



Memorandum

30M3-150

GEOGRES No.

To: G.C.E. Burkhardt (3)
Regional Structural Planning Engineer
Central Region
3501 Dufferin Street, Downsview

From: Soil Mechanics Section
Geotechnical Office
West Building, Downsview

Attention:

Date: January 20, 1976

JAN 30 1976

Our File Ref.

In Reply to

Subject:

FOUNDATION INVESTIGATION REPORT

W.P. 46-74-13
Site 18-233
Hwy. 406, District 4
Twelve Mile Creek Bridge
Bridge #3 (Contract #3)

Attached we are forwarding to you our detailed Foundation Investigation Report on the subsoil conditions existing at the above mentioned site.

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

Please note that additional field information may be required when the locations of the piers and the abutments have been decided on.

K.G. SELBY
Supervising Engineer

cc: R.S. Pillar
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FOUNDATION INVESTIGATION REPORT

for

W.P. 46-74-13

Site 18-233

Hwy. 406, District 4

Twelve Mile Creek Bridge

Bridge #3 (Contract #3)

1. INTRODUCTION

This report contains results of foundation investigations carried out at the following site:

W.P. 46-74-13, Site 18-233

Hwy. 406, Structure Over Twelve Mile Creek

St. Catherines, District 4

Also contained in this report are comments and recommendations pertaining to the design and construction of the structure foundation and approaches.

2. SITE DESCRIPTION

The proposed structure site is located in the southwestern side of the city of St. Catherines, in the section of Twelve Mile Creek valley bounded by New England Slate Ltd., and Niagara College of Applied Arts. At this location, the Twelve Mile Creek is about 160 ft. wide, flowing northwesterly into Lake Ontario and is inferred to be approximately 12 to 14 ft. deep. The Twelve Mile Creek is a fast flowing river. During its course of existence, it has cut into the clay mantle a valley some 65 to 75 ft. lower in elevation than the surrounding terrains. The slopes of the valley are gentle, estimated to be 3:1 to 2.5:1 and appear to be stable at this configuration. The slopes at present are well treed. The river-banks, with variable widths, are 1 to 3 ft. above the river water level (elevation 268. +) and are generally soft and wet, especially so in areas southwest of New England Slate Ltd., because of the presence of organic fluvial deposits and fill material.

The plateaus on the tops of the slopes are relatively level, with residential developments being the major land use.

Geologically, the site is located in a physiographic region referred to as the Niagara Escarpment. The slopes of the Twelve Mile Creek valley are known to be mantled with glacial deposits of silty clay and till. The underlying bedrock is a red shale of Ordovician Age.

3. SUBSURFACE CONDITIONS

(3.1) General

A total of 23 boreholes have been put down at the site. Apart from some isolated shallow fill material (which is composed of sand, cinder, clay and, along the shores, boulderly rockfill), the major deposit in the area is very stiff to stiff silty clay, overlying very dense glacial till. In some areas on the riverbanks, due to erosion and deposition by the Twelve Mile Creek, recent fluvial organic silt, as well as sand and silt, are also encountered. Although no attempts have been made to determine bedrock elevations, from geological maps and results of investigations conducted at adjacent sites the till is believed to be underlain by shale bedrock of Queenston Formation.

Results of the boreholes are summarized in the Borehole Record Sheets attached to this report. A subsoil stratigraphy inferred from the boreholes is shown in Dwg. No. 467413-A & B. A brief description of the subsoil types is given below.

(3.2) Silty Clay

Very stiff to stiff silty clay is the predominant subsoil deposit in the area. This stratum, in general, extends from ground surface to elevation 255-270 approximately, for a maximum thickness of about 70 ft. As the valley is formed by erosion, the thickness of this deposit decreases towards the course of the river. The silty clay is of intermediate plasticity (PI region on the Plasticity Chart), and low sensitivity. It also contains traces of sand and occasional very fine gravel.

The upper 15-17 ft. of the silty clay in the slopes are desiccated, with a very stiff consistency. The undrained shear strengths are in excess of 2000 psf. The natural moisture contents of the desiccated silty clay are found to be generally in the neighbourhood of 21%, which is close to the Plastic Limits of the material and the clay, therefore, is somewhat fissured.

Below the desiccated crust, the silty clay becomes grey and its consistency decreases from very stiff to stiff, with an average undrained shear strength in the order of 1200 psf. Its moisture contents also show a corresponding increase, to about 27% on the average.

The silty clay is known to be overly consolidated, probably due to glaciation and subsequent erosion by the Twelve Mile Creek. As an overly consolidated clay, it would have a low ϕ' value but a high C' value. However, because of its silty nature and the presence of fissures, the upper layer of the silty clay is susceptible to weathering as it may absorb moisture readily. This would result in the destruction of the cohesion component of the shear strength parameters. With these considerations taken into account, the following shear strength parameters are suggested for design of the proposed cuts:

For the desiccated crust: (the upper 15 ft.)

Undrained shear strength	$S_u = 2000$ psf.
Effective cohesion	$C' = 0$
Effective angle of friction	$\phi' = 26^\circ$

Below the desiccated crust:

Undrained shear strength	$S_u = 1200$ psf.
Effective cohesion	$C' = 250$ psf.
Effective angle of friction	$\phi' = 22^\circ$

The unit weights of the silty clay appear to be fairly constant and for design purposes, may be assumed equal to 120 pcf. for both desiccated and undesiccated materials.

(3.3) Glacial Till

This deposit is intercepted everywhere in the area, generally underlying the above mentioned silty clay. Its upper boundary varies from about elevation 270 to 255, descending towards the river. Its lower boundary has not been determined but from available information, the till is believed to be underlain by shale bedrock.

The glacial till is a heterogeneous mixture composed mainly of sandy silt, with some clay and traces of gravel. It is low in plasticity and has low moisture contents. Its unit weights are high. On the basis of the 'N' values, which are generally in excess of 100 blows per foot, the till is a very dense material and is considered to be a good founding stratum.

(3.4) Organic Silt

This material is encountered mainly on the wet riverbank lowlands, near New England Slate Ltd. It extends from ground surface (elev. 271.+) to as deep as elevation 254.+, for a thickness of 5 or 6 ft. to about 17 ft. It is a recent deposit by the Twelve Mile Creek and is unconsolidated. It is dark brown to black in colour and exhibits some apparent cohesion. Its moisture contents are high and variable. Because of its high organic contents it is very compressible and has a low shear strength, around 500 psf. as measured by field vane tests. Beneath the organic silt, a deposit of sand and silt is encountered.

(3.5) Sand and Silt

The above mentioned organic silt is found to be underlain by a layer of sand and silt, the thickness of which ranges from 15 ft. to 20 ft. approximately. It is slightly layered and contains traces of clay. Occasional fine gravel are also noted. The 'N' values for this material vary from 20 blows per foot to over 100 blows per foot, suggesting a relative density of compact to very dense. Underlying this deposit is a layer of very dense glacial till, the description of which is given in Section 3-2.

(3.6) Groundwater Conditions

The groundwater levels were observed in the open boreholes or in the piezometers installed. The results are reported in the Borehole Record Sheets. The observed groundwater levels are variable and do not appear to conform with the topography of the slopes. This may be due to the low permeability of the subsoil and the short duration of observation made in the open boreholes during field investigations. In this regard, we believe the levels recorded in those open boreholes located in the slopes tend to underestimate the groundwater elevations and would not be as reliable as the piezometric readings. Taking into account observations of piezometers installed in the slope near Burgoyne Bridge, we estimate, for design purposes, that the groundwater phreatic surface probably exists at about 15 ft. below ground surface on the top of the slope and drains into the Twelve Mile Creek, following the general topography of the slope. The piezometer installed on the riverbank also revealed an artesian condition in the sand and silt, as well as in the till layers. The artesian head was observed as high as 10 ft. above ground surface (i.e. up to elev. 282.+). This artesian pressure probably originated from the sandy layers in the slopes.

4. DISCUSSION AND RECOMMENDATIONS

Three schemes of structural layouts for the river crossing have been proposed by the Structural Planning Office. Scheme No. 1 shows a cable-stayed structure with no pier in the riverbed. Structures proposed in scheme No. 2 and No. 3 will have one pier and two piers, respectively, in the riverbed for each traffic direction. All the above structure schemes utilize Profile Grade A, but a higher profile grade (Profile Grade B) is also proposed should a high haunch, cantilevered segmentally constructed structure be adopted. Associated with the bridge structure, there are also three grading proposals for the side-hill-cuts near the south approach, as well as one retaining wall proposal to support the south approach fill of the NBL.

Details of the alignment, footing locations, profile grades and extent of the retaining walls are shown in Dwg. 74452-G-14, prepared by the consultant. Based on the subsoil conditions the following recommendations are made:

(4.1) Profile Grade Scheme A & Scheme B

The feasibility of Profile Grade Scheme B is governed by stability of retaining wall No. 3 at the south approach. As shown in Profile Grade Scheme 'B', retaining wall No. 3 will have a maximum height of 24 ft. It is found to be unstable. Berm to stabilize the retaining wall of this height is not feasible, as the berm itself is also unstable. To resolve the stability problems of retaining wall No. 3, a much longer structure for the NBL will be required. Furthermore, in Profile Grade Scheme 'B', the cuts near the north approach are much shallower. This will result in less material available for use as fill elsewhere.

With these considerations, we therefore suggest that Profile Grade Scheme 'B' should not be adopted. Profile Grade Scheme 'A', however, is considered acceptable.

(4.2) Structural Schemes

Structural scheme No. 1 (cable-stayed structure) has one major advantage over schemes No. 2 and 3 in that no pier is located in the riverbed. However, being a slender structure on a curve, the stability of a cable-stayed structure with respect to torsional forces, as we learn, is not as good as structures depicted in schemes No. 2 and 3.

Both structural schemes No. 2 and 3 have the same geometries and the same structure lengths. They differ only in the number of piers in the riverbed and the span lengths.

From our point of view, all three structural schemes are feasible and the choice will be decided by economical considerations.

(4.3) Structure Foundation

For footings located on land, spread footing foundations are considered impractical because of low bearing capacity and non-homogeneity of the surficial subsoil.

Simple concrete filled caissons augered into the very dense till are feasible, but dewatering problems are anticipated because of high groundwater tables and artesian water. The most suitable foundation, in our opinion, would be end-bearing piles driven into the very dense till. The piles should be composed of H-sections. It is recommended that the pile driving be controlled by Hiley Formula (MTC Standard SS-3-11). In this case, the piles can be designed for their maximum allowable loads. For estimation of pile lengths, the founding elevations of the pile tips, where the design capacities will be achieved, are estimated as follows:

<u>Footing</u>	<u>Station</u>	<u>Probable Pile Tip Elevation</u>
N. Abutment of NBL	323 + 50	249.0 ±
N. Abutment of SBL	322 + 50	251.0 ±
S. Abut. of SBL	309 + 00	246.0 ±
S. Abut. of NBL	316 + 00	252.0 ±
Intermediate Piers of NBL	317 + 00 to 318 + 00	252.0 ±
Intermediate Piers of SBL	314 + 00 to 317 + 00	250.0 ±
Intermediate Piers of SBL	310 + 00 to 313 + 00	245.0 ±

For piers located in the riverbed, recommendations pertaining to their design will be given in Section(4.4.)

