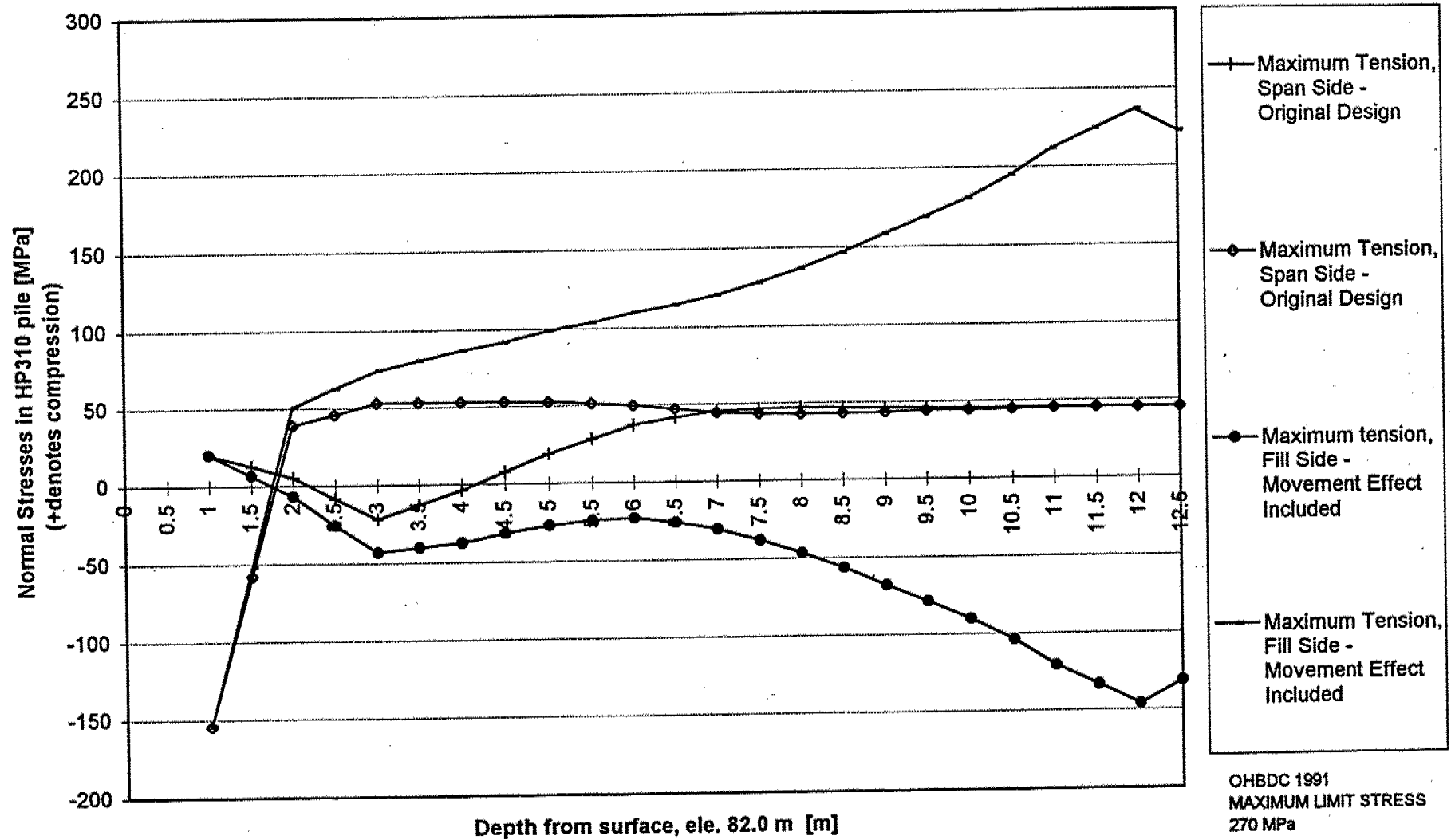
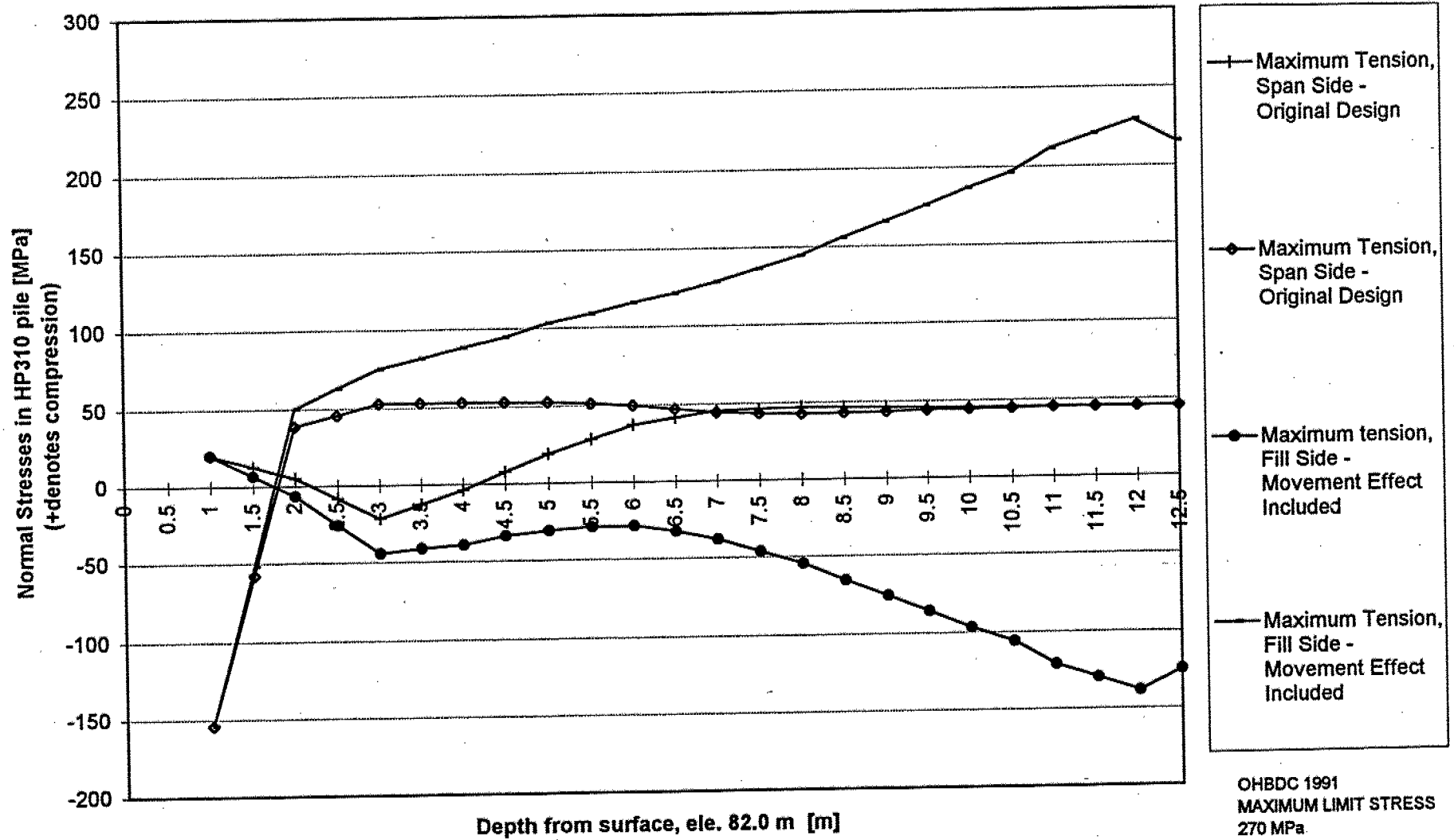
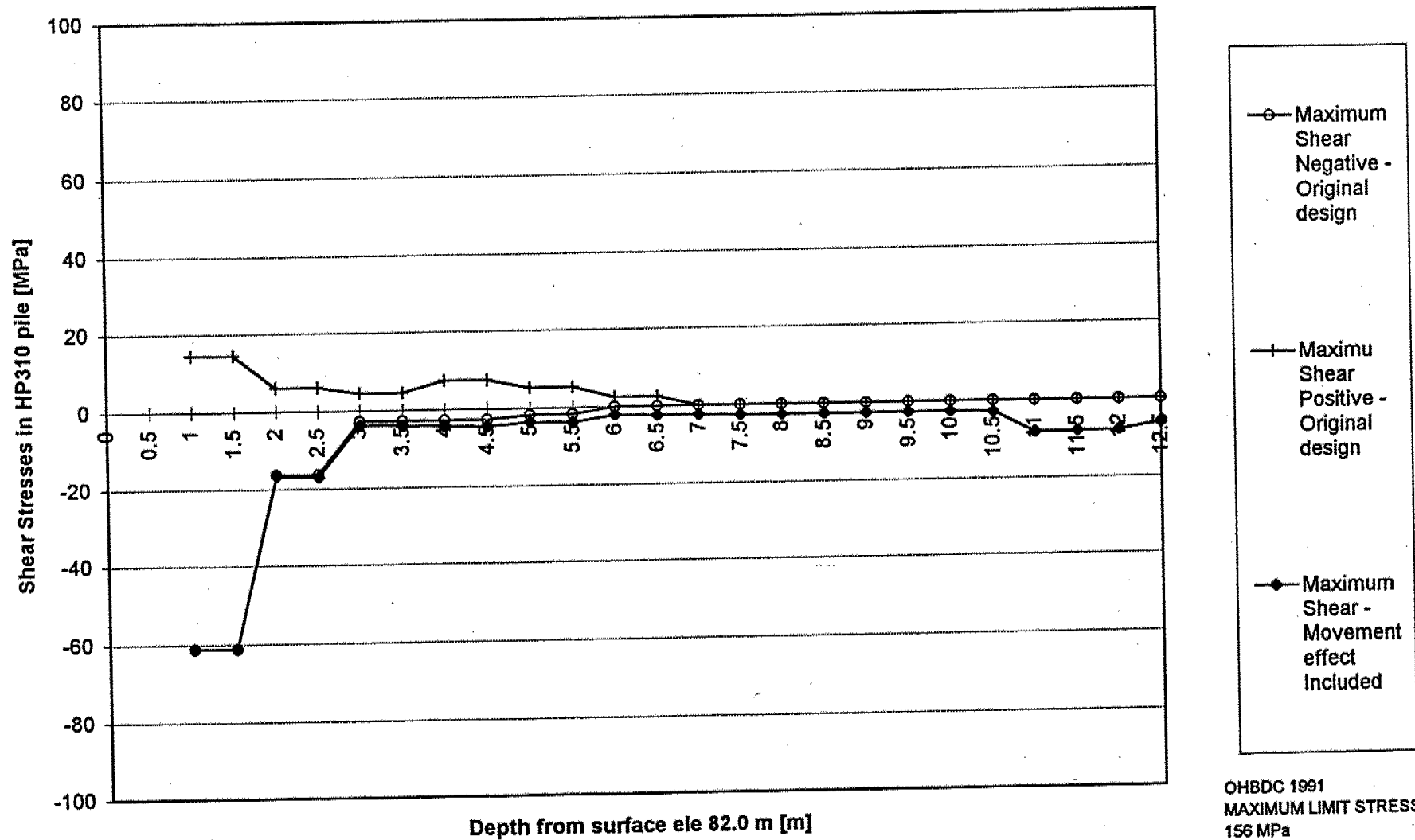


