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FOUNDATION DESIGN SECTION

foundation investigation and design report

ENGINEERING MATERIALS OFFICE
FOUNDATION DESIGN SECTION

WP	427-94-01	DIST	31
HWY	3	STR SITE	5-96

Catfish Creek Bridge Replacement

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GEOCRES 40I14-127

DATE DEC 19 1996

FOUNDATION INVESTIGATION REPORT
For
Catfish Creek Bridge Replacement
W.P. 427-94-01, Site 5-96
Highway 3, District 31, London

INTRODUCTION

This report contains the results of a foundation investigation carried out at the crossing of Catfish Creek and Highway 3. The fieldwork was carried out between 1996 01 22 and 1996 02 07, and comprised of four sampled boreholes and Dynamic Cone Penetration Test adjacent to three of these holes.

Boreholes were advanced to a maximum depth of 40.0 m (El. 172.3) below the existing road level using a 82 mm I.D. continuous flight hollow stem auger and BW casing.

SITE DESCRIPTION

The site under investigation is located approximately 1.1 km east of Highway 74 at the crossing of Highway 3 and Catfish Creek in the Township of Yarmouth, County of Elgin.

The width of the creek along the centreline of Highway 3 is approximately 24.0 m, and the depth of water during peak flood is expected to be about 2.6 m at the deepest location. Rate of flow of the creek is relatively slow and the observations made during the investigation indicate a surface flow of about 2 to 3 m/sec. However, the rate of flow may be increased substantially during the peak flood.

The topography of the area is generally undulating with rolling fields. A succession of ridges and valleys lies in the county of Elgin. The ridges are moraines of calcareous clay or silty clay while in the valley, it is common to find alluvium of gravel, sand or silt. Physiographically, the area is located in the region known as the "Mount Elgin Ridges".

SUBSURFACE CONDITIONS

The underlying subsoil at this site consists of 1.4 m to 2.7 m loose to compact granular fill underlain by a minimum of 0.7 m to a maximum of 2.0 m stiff clayey silt. The clayey silt layer on the west side of the creek is underlain by 2.9 m to 3.9 m dense to very dense sand with occasional silt layers. However, on the east side, the clayey silt layer is underlain by 4.9 m to 6.1 m compact to very dense silt with varying proportion of sand, and occasional gravelly sand and silty sand layers. The sand and silt deposits are underlain by 2.8 m to 3.5 m compact to very dense gravelly sand which is followed by 6.3 m to 11.4 m dense to very dense sand. The sandy deposit is underlain by dense to very dense silty sand which extends to the depth probed. For classification purposes, the soils encountered at this site can be divided into seven different zones.

a) Silty Sand, Some Gravel (Fill)
b) Clayey Silt, Trace of Gravel
c) Sand, Trace of Silt, Trace of Gravel
d) Silt, Some Sand
e) Gravelly Sand, Trace of Silt
f) Sand, Trace of Silt, Trace of Gravel
g) Silty Sand, Trace of Gravel

The subsurface conditions encountered during the course of the investigation, together with the field and laboratory test results are shown on the Record of Borehole Sheets contained in the Appendix of this report. A stratigraphical section is shown on Drawing No: 4279401-A. This drawing also shows the location and elevation of the borings. Description of the strata encountered are given below.

Silty Sand, Some Gravel (Fill)

This granular fill which was placed to raise the final grade of Highway 3, was encountered only in Boreholes #1 & #2, and consists of loose to compact silty sand with varying proportion of gravel sized particles. Thickness of this fill varies from 1.4 m to 2.7 m and extends to elevations 210.9 to 209.6. The Standard Penetration Test results vary from 7 blows/0.3 m to 30 blows/0.3 m indicating loose to compact state of denseness.

Clayey Silt, Trace of Gravel

The granular fill in the vicinity of the abutments is underlain by this clayey silt. However, in other area, it was encountered immediately below the ground level. Thickness of this clayey silt layer varies from a minimum of 0.7 m to a maximum of 2.0 m and extends to elevations 208.9 to 208.1. The natural moisture content varies from 17.5% to 19.5% with an average value of 18%. Atterberg Limits determined for the representative samples of this deposit are shown on figure 1. The Standard Penetration Test values (9 blows/0.3 m to 11 blows/0.3 m) indicate stiff consistency.

Sand, Trace of Silt, Trace of Gravel

The clayey silt layer on the west side of the creek is underlain by this sand deposit. Occasional silt layers varying in thickness from a minimum of 0.75 m to a maximum of 1.5 m were also encountered in this deposit. Thickness of this sand deposit varies from 2.9 m to 3.9 m and extends to elevations 205.3 to 205.0. Standard Penetration Test results (29 blows/0.3 m to 60 blows/0.3 m) indicate dense to very dense state of denseness.

Silt, Some Sand

The clayey silt layer on the east side of the creek is underlain by this silt deposit with varying proportions of sand sized particles. Occasional silty sand and gravelly sand layers varying in thickness from 600 mm to 750 mm were also encountered in this deposit. Thickness of the silt deposit varies from 4.9 m to 6.1 m and extends to elevations 203.7 to 203.2. The Gradation Test carried out on representative samples are shown on Figure 2 in an envelope form. Test results indicate that this deposit is predominantly composed of silt (75% to 90%). Standard Penetration Test results vary over a wide range (12 blows/0.3 m to 69 blows/0.3 m) indicating compact to very dense state of denseness.

Gravelly Sand, Trace of Silt

The sand and silt deposits are underlain by this gravelly sand strata. Thickness of this strata varies from 2.8 m to 3.5 m and extends to elevations 202.5 to 198.8. Gradation test results are shown on Figure 3 in an envelope form. The test results indicate that this deposit is predominantly composed of sand (48% to 61%) and gravel (32% to 64%). Standard Penetration Test results vary over a wide range (15 blows/0.3 m to 82 blows/0.3 m) indicating compact to very dense state of denseness.