Lateral forces on the structure can be resisted by battered piles. All pile caps should have a minimum 4 ft. cover for frost protection. No major dewatering problems are anticipated for the south and north abutments, as the bases of excavation will be in the relatively impervious subsoil and above the groundwater table. In any event, dewatering can be achieved by pumping from sumps. For piers located near the shores, some dewatering schemes will be required so that pile caps can be poured in the dry. One way to achieve this will be by constructing a cofferdam of interlocking sheet-pilings around the pile cap.

Because of the presence of rockfill along the shore, some difficulties in pile driving may be encountered. The problem

can be resolved by excavating the rockfill prior to pile driving and by reinforcing the pile tips with driving shoes to ensure penetration. The rock fill, as revealed by our boreholes, have a thickness of 4 to 6 ft. and should be able to be excavated.

Removal of rockfill would also facilitate driving of the sheet-pilings.

Settlement of the foundation supported on end-bearing piles will be negligible. In view of the rapid current, some protection against scouring will be required for those piers along the shore.

(4.4) Piers in the Riverbed (Sta. 319 + 00 to Sta. 320 + 00)

Results of Boreholes No. 318, 319, and 351 which encompass the piers in the riverbed, revealed a very dense glacial till at elevation 263 and 260, more or less. Considering the speed of the current and the depth of the river, it is possible that the bottom of the Twelve Mile Creek has cut into the very dense till and the overlying silty clay has been eroded away. As far as bearing capacity is concerned, the till is suitable to support end-bearing piles. However, as it may not be possible to advance the piles by means of driving deep enough into the till to achieve sufficient lateral constraints and protection against scouring, we recommend that the piles be pre-augered and then driven to refusal. Considering the extremely high pier loads and the dewatering problems, the following 'caisson' type of piled foundations appears to be suitable. The 'caisson' is to be composed of three H-section piles encased in a heavy steel tube, 48 inches in diameter and $\frac{1}{2}$ inch thick. The tube is to be installed by augering to elevation 240, so that the embedded length would be about 15 ft. The three H-section piles are then driven through the tube to practical refusal. The tube should then be filled with concrete. Tremie concrete will be required for pouring under water. For portion of the 'caisson' within 6 ft. of cut-off elevation, concrete should be placed in the dry. It is desirable to use heavy H-piles so that the design 'caisson' load can be increased. For example, if 3 x 12 BP74 H-sections are used, each caisson can be designed to

carry a safe load of 300 tons. Higher caisson load can be achieved by using larger diameter tubes and heavier H-sections. Pile caps can be formed inside a cofferdam of sheet-pilings, or by using a prefabricated steel box as falsework, as done in Rideau River Bridge Project (Contract #70-233). To avert the necessity of an unwatering scheme, the caisson may be capped at girder level.

The above recommendations are provided for preliminary design.

It will be necessary to carry out additional field investigations when the final structural scheme has been decided on and the exact pier locations are known. This Office will undertake the additional fieldwork required.

(4.5) Abutments

Both the north and south abutments, as mentioned previously in section 4.3, can be supported on end-bearing piles driven into the very dense till.

For reasons of stability, the south abutments of both the NBL and the SBL will need a 3:1 forward slope. For the north abutments, a 2½:1 forward slope is required.

Backfill to the abutments should be composed of free-draining, non-cohesive material and in accordance with M.T.C. Standard SS-5-1. Also, weep holes of 2" diameter and at 10 ft. c/c should be provided to prevent buildup of porewater pressure behind the abutment walls.

Under these conditions, the abutments can be designed to withstand an at-rest horizontal earth pressure exerted by the backfill, of $P_h = K_o \gamma z$ with K_o assumed equal to 0.4 and γ equal to 130 pcf.

(4.6) South Approach

The south approach of the SBL will be on a fill, while that of the NBL will be partly in a cut and partly on a fill which will be supported by retaining wall No. 3. The embankment fill of the SBL should be constructed at a 3:1 side slope because of unfavourable subsoil conditions. In addition, the small bay at Sta. 307 + 00 should be filled with rockfill to ground surface to avoid spill of embankment fill into the river. Retaining wall No. 3 will have

a length of about 630 ft. (from Sta. 316 + 30 to Sta. 310 + 00) and a maximum height of about 16 ft. It can be supported on end-bearing piles driven into the very dense till, designed in accordance with recommendations provided for the piers and the abutments. The founding elevations of the piles for the retaining wall can be interpolated from those estimated for the adjacent piers and abutments, (which are summarized in Section 4.3.) Unwatering for pile cap excavations will be required and can be achieved by pumping from sumps inside a sheeting enclosure. Organic soil under the retaining wall and the fill behind it should be excavated and replaced with granular type material. The limits of excavation will be determined by Regional Materials Office.

There are three proposals for the side-hill-cuts near the south approach. Two of the proposals involve construction of retaining walls, and the third proposal will involve construction of a simple cut. The extents and cross-sections of the retaining walls and of the cuts are shown in Dwg. X-74452-G-14 and X-74452-G-21 provided by the consultant. Stability analyses, in terms of total stresses and effective stresses, have been carried out to determine the feasibility of the various proposals. The results indicate that the retaining wall schemes (retaining walls No. 1 and 2) are not feasible. The cuts are feasible if they are constructed at a 2:1 slope, with a 25 ft. bench at mid-height. Also, longitudinal drainage ditches consisted of 12" ϕ perforated pipe installed below frost-line and backfilled with Granular 'A', should be provided at the toe of the upper slope as well as at the toe of the lower slope, in order to lower the groundwater table. High groundwater table is detrimental to the stability of the slope. Details of our recommendations for the cut slopes are shown in Drawing No. 467413-B, which is attached to the Appendix of this report.

Because differential settlements between the fill and the south abutments are anticipated, 20 ft. approach slabs should be provided at the south approach for both the NBL and the SBL.

Organic silt underneath the south approach fills of the NBL and the SBL should be removed to prevent excessive settlements in the embankments and the development of negative skin friction on

the end-bearing piles of the adjacent footings. The probable limits of excavation will be from Sta. 315 + 00 to Sta. 309 + 50 for the NBL and from Sta. 309 + 00 to Sta. 308 + 00 for the SBL. Additional shallow borings will be carried out by Regional Materials Office to determine the extent of the organic deposit, as well as the width and depth of the excavation required.

Very soft organic subsoil and loose mixed fill were also encountered in the river bank from Lincoln Foundry to Sta. 307 + 00, with a thickness varying from a few ft. to about 17 or 18 ft. in some areas. Embankments built on this material will have large differential settlements and will require long term maintenance. To ensure the satisfactory performance of the highway embankments, it will be necessary that either the soft organic soil be excavated and replaced with granular type material, or the site be preloaded. Considering the extensive amount of excavation involved, it appears that preloading would probably be a more suitable and cheaper alternative. A preloading period of 12 months is considered to be sufficient for most settlement to occur, and it would be preferable that the site be subjected to a surcharge of 2 ft. of fill in excess of the recommended embankment height so that in this way it will be possible to speed up the rate of settlement and to pre-test the bearing capacity of the subsoil.

(4.7) North Approach

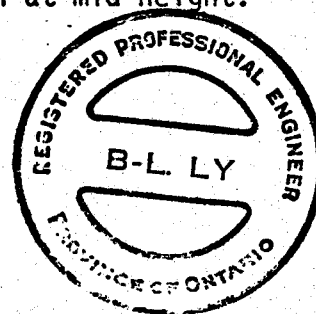
The north approach will be in a cut of some 40 ft. deep. We recommended in our foundation report (W.P. 46-74-36) that it be constructed at a 2:1 slope with a 40 ft. bench at mid height.

B. Ly

B. LY
Project Engineer

K. G. Selby

K.G. SELBY
Supervising Engineer



APPENDIX

RECORD OF BOREHOLE NO 215

W.P. 46-74-13 LOCATION Co-ords. 15,679,710N; 1,066,436 E. ORIGINATED BY K WA
 DIST. 4 HWY. 406 BORING DATE July 13, 14, 1971 COMPILED BY KW
 DATUM Geodetic BOREHOLE TYPE Pendril CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT w_L PLASTIC LIMIT w_p WATER CONTENT w			UNIT WEIGHT γ	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	w_p	w	w_L		
305.6	Ground Level						400	800	1200	1600	2000	20	40	60	P.C.F.	GR SA SI CL
0.0	Silty sand some gravel. (Fill ?) Very Loose		1	SS	5											1 80 (19)
296.6	Brown		2	SS	3											
9.0	Clayey silt to silty clay, traces of sand and gravel.		3	SS	10											119
			4	SS	8											
			5	TW	PM											124
	Stiff to Very Stiff		6	SS	15											
			7	TW	PM											
	Grey		8	SS	19											133
			9	TW	PM/15" PH/3"											
			10	SS	24											137
			11	TW	PH											122
257.6			12	SS	73											
48.0	Clayey silt to silt, traces of sand.		13	SS	100/11"											0 8 75 17
	Hard		14	SS	88											
	Red-Brown		15	SS	105/11"											
236.7			16	SS	60/4"											
68.9	End of Borehole															

RECORD OF BOREHOLE NO 216

W.P. 46-74-13

LOCATION Co-ords. 15,679,834 N; 1,066,169 E.

ORIGINATED BY KW

DIST. 4 HWY. 406

BORING DATE July 8, 9, 1971

COMPILED BY KW

DATUM Geodetic

BOREHOLE TYPE Pendrill

CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT — w_L PLASTIC LIMIT — w_p WATER CONTENT — w			UNIT WEIGHT γ P.C.F.	REMARKS % GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	N VALUES		20	40	60	80	100	w_p	w	w_L		
324.7	Ground Level						400	800	1200	1600	2000	20	40	60		
0.0	Clayey silt with organics. Firm		1	SS	6	323.2										
317.2	Dark Grey		2	SS	5	320										
7.5	Clayey silt to silty clay traces of sand and gravel.		4	SS	16											
			5	SS	25											
			6	SS	31											
			7	SS	34											
	occasionally laminated		8	SS	24											
			9	SS	27											
	Stiff to Hard		10	SS	17											
			11	SS	13											
	Grey & Brown		12	TW	PM											
			13	SS	29											
			14	SS	32											
264.7			15	SS	100/1"											
60.0	Clayey silt some sand & gravel (Glacial Till)		16	SS	100/1"	260										
	Red		17	SS	70/5"											
	Hard		18	SS	50/1 1/2"											
250.1																
74.6	End of Borehole															