CHART 2

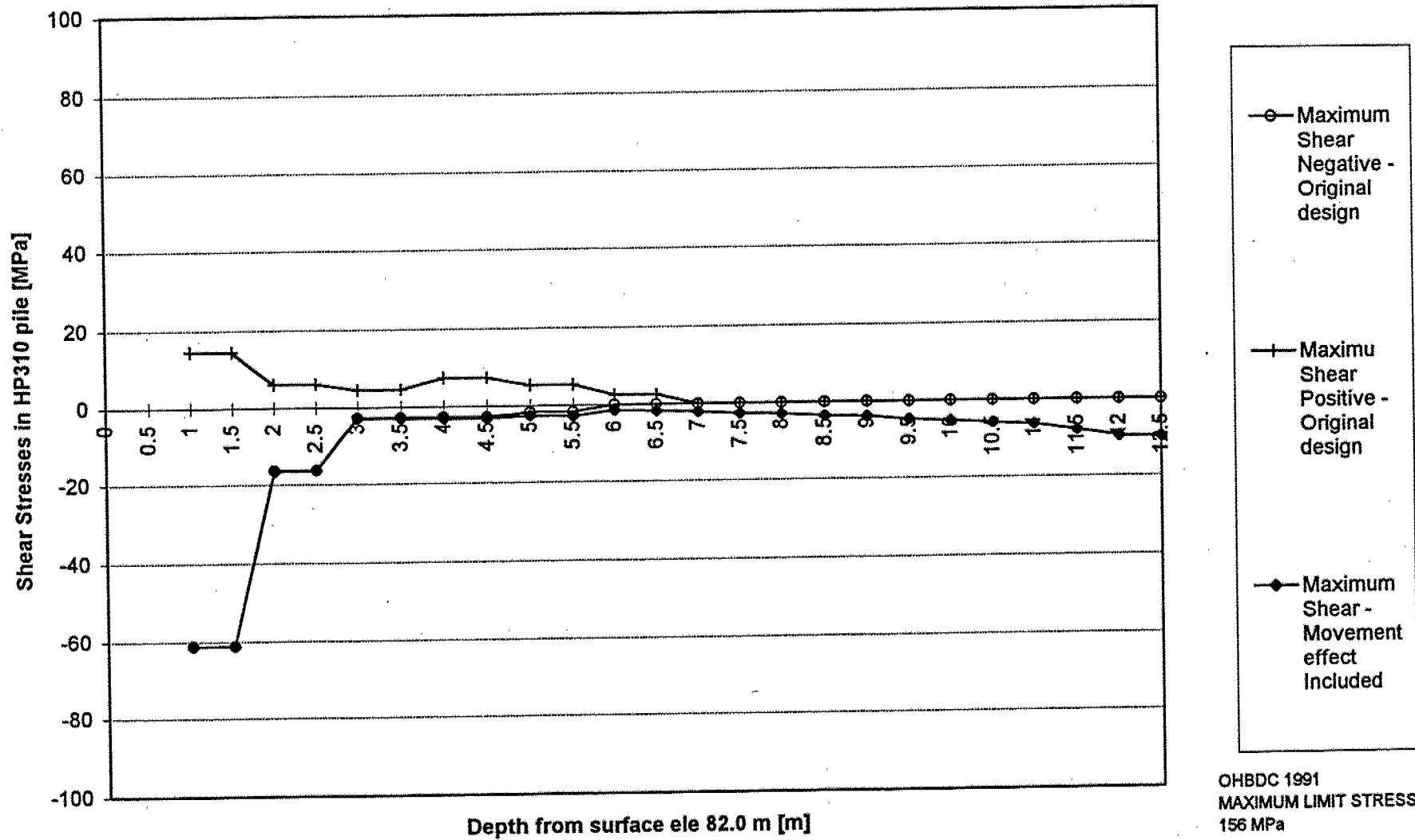
Maximum Tensile Stresses in Piles Trapezoidal Load Distribution