Sand, Trace of Silt, Trace of Gravel

This sand deposit was encountered on both sides of the creek immediately below the gravelly sand strata. Thickness of this deposit varies from 6.3 m to 11.4 m and extends to elevations 194.0 to 191.0. Gradation Test results are shown on Figure 4 in an envelope form. The test results indicate that this deposit is predominantly composed of sand (90% to 99%). Standard Penetration Test in this deposit indicates dense to very dense state of denseness (34 blows/0.3 m to over 100 blows/0.3 m).

Silty Sand, Trace of Gravel

The sand deposit is underlain by this silty sand layer. The results of the Gradation Test are shown on Figure 5 in an envelope form. These results indicate that this layer is predominantly composed of silt (14% to 38%) and sand (62% to 86%). Standard Penetration Test values vary from 31 blows/0.3 m to over 100 blows/0.3 m indicating dense to very dense state of denseness. The full extent of this layer was not proven below elevation 172.3.

Groundwater Conditions

The groundwater level measurements were taken in open boreholes during our investigation, and was observed between elevations 207.0 and 207.8. Seasonal fluctuation of the groundwater level may be expected due to the influence of the creek. The highest water level in the creek was observed at elevation 208.5 during our investigation. However, the record indicates that the water level in the creek may be expected as high as elevation 209.8. The groundwater level in each borehole is as follows:

Borehole No.	Elevation
1	207.8
2	207.0
3	207.8
4	207.7

DISCUSSION AND RECOMMENDATIONS

General

It is proposed to replace the existing structure at the crossing of Highway 3 and Catfish Creek due its state of deterioration. The options that are under consideration for the replacement bridge are as follows:

1) Three span (app. 11.0 m end spans and 18.0 m centre span) structure consisting of reinforced concrete deck supported on CPCI girders. The profile grade will be identical to the existing road level. i.e. El. 212.2. (Option 1)

2) A single span 36.5 m long structure consisting of reinforced concrete deck supported on trapezoidal steel boxes. The profile grade of Highway 3 at the west abutment will be set approximately at elevation 212.6 and at east abutment , it will be set at El. 212.4 (Option 2).

We understand that the old road located approximately 35 m north of the existing structure will be used for the diversion of traffic during construction, and the new structure will be constructed along the same horizontal alignment as the existing bridge.

The existing bridge was built in 1937. Structural Drawing Nos. D2439-1 & 2 dated May 31, 1937 indicate that the bridge is a single span structure with 7.0 m long cantilevers on both sides of the piers and consists of reinforced concrete slab supported on girders. The piers which are located approximately 22.0 m apart are supported on 2.2 m wide footings placed at about elevation 205.1. The footings at both piers are protected from scour by cofferdam consisting of sheet piles driven to approximately elevation 201.0.

The approach embankments appear in good condition. Although, the forward slopes are protected from erosion by sand bags and rip-raps, undercutting of fill by the creek action or erosion is evident, especially on the east side of the creek. The reinforcement of the deck has been exposed and corroded at several locations. In addition, voids have been created at the underside of the deck due to the spalling of concrete. It appears that rehabilitation work at the underside of the deck as well as on the forward slopes was carried out recently.

Structure Foundation
Option 1

The subsoil conditions at this site would permit the proposed structure to be supported on shallow foundation provided that the footings are effectively protected from scour or undercutting by the creek action.

Piers

It is recommended that both piers be supported on spread footing placed at about elevation 205.0, and designed assuming the following bearing pressures.

Factored Bearing Pressure at U.L.S. = 500 kPa
Bearing Pressure at S.L.S. = 300 kPa

Abutments

The footings for the abutments may be placed at about elevation 208.0 and designed assuming the bearing pressures given below.

Factored Bearing Pressure at U.L.S.	=	650 kPa
Bearing Pressure at S.L.S.	=	350 kPa

The bearing pressures (SLS & ULS) recommended above are based on the assumption that the footings will not be less than 2.0 m wide, and will not be placed at a level higher than the elevations indicated. The total settlement for the allowable bearing pressures (SLS) recommended is not expected to exceed 25 mm. The factored bearing pressure at ULS could be increased substantially, if footing width larger than 2.0 m is used.

The footings which are proposed to be located in the river bed should be protected from scour, and the sheet pile for the cofferdam should be driven to at least 3.0 m below the maximum depth of scour. However, the footings at the abutment locations require effective protection from erosion or undercutting by the creek action.

Considering the scouring properties of the subsoil encountered at this site, it may be advisable to support the piers and abutments on HP 310 X 110 steel H-piles driven to about elevation 184.0. The pile within the maximum depth of scour shall be considered laterally unsupported. The following axial capacities are recommended for the design of pile foundation.

Factored Axial Capacity at U.L.S. = 1200 kN
Axial Capacity at S.L.S. = 1000 kN

Driving of piles shall be carefully monitored and controlled employing the Hiley Dynamic Pile Driving Formula driven in accordance with MTO Standards SS103-10 or SS103-11 assuming an ultimate capacity of 3000 kN.

Option 2

The conditions at the abutment locations for this option are similar to that of Option 1. The design of footings as well as pile foundation shall be based on the recommendations given under Option 1.

Spread footings as well as the pile caps should have a minimum of 1.2 m earth cover to protect against the frost penetration.

Lateral Earth Pressure

Earth pressure should be computed as per Section 6.7.4.5 of the O.H.B.D.C., and the coefficient of earth pressure at rest shall be used for rigid and unyielding walls. The granular "A" or "B" backfill should be in accordance with the Special Provision No. 109F03. The following parameters are recommended for the granular backfill.

	Granular "A"	Granular "B"
Angle of Internal Friction	$\phi = 35°$	$\phi = 30°$
Unit Weight (kN/m^3)	$\gamma = 22.8$	$\gamma = 21.2$

The sliding resistance may be estimated assuming an unfactored coefficient of friction value of tan 30°.

Approach Embankment

The finished grade of the replacement bridge will be set between elevations 212.4 and 212.6. No major instability problems are anticipated for the approach embankment constructed with 2 horizontal to 1 vertical side slope. The fill should consist of well compacted acceptable material. The topsoil as well as any spongy or soft area observed within the base width of the embankment should be removed before placing the fill.