ENGINEERING SERVICES BRANCH-GEOTECHNICAL OFFICE - SOIL MECHANICS SECTION

RECORD OF BOREHOLE NO 217

W.P. 46-74-13 LOCATION Co-ords. 15,679,992 N; 1,066,055 E. ORIGINATED BY KW
 DIST. 4 HWY. 406 BORING DATE July 15, 16, 1971 COMPILED BY KW
 DATUM Geodetic BOREHOLE TYPE Pendrill CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT w_L PLASTIC LIMIT w_p WATER CONTENT w			UNIT WEIGHT γ	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	w_p	w	w_L		
325.2	Ground Level															
0.0	Silty sand, some organics		1	SS	7	320										
318.7	Loose		2	SS	12											
6.5	Clayey silt to silty clay, traces of sand and gravel.		3	SS	17											
			4	SS	28											
			5	SS	30	310										
			6	SS	28											
	Stiff to Hard		7	SS	26	300										
			8	SS	28											
	Grey		9	SS	17	290										
			10	SS	10											
			11	TW	PM	280										
			12	SS	45											
272.2																
53.0	Clayey silt to silt, some sand.		13	SS	50/3"	270										
	Hard		14	SS	50/4"											
	Red-Brown		15	SS	50/5"	260										
254.7			16	SS	50/4"											
70.5	End of Borehole Note: Hole caved in to El. 267.± immediately															

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE NO 218

W.P. 46-74-13 LOCATION Co-ords. 15,679,963 N; 1,065,885 E. ORIGINATED BY KW
 DIST. 4 HWY. 406 BORING DATE July 12, 1971 COMPILED BY KW
 DATUM Geodetic BOREHOLE TYPE Pendrill CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT w_L PLASTIC LIMIT w_p WATER CONTENT w WATER CONTENT % w_p w w_L	UNIT WEIGHT γ	REMARKS % GR. SA. SI. CL.
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100			
273.0	Ground Level													
0.0	Silty fine sand.					270								
267.5	Loose		1&2	SS	6	267.9								
5.5	Clayey silt, some sand and organics. Soft to Firm Dark Grey		3	SS	3									
			4	SS	6									
			5	SS	4	260								
256.0			6	TW	PM									
17.0	Clayey silt to silt, some sand & gravel. Hard Dark Brown		7	SS	50/3 1/2"	250								
			8	SS	50/2 1/2"									
243.2			9	SS	50/3"									
29.8	End of Borehole													0 38 44 18

RECORD OF BOREHOLE NO 219

W.P. 46-74-13 LOCATION Co-ords. 15,680,043 N; 1,066,283 E. ORIGINATED BY KW
 DIST. 4 HWY. 406 BORING DATE July 13, 14, 15, 1971 COMPILED BY KW
 DATUM Geodetic BOREHOLE TYPE Pendril CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT w_L PLASTIC LIMIT w_p WATER CONTENT w			UNIT WEIGHT γ	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	w_p	w	w_L		
348.5	Ground Level						400	800	1200	1600	2000	20	40	60	P.C.F.	GR. SA. SI. CL.
0.0	Silty sand with gravel. Fill Loose		1	SS	9							o				4 74 (22)
342.0			2	SS	25											
6.5	Clayey silt to silty clay		3	SS	43	340						o				
	traces of sand and gravel		4	SS	29											
			5	SS	21							o				0 4 41 55
	Hard, becoming Stiff		6	SS	14	330						o				
			7	TW	PM										118	
			8	SS	9	320										
	Grey & Brown		9	TW	PM										119	
			10	SS	11	310										
			11	TW	PM										100	
			12	SS	8	300										
			13	TW	PM/13"										120	
			14	SS	12	290										
			15	TW	PM/12"										114	
			16	SS	20	280									121	
272.0			17	SS	48											
76.5	Clayey silt to silt, some sand & gravel.		18	SS	73	273.4						o				
	Hard		19	SS	50/3"	270						o				
	Red-Brown		20	SS	53/6"	260						o				
253.7			21	SS	50/4"							o				
94.8	End of Borehole															

RECORD OF BOREHOLE NO 220

W.P. 46-74-13 LOCATION Co-ords. 15,679,705 N; 1,066,028 E. ORIGINATED BY KW
 DIST. 4 HWY. 406 BORING DATE July 12, 1971 COMPILED BY KW
 DATUM Geodetic BOREHOLE TYPE Pendril CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT W_L PLASTIC LIMIT W_P WATER CONTENT W			UNIT WEIGHT γ PCF	REMARKS % GR. SA. SI. CL.
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	N' VALUES		20	40	60	80	100	W_P	W	W_L		
273.5	Ground Level															
0.0																
	Clayey silt with some sand & gravel		1	SS	22	270										
			3	SS	67											
	Hard		4	SS	62											
			5	SS	57											
	Grey Brown and Red		6	SS	76	260										
	Brown		7	SS	60/3"											
			8	SS	75/6"	250										
243.7			9	SS	50/3"											4 31 49 16
29.8	End of Borehole															

RECORD OF BOREHOLE NO 235

W.P. 46-74-13 LOCATION Co-ords. 15,679,734 N; 1,066,257 E. ORIGINATED BY DM
 DIST. 4 HWY. 406 BORING DATE Dec. 6-7, 1971 COMPILED BY PK
 DATUM Geodetic BOREHOLE TYPE Auger & Cone Test CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT — w_L PLASTIC LIMIT — w_p WATER CONTENT — w			UNIT WEIGHT γ	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	w_p	w	w_L		
310.6	Ground Level						400	800	1200	1600	2000	20	40	60	P.C.F.	GR. SA. SI. CL.
0.0	Silty clay to clayey silt traces of sand and gravel, pockets of silt. Hard to stiff Greyish brown		1	SS	40	310						2000				
			2	SS	38							+2000				
			3	SS	42							+2000				
			4	SS	27							+2000				
			5	SS	33							2000				
			6	TW	PM	290						2000			120	
			7	TW	PM							+2000			125	
			8	TW	PM	280						2000			119	
			9	SS	11							2000				
			10	TW	PM	270						+2000			127	
			11	TW	PM							2000			126	
262.6	Sandy silt, some clay, traces of gravel (Till) Very dense.		12	SS	63	260						2000				
			13	SS	168/10"											
			14	SS	130/6"	250										
61.0	End of Borehole															

ENGINEERING SERVICES BRANCH-GEOTECHNICAL OFFICE - SOIL MECHANICS SECTION

RECORD OF BOREHOLE NO 236

W.P. 46-74-13 LOCATION Co-ords. 15,679,666 N; 1,066,129 E. ORIGINATED BY DM
 DIST. 4 HWY. 406 BORING DATE Dec. 13, 1971 COMPILED BY PK
 DATUM Geodetic BOREHOLE TYPE Auger & Cone Test CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT				LIQUID LIMIT w_L PLASTIC LIMIT w_p WATER CONTENT w		UNIT WEIGHT γ	REMARKS % GR. SA. SI. CL.
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	w_p — w — w_L		
278.7	Ground Level													
0.0	Clayey silt some sand Hard.		1	SS	39									
270.7			2	SS	45									
8.0	Dense		3	SS	40									
	Sandy silt some clay traces of gravel		4	SS	55									0 15 80 5
	Very dense		5	SS	49									3 23 60 14
			6	SS	116									
			7	SS	100/7 4"									9 10 66 15
	Boulders		8	SS	100/7 6"									
248.2														
30.5	End of Borehole													

ENGINEERING SERVICES BRANCH-GEOTECHNICAL OFFICE-SOIL MECHANICS SECTION

RECORD OF BOREHOLE NO 237

W.P. 46-74-13 LOCATION Co-ords. 15,679,597 N; 1,066,076 E. ORIGINATED BY DM
 DIST. 4 HWY. 406 BORING DATE Dec. 17, 1971 COMPILED BY PK
 DATUM Geodetic BOREHOLE TYPE Auger CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT W_L PLASTIC LIMIT W_P WATER CONTENT W			UNIT WEIGHT γ	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	W_P	W	W_L		
272.2	Ground Level					ELEV.	400	800	1200	1600	2000	20	40	60	P.C.F.	GR. SA. SI. CL.
0.0	Organics, rock fill some sand.		1	SS	17	270										
266.2			2	TW	PH	268.2										3 18 67 12
6.0	Sandy silt some clay, traces of gravel Very Dense		3	SS	8											
			4	SS	74											
			5	SS	148	260										1 7 85 7
253.2			6	SS	102/6"											
19.0	End of Borehole															

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS-ONTARIO
ENGINEERING SERVICES BRANCH-GEOTECHNICAL OFFICE-SOIL MECHANICS SECTION

RECORD OF BOREHOLE NO 238

W.P. 46-74-13 LOCATION Co-ords. 15,679,825 N; 1,066,126 E. ORIGINATED BY DM
DIST. 4 HWY. 406 BORING DATE Dec. 8, 1971 COMPILED BY PK
DATUM Geodetic BOREHOLE TYPE Auger & Cone test CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT <u>W_L</u> PLASTIC LIMIT <u>W_P</u> WATER CONTENT <u>W</u>			UNIT WEIGHT <u>γ</u>	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	W _P	W	W _L		
311.6	Ground Level															
0.0	Fill Sandy silt, silty clay, some brick fragments		1	AS		310										2 39 40 19
			2	SS	15											0 4 47 49
			3	SS	42											
			4	SS	36											
297.6			5	SS	32	300										
14.0	Silty clay traces of sand pockets of silt Stiff to Very Stiff.		6	TW	PH										127	
			7	TW	PH											
			8	SS	15	290									123	0 3 52 45
			9	AS												
			10	TW	PH	280									120	
			11	TW	PM										134.5	
			12	SS	16										136	3 12 54 31
268.6						270										
43.0	Sandy silt, some clay & gravel (till) Very dense		13	SS	28	269.0										
			14	SS	47											
			15	SS	105/6"	260										5 16 69 10
251.1			16	SS	100/6"											
60.5	End of Borehole															

RECORD OF BOREHOLE NO 239

W.P. 46-74-13

LOCATION Co-ords. 15,679,783 N; 1,066,089 E.

