

#69-F-93

W.P. 43-66-09

H.W.Y. #402, LINE 'C',

AND C.A.H.

WATERWORKS ROAD





MEMORANDUM

To: Mr. B. R. Davis,  
Bridge Engineer,  
Bridge Office,  
Admin. Bldg.

FROM: Foundation Section,  
Materials & Testing Office,  
Room 107, Lab. Bldg.

ATTENTION: Mr. S. McCombie

DATE: December 8, 1969

OUR FILE REF.

IN REPLY TO

DEC 10 1969

SUBJECT:

FOUNDATION INVESTIGATION REPORT

For

Proposed Crossing at  
Waterworks Road and C.A.H. #402  
Line 'C', Lots 3 & 4, Conc. VII  
Twp. of Sarnia -- County of Lambton  
District #1 (Chatham, Ont.)  
W.J. 69-F-93 -- W.P. 43-66-09

Attached, we are forwarding to you, our detailed foundation investigation report on the subsoil conditions existing at the above structure site.

We believe that the factual data and recommendations contained therein, will prove adequate for your design requirements. Should additional information be required, please do not hesitate to contact our Office.

AGS/MdeF  
Attach.

cc: Messrs. B. R. Davis (2)  
H. A. Tregaskes  
D. W. Farren  
W. Zonnenberg  
F. C. Brown  
A. P. Watt  
J. Roy  
B. A. Singh

Foundations Files  
Gen. Files ✓

*A. G. Sternac*  
A. G. Sternac  
PRINCIPAL FOUNDATION ENGINEER

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# FOUNDATION INVESTIGATION REPORT

For

Proposed Crossing at  
Waterworks Road and C.A.H. #402  
Line 'C', Lots 3 & 4, Conc. VII  
Twp. of Sarnia -- County of Lambton  
District #1 (Chatham, Ont.)  
W.J. 69-F-93 -- W.P. 43-66-09

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## 1. INTRODUCTION:

A request for a foundation investigation at the crossing of the proposed C.A.H. #402, Line 'C' and Waterworks Road, was received from Mr. A. P. Watt, Regional Bridge Planning Engineer, in a memorandum dated October 6, 1969.

A field investigation was subsequently carried out by the Foundation Section to determine the subsoil conditions existing at the site. This report contains the results of this investigation and our recommendations pertaining to the design of the proposed structure foundations and approach embankments.

## 2. DESCRIPTION OF THE SITE:

The site of the proposed underpass structure is situated about 9 miles east of Sarnia, approx. 3/4 mi. north of Hwy. #7 on Waterworks Road.

The surrounding area is flat. On the east and north-west side the land is cultivated farmland, but on the west and north-east side the land is covered with bush. A drainage ditch runs along the west side of the existing road.

Physiographically, the site is located in the region referred to as the St. Clair Clay Plain.

### 3. FIELD AND LABORATORY INVESTIGATION PROCEDURES:

A total of seven sampled boreholes and seven dynamic cone penetration tests was carried out during the course of the field work. Boring was achieved by means of a continuous flight auger machine, and conventional diamond drilling equipment adapted for soil sampling purposes. During the field work, disturbed samples were obtained by means of a standard split-spoon sampler: the energy used in driving it, conformed to the requirements of the Standard Penetration Test. 'Undisturbed' samples were recovered using 2-inch I.D. Shelby tubes which were pushed into the soil hydraulically or by hand. Where possible, field vane tests were carried out at elevations 12 inches below sample depths.

Dynamic cone penetration tests were carried out adjacent to each borehole with the exception of B.H. #9, and also at four other locations. Driving energy to advance the cone was 350 ft.-lbs. per blow.

The bedrock was proved at two borehole locations using BXL rock coring equipment.

All boreholes were surveyed in the field by personnel from London Region Engineering Surveys Section. The locations and elevations of the borings are shown on Drawing No. 69-F-93A which accompanies this report.

All samples were visually examined and classified at the site as well as in the laboratory. Following this inspection laboratory tests were carried out on selected samples to determine the following physical properties:

- Atterberg Limits
- Moisture Content
- Grain-size Distribution
- Undrained Shear Strength
- Bulk Density

The test results are summarized on the Record of Borehole sheets contained in the Appendix of this report.

#### 4. SOIL TYPES AND SOIL CONDITIONS:

##### 4.1) General:

Generally uniform subsoil conditions were found to prevail over the site area. The subsoil consists of a deep deposit of cohesive material (clayey silt and silty clay) with some sand and traces of gravel, underlain by shale and limestone bedrock. The boundaries between different deposits are shown on the Record of Borehole sheets attached to the Appendix. The estimated stratigraphical profile of Drawing 69-F-93A is based upon this information.

From ground level downward, the various strata are described in some detail with regard to soil types and soil properties, as follows:

##### 4.2) Fill Material:

This material was encountered in B.H. #7 from the existing roadway level (El. 606) to approx. El. 602. The material in the deposit consists of sand and gravel with traces of fines. The relative density may be described as compact.

##### 4.3) Clayey Silt with some Sand and Traces of Gravel:

This deposit was intersected in all borings and extends from immediately below the topsoil, or the above mentioned fill material, down to approx. El. 567. The material in the deposit consists of clayey silt with some sand and traces of gravel. A plot of Plasticity Index versus Liquid Limit (Fig. 1) shows the points to fall within the CL zone.

The upper portion (about 10 ft.) of the stratum is a very stiff desiccated surface crust (except in B.H. #2 where the 'N' value was found to be 8). This zone is brown in colour due to oxidation. The natural moisture content, in general, is at or below the plastic limit. Standard Penetration Test 'N' values ranged from 9 to 47 blows per foot. The undrained shear strength is in excess of 2000 PSF. This zone is highly overconsolidated due to desiccation and/or weathering.



4. SOIL TYPES AND SOIL CONDITIONS: (cont'd.) ...

4.3) Clayey Silt with some Sand and Traces of Gravel: (cont'd.)

Below the desiccated layer, the colour of the deposit gradually changes from brown to grey.

The shear strength of the deposit gradually decreases to a minimum value of 500 PSF at approx. El. 580. From this level on, it increases rapidly down to El. 567.

Physical properties of the overall deposit, as determined from field and laboratory tests, are as follows:

Natural Moisture Content (%)	.....	12.0	to	24.0
Liquid Limit (%)	.....	25.0	to	32.0
Plastic Limit (%)	.....	13.0	to	20.0
Bulk Density (PCF)	.....	127	to	139
Field Vane Test (PSF)	.....	480	to	>2000
Unconfined Shear Strength (PSF)	.....	680	to	>2000
'N' Value (Blows/ft.)	.....	9	to	47
Sensitivity	.....	1.5	to	3.0

Typical grain-size distribution curves are included in the Appendix of this report (Figure 2).

All of the field and laboratory shear strength measurements are plotted on Figure 4.

The consistency of the deposit may be described as firm to stiff, except for the crust.

4.4) Silty Clay with some Sand and Traces of Gravel:

This stratum was found to underlie the clayey silt deposit and extends to approximate El. 540.0. The material in the deposit consists mainly of grey silty clay with some sand and traces of gravel.

4. SOIL TYPES AND SOIL CONDITIONS: (cont'd.) ...

4.4) Silty Clay with some Sand and Traces of Gravel: (cont'd.) ..

The test results are plotted on the Record of Borehole sheets, and also on Figures 1, 3 and 4 of the Appendix. The physical properties of the material are as follows:

Liquid Limit % : 35 - 46      Plastic Limit % : 18 - 23  
Moisture Content % : 24 - 42      Bulk Density PCF: 113 - 122

The Atterberg limits are plotted on Figure 1.

Based on laboratory and field measurements, the consistency may be assumed as firm to stiff.