The forward slopes as well as the side slopes should be protected by rockfill consisting of 150 mm to 200 mm size rock to a height of at least 1.0 m above the high water level, especially on the upstream side.

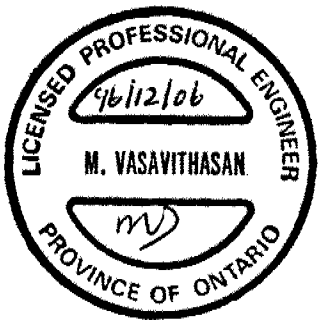
Other Considerations

The construction of pile caps as well as spread footings for both options will have to be carried out below the water level, and for this purpose, a dewatering scheme consisting of cofferdam will be required. The soil at this site is susceptible to conditions of unbalanced hydrostatic head and seepage forces, and is likely to boil and become unstable under such conditions. The contractor shall maintain the stability of the soil at the base of the concrete footings as well as pile caps at all times from commencement of their construction to placing of concrete.

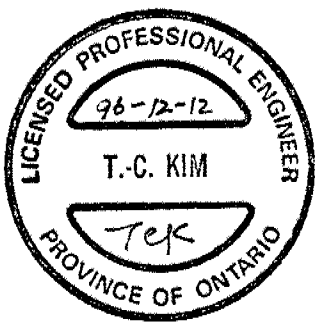
The construction of pile caps for piers will require dewatering scheme and this could be avoided by providing pile bents at these locations.

MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of M. Vasavithasan, Foundation Engineer. The equipment used was owned and operated by London Soil Test Limited. This report was prepared by M. Vasavithasan and reviewed by Tae C. Kim, Senior Foundation Engineer.



M. Vasavithasan, P. Eng.
Foundation Engineer



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

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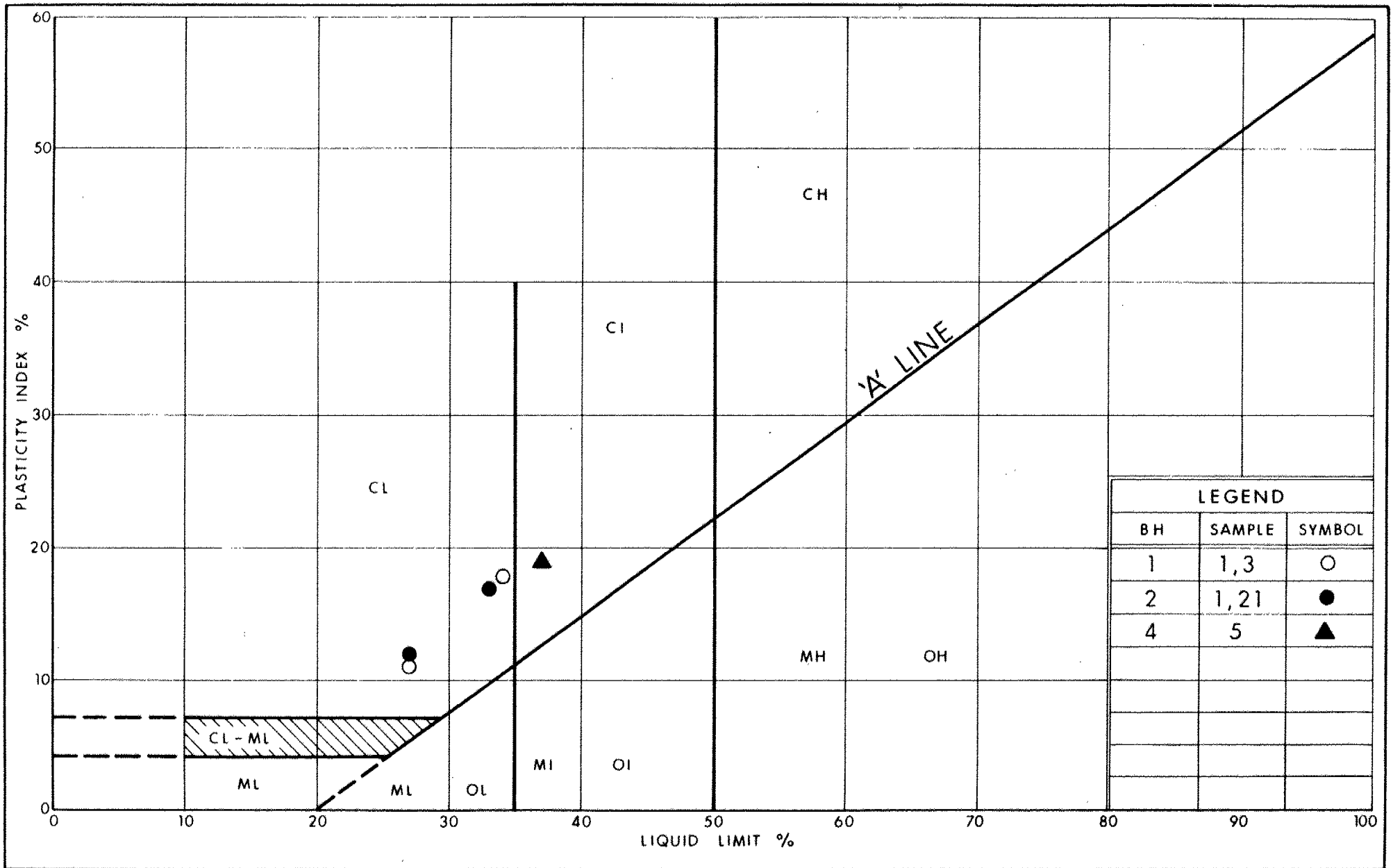
APPENDIX