ORIGINATED BY DM

DIST. 4 HWY. 406

BORING DATE Dec. 9-10, 1971

COMPILED BY PK

DATUM Geodetic

BOREHOLE TYPE Auger & Cone Test

CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT — w_L PLASTIC LIMIT — w_p WATER CONTENT — w			UNIT WEIGHT γ	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	w_p	w	w_L		
300.2	Ground Level						400	800	1200	1600	2000	20	40	60	P.C.F.	GR SA. SI. CL.
0.0	Clayey Silt traces of sand and gravel Very stiff to Hard		1	SS	31	300										
			2	SS	39											
			3	SS	34	290										
			4	TW	PH											
			5	TW	PH											
			6	TW	PM	280										
			7	SS	22											
			8	TW	PM	270										
267.2	Sandy silt some sand traces of gravel Boulders		9	SS	43	266										
			10	SS	85	260										
			11	SS	100/6"											
250.7																
49.5	End of Borehole															

RECORD OF BOREHOLE No 240

W.P. 46-74-13 LOCATION Co-ords. 15,679,683 N; 1,066,015 E. ORIGINATED BY DM
 DIST. 4 HWY. 406 BORING DATE Dec. 16-17, 1971 COMPILED BY PK
 DATUM Geodetic BOREHOLE TYPE Auger CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT w_L PLASTIC LIMIT w_p WATER CONTENT w			UNIT WEIGHT γ P.C.F.	REMARKS % GR. SA. SI. CL.
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	w_p	w	w_L		
271.7	Ground Level						400	800	1200	1600	2000	20	40	60		
0.0	Rock Fill					270										
267.7																
4.0	Organic silt		1&2	SS & AS	6											
261.9			3	TW	PM											
9.8	Silt to sandy silt, traces of clay Very dense		4	SS	45	260										
			5	SS	98											0 4 90 6
253.2			6	SS	178	6"										2 20 68 10
18.5	End of Borehole															

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS-ONTARIO
ENGINEERING SERVICES BRANCH-GEOTECHNICAL OFFICE-SOIL MECHANICS SECTION

RECORD OF BOREHOLE NO 242 A

W.P. 46-74-13 LOCATION Co-ords. 15,679,767 N; 1,065,960 E. ORIGINATED BY DM
DIST. 4 HWY. 406 BORING DATE Dec. 17, 1971 COMPILED BY PK
DATUM Geodetic BOREHOLE TYPE Auger CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT w_L PLASTIC LIMIT w_p WATER CONTENT w			UNIT WEIGHT γ	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	w_p	w	w_L		
271.2	Ground Level															
0.0	Rock Fill	◆				270									P.C.F	GR. SA. SI. CL.
267.7						267.2										
3.5	Organic silt	○	1	SS	61											
	some sand & gravel	○	2	SS	5											
	Very loose	○	3	SS	2	260										
		○	4	SS	2											
256.2		○	5	TW	N/R											
15.0	Silty sand, some	○	6	SS	145/	11"										
	gravel, trace of	○														
	clay,	○	7	SS	130/	3"										
	Very Dense	○				250										
245.7		○	8	SS	140/	6"										
25.5	End of Borehole															

RECORD OF BOREHOLE NO 315

W.P. 46-74-13 LOCATION Co-ords. 15,679,572 N; 1,066,212 E. ORIGINATED BY Golder
 DIST. 4 HWY. 406 BORING DATE Sept. 28 - Oct. 8, 1963 COMPILED BY MW
 DATUM Geodetic BOREHOLE TYPE Power Auger, Washboring & BX Casing CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT w_L PLASTIC LIMIT w_p WATER CONTENT w			UNIT WEIGHT γ P.C.F.	REMARKS % GR. SA. SI. CL.
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	N' VALUES		20 40 60 80 100					w_p w w_L				
							SHEAR STRENGTH P.S.F. kPa									
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE					WATER CONTENT %				
270.6	Ground Level					400	800	1200	1600	2000	20	40	60			
268.1	0.8 Br. cl. si. with sa., gr. & boulders (Fill)					270										
261.3	2.5 Firm to very stiff brown to grey-green silty clay with occas. sand & gravel & a few pieces decayed wood		1	SS	4	W.L. in pipe @ 266.5 Oct. 25, 1963								122		
242.1	9.3 Compact to very dense reddish brown (grey below 22 ft. depth \pm) silty sand to sandy silt occasional gravel		2	TW	PM											
234.8	28.5 Very dense reddish-brown clayey silt with sand & gravel (Till)		3	SS	16					2000						
234.8			4	SS	26											
234.8			5	SS	100											
234.8			6	SS	100											
234.8			7	SS	100											
234.8			8	SS	100											
35.8	End of Borehole															

RECORD OF BOREHOLE NO 317

W.P. 46-74-13 LOCATION Co-ords. 15,680,015 N; 1,065,805 E. ORIGINATED BY Golder
 DIST. 4 HWY. 406 BORING DATE Oct. 8-9, 1963 COMPILED BY MW
 DATUM Geodetic BOREHOLE TYPE Wash Boring BX Casing CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT —WL PLASTIC LIMIT —WP WATER CONTENT —W			UNIT WEIGHT γ	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	WP	W	WL		
270.6	Ground Level					ELEV.	400	800	1200	1600	2000	20	40	60	P.C.F.	GR. SA. SI. CL.
0.0	Compcat crushed graded rockfill		1	SS	13	210										
266.6						W.L. in pipe										
4.0	Soft to firm grey clayey silt, containing wood fragments		2	TW	PM	@el										
260.1			3	TW	PM	266										
10.5	Firm grey silty clay		4	TW	PM	Oct. 25, 1963					3100					
254.1			5	SS	14	260										
16.5	very dense reddish brown silt with some sand and clay & scattered shale fragments (Till)		6	SS	100											
245.1			7	SS	100	250										
25.5	End of Borehole					246										

ENGINEERING SERVICES BRANCH-GEOTECHNICAL OFFICE-SOIL MECHANICS SECTION

RECORD OF BOREHOLE NO 318

W.P. 46-74-13 LOCATION Co-ords. 15,680,436 N; 1,065,496 E. ORIGINATED BY Golder
 DIST. 4 HWY. 406 BORING DATE Oct. 10-11, 1963 COMPILED BY MW
 DATUM Geodetic BOREHOLE TYPE Washboring HX & BX Casing CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT — w_L PLASTIC LIMIT — w_p WATER CONTENT — w			UNIT WEIGHT γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20 40 60 80 100					w_p — w — w_L				
							SHEAR STRENGTH P.S.F. kPA					WATER CONTENT %				
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE									
272.5	Ground Level					ELEV.	400	800	1200	1600	2000	20	40	60		
0.0	Very stiff mottled reddish brown & grey clayey & sandy silt with some gray (Till)		1	SS	15	270										
268.0	Very stiff mottled brown silty clay with a few black streaks		2	SS	14	268.5										
4.5	Very dense reddish brown silt with scattered gravel size particles, trace fine sand & clay (Till)		3	TW	12	W.L. in pipe Oct. 25, 1963									130	
264.0			4	SS	100	260										
8.5			5	SS	100	258										
257.0																
15.5	End of Borehole															

RECORD OF BOREHOLE NO 319

W.P. 46-74-13 LOCATION Co-ords. 15,680,638 N; 1,065,365 E. ORIGINATED BY Golder
 DIST. 4 HWY. 406 BORING DATE Oct. 10-11, 1963 COMPILED BY MW
 DATUM Geodetic BOREHOLE TYPE Washboring HX & BX Casing, BX Core CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT w_L PLASTIC LIMIT w_p WATER CONTENT w			UNIT WEIGHT γ	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	w_p	w	w_L		
270.9	Ground Level						400	800	1200	1600	2000	20	40	60	P.C.F.	GR. SA. SI. CL.
0.0	Very stiff mottled brown silty clay containing a few rock fragments & occasional roots (Fill)		1	SS	13	270										
263.9	Soft to firm brown silty clay		2	SS	16	263.5										
7.0	Soft to firm brown silty clay		3	SS	PM											
260.7	Grey sandy silt		4	SS	70	260										
10.2	7.8 ft. depth.															
	Very dense reddish brown silt with scattered gravel size particles, trace fine sand & clay (Till)		5	SS	100											
			6	AX	-											
250.6			7	SS	100	251										
20.3	End of Borehole															

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS-ONTARIO
ENGINEERING SERVICES BRANCH-GEOTECHNICAL OFFICE-SOIL MECHANICS SECTION

RECORD OF BOREHOLE NO 320

W.P. 46-74-13 LOCATION Co-ords. 15,680,947 N; 1,064,960 E. ORIGINATED BY Golder
DIST. 4 HWY. 406 BORING DATE Oct. 21-22, 1963 COMPILED BY MW
DATUM Geodetic BOREHOLE TYPE Washboring NX & BX Casing, AX Core CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT w_L PLASTIC LIMIT w_p WATER CONTENT w			UNIT WEIGHT γ	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	w_p	w	w_L		
273.3	Ground Level															
0.0	Hard brown fissured silty clay with some roots (weathered & desiccated zone)		1	SS	27											
269.8			2	SS	17											
3.5	Compact brown sandy silt with trace grav. few roots in upper portion & some sand in lower portion		3	SS	11											
263.8			4	SS	100											
9.5	Very dense reddish brown clayey silt matrix with sand and gravel (Till)		5	AX	-											
			6	SS	100											
			7	AX	-											
			8	Core	-											
			9	SS	100											
			10	AX	-											
			11	Core	-											
248.2			12	SS	100											
25.1	End of Borehole															

ENGINEERING SERVICES BRANCH-GEOTECHNICAL OFFICE-SOIL MECHANICS SECTION

RECORD OF BOREHOLE NO 321

W.P. 46-74-13 LOCATION Co-ords. 15,680,935 N; 1,064,587 E. ORIGINATED BY Golder
 DIST. 4 HWY. 406 BORING DATE Oct. 21-22, 1963 COMPILED BY MW
 DATUM Geodetic BOREHOLE TYPE Washboring HX & BX Casing CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT W_L PLASTIC LIMIT W_P WATER CONTENT W			UNIT WEIGHT γ	REMARKS % GR. SA. SI C
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	W_P	W	W_L		
266.0	Ground Level															
263.1																
2.9	Very dense reddish brown sandy silt with scattered subangular sand & gravel size particles (Till)		1	SS	27											
			2	SS	100											
			3	SS	100											
255.6			4	SS	100											
10.4	End of Borehole															

ENGINEERING SERVICES BRANCH-GEOTECHNICAL OFFICE - SOIL MECHANICS SECTION

RECORD OF BOREHOLE NO 350

W.P. 46-74-13 LOCATION Co-ords. 15,679,605 N: 1,065,816 E. ORIGINATED BY Golder
 DIST. 4 HWY. 406 BORING DATE Oct. 28-30, 1963 COMPILED BY MW
 DATUM Geodetic BOREHOLE TYPE Washboring HX & BX Casing CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT w_L PLASTIC LIMIT w_p WATER CONTENT w			UNIT WEIGHT γ	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	w_p	w	w_L		
275.9	Ground Level															
0.0	Stiff to very stiff mottled grey & brown silty clay, few roots & twigs & small shale fragments		1	SS	9	W.L. in pipe										
			2	SS	16	@ El. 275.7 Nov. 1, 1963										
267.8	Rusty brown sandy silt		3	SS	14	270										
266.4	occasional gravel		4	SS	13											
9.5	Compact to dense reddish-grey fine sand, trace silt.		5	SS	17											
259.2			6	SS	46	260										
16.7	Very dense reddish brown sandy & clayey silt															
255.3	some gravel (fill)		7	SS	100	255.5										
20.6	End of Borehole															

ENGINEERING SERVICES BRANCH-GEOTECHNICAL OFFICE - SOIL MECHANICS SECTION

RECORD OF BOREHOLE NO 351

W.P. 46-74-13 LOCATION Co-ords. 15,680,440 N: 1,065,206 E. ORIGINATED BY Golder
 DIST. 4 HWY. 406 BORING DATE Oct. 29, 1963 COMPILED BY MW
 DATUM Geodetic BOREHOLE TYPE Wash Boring BX Casing CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT w_L PLASTIC LIMIT w_p WATER CONTENT w			UNIT WEIGHT γ	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	w_p	w	w_L		
268.8	Ground Level					ELEV.	400	800	1200	1600	2000	20	40	60	P.C.F	GR. SA. SI. CL.
0.0	Stiff becoming soft to firm below about 4' depth, silty clay to clayey silt with some roots & twigs		1	CS	--	W.L. in										
			2	SS	9	pipe										
			3	SS	4	@El. 268.1										
259.3	sand & gravel layer at 5.5 ft. depth					Nov. 260	1, 1963	+s=3.0								
9.5	Very dense reddish brown sandy and clayey silt with some gravel (Till)		4	SS	100											
			5	SS	100											
248.8			6	RC	--	Y-250										
20.0	End of Borehole															