4.5) Clayey Silt to Silty Clay, some Sand, Traces of Gravel:

This deposit was encountered in all boreholes from approx. El. 540.0 down to bedrock. It consists of dark grey clayey silt to silty clay with some sand and traces of gravel. In some samples thin layers of silt and sand were found. The shear strength of the material, as measured by field vane and indicated by standard penetration tests, shows a consistency ranging from stiff to hard.

The physical properties of the material are as follows:

Liquid Limit % : 33 - 38  
Plastic Limit % : 18 - 20  
Moisture Content % : 22 - 31  
Bulk Density PCF : 124

The results of Atterberg limit tests carried out on selected samples, are plotted on Fig. 1, and those of grain-size analyses are plotted on Fig. 3.

4. SOIL TYPES AND SOIL CONDITIONS: (cont'd.) ...

4.6) Bedrock:

The bedrock was proven in B.H.'s 1 and 5. In other boreholes the bedrock surface was assumed to be the level at which practical refusal to washing, augering, or to driving the split-spoon was reached. The rock cores obtained, show the bedrock to be limestone and shale in sound condition as indicated by almost 100% recovery. The bedrock surface varies from El. 493.8 to 498.4.

5. GROUNDWATER CONDITIONS:

The groundwater levels, as observed in the field, are shown on the Record of Borehole sheets. As shown, the water level is close to the ground surface. The augered boreholes were dry at the time of augering, except B.H. #2, and were filled with water later on. This indicates that the material is relatively impermeable and probably most of the water seeped in through the permeable silt seams in the underlying layer.

6. DISCUSSION AND RECOMMENDATIONS:

6.1) General:

It is proposed to build a six-span (30'-67.7'-67.7'-67.7'-67.7'-30') underpass structure at the crossing of new Hwy. #402, Line 'C' and Waterworks Road. The proposed profile grade of Waterworks Road will be approximately 20 ft. above the proposed Hwy. #402 grade of elevation 607.

As described in the previous paragraphs of this report, the subsoil at the site consists of a deep deposit of clayey silt and silty clay, containing some sand and traces of gravel. The upper portion (about 10 ft.) of the deposit is a very stiff desiccated surface crust. Below this depth the shear strength of the material decreases until a minimum value is reached, then increases again with depth, with some random variation. The desiccated surface crust appears to be suitable for spread footing type foundations.

6. DISCUSSION AND RECOMMENDATIONS: (cont'd.) ...

6.1) General:

Because of the compressible nature of the subsoil, it is inevitable that consolidation settlements will occur over a long-term period due to the imposed loads of structure and embankment. Past experience, however, indicates that these settlements will be of a minor nature.

6.2) Foundations: -

(a) Spread Footings in Original Ground:

The entire structure may be supported on spread footings placed within the very stiff to hard desiccated zone of the subsoil at or above El. 598'. A safe net pressure of 2.0 TSF may be assumed for design purposes.

The desiccated zone is susceptible to softening on contact with water, therefore, it is recommended that the base of the footing excavations be protected by a concrete working slab, immediately on exposure.

All foundations should be protected against frost action by at least 4 feet of earth cover. No dewatering problems are anticipated.

The estimated maximum settlement will be in the order of 1.0 and 1.5 inches under the pier footings.

(b) Spread Footings on Compacted Fill:

As an alternative, the abutments may be supported on spread footings placed on well compacted, suitable granular material within the approach fills. A safe design load of 2.0 TSF may be assumed. The granular material should consist of G.B.C. Class 'A' and should be fully compacted according to the current D.H.O. Standards. A detailed construction scheme is outlined on Figure 5 of the Appendix.

6. DISCUSSION AND RECOMMENDATIONS: (cont'd.) ...

6.2) Foundations: - (cont'd.) ...

(c) Perched Abutments on Short Piles:

As a second alternative, the abutments may be constructed within the approach fills and supported on short piles driven through the fill and some 5.0 ft. into the desiccated crust. In the case of 12-3/4" O.D. and 1/4" thick wall steel tube piles, a safe design load of 25 tons per pile may be used.

It should be pointed out, that this latter proposal is based on experience with similar structures and similar subsoil conditions in the general area. To obtain more detailed information about pile lengths, pile types and design loads, a full-scale pile loading test would be advantageous and it is strongly recommended that such tests be carried out. Therefore, the recommendations given for this type of foundation are subject to change, depending on the results of the planned pile loading tests.

Regardless of which method is adopted, the structure should be built to accommodate the 3.0 to 3.5 inches differential settlement between the abutments and piers.

(d) End-Bearing Piles:

As another alternative, the abutments and piers may be supported on steel H-piles driven to bedrock. For 12 BP @ 53, a safe design load of 70 tons per pile may be assured.

6.3) Approach Embankments:

The shear strength of the subsoil is such that it will be able to safely support the 22-ft. high approach embankments constructed with 2:1 side slopes. The fill should consist of well compacted acceptable material. Care should be taken to ensure that no bouldery fill is placed within the approaches through which piles have to be driven, and it is recommended that this portion of the fill contain no larger grain sizes than 3 inches.

6. DISCUSSION AND RECOMMENDATIONS: (cont'd.) ...

6.3) Approach Embankments: (cont'd.) ...

Based on the performance of structures and embankments built in the same general area and with somewhat similar subsoil conditions, it is our opinion that maximum settlements of 3 to 4 inches will occur beneath the abutment locations. To minimize the effect of differential settlements between the abutments and pier footings, it is recommended that the approach embankments be built in advance of the structure for as long a period as possible. The topsoil and the soft organic material should be removed in accordance with the pertinent D.H.O. Standards within the construction area.

7. MISCELLANEOUS:

The field investigation was carried out during the period October 23 - November 3, 1969, under the supervision of Mr. A. Prakash, Project Foundation Engineer, who also prepared this report.

Equipment was owned and operated by George Wimpey & Co. Ltd., and Dominion Soil Investigation Ltd.

This report was reviewed by Mr. K. G. Selby, Supervising Foundation Engineer.