Oct 75, FF-S-21



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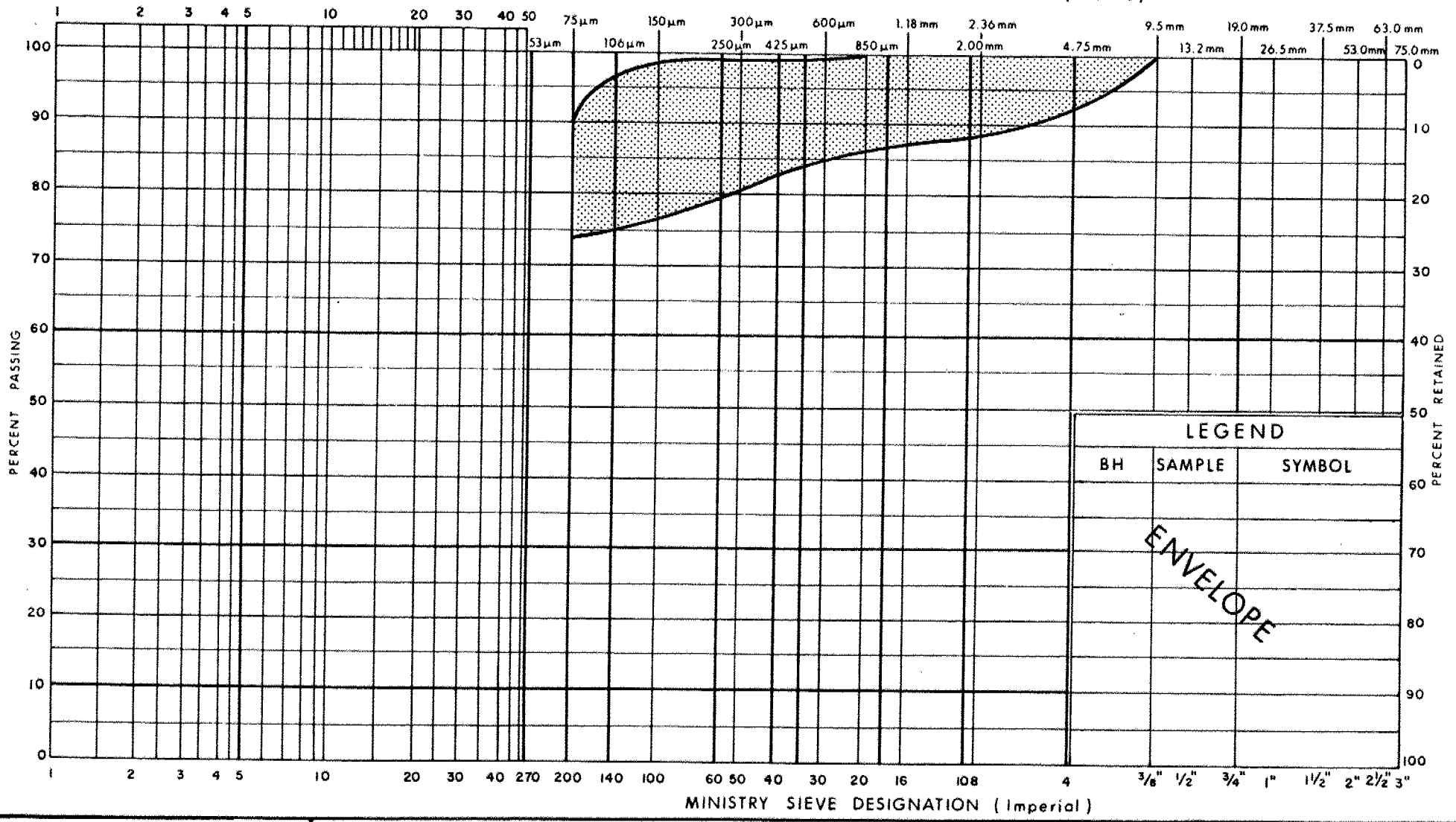
PLASTICITY CHART
CLAYEY SILT

FIG No 1
WP 427-94-01

78 12 M

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



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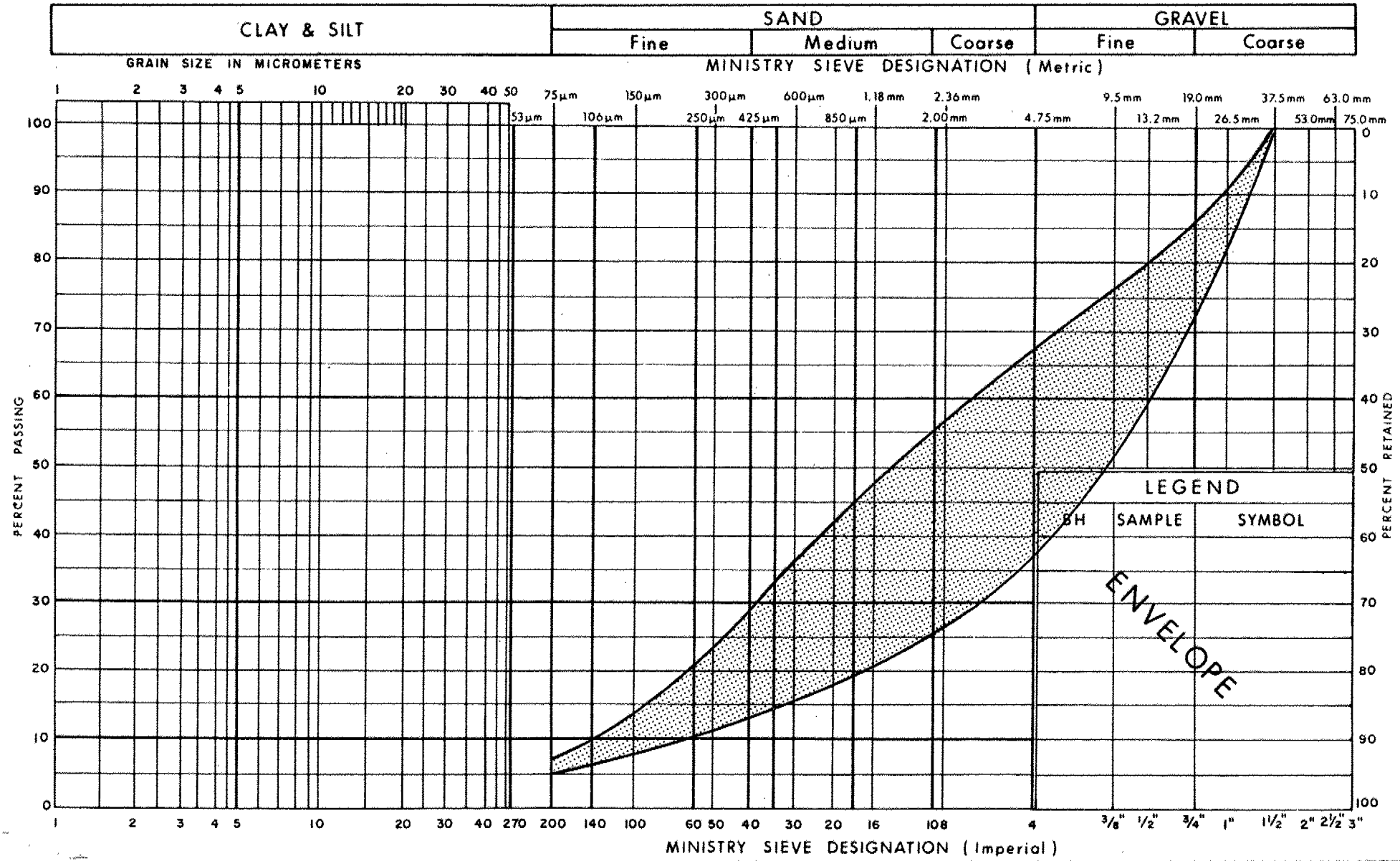
GRAIN SIZE DISTRIBUTION