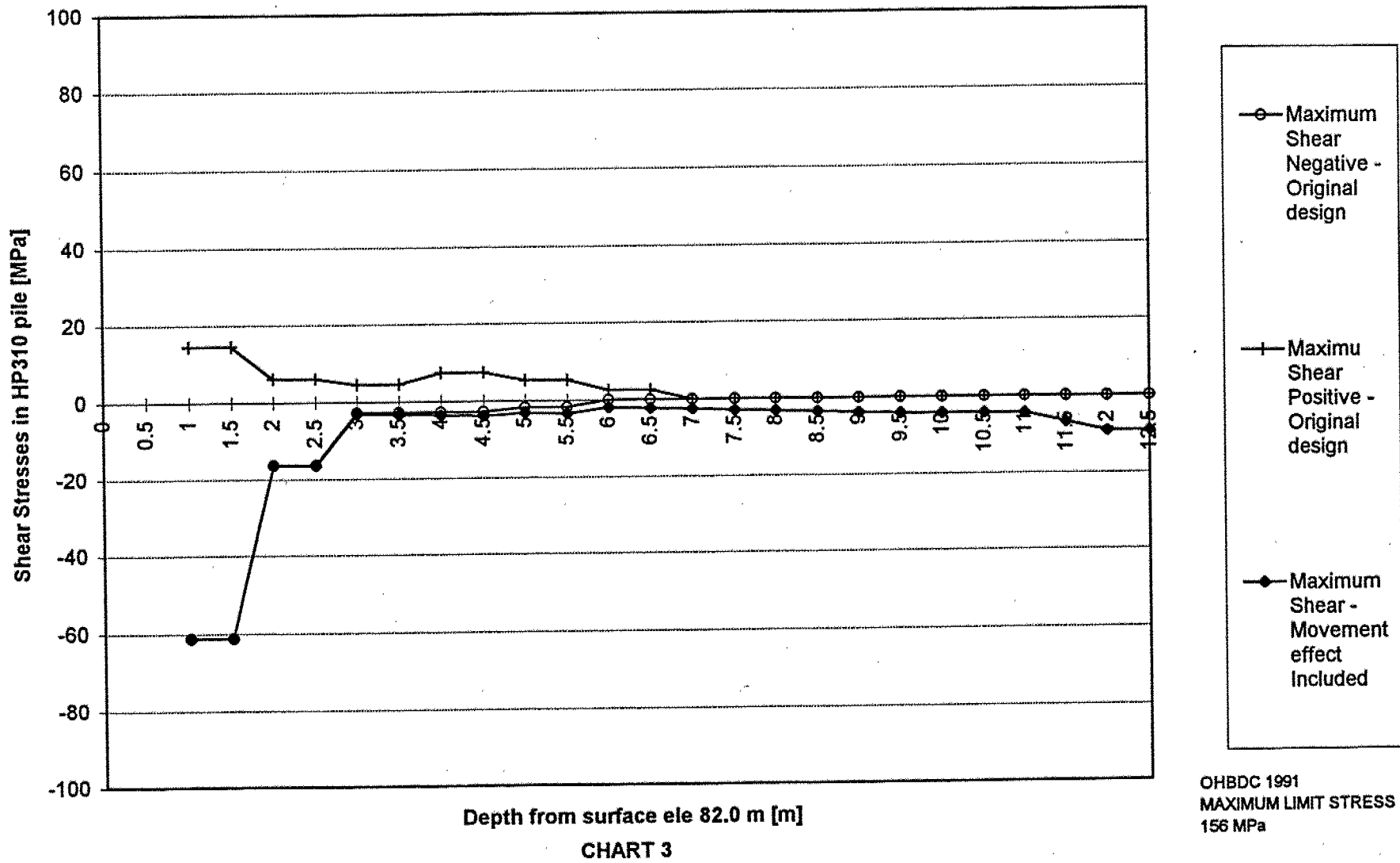
Shear Stresses in Piles Soil Displacement Load Distribution



Shear Stresses in Piles Triangular Load Distribution



Shear Stresses in Piles Trapezoidal Load Distribution



MEMORANDUM



To: V.F. Boehnke
Head, Structural Section
4th Floor, Atrium Tower

Date: June 29, 1994

Attn: K. Wong, Sr. Structural Engineer

From: Foundation Design Section
Room 315, Central Bldg.

Tel: 235-3731
Fax: 235-5240

Re: Caisson Foundation
Q.E.W. - Eighteen Mile Creek
W.P. 624-90-01/02/03/04, Site 18-20
District 4, Burlington

A Contractor inquired if we intend to socket bell of caisson into bedrock, as he claims this is a very difficult and expensive operation.

Based on the above concern, we had a meeting with George Al-Bazi, Dave Dundas and myself on June 29, 1994. In our meeting, we agreed to propose some design revision on caisson foundation after the Award of Tender.

We have calculated additional socket required for equivalent capacity as bell and determined total socket into bedrock should be 3 m (instead of 1.5 m) for straight 900 mm diameter shaft.

It is also agreed, to propose for Construction Office to negotiate change with the Contractor by offering this alternative if there are no extra costs.

If you have any questions, please contact this office.

A handwritten signature in black ink that reads "Tae C. Kim".

Tae C. Kim, P. Eng.
Sr. Foundation Engineer

for

D. Dundas, P. Eng.
Chief Foundation Engineer
(Acting)

DD/TCK/jb

MEMORANDUM



To: V.F. Boehnke
Head, Structural Section
4th Floor, Atrium Tower

Date: May 2, 1994

Attn: K. Wong, Sr. Structural Engineer

From: Foundation Design Section
Room 315, Central Bldg.

Tel: 235-3731
Fax: 235-5240

Re: Review of Preliminary Drawings and NSSP
Q.E.W. - Eighteen Mile Creek
W.P. 624-90-01/02/03/04, Site 18-20
District 4, Burlington

Further to your speedy memos dated April 27, 1994, the Contract Drawings and Special Provisions for the aforementioned structure have been reviewed by this office.

Based on the review, it is our opinion that the design conforms to our comments on the preliminary drawings. However, the following comments should be made.

- 1) During the pile driving, the steel "H" piles should be set to a termination of 8 blows for the last 12 millimetres of penetration using a hammer transferring about 60 kilojoules energy per blow to the pile.
- 2) Based on recent experience in the vicinity of Jordan Harbour, due to the possible difficulty removing loose material from the bottom of caissons, the caissons should be socketed at least 1.5 metre (previous recommendation, 0.5 m) into the sound shale bedrock. Accordingly, the caisson bottom elevations should be revised on Dwg. No. 4.
- 3) NSSP for caisson piles should be replaced by enclosed new NSSP with the Instruction to Contractor.
- 4) Excavation cut of the forward slope toward 18 Mile Creek should be delayed until the four bridge structures are completed in order to avoid expensive roadway protection schemes.
- 5) The embankment cut should be protected from erosion of slope surface as per M.T.O. practice (OPSD 218.01).

We have no further comments. If you have any questions, please contact this office.



Tae C. Kim, P. Eng.
Sr. Foundation Engineer

for

D. Dundas, P. Eng.
Chief Foundation Engineer
(Acting)

DD\TCK\jb

CAISSON PILES

Instructions to Contractor

Q.E.W. Crossing at 18 Mile Creek

W.P. 624-90-01 to 04

District 4, Burlington

- 1) These instructions are to be read in conjunction with
 - the Contract Drawings
 - NSSP for Caisson Piles
- 2) A total of 20 cast-in-place caissons are required. Caisson diameter shall be 900 mm. Refer to the Contract Drawings for caisson lengths.
- 3) The Contractor is alerted that the overburden has zones of non-cohesive sands or silts which are susceptible to disturbance and boiling under conditions of unbalanced hydrostatic head. These conditions should be addressed in the installation method proposed by the Contractor.
- 4) The Contractor is advised that occasional cobbles and boulders should be anticipated and addressed in his construction proposal.
- 5) The casing shown on the drawings is a temporary casing and hence shall be removed.
- 6) The details of the steel casing, as specified or as shown on the Contract Drawings, are the minimum dimension required for structural design. The Contractor shall evaluate site conditions and increase casing dimensions as required to ensure practicality of caisson construction.
- 7) The Contractor is advised that caissons will be socketed in bedrock and the bedrock socketing should be addressed in his proposal and costs.



SEND TO

S Holmes
PED C/R

FROM

S JONES

DEPT.

GEOTECH

DATE

Oct 25/93

SUBJECT

WP 435-92-00

SETTLEMENT IN VICINITY OF 18 mile Cr STR. APPROACHES
QEW MAINLINE

Discussion with Tae Kim Foundation section Oct 25/93

- Foundation Report, prediction of 40mm settlement for 1.7m fill
- Foundation section recommends preloading prior to building pavement stack.
- Majority of settlement will be during preloading stage (i.e. 3-4 months)
- Settlement will be no differential

REPLY

∞ It is recommended to ~~maintain~~ use
 composite pavement structure for
 full length of project

cc. Rick Gritter & Parker
 Tae Kim Foundation section

REPLY FROM

REPLY DATE

MEMORANDUM



To: G. Al-Bazi
Principal Design Engineer
Structural Office
4th Floor, Atrium Tower

Date: September 16, 1993

Attn: E. Chan, Project Engineer

From: Foundation Design Section
Room 315, Central Bldg.

