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G.I.-30 SEPT. 1976

GEOCRES No. 52A-17

DIST. 19 REGION

W.P. No. 59-69-00

CONT. No.

W. O. No.

STR. SITE No.

HWY. No. 11 & 17

LOCATION PROPOSED APPROACH

EMBANKMENTS AT THE CROSSING

NO OF THUNDER BAY EXPRESSWAY

=====

OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

## DEPARTMENT OF HIGHWAYS ONTARIO

## MEMORANDUM

52A - 17

GEOCRES No.

TO: Mr. R. Morgenroth,  
Regional Materials Engineer,  
Regional Office,  
THUNDER BAY, Ontario.

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

ATTENTION:

DATE: October 7, 1970

OUR FILE REF.

IN REPLY TO

OCT 14 1970

SUBJECT:

## FOUNDATION INVESTIGATION REPORT

For

Proposed Approach Embankments at the  
Crossing of Thunder Bay Expressway  
And Hwys. #11 and #17 - Scheme 'B'

City of Thunder Bay

District No. 19 (Thunder Bay)

W.O. 70-11070 -- W.P. 59-69

Attached, we are forwarding to you, the results  
of our subsoil investigation in connection with the  
stability of the above mentioned proposed approach  
embankments.

We believe that the factual data and recommendations  
contained therein, will prove adequate for your design  
requirements. Should additional information be required,  
please feel free to contact our Office.

AGS/MdeF  
Attach.

cc: Messrs. R. Morgenroth (2)

B. R. Davis

H. A. Tregaskes

D. W. Farren

H. W. Hurrell

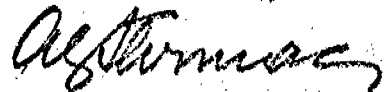
J. G. Tillcock

P. Lester (2)

B. A. Singh

Foundations Files ✓

Gen. Files



A. G. Stermac  
PRINCIPAL FOUNDATION ENGINEER

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FOUNDATION INVESTIGATION REPORT  
For  
Proposed Approach Embankments at the  
Crossing of Thunder Bay Expressway  
And Hwys. #11 and #17 - Scheme 'B'  
City of Thunder Bay  
District No. 19 (Thunder Bay)  
W.O. 70-11070      --      W.P. 59-69

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1. INTRODUCTION:

The Foundation Section was requested to carry out a subsurface investigation for the aforementioned embankments. The request was contained in a memo from the Northwestern Region Materials Section (Mr. R. Morgenroth, Regional Materials Engineer), dated July 13, 1970. An investigation was subsequently carried out by the Foundation Section to determine the subsoil and ground-water conditions at the site.

This report contains the results of the investigation, together with our assessment of the stability and settlement considerations pertaining to the approach embankments.

A detailed foundation investigation will be required for the structure to be placed at this site, once final design details become available.

2. DESCRIPTION OF THE SITE AND GEOLOGY:

The site is located in the residentially developed western outskirts of the City of Thunder Bay - specifically, at the intersection of Hwys. #11 and #17 (Arthur St.) and the Thunder Bay Expressway. The Air Lane Motel is located on the southeast corner of this intersection. The terrain in the area, which is grass-covered, is flat-lying between elevations 626 to 629.

The highways each have two paved lanes. Drainage ditches, approximately 3 feet in depth, are located along either side of the highways.

2. DESCRIPTION OF THE SITE AND GEOLOGY: (cont'd.) ...

The geologic history of the Great Lakes region is known to be quite complex. The lakes are located almost wholly within the Precambrian Shield. Further, they are nearly surrounded with highlands - i.e., the general pattern is that of a syncline with the Great Lakes occupying the trough. In the geologic past the area was inundated by glacial Lake Algonquin, the main stage of which existed at about elevation 605. Terraces, composed of material of quite variable composition, were formed during successive stages of the Algonquin period. In the vicinity of the area under investigation, the deposits were laid down in an easterly advancing delta, formed by a river which occupied the Kaministiquia River valley and flowed into glacial Lake Algonquin. Finer material (silty clay) was deposited over a very considerable area in the bottom of the lake and the relatively coarser material (stratified silts and sands) were deposited over a less extensive area near the mouth of the glacial river. At one time, however, the mouth of this river was located at least 15 miles west of the existing shoreline of Lake Superior. The complexly interbedded deltaic deposits, which are of considerable thickness, are underlain by a basal glacial till sheet.