SILT, SOME SAND

FIG No 2

WP 427-94-01

UNIFIED SOIL CLASSIFICATION SYSTEM



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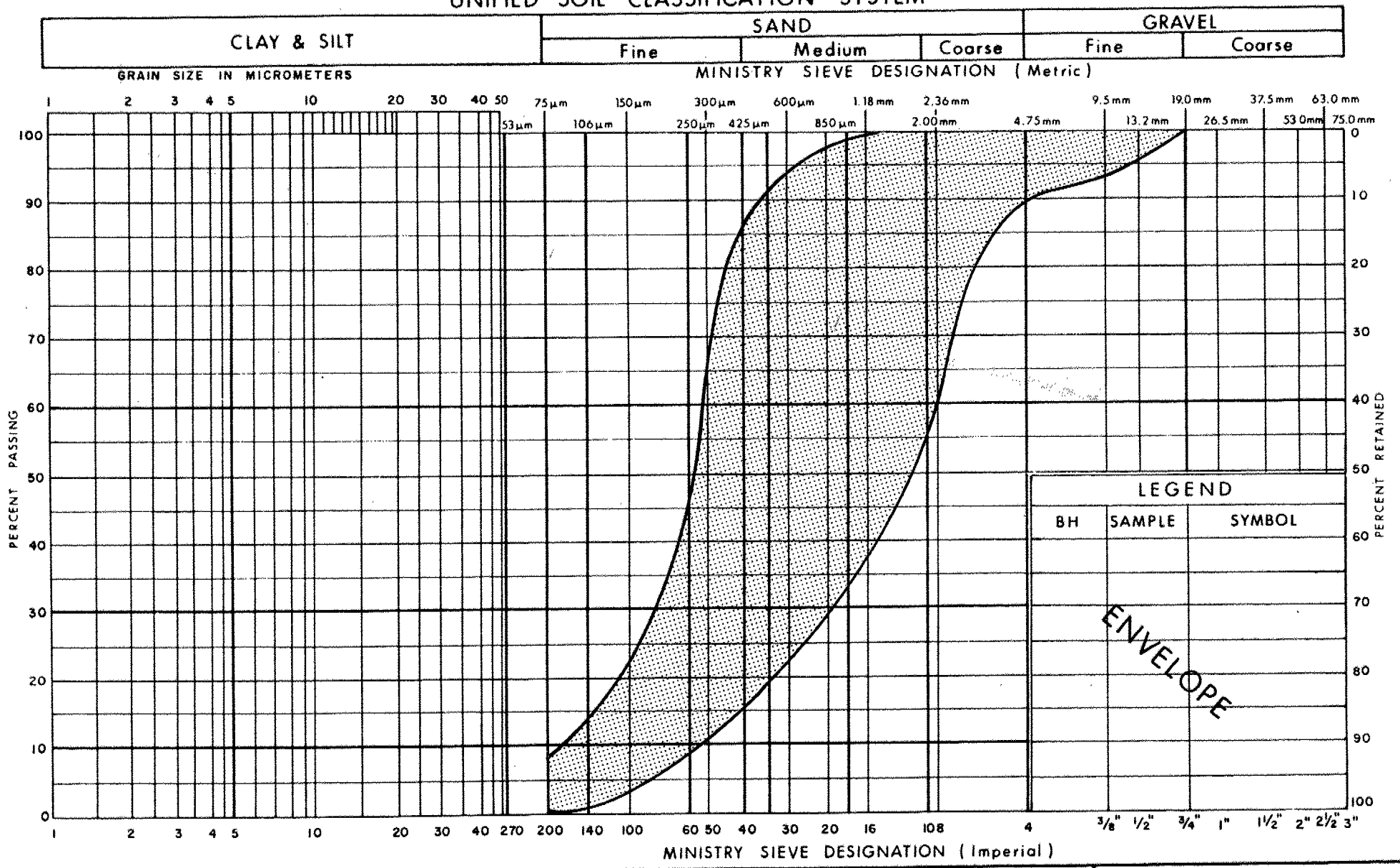
GRAIN SIZE DISTRIBUTION
GRAVELLY SAND, TR OF SILT