December 1969

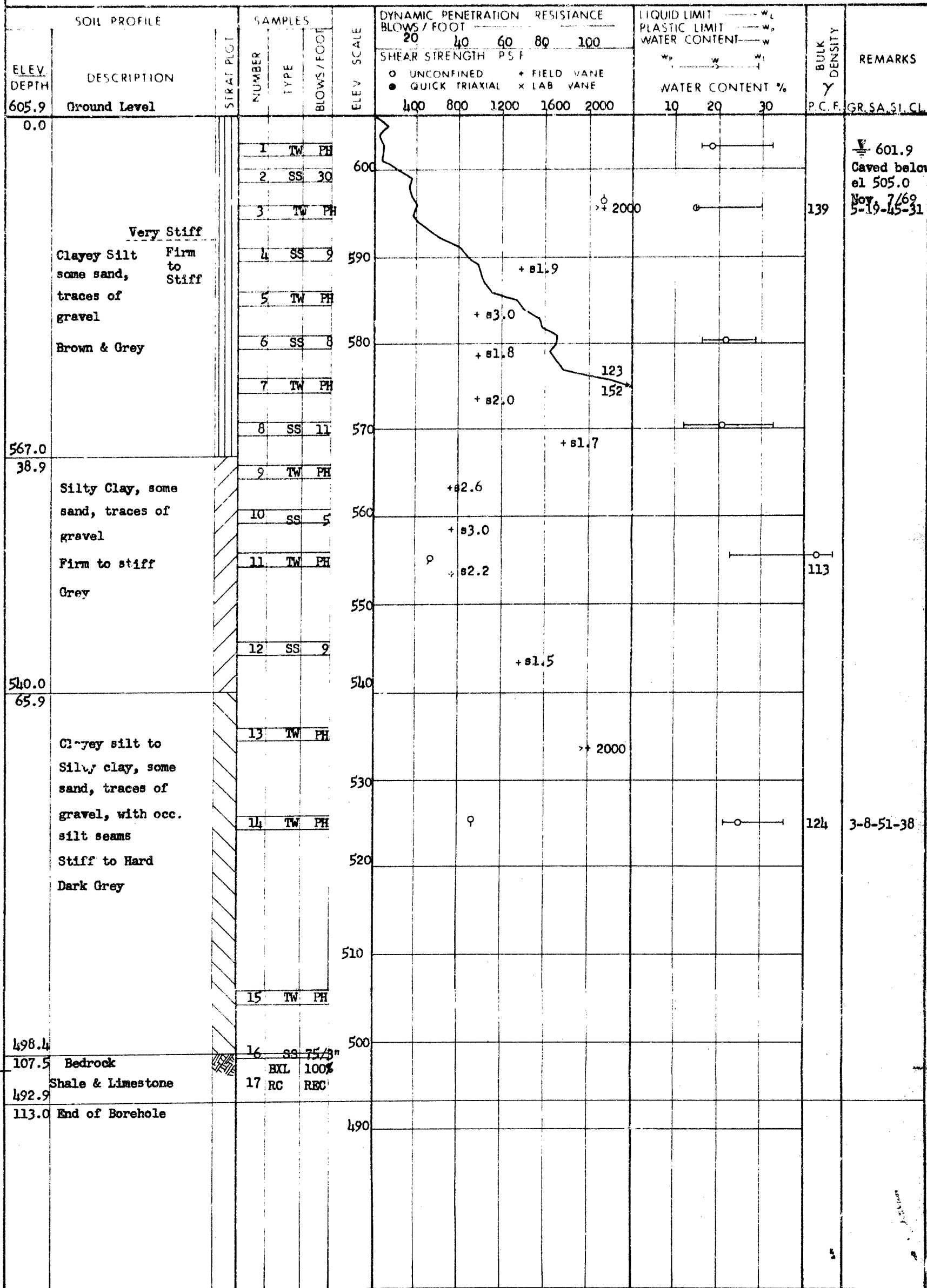
APPENDIX I

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DEPARTMENT OF HIGHWAYS - ONTARIO  
MATERIALS & TESTING OFFICE

## RECORD OF BOREHOLE No. 1

FOUNDATION SECTION

JOB 69-F-93  
W.P. 43-66-09  
DATUM GeodeticLOCATION Waterworks Rd Sta 16+67, 8' Rt  
BORING DATE Oct. 23-28, 69  
BOREHOLE TYPE Continuous Flight Auger, Core & ConeORIGINATED BY AP  
COMPILED BY AP  
CHECKED BY



## FOUNDATION SECTION

ORIGINATED BY AP

COMPILED BY AP

CHECKED BY *[Signature]*

20  
15  $\pm$  5 % STRAIN AT FAILURE  
10

DEPARTMENT OF HIGHWAYS - ONTARIO  
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 3

FOUNDATION SECTION

JOB 69-F-93  
W.P. 43-66-09  
DATUM Geodetic

LOCATION Waterworks Rd. Sta. 15+65, O/S 8' It.  
BORING DATE Oct. 28-30, 1969  
BOREHOLE TYPE Continuous Flight Auger & Cone

ORIGINATED BY AP  
COMPILED BY AP  
CHECKED BY

SOIL PROFILE		SAMPLES		ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE					LIQUID LIMIT — w <sub>L</sub> PLASTIC LIMIT — w <sub>p</sub> WATER CONTENT — w			BULK DENSITY Y P.C.F.	REMARKS	
ELEV. DEPTH	DESCRIPTION	NUMBER	TYPE		BLOWS / FOOT					SHEAR STRENGTH P.S.F.					WATER CONTENT %
					20 40 60 80 100					○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB. VANE					
					400 800 1200 1600 2000					w <sub>p</sub> — w — w <sub>L</sub>					
										10 20 30					
605.9	Ground Level													GR. SA. SI. CL.	
		1	SS	36	600										604.0 Caved in at El. 604.0 Nov. 7, 69
		2	SS	32											
	Very Stiff Firm to Stiff														
	Clayey silt, some sand	3	TW	PH	590									130	
	traces of gravel	4	SS	12											
	Brown & Grey	5	TW	PH	580										
		6	SS	7											1-11-49-39
		7	TW	PH	570										
567.0		8	SS	6											
38.9		9	TW	PH	560										
	Silty Clay, some sand, traces of gravel	10	SS	12											
	Firm to Stiff	11	TW	PH	550										
	Grey	12	SS	14											
538.0		13	SS	40											
67.9		14	SS	75/6"											
	Clayey silt to Silty Clay, some sand, traces of gravel, with occ. silt seams														0-2-53-43
	Stiff to Hard														
	Dark Grey														
495.4															
110.5	Probable Bedrock End of Borehole														3-18-48-31

DEPARTMENT OF HIGHWAYS - ONTARIO  
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 4

FOUNDATION SECTION

JOB 69-F-93  
W.P. 43-66-09  
DATUM Geodetic

LOCATION Waterworks Rd. Sta. 15+03, O/S 21' Rt.  
BORING DATE Oct. 27-30, 1969  
BOREHOLE TYPE Washboring, NX Casing, & Cone

ORIGINATED BY AP  
COMPILED BY AP  
CHECKED BY K

SOIL PROFILE		STRAT. PLT.	SAMPLES		ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT					LIQUID LIMIT — w <sub>L</sub> PLASTIC LIMIT — w <sub>p</sub> WATER CONTENT — w			BULK DENSITY Y P.C.F.	REMARKS	
ELEV. DEPTH	DESCRIPTION		NUMBER	TYPE		BLOWS / FOOT	SHEAR STRENGTH P.S.F.					w <sub>p</sub> — w — w <sub>L</sub>				
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB. VANE					WATER CONTENT %				
							20	40	60	80	100	10	20			30
						400	800	1200	1600	2000	10	20	30			
605.2	Ground Level															
	Very Stiff Firm to Stiff Clayey Silt, some sand, traces of gravel Brown & Grey	1	SS	29	600										▼ 597.2 Caved in at el. 567.7 Nov. 7/69  1-18-46-35	
		2	SS	29												
		3	TW	PH	590											
		4	SS	9												
		5	TW	PH	580											
		6	SS	7												
567.0	Silty clay, some sand, traces of gravel Firm to Stiff Grey	7	TW	PH	570										115.5	
38.2		8	SS	6	560											
		9	TW	PH	550											
					540											
540.0	Clayey silt to silty clay, some sand, traces of gravel with occ. silt seams Stiff to Hard Dark Grey	10	SS	15	530										2-8-50-40	
65.2		11	SS	16	520											
		12	SS	49	510											
					500											
496.2	Probable Bedrock	13	SS	102/6"	490										1-16-53-30	
109.0																