Tel: 235-3731
Fax: 235-5240

Re: Review of Preliminary Drawing P-1
Q.E.W. - Eighteen Mile Creek Structures
W.P. 624-90-01/02/03/04, Site 18-20
District 4, Burlington

Further to your memo dated August 16, 1993, the preliminary general arrangement drawing 18-20-P1 for the aforementioned structures, has been reviewed by this office.

Based on the review, it is our opinion that the design conforms to our recommendations. However, the following comments should be made on the above-mentioned drawings.

1. Due to the variation of the sound bedrock surface, the following pile tip elevation should be specified at each abutment and pier locations.

	<u>Q.E.W. Structures</u>	<u>South Service Rd.</u>	<u>North Service Rd.</u>
West Abutment	58.7 - 59.0	59.1	59.0
Piers #1	57.8	57.1	58.3
Piers #2	57.6	57.3	57.8
East Abutment	57.3 - 58.3	56.4 - 57.5	57.3

2. The end-bearing steel 'H' piles should be equipped with standard MTO tip reinforcement and driven to sound bedrock (OPSD-3301.00). During the pile driving, the steel 'H' piles should be set to a termination of 8 blows for the last 12 millimetres of penetration using a hammer transferring about 60 kilojoules energy per blow to the pile.

3. During the caisson installation, groundwater infiltration may have to be controlled by using drilling mud coupled with telescoping liners or other methods. However, regardless of the method used, during withdrawal of the innermost liner, it is recommended that, while pouring, a positive head of concrete should be maintained at all times to prevent intrusion of the surrounding soils, groundwater and/or bentonite slurry (OPSS903.07.03).

4. If an integral abutment is adopted, predrilled oversized holes filled with loose sand will be required to reduce resistance to lateral movements and reduce stresses on the piles. The annular space between the preaugered oversized hole and the pile shall be backfilled with uniformly graded sand (Ottawa type sand). The gradation for the uniformly graded sand shall be as follows:

Backfill to Integral Abutment - Augered Hole

<u>MTO Sieve</u> <u>Designation</u>	<u>Percentage Passing</u> <u>Mass</u>
2 mm (# 10)	100%
600 µm (# 30)	80% - 100%
425 µm (# 40)	40% - 80 %
250 µm (# 60)	5% - 25 %
150 µm (#100)	0% - 6 %

Commercially available materials which meet the above gradation may be considered. The depth of such holes below the abutment shall be at least 3.0 m.

- ✓ 5. Excavation cut of the forward slope toward 18 Mile Creek should be delayed until the four bridge structures are completed in order to avoid expensive roadway protection schemes such as very high temporary shoring system.
- ✓ 6. The embankment cut should be protected from erosion of slope surface as per M.T.O. practice.

We have no further comments. If you have any questions, please contact this office.

Tae C. Kim
Tae C. Kim, P. Eng.
Sr. Foundation Engineer

for

M. Devata, P. Eng.
Chief Foundation Engineer

MD\TCK\mmj

c.c. - V. Boehnke

memorandum



To: V.F. Boehnke
Head, Structural Section
4 th Floor, Atrium Tower

Att: Ken Wong
Sr. Structural Engineer

From: Foundation Design Section
Rm. 315, Central Building

Re: QEW - Eighteen Mile Creek Structures
W.P. 624-90-01 to 04, Site 18-20

July 9/93

This memo was written in response to inquiries from the Structural Consultant concerning detail design of the aforementioned structures. In particular, questions 2 and 3 from the letter dated June 18/93 by C.A. Laborde-Basto, Hatch Associates are addressed below.

1. Horizontal capacities shall be computed in accordance with Section 6-8.3.8 of the O.H.B.D.C. Please find attached a table of the parameters per stratum at the abutment and pier locations for all three proposed structures. These should be adequate for the design purposes of calculating K_s .
2. If sheet piling is to be utilized for the roadway protection the following parameters may be used for their design,
 $\phi' - 30^\circ$
 $c' - 0 \text{ kPa}$
 $\gamma - 20 \text{ kN/m}^3$

Alternatively roadway protection could be considered at this location consisting of soldier piles and timber lagging.

If the schemes above do not provide adequate lateral resistance, soil anchors may be utilized. For design, an Allowable Bond stress of 50 kPa may be used, provided that the anchors are installed using pressure grouting techniques. If post grouting techniques are used, an allowable bond stress of 100 kPa can be used.

We trust this would be sufficient for the purpose of design. Please contact us if you require further assistance.

Taeheul Kim

T.Kim, P.Eng.

Sr.Foundation Engineer

For:

M. Devata, P. Eng.

Chief Foundation Engineer

c.c. - G. Al-Bazi

	ELEVATION (m)	TYPE OF SOIL	AVERAGE DENSENESS OR COMPACTNESS	AVERAGE BLOW COUNT N	ϕ (deg.)	qu (kPa)	γ (kN/m ³)
EAST ABUTMENT	84 - 72 m	Clayey Silt to Silt (FILL)	Firm to Stiff	9	0	100	19.5
	72 - 69 m	Organic Clayey Silt to Silty Clay	Stiff	13	0	130	20.0
	69 - 60 m	Clayey Silt	Stiff	17	0	160	20.5
	60 - 57 m	Het. Mix. of Clayey Silt (TILL)	Hard	>100	0	2000	21.0
	< 57 m	Bedrock (Queenston Shale)	----	----	0	3000	22.0
WEST ABUTMENT	85 - 76 m	Clayey Silt to Silt (FILL)	Firm to Stiff	8	0	100	19.5
	76 - 75 m	Organic Clayey Silt to Silty Clay	Firm	6	0	80	18.0
	75 - 62 m	Clayey Silt	Stiff	12	0	130	20.0
	62 - 59 m	Het. Mix. of Clayey Silt (TILL)	Hard	>100	0	2000	21.0
	< 59 m	Bedrock	----	----	0	3000	22.0
EAST PIER	84 - 75 m	Clayey Silt to Silt (FILL)	Firm to Stiff	14	0	100	19.5
	75 - 70 m	Organic Clayey Silt to Silty Clay	Stiff	13	0	130	20.0
	70 - 69 m	Silty Sand	Compact	18	32	----	20.0
	69 - 60 m	Clayey Silt	Very Stiff	27	0	250	21.0
	60 - 58 m	Het. Mix. of Clayey Silt (TILL)	Hard	>100	0	2000	21.0
	< 58 m	Bedrock	----	----	0	3000	22.0
WEST PIER	84 - 75 m	Clayey Silt to Silt (FILL)	Firm to Stiff	8	0	100	19.5
	75 - 69 m	Organic Clayey Silt to Silty Clay	Firm	6	0	80	18.0
	69 - 68 m	Silty Sand	Compact	15	31	----	19.8
	68 - 60 m	Clayey Silt	Stiff to Very Stiff	21	0	200	20.0
	60 - 58 m	Het. Mix. of Clayey Silt (TILL)	Hard	>100	0	2000	21.0
	>58	Bedrock	----	----	0	3000	22.0



HATCH ASSOCIATES LTD.

HATCH

2800 Speakman Drive, Mississauga, Ontario L5K 2R7, Canada
Telephone (416) 855-7600 Fax (416) 855-8270

June 18, 1993

Mr. G. Al-Bazi, P.Eng.
Ministry of Transportation
Structural Office
Atrium Tower, 7th Floor
1201 Wilson Avenue
Downsview, ON M3M 1J8

Dear Mr. Al-Bazi:

Re: QEW - Eighteen Mile Creek Structures
WP 624-90-01 to 04, Site 18-20

Herewith attached please find 10 prints separately folded, of the Preliminary General Arrangement drawing for approval. Clarification is sought for the following matters:

- there is potential for interference between the north caisson of pier 1 for the westbound QEW bridge and the wingwall of the existing culvert; the relative positions of the new centreline QEW and of that shown on the existing culvert drawings, is required
- provision of riprap across the channel bottom is implied in Figure 4 of the SDR but not required by the hydraulic report
- service duct requirements (e.g. FTMS), number, size and location
- lighting duct requirements and type of barrier wall to accommodate same
- slope protection requirements under the bridges
- anchorage connections to guide rails to OPSP 4010.00 and 918.01, do not appear to allow for unrestrained movement of the barrier walls on integral-abutment bridges; modifications may be necessary.