FIG No 3

WP 427-94-01

UNIFIED SOIL CLASSIFICATION SYSTEM



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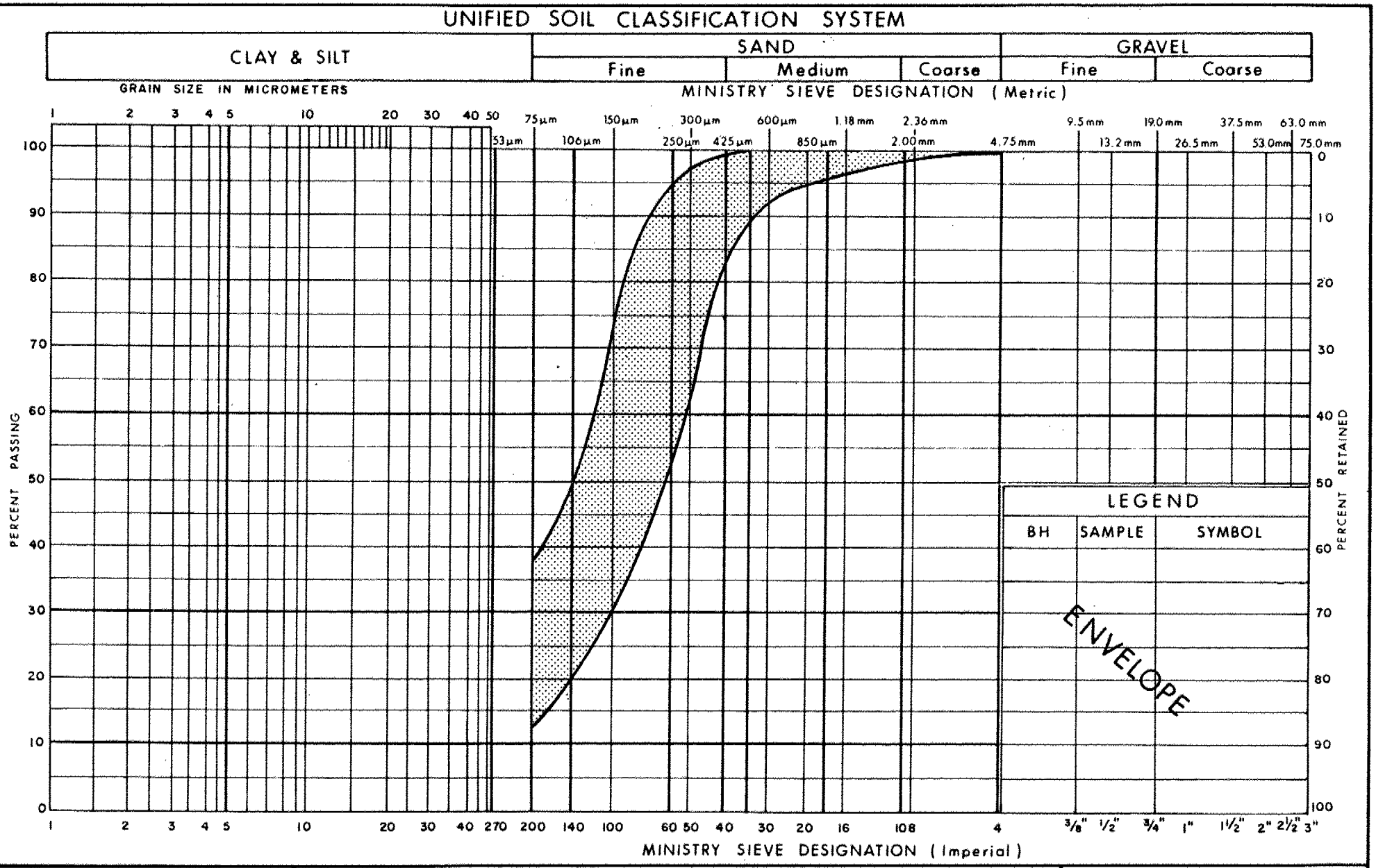
GRAIN SIZE DISTRIBUTION

SAND, TR OF SILT, TR OF GRAVEL

FIG No 4

W P 427-94-01

78 12 M



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GRAIN SIZE DISTRIBUTION
SILTY SAND

FIG No 5
W P 427-94-01

RECORD OF BOREHOLE No 1 — 1 OF 1 — METRIC

W.P. 427 - 94 - 01 | LOCATION CO - ORDS: N 4 738 151.8; E 421 616.4 | ORIGINATED BY M V

DIST 31 HWY 3 | BOREHOLE TYPE HOLLOW STEM AUGER, WASHING & CONE TEST | COMPILED BY M V

DATUM GEODETIC | DATE 1996 01 22 to 25 | CHECKED BY T C K

SOIL PROFILE ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L / WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
212.3	Highway 3 W B L									
0.0 / 210.9	Asphalt — SILTY SAND With Gravel, Compact (Fill)						212	AUGER		
1.4 / 208.9	CLAYEY SILT, Trace of Gravel, Stiff		1	SS	13					
			2	SS	9		210			
			3	SS	9					
3.4	Some Gravel		4	SS	37	▼	208			
	Silt, Some Sand		5	SS	45					
			6	SS	48					5 17 (78)
205.0	SAND, Trace of Silt, Trace of Gravel, Dense to Very Dense		7	SS	60		206	120/ 25cm		
			8	SS	31					10 85 (5)
7.3 / 201.8	GRAVELLY SAND, Trace of Silt, Compact to Very Dense		9	SS	15		204			
			10	SS	82					40 52 (8)
			11	SS	61		202			
10.5			12	SS	48					0 95 (5)
			13	SS	66		200			
			14	SS	89		198			1 90 (9)
	SAND, Trace of Silt, Trace of Gravel, Dense to Very Dense		15	SS	67					0 91 (9)
			16	SS	58		196			
			17	SS	162		194			
191.0							192			
21.3			18	SS	88					
							190			
	SILTY SAND, Trace of Gravel, Very Dense		19	SS	102		188			0 66 (14)
184.4							186			
			20	SS	31					
27.9	End of Borehole									

+3, ×5 : Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No 2 — 1 OF 2 — METRIC