The overburden deposits are underlain by shale bedrock of the Onimikie formation, Late Precambrian Period.

3. FIELD AND LABORATORY INVESTIGATION:

Five sampled boreholes were put down using a power auger machine (Penndrill). At those locations where the uncased holes caved, the borings were completed using a diamond drill rig adapted for soil testing purposes.

Samples of the overburden were obtained in a 2" O.D. split-spoon sampler, which was hammered into the ground in accordance with the specifications for the Standard Penetration Test. In addition, some 2" I.D. Shelby tubes were manually

3. FIELD AND LABORATORY INVESTIGATION: (cont'd.) ...

pushed into the more cohesive zones. In situ vane tests were also carried out within these zones to determine the undrained shear strength and sensitivity of such subsoils.

The groundwater level conditions across the site were determined by recording the water levels in the open boreholes during the course of the investigation.

The locations and elevations of all the boreholes are shown on Drawing No. W.O. 70-11070A, together with two estimated stratigraphical cross-sections. The surveying was carried out by personnel from the Northwestern Region Engineering Surveys Section. All elevations are referenced to Geodetic datum.

All the samples were subjected to careful visual examination both in the field and in the laboratory. In addition, laboratory tests were performed on selected samples to determine the engineering properties of the various soil types, namely:

Natural Moisture Content  
Grain-size Distribution  
Atterberg Limits  
Organic Content  
Undrained Shear Strength  
Consolidation Testing

The results of the laboratory testing are plotted on the "Record of Borehole" sheets and summarized on Figures No. 1 to 5, all of which are contained in Appendix I of this report.

4. SUBSOIL CONDITIONS:

4.1) General:

As discussed in Section #2, the overburden in this area is composed of complexly interbedded deposits. The upper 55 feet is composed of very loose to compact silts and sands which are

4. SUBSOIL CONDITIONS: (cont'd.) ...

4.1) General: (cont'd.) ...

occasionally layered and stratified. The granular deposits are underlain by stiff silty clay, which, in turn, is followed by a basal glacial till sheet.

The boundaries of the various deposits are shown on the accompanying borelog sheets. The two stratigraphical sections, shown on Drawing No. W.O. 70-11070A, were inferred from this data.

From ground surface downward, the various soil types encountered are as follows:

4.2) Silty Fine Sand (Upper Deposit):

The topsoil across the site is underlain by a 8.5 to 13 feet thick deposit composed of loose to compact ('N' values 7 to 23 blows/ft.) brown to grey silty fine sand. Occasional seams (up to 1/4 inch thick) of silty clay are present throughout the deposit. A typical grain-size distribution curve, obtained on a sample from the granular deposit (B.H. #1, Sample No. 2), is plotted on Figure #1 in Appendix I of this report.

4.3) Silt with a trace of Organic Matter:

The silty sand deposit is followed by a very loose to loose ('N' values 2 to 4 blows/ft.) grey-brown silt with some sand; the overall thickness of this stratum ranges from 11 to 20.5 feet. A trace of organic matter, in the form of sea shells, root fibre, etc., are present throughout. Laboratory testing carried out indicates that the organic content is of the order of 1 to 1-1/2% (by weight). In addition, numerous clayey silt layers, up to 1 inch in thickness, are encountered within this deposit; the frequency of these layers increases with depth. Grain-size distribution curves, obtained on samples from this material, are plotted on Figure #2. The natural moisture content of the deposit varies from 25 to 36%. These values would indicate that this material is in a saturated condition.

4. SUBSOIL CONDITIONS: (cont'd.) ...

4.3) Silt with a trace of Organic Matter: (cont'd.) ...

Some in situ field vane tests were carried out within the stratum in an attempt to determine the undrained shear strength of the cohesive layers; the results are plotted on the Borelog sheets. This testing gave values which range from 600 to 1,200 p.s.f. Since, i) the deposit is basically granular in nature, and ii) the cohesive layers are relatively thin, it is inferred that these values cannot be considered representative.