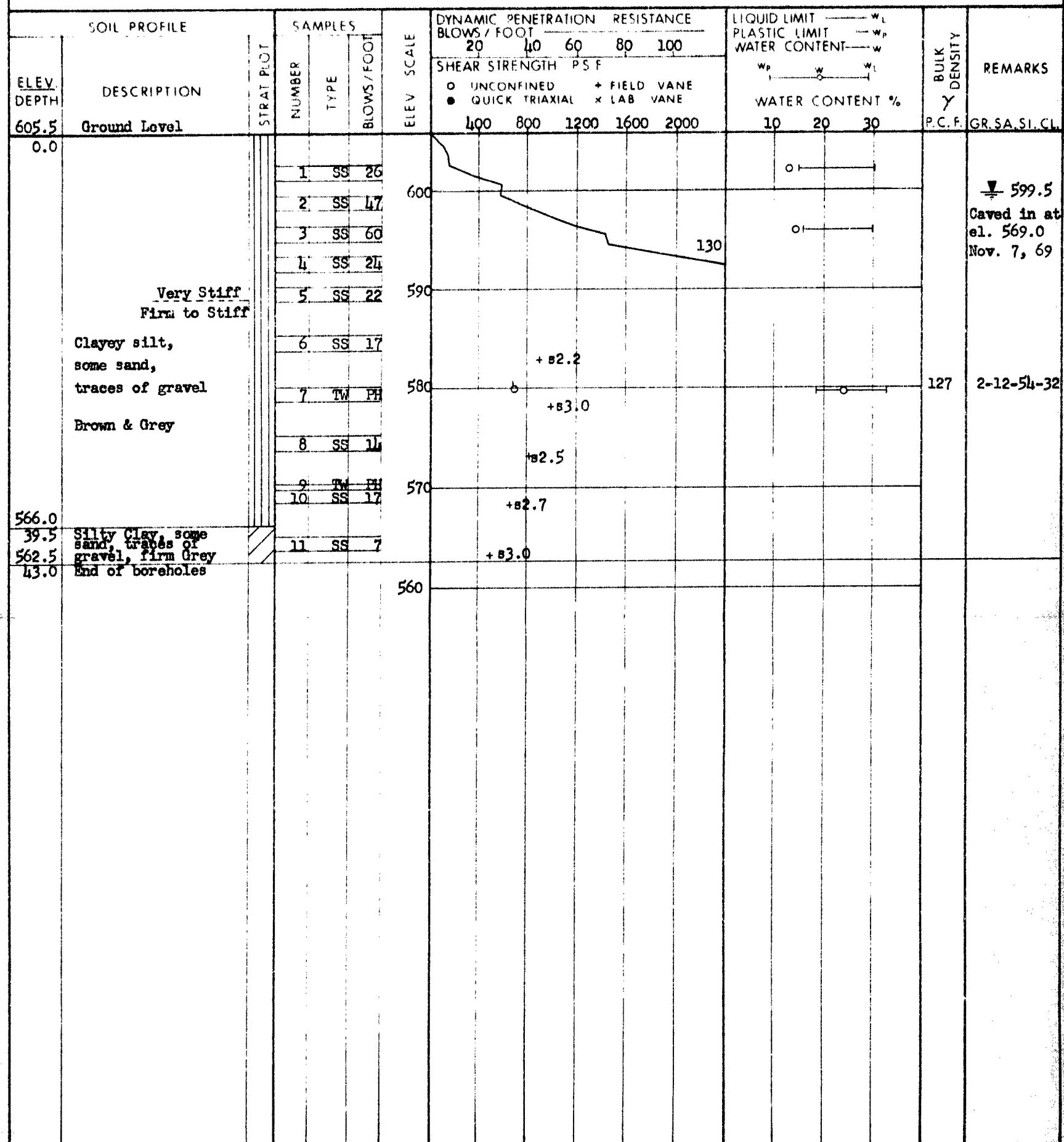
20  
10  $\phi$  5 % STRAIN AT FAILURE

DEPARTMENT OF HIGHWAYS - ONTARIO  
 MATERIALS & TESTING OFFICE

## RECORD OF BOREHOLE No. 6

FOUNDATION SECTION

 JOB 69-F-93 LOCATION Waterworks Rd. Sta. 13+62, O/S 21' Rt.  
 W.P. 43-60-09 BORING DATE Oct. 30-31, 1969  
 DATUM Geodetic BOREHOLE TYPE Washboring, NX Casing & Cone

 ORIGINATED BY AP  
 COMPILED BY AP  
 CHECKED BY


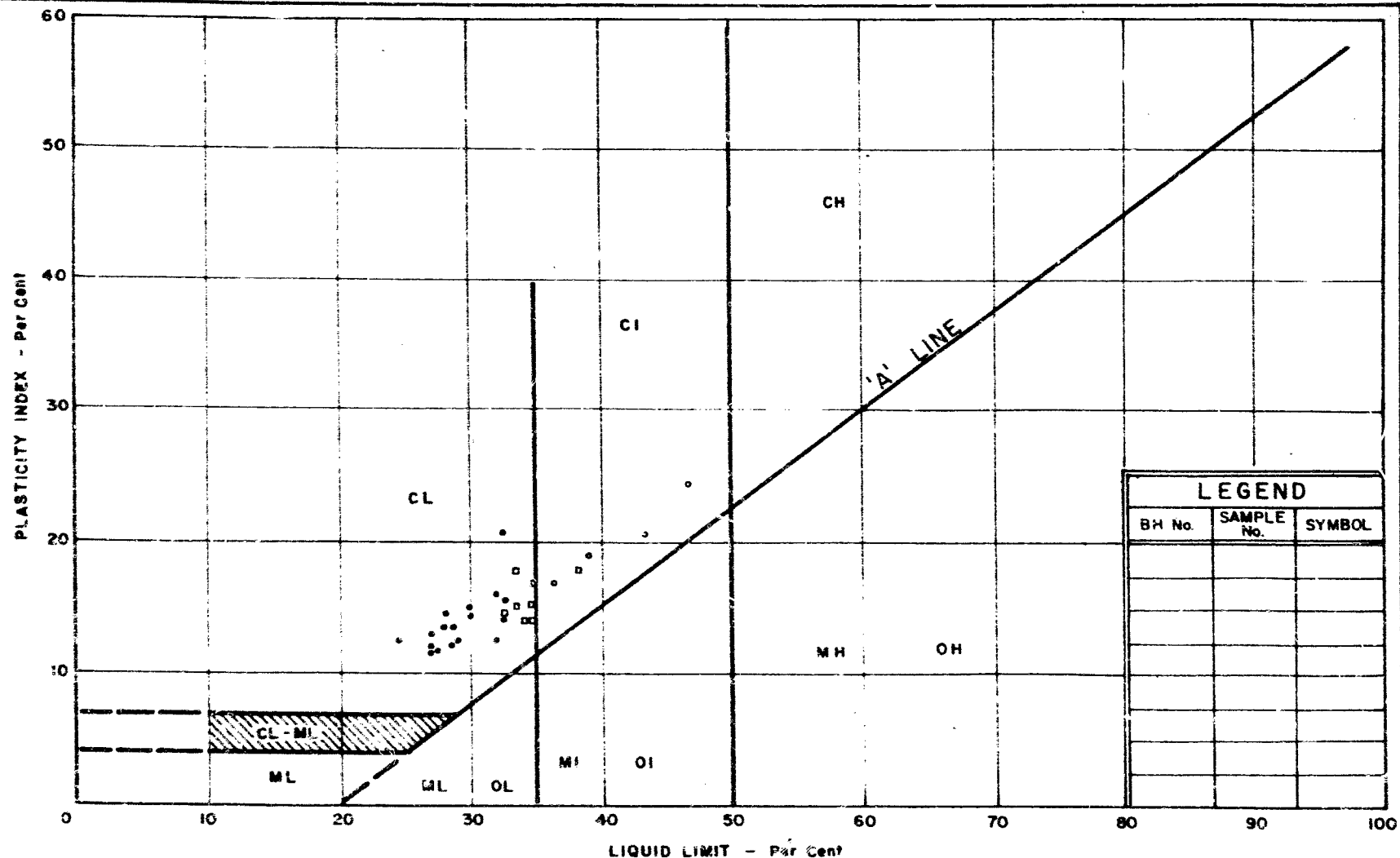
DEPARTMENT OF HIGHWAYS - ONTARIO  
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No.7