W.P. 427 - 94 - 01 LOCATION CO - ORDS: N 4 738 140.1; E 421 641.7 ORIGINATED BY M V

DIST 31 HWY 3 BOREHOLE TYPE HOLLOW STEM AUGER, WASHING & CONE TEST COMPILED BY M V

DATUM GEODETIC DATE 1996 02 02 to 06 CHECKED BY T C K

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
209.3	Ground Surface				
0.0 / 208.2	CLAYEY SILT, Trace of Gravel, Stiff	1	SS	9	
1.1	Silt	2	SS	29	
	SAND, Trace of Silt, Trace of Gravel, Dense to Very Dense	3	SS	33	
205.3		4	SS	35	
4.0		5	SS	48	64 31 (5)
	GRAVELLY SAND, Trace of Silt, Dense to Very Dense	6	SS	43	
		7	SS	66	45 48 (7)
202.5		8	SS	42	
6.8		9	SS	56	
		10	SS	34	
		11	SS	73	0 95 (5)
		12	SS	44	
	SAND, Trace of Silt, Trace of Gravel, Dense to Very Dense	13	SS	97	
		14	SS	62	
		15	SS	73	0 99 (1)
191.1					
18.2		16	SS	64	
	Sandy Silt	17	SS	74	1 49 (50)
	SILTY SAND, Trace of Gravel, Very Dense	18	SS	72	
		19	SS	50	
179.8					
30.5	Continued				Continued

GROUND WATER CONDITIONS

ELEVATION SCALE: 208, 206, 204, 202, 200, 198, 196, 194, 192, 190, 188, 186, 184, 182, 180

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

WATER CONTENT (%): 10 20 30

120/25cm

UNIT WEIGHT γ kN/m^3

$^{+3}_{-5}$: Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 2 — 2 OF 2 — METRIC

W.P. 427 - 94 - 01 LOCATION CO - ORDS: N 4 738 140.1; E 421 641.7 ORIGINATED BY M V

DIST 31 HWY 3 BOREHOLE TYPE HOLLOW STEM AUGER, WASHING & CONE TEST COMPILED BY M V

DATUM GEODETIC DATE 1996 02 02 to 06 CHECKED BY T C K

SOIL PROFILE ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
178.8	Continued										
30.5	SILTY SAND, Trace of Gravel, Very Dense		20	SS	62		178				
	Clayey Silt Silt		21	SS	107	/15cm	176				
							174				
172.3			22	SS	60						0 78 (22)
37.0	End of Borehole										

+3, ×5 : Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 3 — 1 OF 2 — METRIC

W.P. 427 - 94 - 01 | LOCATION CO - ORDS: N 4 738 158.2; E 421 657.7 | ORIGINATED BY M V
DIST 31 HWY 3 | BOREHOLE TYPE HOLLOW STEM AUGER, BW CASING & CONE TEST | COMPILED BY M V
DATUM GEODETIC | DATE 1996 01 24 to 30 | CHECKED BY T C K

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS
210.5	Ground Surface					
0.0	Topsoil					
	CLAYEY SILT, Trace of Gravel					
0.7	Silty Sand, Tr. of Gravel		1	SS	34	
			2	SS	12	
			3	SS	39	▼
	SILT,		4	SS	22	
	Some Sand, Trace of Gravel,		5	SS	38	
	Compact to Dense		6	SS	44	
			7	SS	43	
203.7			8	SS	31	
6.8	Sand, Tr. of Silt		9	SS	26	
			10	SS	20	
	GRAVELLY SAND, Some Silt,		11	SS	74	
	Dense to Very Dense		12	SS	41	
198.8						
11.7			13	SS	33	
	SAND,		14	SS	52	
	Trace of Silt, Trace of Gravel,		15	SS	119	
	Dense to Very Dense					
192.5						
18.0			16	SS	84	
			17	SS	82	
	SILTY SAND, Trace of Gravel,		18	SS	122	
	Very Dense		19	SS	116	
180.0						
30.5	Continued					

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

ELEVATION SCALE: 210, 208, 206, 204, 202, 200, 198, 196, 194, 192, 190, 188, 186, 184, 182

120/25cm

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L
WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)	GR	SA	SI	CL
	0	10	(90)	
	8	17	(75)	
	2	95	(3)	
	32	61	(7)	
	7	90	(3)	
	1	75	(24)	

Continued

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

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

RECORD OF BOREHOLE No 3 2 OF 2 METRIC

W.P. 427 - 94 - 01 LOCATION CO - ORDS: N 4 738 158.2; E 421 657.7 ORIGINATED BY M V

DIST 31 HWY 3 BOREHOLE TYPE HOLLOW STEM AUGER, BW CASING & CONE TEST COMPILED BY M V

DATUM GEODETIC DATE 1996 01 24 to 30 CHECKED BY T C K

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
1029.5	Continued										
30.5			20	SS	121						
	SILTY SAND, Trace of Gravel, Very Dense						178				
			21	SS	87		176				
	Clayey Silt										
173.5			22	SS	75		174				0 75 (25)
37.0	End of Borehole										

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

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

RECORD OF BOREHOLE No 4 — 1 OF 1 — METRIC

W.P. 427 - 94 - 01 LOCATION CO - ORDS: N 4 738 144.1; E 421 678.1 ORIGINATED BY M V

DIST 31 HWY 3 BOREHOLE TYPE HOLLOW STEM AUGER & WASHING COMPILED BY M V

DATUM GEODETIC DATE 1996 01 31 & 02 01 CHECKED BY T C K

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
212.3	Highway 3 E B L						
0.0	Asphalt						
	SILTY SAND, Some Gravel, Loose to Compact (Fill)		1	SS	17		
			2	SS	30		
209.6			3	SS	7		
2.7	CLAYEY SILT, Trace of Gravel, Stiff		4	SS	11		
208.1			5	SS	11		
4.2	Gravelly Sand		6	SS	45	▼	
	SILT, Some Sand, Dense to Very Dense		7	SS	32		0 16 (84)
			8	SS	69		
	Silty Sand		9	SS	65		
			10	SS	56		
203.2							
9.1	Silty Sand		11	SS	38		7 51 (42)
			12	SS	34		
			13	SS	128	/23cm	
	SAND, Trace of Silt, Trace of Gravel, Dense to Very Dense		14	SS	42		0 94 (6)
			15	SS	55		
194.0							
18.3			16	SS	119		
			17	SS	123		
	SILTY SAND, Trace of Gravel, Very Dense		18	SS	133		
184.4			19	SS	112		0 5 (95)
27.9	End of Borehole						