4.4) Silty Sand, Silt and Clayey Silt (Layered):

The loose silt stratum is underlain by a 5 to 6.5 foot thick layer of compact stratified silty fine sand. The silty fine sand is underlain by a complexly layered stratum whose overall thickness ranges from 8 to 11.5 feet. The composition of the individual layers, which range randomly from 1/2 to 2 inches in thickness, vary from silty sand to silt to clayey silt. In general, the granular layers predominate; however, the frequency of the cohesive layers increases markedly with depth.

Atterberg limit tests were carried out on material obtained from the cohesive layers; the results are plotted on the Record of Borelog sheets as well as on the Plasticity Chart, Figure #4. The values recorded indicate that the clayey silt layers have a plasticity in the low range.

Standard penetration testing carried out within the layered stratum gave 'N' values between 1 and 5 blows/ft. In addition, the undrained shear strength of the cohesive portions of the deposit was determined by performing field vane testing. This testing gave values which range from 600 to 1,400 p.s.f. Based on these results, it is estimated that the relative density of the granular layers is in the very loose to loose range, while the consistency of the cohesive layers varies from firm to stiff.



4. SUBSOIL CONDITIONS: (cont'd.) ...

4.5) Silty Fine Sand to Sandy Silt (Lower Deposit):

The layered deposit is underlain by a loose to compact ('N' values 5 to 12 blows/ft.) faintly stratified silty fine sand to sandy silt. All the borings, with the exception of B.H. #1, were terminated within this deposit. At B.H. #1 the deposit is 15.5 feet thick.

4.6) Silty Clay:

At B.H. #1 the lower granular deposit is followed by a stratum composed of stiff silty clay. This stratum was not fully penetrated at this location; it was, however, proven to extend for a depth of 22 feet. Occasional seams (approximately 1/2 inch thick) of silt are present throughout. A grain-size distribution test, carried out on a sample of the cohesive subsoil, is plotted on Figure #3. Two Atterberg limit tests, carried out on this subsoil, indicate that the silty clay is inorganic and of intermediate plasticity.

The compressibility characteristics of this cohesive deposit were determined by carrying out a laboratory oedometer test, the results of which are shown as a Void Ratio (e) vs. Pressure plot on Figure #5. Based on this test, it is estimated that the stratum is preconsolidated by about 500 p.s.f. in excess of existing overburden pressure. The values for the Initial Void Ratio ( $e_0$ ) and the Compression Index ( $C_c$ ) are 1.2 and 0.54, respectively.

5. GROUNDWATER CONDITIONS:

Groundwater level observations have been carried out, during the period of the investigation, in the open boreholes. The observations are recorded on the Borelog sheets and summarized on Drawing No. W.O. 70-11070A. These readings indicate that the groundwater level generally ranges from elevation 621 to 624. These elevations correspond to depths below ground surface of 4 to 8 feet.

6. DISCUSSION AND RECOMMENDATIONS:

6.1) General:

It is proposed to eventually construct an overpass structure to carry the Thunder Bay Expressway over Hwys. #11 and #17 (Arthur Street), in the western outskirts of the City of Thunder Bay.

It is understood that the profile grade of the Expressway, in the vicinity of the structure, will vary from elevation 650 to 651. At this grade the maximum height of the approach fills will be of the order of 21 feet. At the time of writing, structure design details, such as the number and length of the individual spans, have not been finalized.

In this general area, the upper 55 feet of the overburden is composed of complexly interbedded deposits of deltaic origin. The deposits are primarily composed of very loose to compact silts and sands; occasional seams of clayey silt are present throughout the major portion of the deposits. The granular deposits are underlain by stiff silty clay, which, in turn, is followed by a basal glacial till sheet.

The stability and settlement considerations, associated with the approach fills, will be discussed in the sub-sections to follow. Recommendations pertaining to the structure foundations will be presented in a future report once design details become available.

6.2) Approach Embankments:

6.2.1) Stability Considerations -

The approach fills will be underlain, at a shallow depth, by the very loose to loose deltaic granular deposits which contain a trace of organic matter. The overall thickness of these deposits is of the order of 55 feet. It will be necessary to ensure that these materials are not 'overstressed' by the fill surcharge loadings.

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

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

6.2.1) Stability Considerations - (cont'd.) ...