FOUNDATION SECTION

JOB	69-F-23	LOCATION	Waterworks Rd. Sta. 13+35, O/S 5' Lt.	ORIGINATED BY	AP
W.P.	113-66-09	BORING DATE	Oct. 30-31, 1969	COMPILED BY	AP
DATUM	Geodetic	BOREHOLE TYPE	Continuous Flight Auger & Cone	CHECKED BY	

SOIL PROFILE		STRAT. PLT	SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT					LIQUID LIMIT ——— w <sub>L</sub> PLASTIC LIMIT ——— w <sub>p</sub> WATER CONTENT ——— w			BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION		NUMBER	TYPE	BLOWS / FOOT		20 40 60 80 100					w <sub>p</sub> ——— w ——— w <sub>L</sub>				
							SHEAR STRENGTH P.S.F.					WATER CONTENT %				
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB. VANE									
606.3	Ground Level					400	800	1200	1600	2000	10	20	30		GR. SA. SL. CL.	
0.0	Fill Material Sand & Gravel Compact		1	SS	11										602.3	
601.8			2	SS	33										Caved in at El. 529.0 Nov. 7/69	
4.5			3	SS	21											
	Very Stiff Firm to Stiff		4	SS	25											
			5	SS	15											
	Clayey Silt, some sand, traces of gravel, Brown & Grey		6	TW	PH		q	+s2.2						131	1-18-51-30	
			7	SS	13			+s1.8								
			8	TW	PH		q	+s2.2						127.5	1-11-48-40	
			9	SS	11			+s2.2								
566.3			10	TW	PH			+s2.5								
40.0	Silty clay, some sand, traces of gravel Firm Grey		11	SS	8			+s2.2								
			12	TW	PH			+s2.0								
540.0			13	SS	31											
66.3	Clayey silt to Silty Clay, some sand, Traces of Gravel with occ. silt seams Stiff to Hard Dark Grey		14	TW	PH										3-8-56-33	
			15	SS	53											
495.3			16	SS	100/6"											
111.0	Probable Bedrock End of Borehole															