ELEVATION SCALE: 212, 210, 208, 206, 204, 202, 200, 198, 196, 194, 192, 190, 188, 186

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m³

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

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

EXPLANATION OF TERMS USED IN REPORT

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

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

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

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

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

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

STRESS AND STRAIN

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

MECHANICAL PROPERTIES OF SOIL

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

PHYSICAL PROPERTIES OF SOIL

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

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

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METRIC

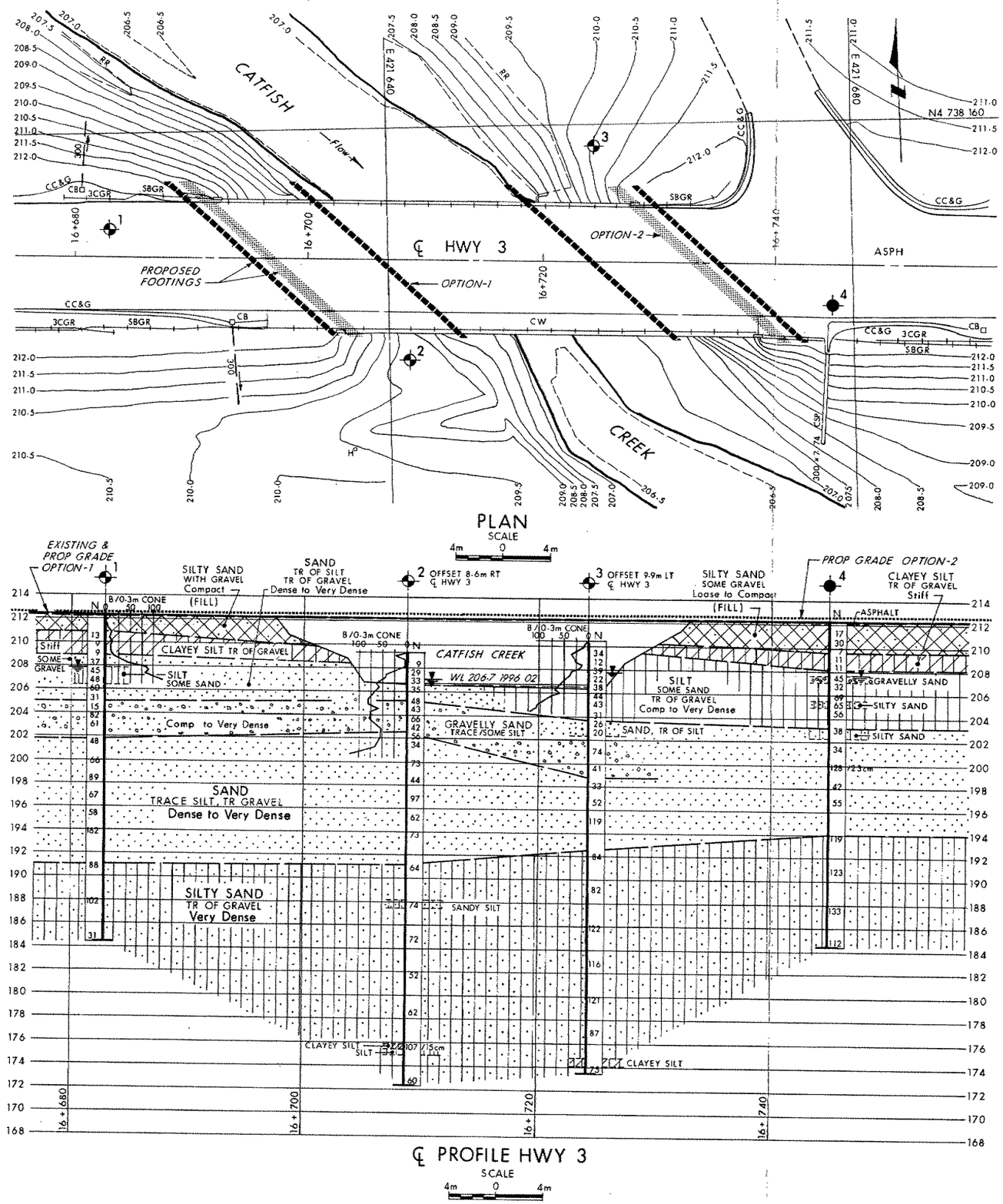
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

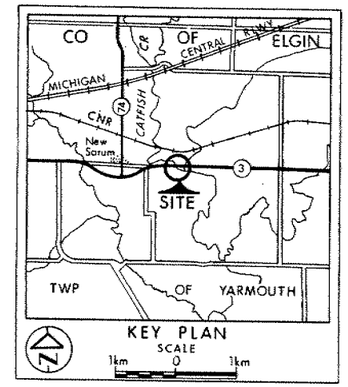
CONT No
WP No 427-94-01

CATFISH CREEK

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)
- WL at time of investigation 1996 01 & 02

No	ELEVATION	CO-ORDINATES NORTH	EAST
1	212.3	4 738 151.8	421 616.4
2	209.3	4 738 140.1	421 641.7
3	210.5	4 738 158.2	421 657.7
4	212.3	4 738 144.1	421 678.1

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

LICENSED PROFESSIONAL ENGINEER N. VASANTHASAN PROVINCE OF ONTARIO

Geocres No 40114-127

HWY No 3			DIST 31
SUBM'D MV	CHECKED [illegible]	DATE 1996 11 28	SITE 5-96
DRAWN DT	CHECKED BS	APPROVED	DWG 4279401-A

REF No E-120-3-1, 1996 04