The stability of the fill sections in this area were determined by carrying out effective stress analyses both manually and by the use of the electronic computer. In this method of analyses, the stability is governed by the effective stress parameters, namely, the apparent effective cohesion ( $C'$ ) and the effective angle of internal friction ( $\phi'$ ), as well as the estimated excess hydrostatic pore water pressure ( $u$ ) induced in the foundation subsoil by the surcharge fill loadings. The excess hydrostatic pore water pressure is represented by the expression:

$$u = \bar{B} \Delta \sigma_z \quad (\text{p.s.f.})$$

where -  $\bar{B}$  - dimensionless parameter

$\Delta \sigma_z$  - effective vertical stress increase due to the surcharge loading (p.s.f.).

The critical period, as far as stability is concerned, will be during and immediately following construction, since during this phase the induced pore water pressure will be at its peak. Following this period the pore water pressure will begin to dissipate and the fills will become more stable.

The following were assumed in the computations:

| <u>Subsoil</u>          | <u>Effective Cohesion (<math>C'</math>)</u> | <u>Effective Angle of Friction (<math>\phi'</math>)</u> | <u><math>\bar{B}</math> (During Construction)</u> |
|-------------------------|---|---|---|
| Fill                    | 0   | 30°   | 0   |
| Silty Sand              | 0   | 30°   | 0   |
| Silt, trace of Organics | 0   | 24°   | 0.7   |
| Silty Sand (Strat.)     | 0   | 28°   | 0   |
| Layered Material        | 0   | 24°   | 0.7   |

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

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

6.2.1) Stability Considerations - (cont'd.) ...

Based on the results of the analyses, it is estimated that, during the critical period, fills of the height contemplated (21 feet maximum), should be inherently stable, provided:

i) standard 2:1 slopes are employed, and ii) the excess pore water pressures built up are within the range quoted in the previous table.

6.2.2) Settlement Considerations -

The underlying interbedded granular deposits will undergo settlement under the weight of the approach embankments. Based on computations carried out, it is estimated that the maximum amount of this settlement could be of the order of 1-1/2 to 2 inches. This settlement will be elastic in nature - i.e., take place during or immediately following the placement of the fill.

In addition to the aforementioned, the silty clay stratum, underlying the interbedded granular deposits, will undergo consolidation due to the induced pressure. The maximum amount of consolidation settlement expected is approximately 3 to 4 inches. It is estimated that this settlement will be realized within a period of 2 to 2-1/2 years.

6.2.3) Recommended Instrumentation During Construction -

The Department has never fully determined, under actual field conditions, the load - deformation characteristics of loose recent granular deposits, particularly in relation to the settlement and stability considerations associated with approach fills. It would be advantageous, therefore, to carry out an instrumentation programme on this project in order to determine the above under full-scale field loading conditions. The scope of this programme is discussed in the paragraphs to follow.

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

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

6.2.3) Recommended Instrumentation During Construction -  
(cont'd.) ...

It is recommended that settlement plates be placed at a shallow depth below original ground surface, in areas where fills are to be placed, in order to monitor the magnitude and time-rate of the settlement induced in the overburden deposits by the surcharge fill loadings.

It would be advantageous to install piezometers within the overburden deposits in order to monitor the buildup of excess pore water pressures, due to the induced stresses. The stability of the fill sections are related to the excess pore water pressures, as discussed in detail in Sub-section 6.2.1). Therefore, the stability of the fills, during the construction period, could be assessed periodically knowing the actual magnitude of these pressures at any given time.

7. MISCELLANEOUS:

The field work for this project was carried out during the period of August 4 to 8, 1970, under the supervision of Mr. B. T. Darch, Senior Foundation Engineer, who also wrote this report.

The entire project was carried out under the general supervision of Mr. M. Devata, Supervising Foundation Engineer, who also reviewed this report.

The equipment used was owned and operated by Dominion Soil Investigation Ltd., Toronto.