HATCH

Mr. G. Al-Bazi
Ministry of Transportation
June 18, 1993
Page 2

For detail design, additional information is also required from Planning and Design and Foundation sections.

1. To minimize the sheetpiling for roadway protection due to excavation for the abutments in the QEW median, the following minimum distances to the back of the Jersey barriers from centreline of QEW are necessary; to the south of QEW centreline 3 m and to the north 3.7 m. Temporary slopes of 1:1.5 were allowed for. Please confirm availability of space required.
2. Soil resistance to lateral displacement of 900 mm diameter pier caissons and HP310x79 abutment piles (single row), in the form of the lateral compressibility k_s [MN/m³] is necessary. The short term actions to be resisted at SLS are acceleration forces and daily temperature range and at ULS seismic forces.
3. To retain about 4 m depth of excavation at each abutment about 12m of unsupported sheetpiling roadway protection, approximately on centreline of QEW, is necessary. Estimated elevations of top and bottom of sheetpiling are 84.5 and 72 respectively. For designing the sheetpiling, appropriate ϕ' and c' parameters per stratum are required.

Please advise if you require further information.

Yours truly,

Carlos A. Laborde-Basto, P.Eng.

CAL:bk
Attachments
Ref CO58808.003



Ministry
of
Transportation

Ministère
des
Transports

Tel: (416) 235-3731

Engineering Materials Office
Foundation Design Section
Room 315, Central Bldg.
1201 Wilson Avenue
Downsview, Ontario
M3M 1J8

March 4, 1993

R. Gritter, P. Eng.
Project Manager
C.C. Parker Consultants Limited
1400 Rymal Road East
Hamilton, Ontario
L0R 1P0

Dear Mr. Gritter:

Re: Review of Profile Revision, Q.E.W. Crossing at 18 Mile Creek
W.P. 435-92-00, District 4, Burlington

Further to your letter dated February 22, 1993, the revised Q.E.W. profile between Stations 13 + 700 and 15 + 100, has been reviewed by this office.

We have no comments on the revised profile.

Tae C. Kim

Tae C. Kim, P. Eng.
Sr. Foundation Engineer

for

M. Devata, P. Eng.
Chief Foundation Design

TCK/hh

cc: V. Boehnke

PARKER CONSULTANTS

Done

C.C. Parker Consultants Limited
Consulting Professional Engineers
1400 Rymal Road East, Hamilton,
Ontario L0R 1P0 (416) 385-3234
Fax (416) 385-3534

February 22, 1993

File No. 0472

MINISTRY OF TRANSPORTATION
W.P. 435-92-00, Q.E.W. - JORDAN RD. TO SIXTEEN MILE CREEK
DISTRICT #4 - BURLINGTON

NOTICE OF PROFILE REVISION

A revision will be made to the QEW profile at 18 Mile Creek to move the sag point off the proposed bridges.

Two contract drawings which were distributed for the Final Engineering Review Meeting will be affected by this change. Please review the attached drawings, Sheet 18 and 19 of W.P.435-92-00 which covers the QEW profile from 13+700 to 15+100. The profile control as presented at the Final Engineering Review Meeting is shown as well as a revised profile control.

Please provide any comments of this revised profile control to Mr. R. Gritter at Parker Consultants prior to March 10, 1993.

Distribution:	Mr. A. De Vos	MTO Construction
	Mr. B. Bendall	MTO Electrical
	Mr. D. Gray	MTO Engineering Support
	Mr. T. Steele	MTO Environmental
	Mr. C. Curtis	MTO Geotechnical
	Mr. L. Politano	MTO Planning & Design
	Mr. S. Holmes	MTO Planning & Design
	Mrs. T. Bucci	MTO Property
	Mr. K. Wong	MTO Structural
	Mr. K. Jones	MTO Traffic
	Mr. E. Dufresne	MTO District 4, Burlington
	Mr. N. Close	MTO Landscape Unit
	Mr. T. Kim	MTO Foundations
	Mr. A. Ahmed	MTO Engineering R.O.W.
	Mr. E. Wilson	Parker Consultants
	Mr. P. Hutchinson	Parker Consultants
	Mr. R. Smith	Parker Consultants