DEPARTMENT OF HIGHWAYS  
MATERIALS and  
TESTING  
DIVISION

# PLASTICITY CHART

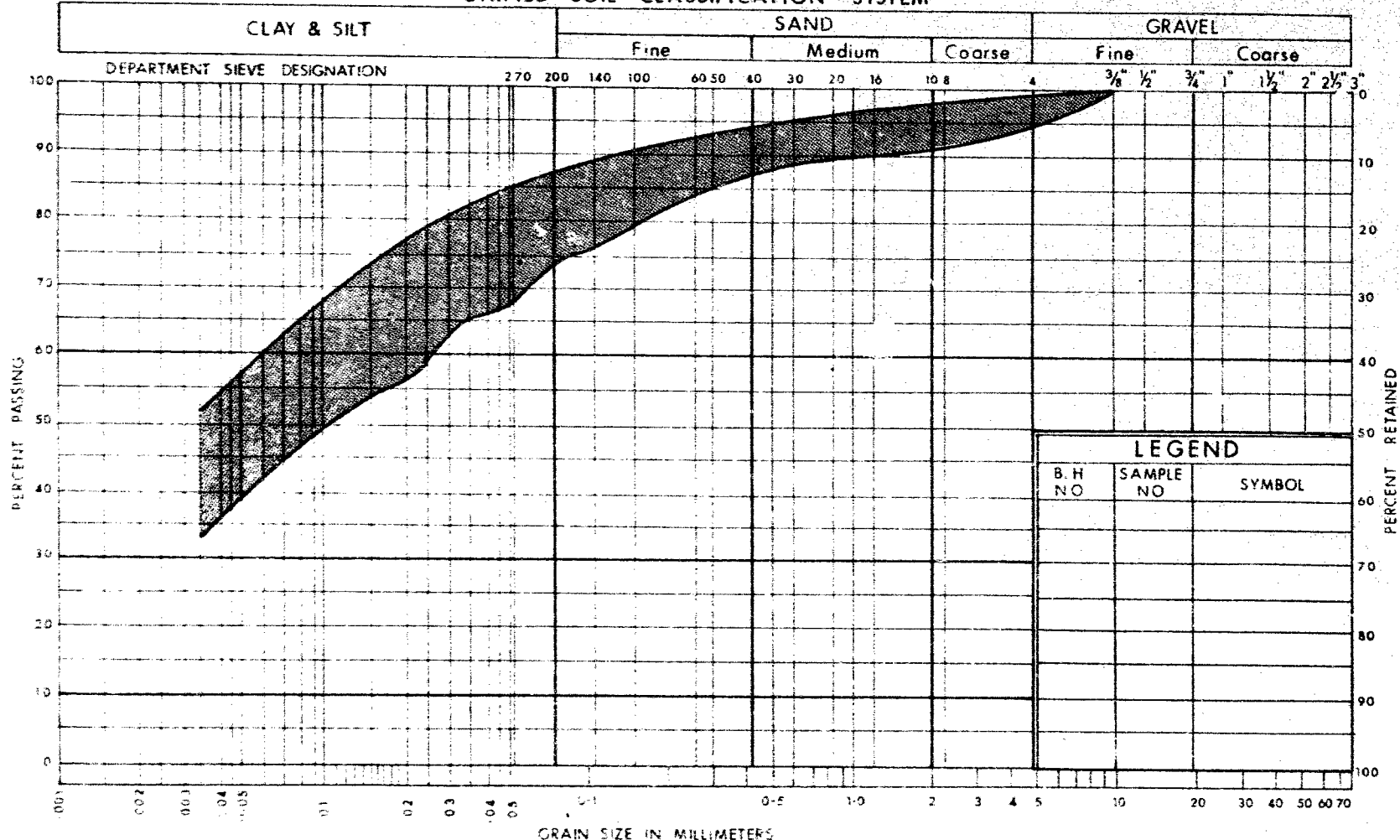
● CLAYEY SILT    ○ CLAYEY SILT TO SILTY CLAY    □ SILTY CLAY

W.P. No. 43-66-09

JOB No. 69-5-93

FIG. 1

# UNIFIED SOIL CLASSIFICATION SYSTEM

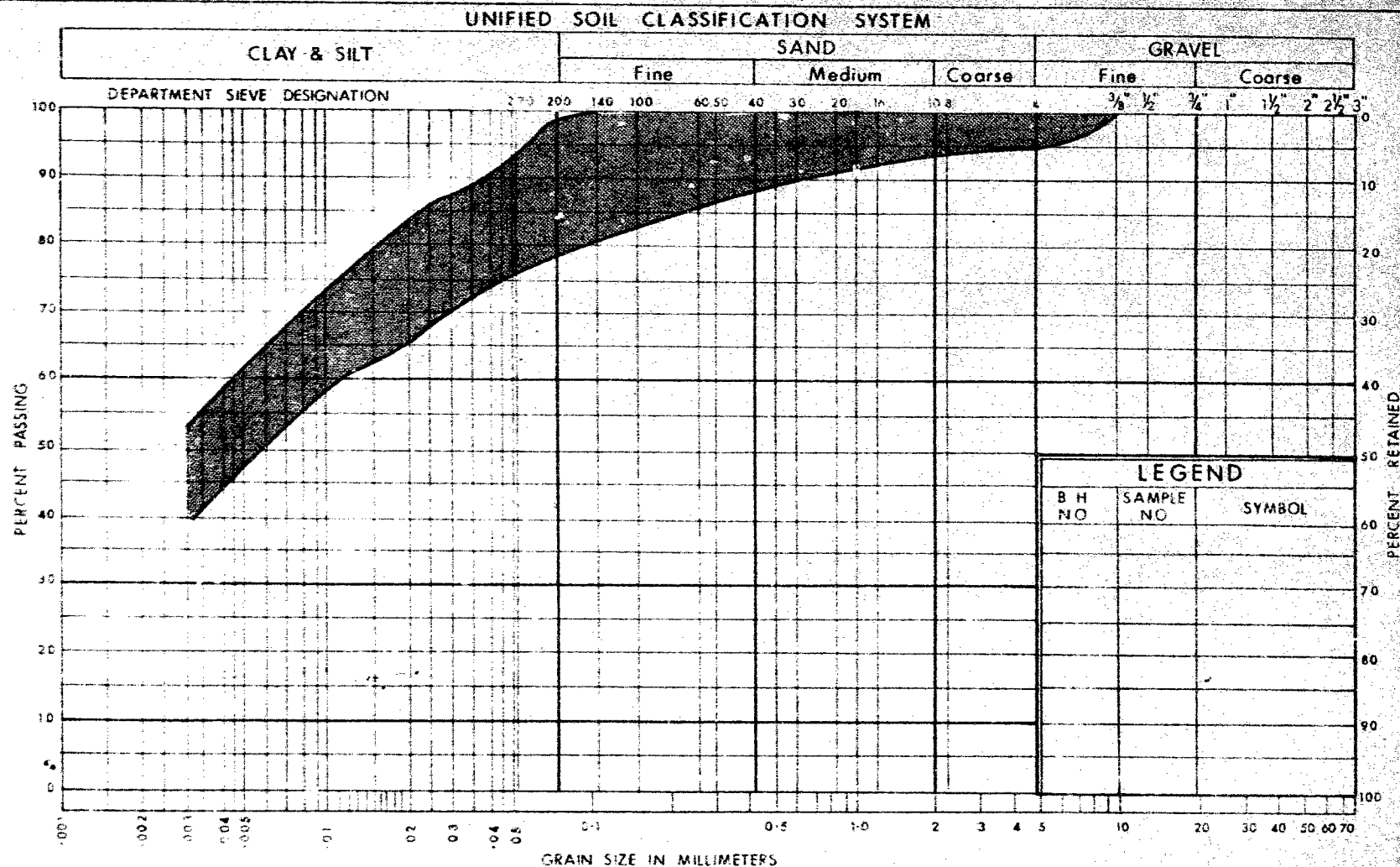


DEPARTMENT OF HIGHWAYS  
MATERIALS and  
TESTING  
DIVISION

GRAIN SIZE DISTRIBUTION  
CLAYEY SILT

WP No. 43-66-09  
JOB No. 69-F-93  
FIG. 2





DEPARTMENT OF HIGHWAYS  
MATERIALS and  
TESTING  
DIVISION

GRAIN SIZE DISTRIBUTION  
CLAYEY SILT TO SILTY CLAY

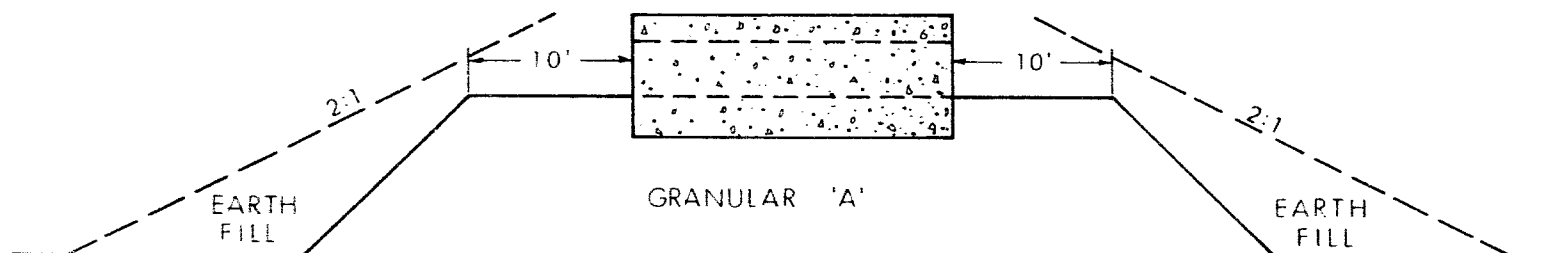
W P No. 43-66-09

JOB No. 69-F-93

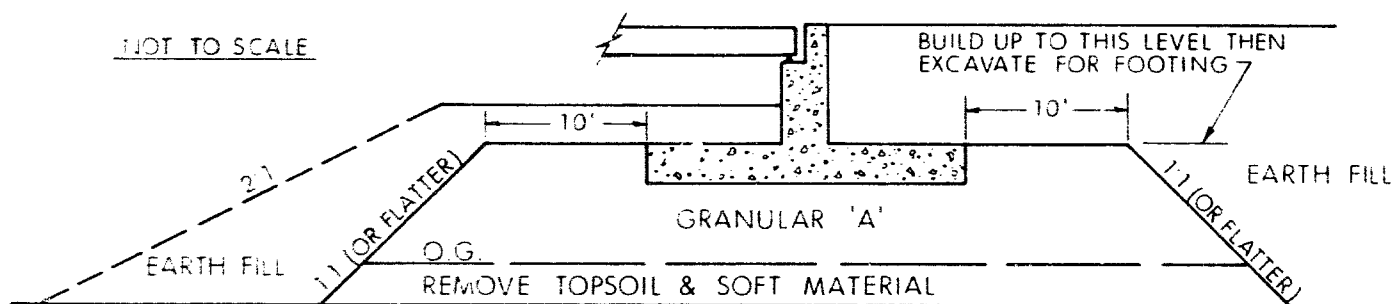
FIG. 3



## ABUTMENT ON COMPACTED FILL SHOWING GRANULAR 'A' CORE



X - SECTION



LONGITUDINAL SECTION

### NOTES

- 1 - REMOVE TOPSOIL &/OR SOFT SUBSOIL UNDER AREA OF COMPACTED GRANULAR 'A'
- 2 - PLACE GRANULAR 'A' TO TOP OF FOOTING LEVEL, COMPACTED ACCORDING TO CURRENT D.H.O. STANDARDS
- 3 - EXCAVATE COMPACTED GRANULAR 'A' MATERIAL FOR FOOTING

## ABBREVIATIONS USED IN THIS REPORT

### PENETRATION RESISTANCE

STANDARD PENETRATION RESISTANCE 'N' - THE NUMBER OF BLOWS REQUIRED TO ADVANCE A STANDARD SPLIT SPOON SAMPLER 12 INCHES INTO THE SUBSOIL, DRIVEN BY MEANS OF A 140 POUND HAMMER FALLING FREELY A DISTANCE OF 30 INCHES.

DYNAMIC PENETRATION RESISTANCE :- THE NUMBER OF BLOWS REQUIRED TO ADVANCE A 2 INCH, 60 DEGREE CONE, FITTED TO THE END OF DRILL RODS, 12 INCHES INTO THE SUBSOIL. THE DRIVING ENERGY BEING 350 FOOT POUNDS PER BLOW.