ENGINEERING SERVICES BRANCH-GEOTECHNICAL OFFICE-SOIL MECHANICS SECTION

RECORD OF BOREHOLE NO 352

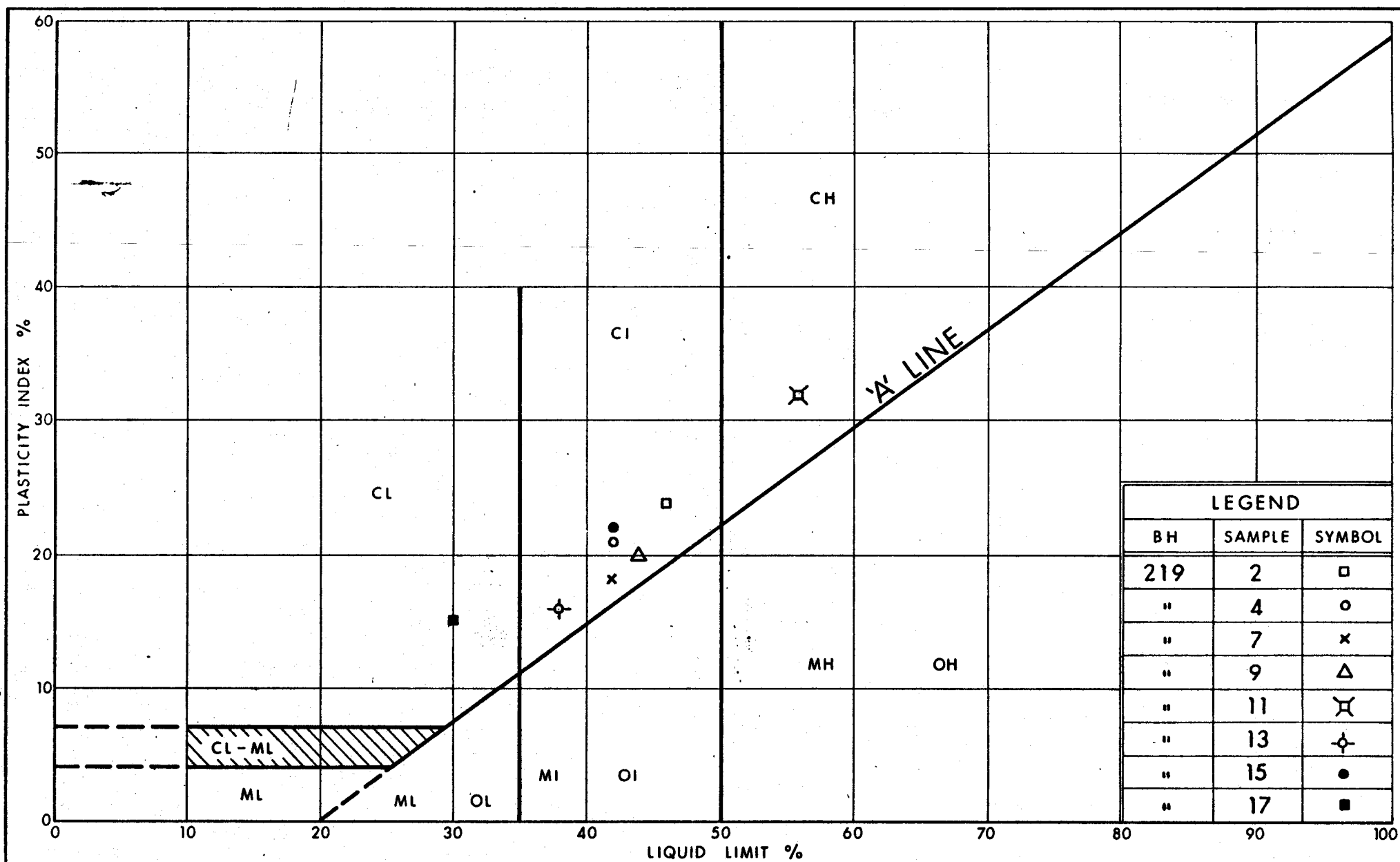
W.P. 46-74-13 LOCATION Co-ords. 15,680,580 N: 1,064,945 E. ORIGINATED BY Golder
 DIST. 4 HWY. 406 BORING DATE Oct. 30-31, 1963 COMPILED BY MW
 DATUM Geodetic BOREHOLE TYPE Wash Boring HX & BX Casing CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT — w_L PLASTIC LIMIT — w_p WATER CONTENT — w			UNIT WEIGHT γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	w_p	w	w_L		
333.0	Ground Level						400	800	1200	1600	2000	20	40	60		
0.0	Hard to very stiff		1	CS	--											
	Brown-grey silty		2	SS	26	330										
	clay with some		3	SS	--											
	fissures, some		4	SS	27											
	scattered sand and		5	SS	26											
	gravel size partic-		6	SS	25											
	les, some roots &		7	TW	21	320									132	
	twigs in upper por-		8	SS	23											
	tion															
311.0	(desiccated zone)		9	SS	33											
22.0	Very stiff to firm		10	SS	26	310										
	grey silty clay															
	with a few grey		11	TW	20											
	silt pockets					300										119
	(generally less than		12	SS	11											
	1/2 inches in size)															
	and some scattered		13	TW	PM											
	sand and gravel					290										121
	size particles		14	SS	6											
			15	TW	PM											122
						280										
			16	SS	12											
273.5	Dense reddish brown															
277.5	stiff fine sa., few pebbles		17	TW	31	278.1										138
61.5	Very dense reddish															
	brown sandy & clayey		18	SS	100											
265.2	silt, some grav. (Till)		19	SS	100	270										
67.8	End of Borehole					266										

RECORD OF BOREHOLE NO 355

W.P. 46-74-13 LOCATION Co-ords. 15,679,605 N; 1,065,817 E. ORIGINATED BY Golder
 DIST. 4 HWY. 406 BORING DATE Nov. 5, 1963 COMPILED BY MW
 DATUM Geodetic BOREHOLE TYPE Washboring - HX & BX Casing CHECKED BY BL

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT w_L PLASTIC LIMIT w_p WATER CONTENT w			UNIT WEIGHT γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	N' VALUES		20	40	60	80	100	w_p	w	w_L		
272.8	Ground Level															
0.0	Hard to firm, brown silty clay with some gravel, few roots & twigs		1	HX Casing	--	270										
266.8			2	SS	14											
6.0	Compact to very dense reddish grey fine sandy silt, trace clay with some gravel		3	SS	24								00	0		
			4	SS	14											
			5	SS	30	260										
			6	SS	49											
254.3			7	SS	100											
18.5	End of Borehole															