Hamilton

London

Ottawa



METRIC

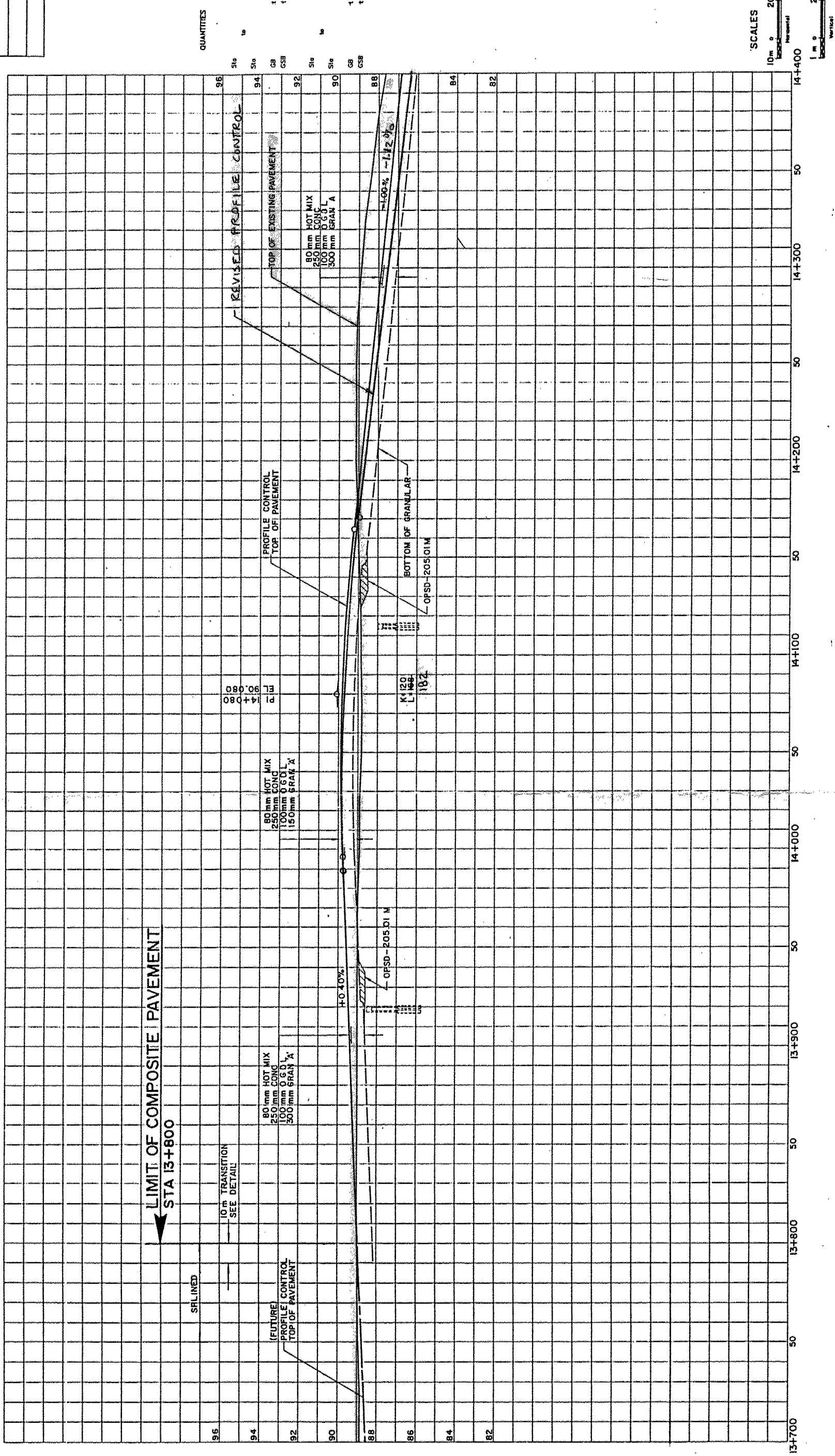
DATE No

CONT No
WP No 435-92-00

PROFILE Q EW
STA 13+700 TO STA 14+400
Survey Revised

SHEET
18

PARKER
CONSULTANTS
Consulting Professional Engineers
Hamilton · London · Ottawa



SCALES
10m 0 20m
Horizontal
1m 0 2m
Vertical

CONT No
WP No 435-92-00

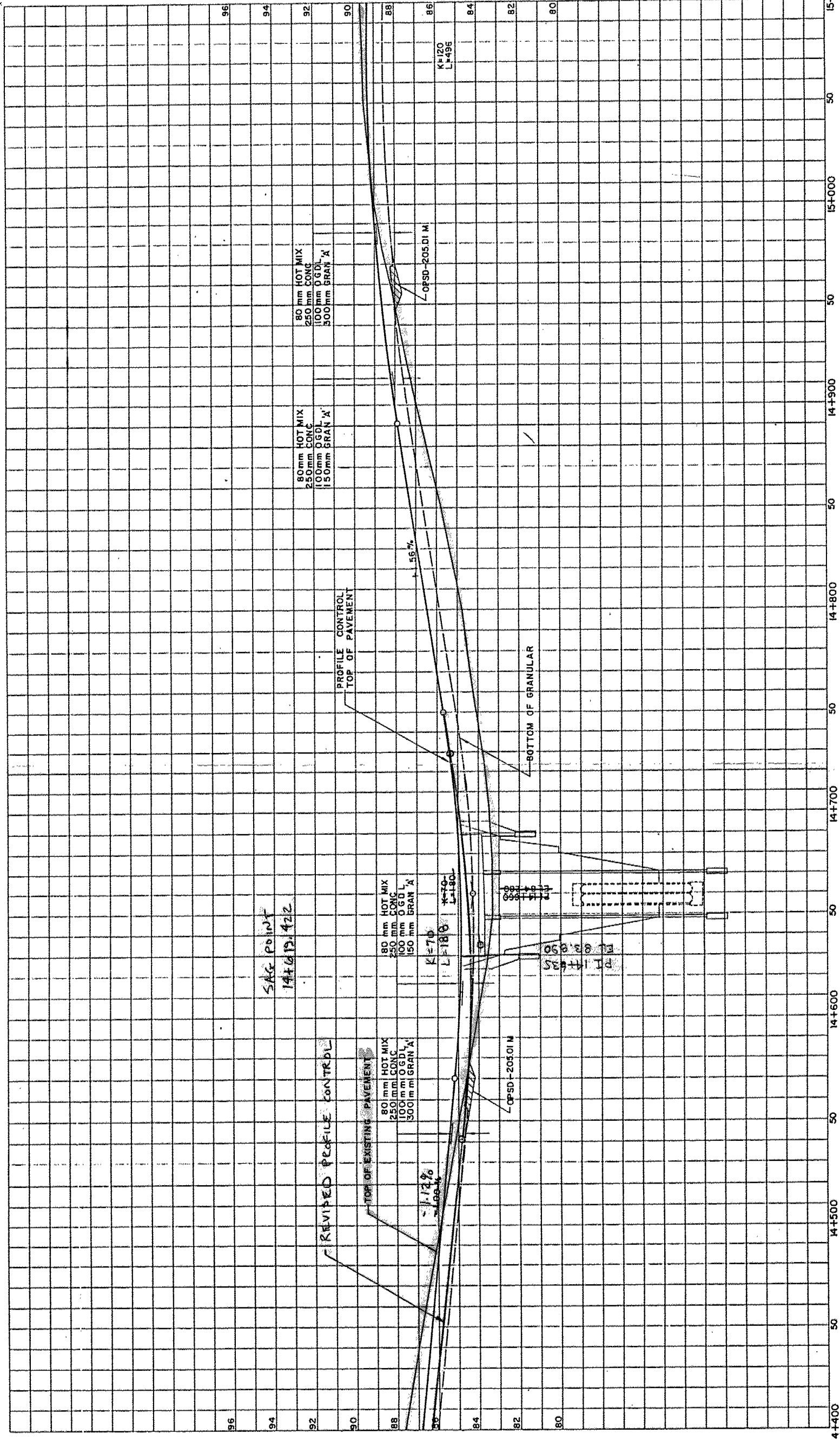
PROFILE Q E W STA 14+400 TO STA 15+100 Survey Revised	SHEET 19
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PARKER
CONSULTANTS

Consulting Professional Engineers
Hamilton • London • Ottawa

→ St Catharine

← Jordan Harbour



SCALES

10m 0 20m
Near ground

1m 0 2m
Near sheet

memorandum



To: V. Boehnke
Head, Structural Section
Central Region
4th Floor, Atrium Tower

Date: 1992 07 26

Attn: K. Wong, Sr. Structural Engineer

From: Foundation Design Section
Room 315, Central Building

Re: Proposed Bridge Structures
Q.E.W. Crossing at 18 Mile Creek
W.P. 624-90-01/02/03/04, Site No. 18-20
District 4, Burlington

The field work for the foundation investigation for the above-mentioned project has been completed. Ten boreholes (BH 91-1 to BH 91-9 inclusive, plus BH 91-5A) for the proposed original large twin culverts (5.9 m x 5.9 m x 137 m) were advanced and sampled between December 2, 1991 and December 20, 1991 to replace the existing twin culverts.

The original design scheme was found to be not environmentally viable. Therefore, a new proposal was brought forth to replace the existing culverts with four (4) bridge structures. An additional nine boreholes (BH 92-1 to BH 92-9) were advanced and sampled as part of this project between May 11, 1992 and May 29, 1992. Due to the urgency of this project, as per your request, we are herewith submitting our advanced recommendations. This memo provides a summary of subsurface conditions and recommendations which will permit your office to proceed with design of the above structure.

The complete foundation investigation and design reports will be forwarded to your office at a later date upon the completion of laboratory tests and drafting. In the meantime, if additional information is required, please contact this office immediately.

SITE DESCRIPTION AND GEOLOGY

The site is located on the existing alignment of Q.E.W. where it crosses the Eighteen Mile Creek in the Town of Lincoln, Regional Municipality of Niagara. The proposed structures are located approximately 2.5 km east of Jordan Harbour. The topography in the area is gently undulating with a valley. Land use in the vicinity of the site is primarily agricultural known as the Niagara Fruit Belt.

Physiographically, the site is located in the "Iroquois Plain" region (Ref: Chapman and Putnam, 1984). The general area was inundated by the Pleistocene Lake Iroquois. As the lake level receded much below the present level of Lake Ontario, the Eighteen Mile Creek cut a valley through the till. Underlying the glacial deposit is the red Queenston Shale from which the till's reddish colour is derived. Later, the rise in the Lake Ontario water level to

approximately its present level, drowned the outlet of the creek and created a lagoon and marsh separated from the lake by a barrier beach. Water flow is to the north into Lake Ontario.

SUBSURFACE CONDITIONS

The subsoil conditions are generally consistent across the site. The Q.E.W crosses the Eighteen Mile Creek at this location. The road embankment fill of the existing Q.E.W. consists of bedding sand, mainly clayey silt and some crushed stone as much as 13.6 m in the middle of valley.

Underlying the fill is a layer of organics which was encountered at all borehole locations except at one borehole location (BH 92-7). The thickness of this layer ranges from 1.1 m at BH 91-1 to 5.6 m at BH 91-2.

Underneath this layer, clayey silt with some sand and trace of gravel was encountered. The thickness of this layer ranges from 6.1 m at BH 91-9 to 18.3 m at 92-7. A thin layer of silty sand and gravel was found at 6 borehole locations (BH's 91-2, 91-3, 91-5, 91-5A, 91-6, and 92-2) in between the organic material and clayey silt with a maximum thickness of about 1.2 m at BH 92-7.

Cohesive glacial till was encountered underneath the clayey silt at all boreholes locations. This material can be described as a heterogeneous mixture of clayey silt, sand and gravel. The maximum thickness of this deposit was found to be about 5.2 m at BH 92-9. This layer is underlain by shale and siltstone bedrock. A thin layer of non-cohesive glacial till, which can be described as a heterogeneous mixture of silt, sand and gravel, was found with a thickness of 2.4 m at BH 91-9.