### DESCRIPTION OF SOIL

THE CONSISTENCY OF COHESIVE SOILS AND THE RELATIVE DENSITY OR DENSENESS OF COHESIONLESS SOILS ARE DESCRIBED IN THE FOLLOWING TERMS :-

<u>CONSISTENCY</u>	<u>'N' BLOWS / FT.</u>	<u>c LB. / SQ. FT.</u>	<u>DENSENESS</u>	<u>'N' BLOWS / FT.</u>
VERY SOFT	0 - 2	0 - 250	VERY LOOSE	0 - 4
SOFT	2 - 4	250 - 500	LOOSE	4 - 10
FIRM	4 - 8	500 - 1000	COMPACT	10 - 30
STIFF	8 - 15	1000 - 2000	DENSE	30 - 50
VERY STIFF	15 - 30	2000 - 4000	VERY DENSE	> 50
HARD	> 30	> 4000		

### TYPE OF SAMPLE

S.S	SPLIT SPOON	T.W	THINWALL OPEN
WS	WASHED SAMPLE	T.P	THINWALL PISTON
S.B	SCRAPER BUCKET SAMPLE	O.S	OESTERBERG SAMPLE
A.S	AUGER SAMPLE	F.S	FOIL SAMPLE
C.S	CHUNK SAMPLE	R.C	ROCK CORE
S.T	SLOTTED TUBE SAMPLE		
	P.H. SAMPLE ADVANCED HYDRAULICALLY		
	P.M. SAMPLE ADVANCED MANUALLY		

### SOIL TESTS

Qu	UNCONFINED COMPRESSION	L.V.	LABORATORY VANE
Q	UNDRAINED TRIAXIAL	F.V	FIELD VANE
Qcu	CONSOLIDATED UNDRAINED TRIAXIAL	C	CONSOLIDATION
Qd	DRAINED TRIAXIAL	S	SENSITIVITY

# ABBREVIATIONS USED IN THIS REPORT

## SOIL PROPERTIES

$\gamma$	UNIT WEIGHT OF SOIL (BULK DENSITY)
$\gamma_s$	UNIT WEIGHT OF SOLID PARTICLES
$\gamma_w$	UNIT WEIGHT OF WATER
$\gamma_d$	UNIT DRY WEIGHT OF SOIL (DRY DENSITY)
$\gamma'$	UNIT WEIGHT OF SUBMERGED SOIL
G	SPECIFIC GRAVITY OF SOLID PARTICLES $G = \frac{\gamma_s}{\gamma_w}$
e	VOID RATIO
n	POROSITY
w	WATER CONTENT
$S_r$	DEGREE OF SATURATION
$w_L$	LIQUID LIMIT
$w_p$	PLASTIC LIMIT
$i_p$	PLASTICITY INDEX
s	SHRINKAGE LIMIT
$I_L$	LIQUIDITY INDEX = $\frac{w - w_p}{i_p}$
$i_c$	CONSISTENCY INDEX = $\frac{w_L - w}{i_p}$
$e_{max}$	VOID RATIO IN LOOSEST STATE
$e_{min}$	VOID RATIO IN DENSEST STATE
$I_D$	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
	RELATIVE DENSITY $D_r$ IS ALSO USED
h	HYDRAULIC HEAD OR POTENTIAL
q	RATE OF DISCHARGE
v	VELOCITY OF FLOW
i	HYDRAULIC GRADIENT
k	COEFFICIENT OF PERMEABILITY
j	SEEPAGE FORCE PER UNIT VOLUME
$m_v$	COEFFICIENT OF VOLUME CHANGE = $\frac{-\Delta e}{(1+e)\Delta\sigma}$
$c_v$	COEFFICIENT OF CONSOLIDATION
$C_c$	COMPRESSION INDEX = $\frac{\Delta e}{\Delta \log_{10} \sigma}$
$T_v$	TIME FACTOR = $\frac{c_v t}{d^2}$ (d, DRAINAGE PATH)
U	DEGREE OF CONSOLIDATION
$\tau_f$	SHEAR STRENGTH
$c'$	EFFECTIVE COHESION
$\phi'$	EFFECTIVE ANGLE OF SHEARING RESISTANCE, OR FRICTION
$c_u$	APPARENT COHESION
$\phi_u$	APPARENT ANGLE OF SHEARING RESISTANCE, OR FRICTION
$\mu$	COEFFICIENT OF FRICTION
$S_r$	SENSITIVITY

## GENERAL

$\pi$	= 3.1416
e	BASE OF NATURAL LOGARITHMS 2.7183
$\log_e a$ OR $\ln a$	NATURAL LOGARITHM OF a
$\log_{10} a$ OR $\log a$	LOGARITHM OF a TO BASE 10
t	TIME
g	ACCELERATION DUE TO GRAVITY
V	VOLUME
W	WEIGHT
M	MOMENT
F	FACTOR OF SAFETY

## STRESS AND STRAIN

u	PORE PRESSURE
$\sigma$	NORMAL STRESS
$\bar{\sigma}$	NORMAL EFFECTIVE STRESS ( $\bar{\sigma}$ IS ALSO USED)
$\tau$	SHEAR STRESS
$\epsilon$	LINEAR STRAIN
$\gamma$	SHEAR STRAIN
$\nu$	POISSON'S RATIO ( $\mu$ IS ALSO USED)
E	MODULUS OF LINEAR DEFORMATION (YOUNG'S MODULUS)
G	MODULUS OF SHEAR DEFORMATION
K	MODULUS OF COMPRESSIBILITY
$\eta$	COEFFICIENT OF VISCOSITY