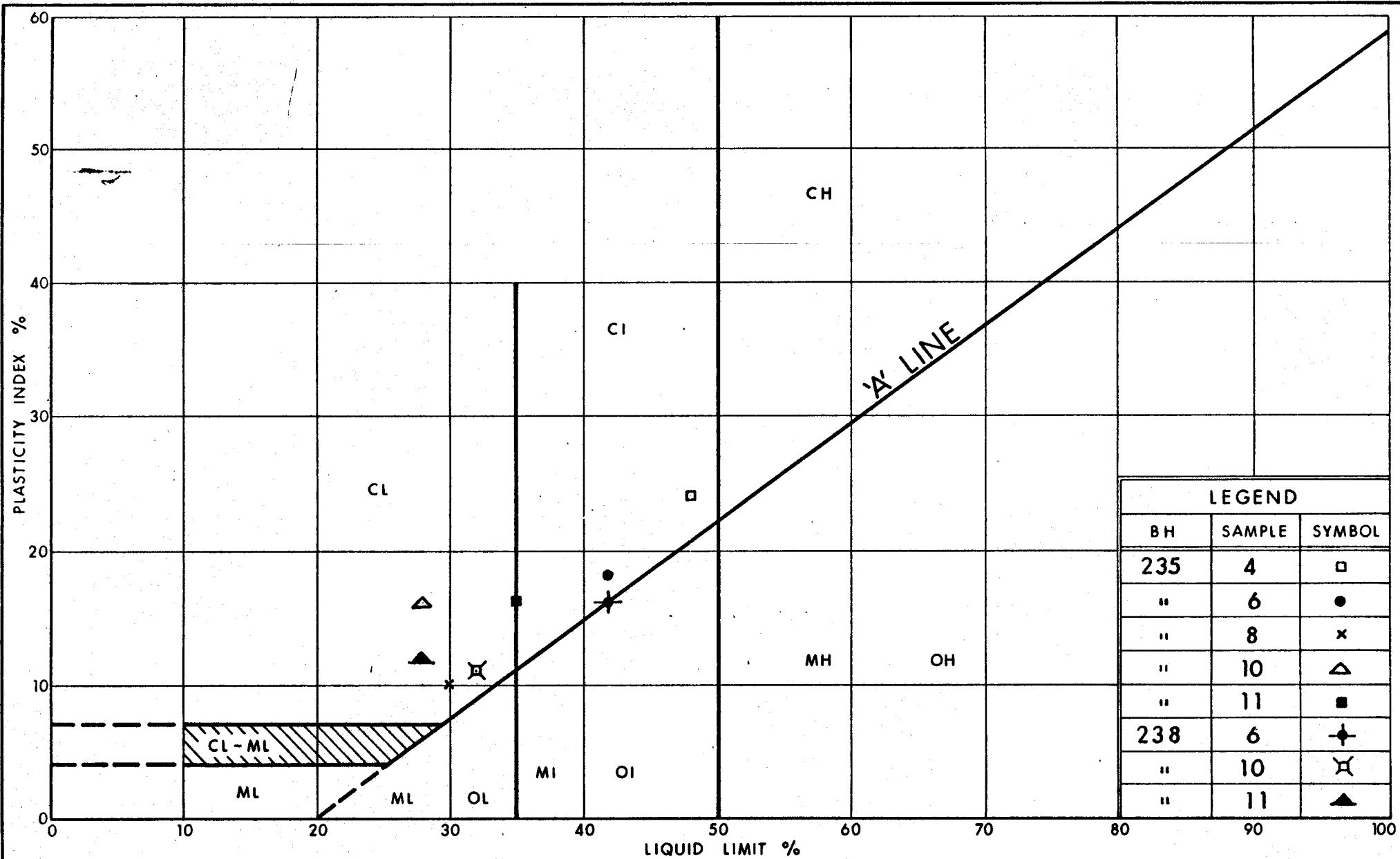
PLASTICITY CHART SILTY CLAY

FIG No 1

W P 46-74-13



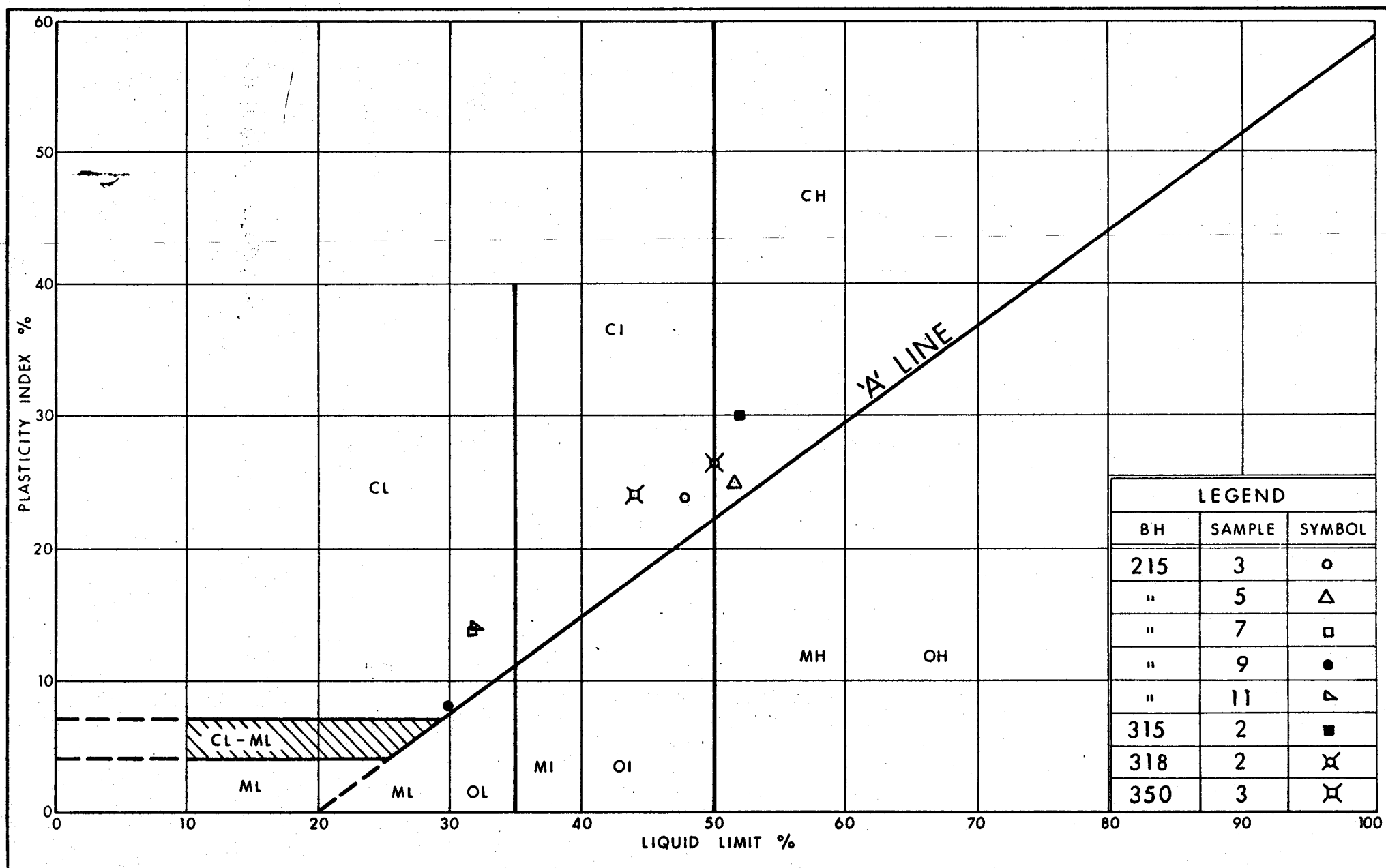
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Ontario
ENGINEERING SERVICES BRANCH



PLASTICITY CHART SILTY CLAY

FIG No 2

W P 46-74-13

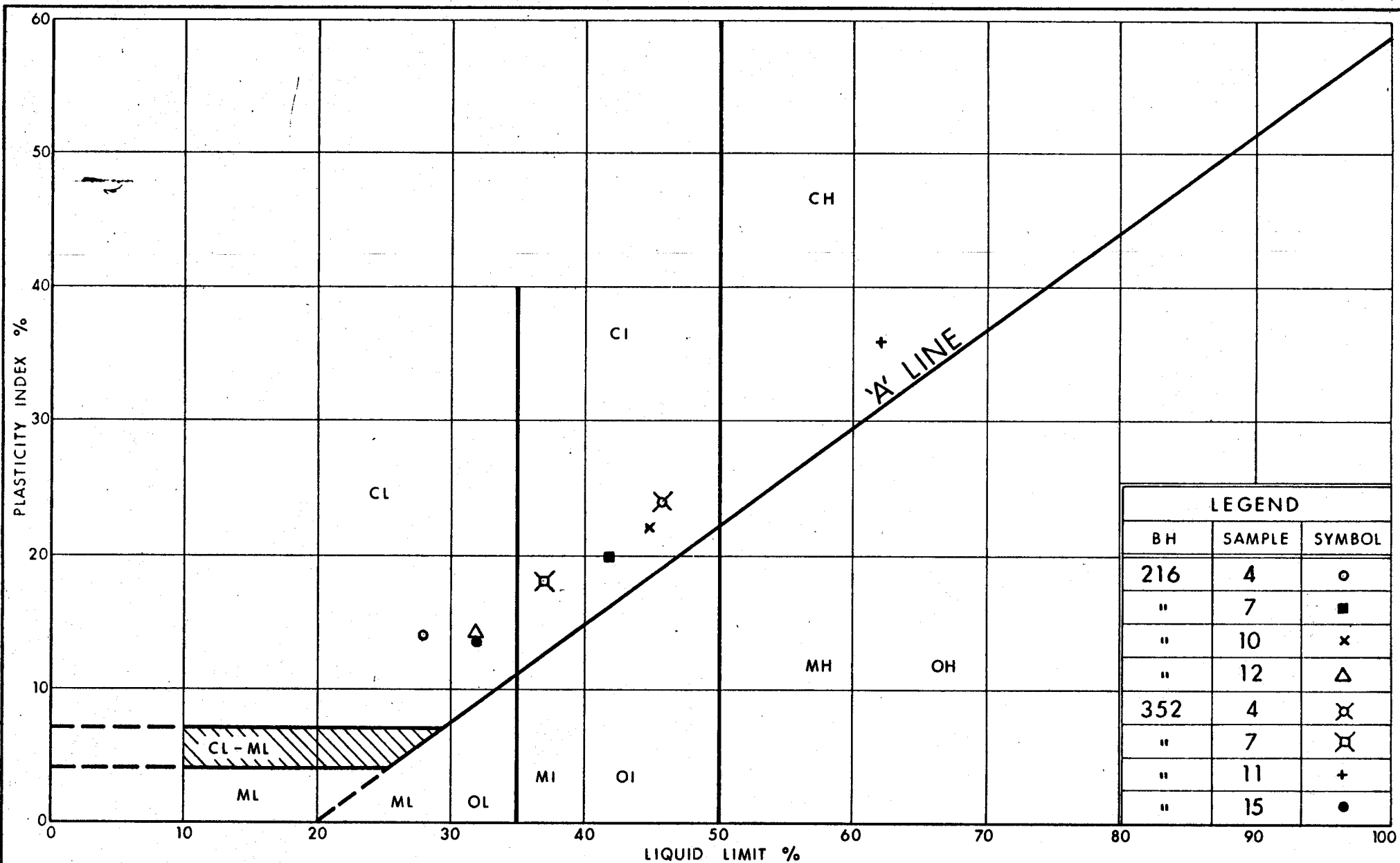


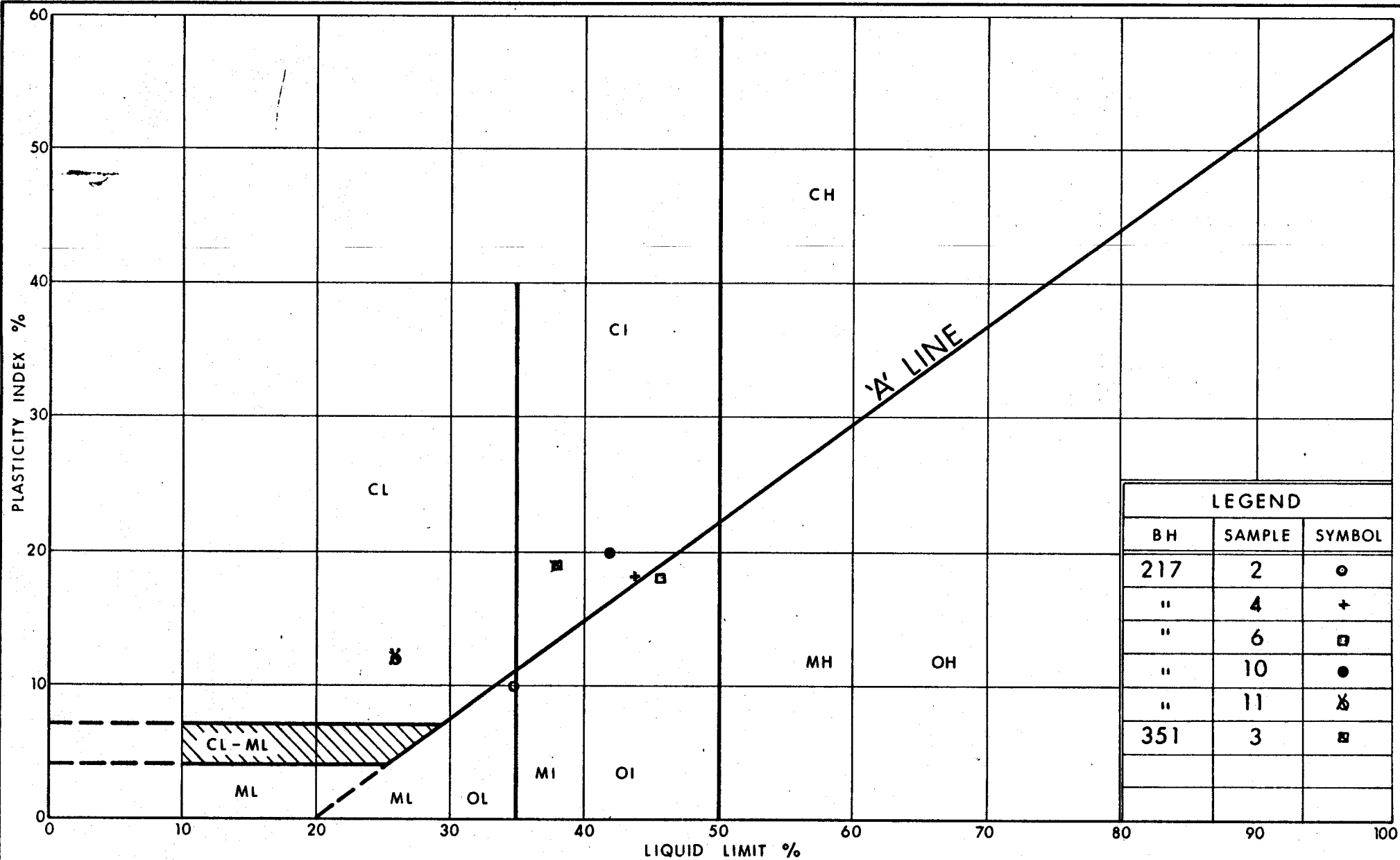
PLASTICITY CHART
SILTY CLAY

FIG No 3

W P 46-74-13







PLASTICITY CHART SILTY CLAY

FIG No 5

W P 46-74-13

ABBREVIATIONS & SYMBOLS USED IN THIS REPORTPENETRATION RESISTANCE

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

TERMS TO BE USED IN DESCRIBING SOILS:-

TRACE < 10% , SOME 10-25% , WITH 25-40% , > 40% SILTY, SANDY, GRAVELLY, CLAYEY ETC.