Sound bedrock was proven in 14 borehole locations by obtaining up to 2.7 m of NQ rock core. The top of bedrock surface ranges from an elevation of 56.4 m at BH 92-9 to an elevation of 60.0 m at BH 91-4 which corresponds to 29.0 m and 23.0 m below the existing surface respectively. The upper portion of bedrock was highly to moderately weathered for a maximum 1.2 m below the rock surface. The sound bedrock surface ranges from an elevation of 56.4 m at BH 92-9 to an elevation of 59.3 m which corresponds to 29.0 m and 23.7 m below the existing ground surface.

Groundwater conditions were observed by measurement of water levels in the open boreholes. The groundwater level was found to be at approximate elevation between 63.7 m at BH 92-7 and 74.6 at BH 91-4 which correspond to depths of 21.5 m and 8.4 m below the existing ground surface. However, it is likely that the groundwater level was the same as the creek level and is subject to seasonal fluctuations.

DISCUSSION AND RECOMMENDATIONS

It is proposed to construct four (4) three span bridge structures (19 m x 22 m x 19 m) which will replace the existing twin concrete culverts along the Q.E.W. crossing the Eighteen Mile Creek. It is understood that an increase in grade for the Q.E.W. embankment will be required to avoid some snow accumulation within the Q.E.W. during the winter season due to the ditch effect on the highway. This would involve the additional placement and compaction of up to 1.7 m fill for the permanent approach along the Q.E.W. to the same level with the existing South and North Service Roads.

Recommendations pertaining to the foundations of the new bridges and related earth works are summarized as follows.

Structure Foundations

East and West Abutments

In view of the low shear strength and compressibility of the organic silt and clayey silt with organics, and the extensive clayey silt layers, conventional spread footing shallow foundations are not applicable at this site. It is recommended that the abutment may be supported on end-bearing steel "H" piles, equipped with reinforced tips in order to facilitate pile penetration through the basal glacial structure and driven to sound bedrock.

In consideration of no additional load application underneath the pile cap at the both abutments, the following design parameters are suggested for the purpose of the O.H.B.D.C..

<u>Pile Type</u>	<u>Factored Axial Capacity at U.L.S.</u>	<u>Axial Capacity at S.L.S. Type II</u>
HP 310 x 79	1150 KN	900 KN
HP 310 x 110	1600 KN	1150 KN

Pile tip elevations for estimating the pile lengths are given below.

<u>Structure</u>	<u>East Abutment(Elevation)</u>	<u>West Abutment(Elevation)</u>
Q.E.W. Eastbound and Westbound lanes (WP 624-90-01/02)	57.3 m - 58.3 m	58.7 m - 59.0 m
Q.E.W. South Service Road (WP 624-90-03)	56.4 m - 57.5 m	59.1 m
Q.E.W. North service Road (WP 624-90-04)	57.3 m	59.0 m

Battered piles should be installed, where required, to resist lateral load on abutments.

In view of the extreme denseness of the glacial till stratum located immediately above the bedrock, some piles may not penetrate this dense stratum. In such a case, the pile capacity should be controlled in the field using current MTO pile driving standards. However, attempts should be made in all cases to drive the piles to the bedrock surface. It should also be noted that the pile driving be controlled by maximum capacity of piles.

During pile driving, the steel "H" pile should be set to a termination of 8 blows for the last 12 millimetres of penetration using a hammer transferring about 60 kilojoules of energy per blow to the pile.

Provision should be made to restrike all piles to confirm the set after adjacent piles have been driven. Piles that do not meet the design set criteria on the first restrike would require additional restriking. A minimum of 48 hour should be allowed before restriking a pile.

In order to enhance pile driving, the fill material immediately below pile caps, should not contain particle sizes greater than 75 mm.

Alternatinetly, caisson foundations can be considered for the both abutments. Details for caissons will be discussed in Pier Foundations.

East and West Piers

In consideration of the existence of weak and compressible organic silt, clayey silt with organics, and extensive clayey silt layers, conventional spread shallow foundations are not applicable for the piers at this site. It should be noted that during the construction, to avoid the problems associated with excavation through embankment toward longitudinal direction , it is

recommended that the structural loading at the piers be transferred to the underlying sound bedrock by means of bored cast-in-place caissons installed through the embankment and overburden.

The caisson should have a minimum length to diameter ratio of 3 within the bedrock and should be socketed at least 0.5 metre into the sound shale bedrock. The caissons may be design using an end bearing factored capacity at Ultimate Limit States of 3500 kilopascals. Serviceability Limit States is not relevant to caissons founded on bedrock since the stresses required to produce detrimental settlements will be larger the value given for the factored bearing capacity at ULS.

An ultimate axial load bearing capacity of 1600 kN may be assumed for 760 millimetre diameter caissons founded as outlined above and with a tip elevation at or between 57.1 m and 58.8 m.

The following caisson bottom elevations are suggested for estimating the caisson length.

<u>Structure</u>	<u>East Pier (Elevation)</u>	<u>West Pier (Elevation)</u>
Q.E.W. Eastbound and Westbound lanes (WP 624-90-01/02)	57.6 m - 58.0 m	57.8 m - 58.8 m
Q.E.W. South Service Road (WP 624-90-03)	57.3 m	57.1 m
Q.E.W. North Service Road (WP 624-90-04)	57.8 m	58.3 m

Caissons should be a minimum diameter of 760 mm to allow for both the clean out of any basal debris and final evaluation of the rock surface in order to confirm the above-stated capacities.

Groundwater infiltration may have to be controlled by using drilling mud coupled with telescoping liners or other methods. However, regardless of the method used, during withdrawal of the innermost liner, it is recommended that, while pouring, a positive head of concrete should be maintained at all times to prevent intrusion of the surrounding soils, groundwater and/or bentonite slurry.

The proposed method of caisson installation be in accordance OPSS 903.07.03 and subject to review by this office.

It should be noted that to avoid the need for deep excavation of the existing

embankment and frost protection, caisson cap for the piers should be placed immediately below the bridge decks.

Other Considerations

Lateral Earth Pressures

Free draining material such as Granular "A" or Granular "B" is recommended as an appropriate backfill material to prevent hydrostatic pressure build-up on the abutment walls. Design parameters of the soil are given below for the purpose of the O.H.B.D.C.

	Granular "A"	Granular "B"
Angle of Internal Friction (ϕ)	35°	30°
Unit Weight (kN/m ³), γ	22.8	21.2
Coefficient of Active Earth Pressure (Ka)	0.27	0.33
Coefficient of Earth Pressure at Rest (Ko)	0.43	0.5

The earth pressure coefficient at rest is to be used when the design of abutment walls are rigid and unyielding.

Dewatering

No major dewatering difficulties are anticipated for footing excavation in consideration of lower groundwater levels and the relatively low permeability of the clayey silt fill. However, if localized seepage or surface water to accumulates in excavations, it can be controlled by perimeter ditches and pumping from corner sumps.

Frost Protection

The pile caps should be placed so as to have a minimum earth cover of 1.2 m to allow for frost protection.

Settlement of Approach Embankments

Based on currently available information, it is our understanding that the proposed grade of the roadway at the approach embankments will be raised by up to 1.7 m. Consequently, the additional fill will act as a surcharge and induce settlement within the underlying organic silt and clayey silt with organics.

To minimize settlement, total embankment loading should not exceed the preconsolidation pressure, (6'p), of the silty clay to clay. Based on the results of the consolidation test and our previous experience with similar organic deposits, it is estimated that (6'p), is about 330 kPa. Since the field

vane shear strengths were found to be reasonably constant with this deposit, it is anticipated that $6'p$, would not vary significantly with depth. Accordingly, the clayey with organics at mid-level of the stratum is considered to be preconsolidated by about 66 kPa in excess of the existing effective overburden stress. Assuming that the unit weight of compacted granular fill is about 21 kN/m^3 , 1.7 m of such fill would correspond to a surcharge of 36 kPa. As such, the proposed additional embankment loading will not result in stresses higher than $6'p$. Based on the compression index, C_r , obtained from the consolidation test, the magnitude of settlement of the approach embankment will be modest, being in the order of 40 mm. Consideration should be given to placing and compacting the additional fill well in advance of bridge construction to allow some settlement to take place prior to final road paving.