## EARTH PRESSURE

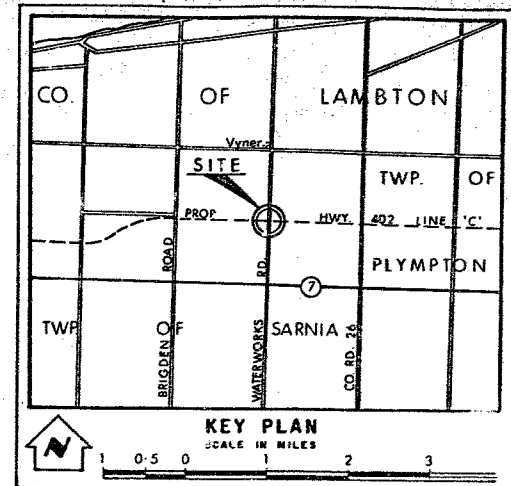
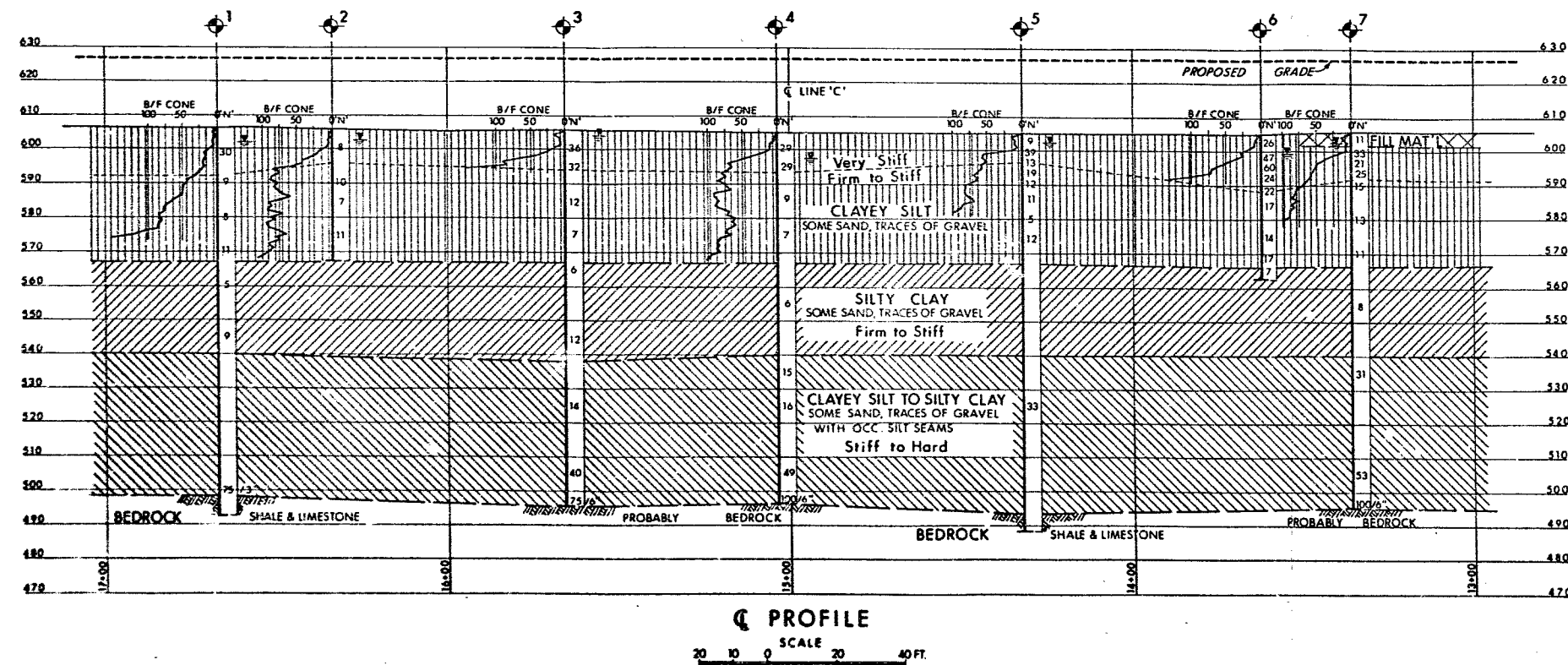
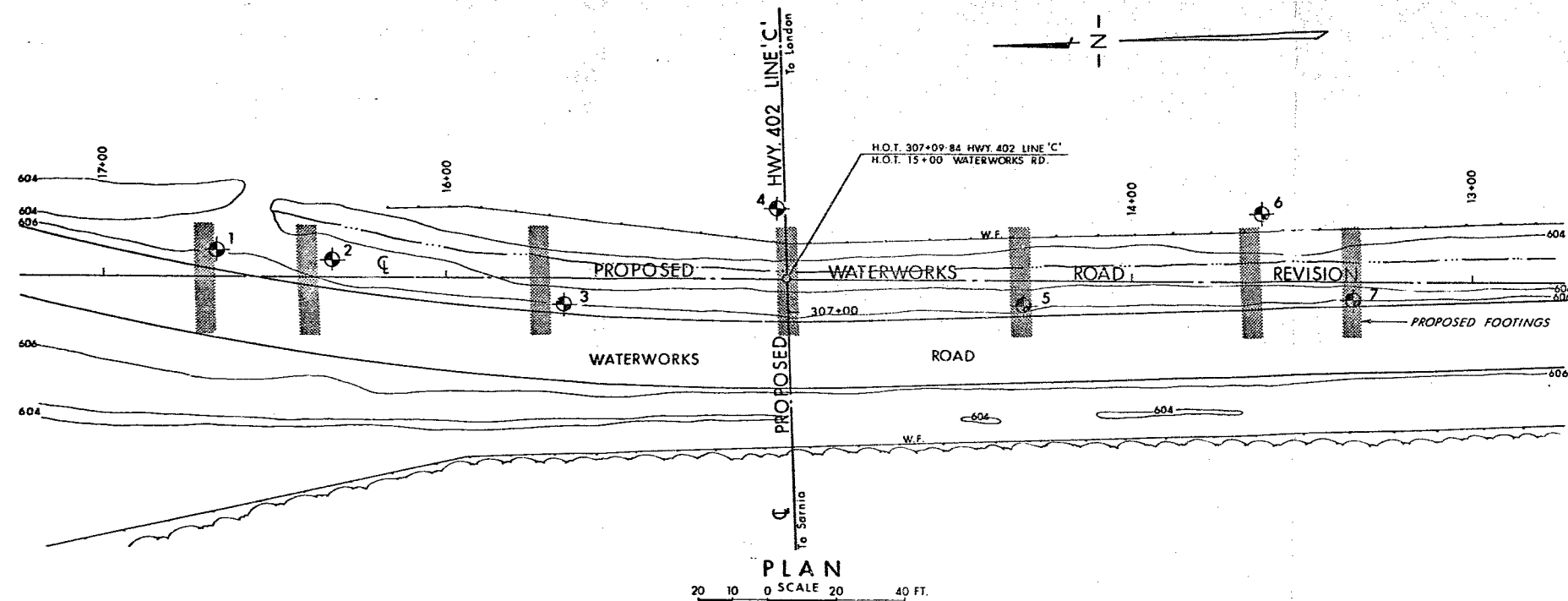
d	DISTANCE FROM TOP OF WALL TO POINT OF APPLICATION OF PRESSURE
$\delta$	ANGLE OF WALL FRICTION
K	DIMENSIONLESS COEFFICIENT TO BE USED WITH VARIOUS SUFFIXES IN EXPRESSIONS REFERRING TO NORMAL STRESS ON WALLS
$K_0$	COEFFICIENT OF EARTH PRESSURE AT REST

## FOUNDATIONS

B	BREADTH OF FOUNDATION
L	LENGTH OF FOUNDATION
D	DEPTH OF FOUNDATION BENEATH GROUND
N	DIMENSIONLESS COEFFICIENT USED WITH A SUFFIX APPLYING TO SPECIFIC GRAVITY, DEPTH AND COHESION ETC. IN THE FORMULA $FC^N$ BEARING CAPACITY
$k_s$	MODULUS OF SUBGRADE REACTION

## SLOPES

H	VERTICAL HEIGHT OF SLOPE
D	DEPTH BELOW TOE OF SLOPE TO HARD STRATUM
$\beta$	ANGLE OF SLOPE TO HORIZONTAL



LEGEND			
	Bore Hole		
	Cone Penetration Hole		
	Bore & Cone Penetration Hole		
	Water Levels established at time of field investigation. OCT. 1969		
NO.	ELEVATION	STATION	OFFSET
1	605.9	16+67	8' RT.
2	605.6	16+33	5' RT.
3	605.9	15+65	8' LT.
4	605.2	15+03	21' RT.
5	605.9	14+32	7' LT.
6	605.5	13+62	21' RT.
7	606.3	13+35	5' LT.

**NOTE**

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence and may be subject to considerable error.

REVISIONS	DATE	BY	DESCRIPTION

DEPARTMENT OF HIGHWAYS - ONTARIO  
MATERIALS & TESTING OFFICE - FOUNDATION SECTION

**WATERWORKS ROAD**

KING'S HIGHWAY NO. 402 LINE 'C' DIST. NO. 1  
CO. LAMBTON  
TWP. SARNIA LOT 3&4 CON. VII

**BORE HOLE LOCATIONS & SOIL STRATA**

DRAWN A.P.	CHECKED	W.P. NO. 43-66-09	M.T. DRAWING NO.
DATE 5 DEC. 1969	CHECKED	JOB NO. 69-F-3	69-F-93A
APPROVED	SITE NO.	CON. NO.	PRINTED DRAWING NO.

## MEMORANDUM

TO: Mr. A. Stermac,  
Principal Foundation Engineer,  
Room 107, Lab. Bldg.

FROM: C.S. Grebski,  
Bridge Office

ATTENTION:

DATE: October 30, 1970

OUR FILE REF.

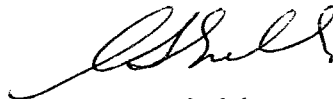
IN REPLY TO

SUBJECT: Waterworks Road Underpass  
1.2 Mi. West of County Road No. 26  
W.P. 43-66-09, Site No. 14-346  
Highway 402, District No. 1

69-F-93

Attached herewith we are submitting the final  
bridge drawings which show the foundation design  
for this structure.

Kindly give us your comments at your earliest  
convenience.



C.S. Grebski,  
Bridge Design Engineer

CSG:rd

Attach.


c.c. Foundation Office

No comments

Submitted to review in Jan/71 (Full Load Test)

Nov 24/70

L.A.S.

  
26 Nov. 70