TYPE OF SAMPLE

S.S.	SPLIT SPOON	T.W.	THINWALL OPEN
W.S.	WASHED SAMPLE	T.P.	THINWALL PISTON
S.T.	SLOTTED TUBE SAMPLE	O.S.	OESTERBERG SAMPLE
A.S.	AUGER SAMPLE	F.S.	FOIL SAMPLE
C.S.	CHUNK SAMPLE	R.C.	ROCK CORE

P.H. SAMPLE ADVANCED HYDRAULICALLY

P.M. SAMPLE ADVANCED MANUALLY

SOIL TESTS

U	UNCONFINED COMPRESSION	L.V.	LABORATORY VANE
UU	UNCONSOLIDATED UNDRAINED TRIAXIAL	F.V.	FIELD VANE
CIU	CONSOLIDATED ISOTROPIC UNDRAINED TRIAXIAL	C	CONSOLIDATION
CID	" " DRAINED "	S	SENSITIVITY
CAU	" ANISOTROPIC UNDRAINED "		
CAD	" " DRAINED "		

ABBREVIATIONS & SYMBOLS USED IN THIS REPORT

SOIL PROPERTIES

γ	UNIT WEIGHT OF SOIL (BULK DENSITY)
γ_s	UNIT WEIGHT OF SOLID PARTICLES
γ_w	UNIT WEIGHT OF WATER
γ_d	UNIT DRY WEIGHT OF SOIL (DRY DENSITY)
γ'	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
w_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
τ_f	SHEAR STRENGTH
c'	EFFECTIVE COHESION INTERCEPT
ϕ'	EFFECTIVE ANGLE OF SHEARING RESISTANCE, OR FRICTION
c_u	APPARENT COHESION
ϕ_u	APPARENT ANGLE OF SHEARING RESISTANCE, OR FRICTION
μ	COEFFICIENT OF FRICTION
S_t	SENSITIVITY

GENERAL

π	= 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
σ	NORMAL STRESS
σ'	NORMAL EFFECTIVE STRESS ($\bar{\sigma}$ IS ALSO USED)
τ	SHEAR STRESS
ϵ	LINEAR STRAIN
γ	SHEAR STRAIN
ν	POISSON'S RATIO (μ IS ALSO USED)
E	MODULUS OF LINEAR DEFORMATION (YOUNG'S MODULUS)
G	MODULUS OF SHEAR DEFORMATION
K	MODULUS OF COMPRESSIBILITY
η	COEFFICIENT OF VISCOSITY

EARTH PRESSURE

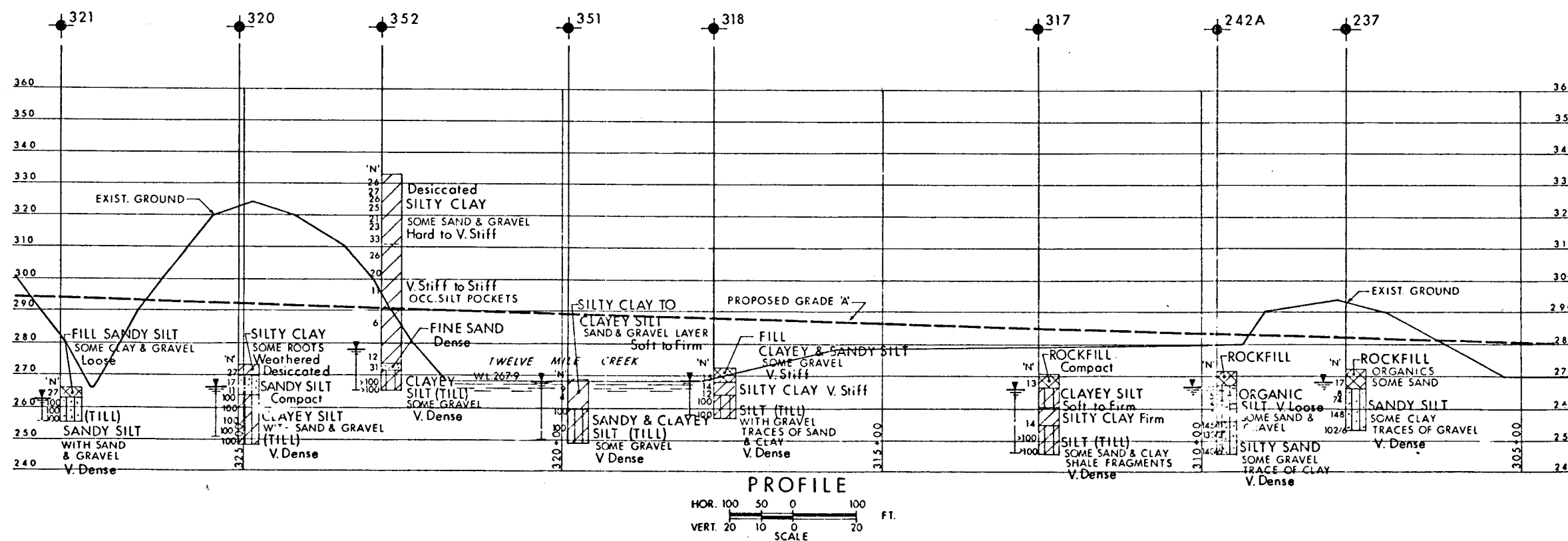
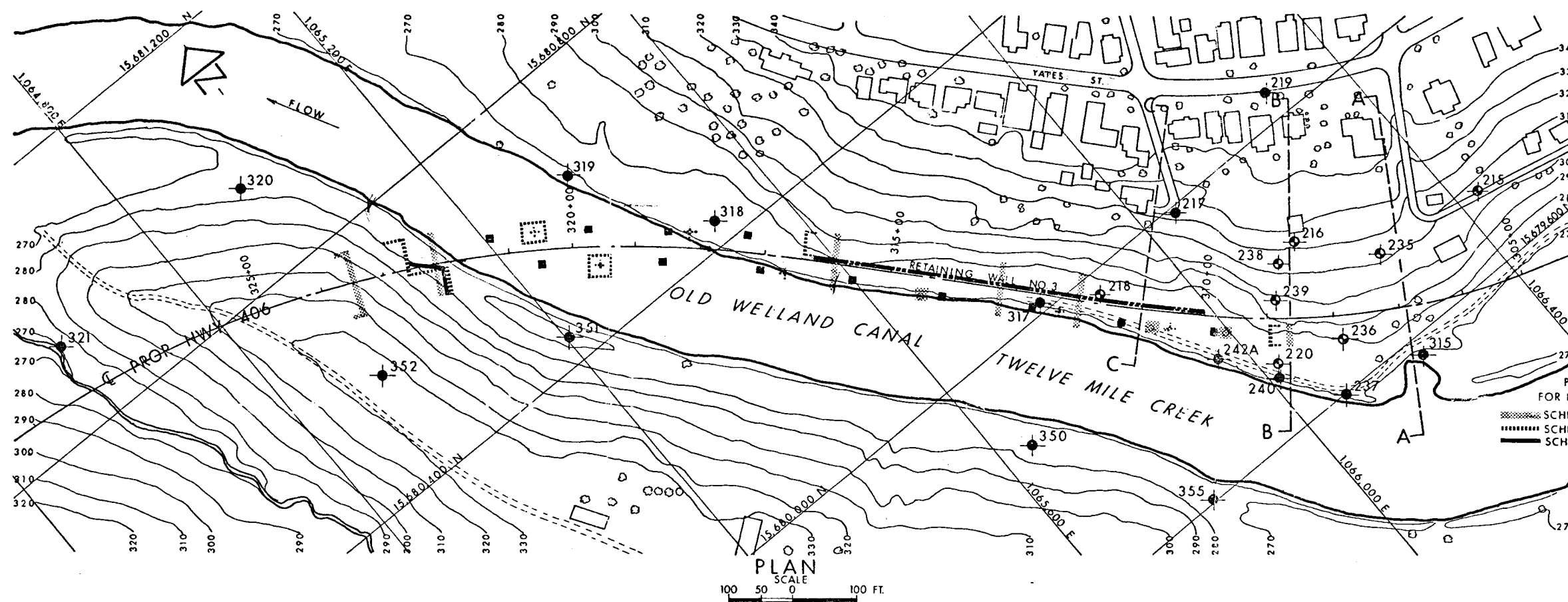
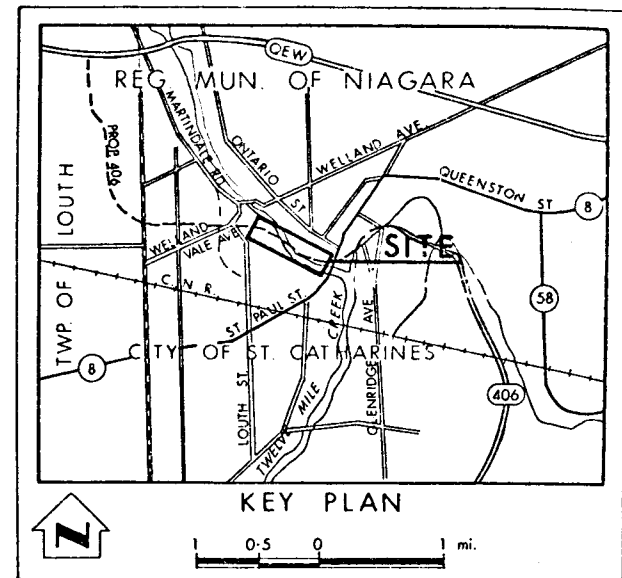
d	DISTANCE FROM TOP OF WALL TO POINT OF APPLICATION OF PRESSURE
δ	ANGLE OF WALL FRICTION
K	DIMENSIONLESS COEFFICIENT TO BE USED WITH VARIOUS SUFFIXES IN EXPRESSIONS REFERRING TO NORMAL STRESS ON WALLS
K_0	COEFFICIENT OF EARTH PRESSURE AT REST

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 FOR BEARING CAPACITY
k_s	MODULUS OF SUBGRADE REACTION

SLOPES

H	VERTICAL HEIGHT OF SLOPE
D	DEPTH BELOW TOE OF SLOPE TO HARD STRATUM
β	ANGLE OF SLOPE TO HORIZONTAL



PROPOSED LOCATIONS FOR FOOTINGS & PIERS

SCHEME 1 CABLE STAYED
SCHEME 2 1 PIER
SCHEME 3 2 PIERS

LEGEND

- Bore Hole
- Dynamic Cone Penetration Resistance Test
B/F CONE - Blows/Ft. Cone Test (350 ft. lbs. energy/blow)
- Bore Hole & Cone Test
- Water Levels established at time of field investigation, Oct. 1963 & Dec. 1971