Stability of Approach Embankment

The stability analyses were carried out based on a minimum design underdrained shear strength of 50 kPa for the clayey silt with organics, as established by field vane tests. Since no additional fill will be placed on the South and North Service Road, the existing slope will be stable in the transverse direction.

However, since additional earth fill of 1.7 m will be placed within Q.E.W. Lanes and the existing embankment fill of about 11 m will be cut down to creek level, stability analyses were carried out to evaluate the overall stability of the approach fill in the longitudinal direction and also the internal stability of the fills were examined. Based on the "Total Stress" analyses, the forward slope for the Q.E.W. structures and North and South Service Road Structures will require a 3 m wide mid-height beam with a 2H to 1V side slope to meet a minimum factor of safety of 1.3.

Construction Consideration

Prior to raising the existing embankment, topsoil, organics and other foreign materials should be removed from the fill placement area. Such locations, should be excavated and backfilled with an approved, compacted fill material. Clean earth fill at suitable water contents should be used as embankment fill.

The additional fill should be placed in thin layers and compacted as per MTO standards. The fill should be keyed into the pre-existing slope in accordance with current MTO standards and practice.

Excavations for abutments, pile-caps construction may be carried out in temporary open cuts with side slopes maintained at gradients not steeper than 1.5H:1V through the clayey silt fill. All excavations should be carried out according to the guidelines contained in the latest edition of the Ontario Occupational Health and Safety Act. To prevent softening of the exposed clayey silt fill, it is recommended that Granular "A" material be placed on the

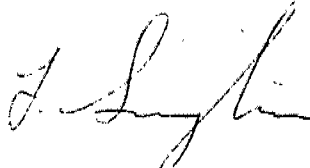

excavation base to provide protection to the founding stratum as soon as the base of the excavation has been inspected.

Excavation cut of the forward slope toward 18 Mile Creek should be delayed until the four bridge structures are completed in order to avoid expensive roadway protection scheme such as very high temporary shoring system.

For erosion protection purposes, the embankment forward slopes should be covered with a layer of topsoil and property seeded in order to enhance adequate vegetation cover. Suitable protection measures should also be provided to the creek banks adjacent the abutments. Such measures may include appropriately sized rip-rap underlain by suitable granular filter.

We believe that this memorandum meets with your present requirements.

If you have any questions, Please contact this office.

Tae C. Kim, P. Eng.
Sr. Foundation Engineer

for

M. Devata, P. Eng.
Chief Foundation Engineer

MD/TCK/nd

cc: K. Bassi

memorandum



To: V. Boehnke
Head, Structural Section
Central Region
4th Floor, Atrium Tower

Date: 1992 04 02

Attn: K. Wong, Sr. Structural Engineer

From: Foundation Design Section
Room 315, Central Building

Re: Stability of Forward Slope for the
Proposed Bridge Structures at
Q.E.W. Crossing 18 Mile Creek
District 4, Burlington

Further to the telephone conversation between your Mr. K. Wong and the writer on March 27, 1992, the stability of forward slope for the proposed bridge structures at the above site has been reviewed by this office.

Based on the preliminary analysis, the forward slope for the Q.E.W. structures will require a 3 m wide mid-height berm with a 2H to 1V side slope to meet minimum factor of safety. A typical section is shown on an attached figure.

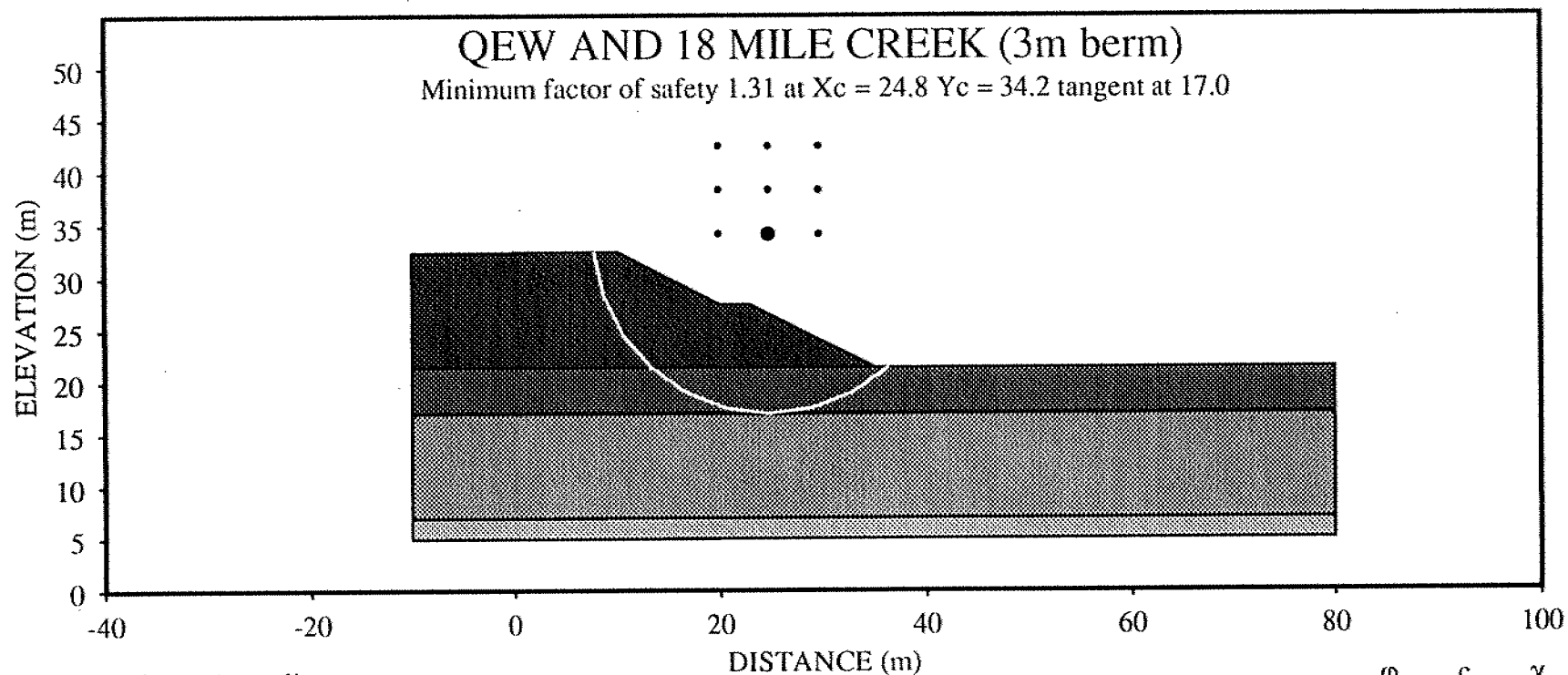
A more detailed analyses will follow, pending future additional field investigation.

If you have any questions regarding this memo, please contact this office.

Tae C. Kim
Tae C. Kim, P. Eng.
Sr. Foundation Engineer

TCK/mmj

c.c. - D. Wilson - Marshall, Macklin, Monaghan Ltd.
R. Gritte - C.C. Parker Consultants
E. Ellard - Planning & Design

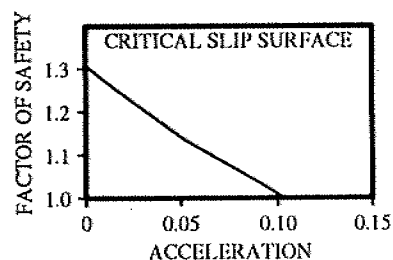


ϕ	c	γ
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30.0	0.0	21.0	CLAYEY SILT (FILL)
0.0	50.0	18.0	ORGANIC SILT

CRITICAL ACCELERATIONS

0.090	0.105	0.165
0.087	0.100	0.173
0.097	0.104	0.204



ϕ	c	γ
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0.0	92.0	21.3	CLAYEY SILT
35.0	0.1	22.0	COHESIVE TILL

FACTORS OF SAFETY

1.362	1.348	1.496
1.332	1.311	1.498
1.348	1.308	1.588