NO.	ELEVATION	CO-ORDINATES	
		NORTH	EAST
237	272.2	15,679,597	1,066,076
242A	271.2	15,679,767	1,065,960
317	270.6	15,680,015	1,065,805
318	272.5	15,680,436	1,065,496
319	270.9	15,680,638	1,065,365
320	273.3	15,680,947	1,064,960
321	266.0	15,680,935	1,064,587
350	275.9	15,679,605	1,065,516
351	268.8	15,680,440	1,065,206
352	333.0	15,680,580	1,064,945
355	272.8	15,679,605	1,065,817
215	305.6	15,679,710	1,068,436
216	324.7	15,679,834	1,066,169
217	325.2	15,679,992	1,066,055
218	273.0	15,679,963	1,065,885
219	348.5	15,680,043	1,066,283
220	273.5	15,679,705	1,066,028
235	310.6	15,679,734	1,066,257
236	278.7	15,679,666	1,066,129
238	311.6	15,679,825	1,066,125
239	310.2	15,679,783	1,066,089
240	271.7	15,679,683	1,066,015
315	270.6	15,679,572	1,066,212

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

REVISIONS	DATE	BY	DESCRIPTION

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS—ONTARIO
ENGINEERING SERVICES BRANCH—GEOTECHNICAL OFFICE—SOIL MECHANICS SECTION

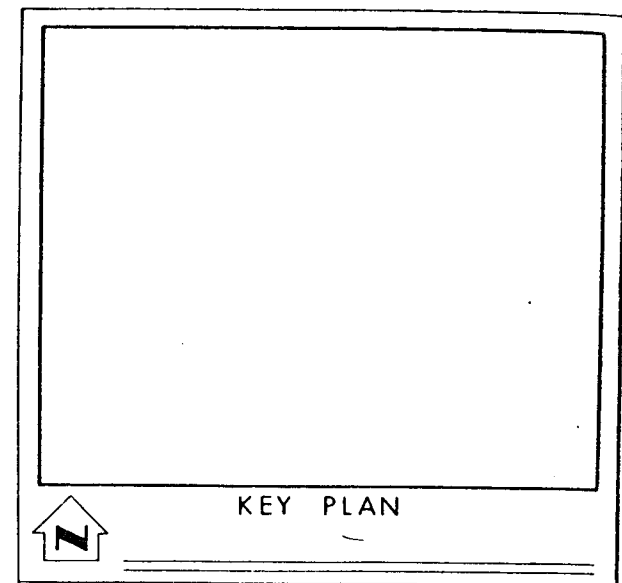
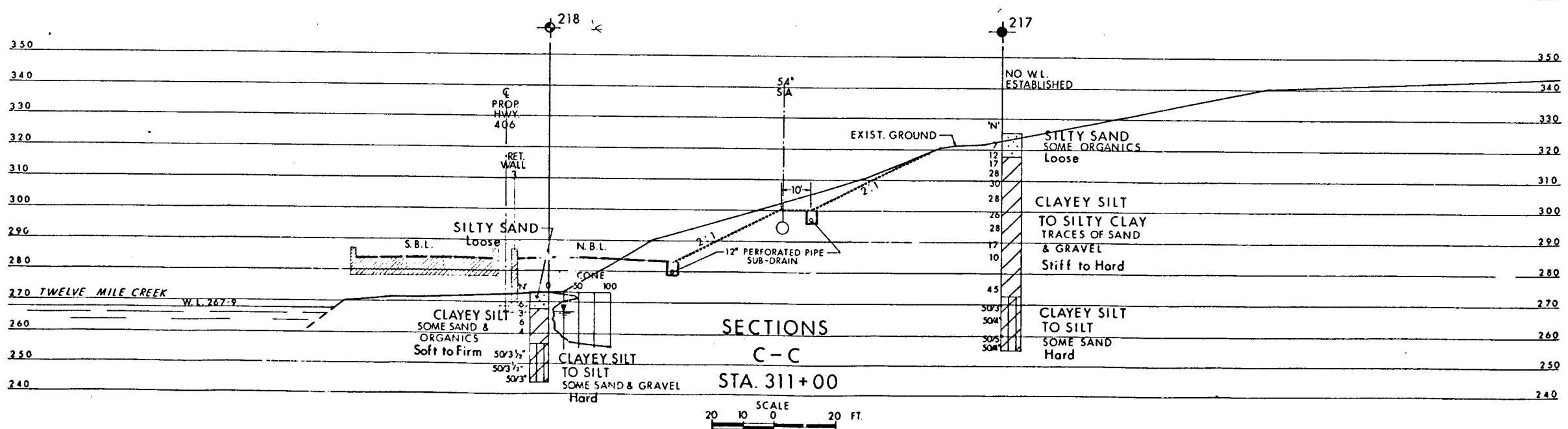
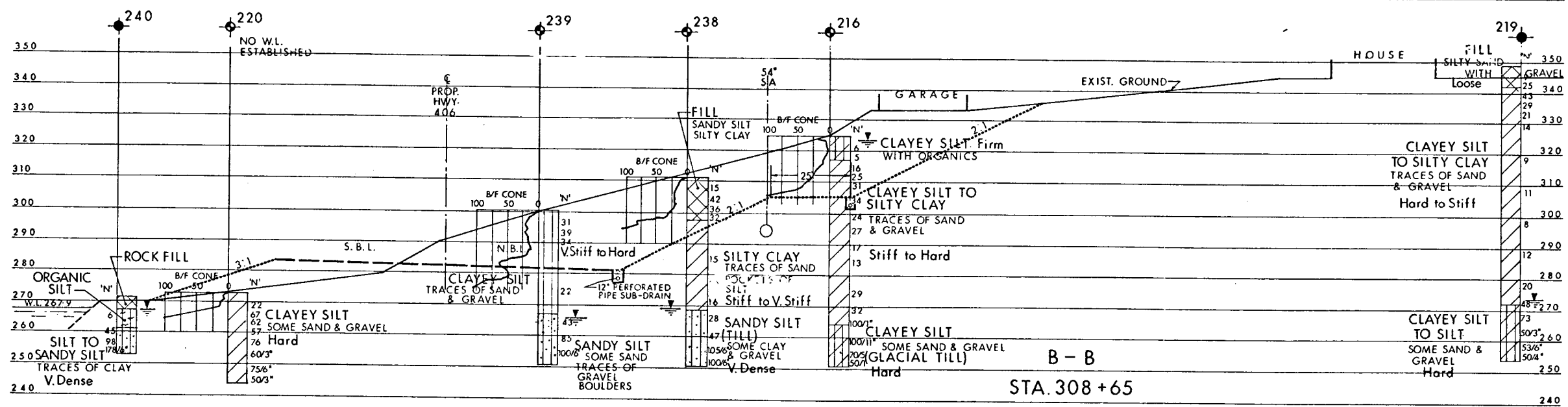
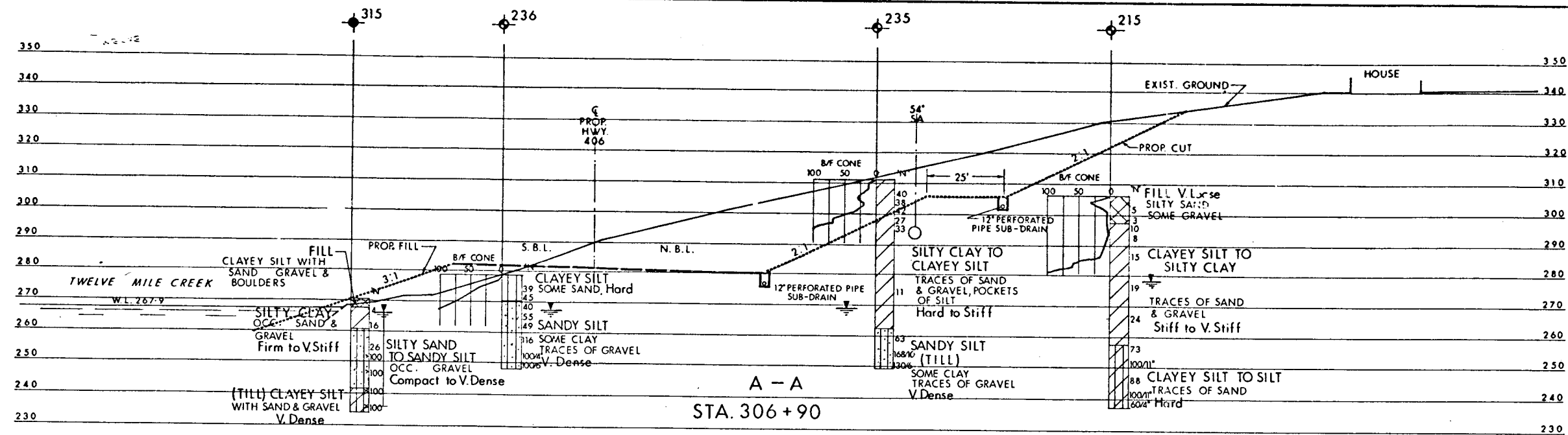
TWELVE MILE CREEK

HIGHWAY NO. PROP. 406 DIST. NO. 4
REGIONAL MUNICIPALITY OF NIAGARA
CITY OF ST. CATHARINES LOT 19 CON. 6

BORE HOLE LOCATIONS & SOIL STRATA

SUBMD B L	CHECKED	W.P. NO. 46-74-13	DRAWING NO.
DRAWN O.L.J.	CHECKED	W.C. NO.	467413-A
DATE 14 JAN. 1976		SITE NO. 18-233	BRIDGE DRAWING NO.
APPROVED		CONT. NO.	

REF. PROCTOR & REDFERN LTD.
X-74452-G14



LEGEND			
	Bore Hole		
	Dynamic Cone Penetration Resistance Test B/F CONE - Blows/Ft. Cone Test (350 ft. lbs. energy/blow)		
	Bore Hole & Cone Test		
	Water Levels established at time of field investigation. July & Dec. 1971 No W. L. established on B.H. 217, 220		
NO.	ELEVATION	CO-ORDINATES	
		NORTH	EAST

— NOTE —

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

REVISIONS	DATE	BY	DESCRIPTION

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS—ONTARIO ENGINEERING SERVICES BRANCH—GEOTECHNICAL OFFICE—SOIL MECHANICS SECTION			
TWELVE MILE CREEK			
HIGHWAY NO. <u>PROP. 406</u>	DIST. NO. <u>4</u>		
REGIONAL MUNICIPALITY OF NIAGARA			
CITY OF ST. CATHARINES LOT 19		CON. <u>6</u>	
SECTIONS & SOIL STRATA			
SUBMD. B. L.	CHECKED	WP NO. 46-74-13	DRAWING NO.
DRAWN. O. L. J.	CHECKED	W. O. NO.	467413-B
DATE 14 JAN. 1976	SITE NO. 18-233	BRIDGE DRAWING NO.	
APPROVED	CONT. NO.		