October, 1970

APPENDIX I

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DEPARTMENT OF HIGHWAYS- ONTARIO  
MATERIALS & TESTING OFFICE

## RECORD OF BOREHOLE No. 1

FOUNDATION SECTION

JOB 70-11070

LOCATION

Thunder Bay Expressway &amp; Hwy. 11 &amp; 17

ORIGINATED BY BTB

W.P. 59-69

BORING DATE

Aug. 4 and 5, 1970

COMPILED BY BTB

DATUM Geodetic

BOREHOLE TYPE

Auger-Washboring-NX, BX Casing

CHECKED BY

BTB

| SOIL PROFILE |   |             | SAMPLES |      |              | ELEV. SCALE | DYNAMIC PENETRATION RESISTANCE |  |  |  |  | LIQUID LIMIT ——— $w_L$<br>PLASTIC LIMIT ——— $w_p$<br>WATER CONTENT ——— $w$ |  |           | BULK DENSITY<br>$\gamma$<br>P.C.F. | REMARKS |
|--------------|---|-------------|---------|------|--------------|-------------|--------------------------------|--|--|--|--|--|--|-----------|------------------------------------|---------|
| ELEV. DEPTH  | DESCRIPTION   | STRAT. PLOT | NUMBER  | TYPE | BLOWS / FOOT |             | SHEAR STRENGTH P.S.F.          |  |  |  |  | WATER CONTENT %  |  |           |                                    |         |
|              |   |             |         |      |              |             |                                |  |  |  |  | $w_p$ ——— $w$ ——— $w_L$  |  |           |                                    |         |
|              |   |             |         |      |              |             |                                |  |  |  |  |  |  |           |                                    |         |
| 629.3        | Ground Level<br>Topsoil   |             |         |      |              |             |                                |  |  |  |  |  |  |           | GR. SA. SI. CL.                    |         |
| 0.5          | Silty fine sand (occ. seams of silty clay up to 1/2" thick)<br>(Brown to grey)  |             | 1       | SS   | 15           |             |                                |  |  |  |  |  |  |           | 0 67 (33)                          |         |
|              |   |             | 2       | SS   | 23           |             |                                |  |  |  |  |  |  |           | 621.                               |         |
|              |   |             | 3       | SS   | 15           | 620         |                                |  |  |  |  |  |  |           | in open BH                         |         |
| 616.3        | Compact   |             | 4       | SS   | 7            |             |                                |  |  |  |  |  |  |           | Aug. 5/70                          |         |
| 13.0         | Silt, with some sand & trace of organic matter-sea shells, root fibre etc. (numerous clayey silt layers up to 3/4" thick) |             | 5       | SS   | 4            |             |                                |  |  |  |  |  |  | Orgs 1.0% | 0 24 66 10                         |         |
|              |   |             | 6       | SS   | 3            | 610         |                                |  |  |  |  |  |  |           |                                    |         |
|              |   |             | 7       | SS   | 2            |             |                                |  |  |  |  |  |  | Orgs 1.4% | 0 7 79 14                          |         |
| 604.3        | Very Loose  |             | 8       | TW   | PM           |             |                                |  |  |  |  |  |  |           |                                    |         |
| 25.0         | Silty Sand (stratified)   |             | 9       | SS   | 14           | 600         |                                |  |  |  |  |  |  |           | 0 78 (22)                          |         |
| 599.3        | Grey Compact  |             | 10      | SS   | 5            |             |                                |  |  |  |  |  |  |           |                                    |         |
| 30.0         | Silty sand, silt & clayey silt (layered-irregular thickness)<br>(Grey)  |             | 11      | SS   | 1            |             |                                |  |  |  |  |  |  |           |                                    |         |
| 590.3        | Very loose to Loose   |             | 12      | TW   | PM           | 590         |                                |  |  |  |  |  |  |           | 0 55 (45)                          |         |
| 39.0         | Silty Fine Sand to sandy silt<br>(faintly stratified)   |             | 13      | SS   | 12           |             |                                |  |  |  |  |  |  |           |                                    |         |
|              |   |             | 14      | SS   | 5            |             |                                |  |  |  |  |  |  |           |                                    |         |
|              | Grey  |             | 15      | SS   | 9            | 580         |                                |  |  |  |  |  |  |           | 0 23 66 11                         |         |
| 574.8        | Loose to Compact  |             | 16      | SS   | 2            |             |                                |  |  |  |  |  |  |           |                                    |         |
| 54.5         | Silty Clay<br>(occ. seams of silt up to 1/2" thick throughout)  |             | 17      | TW   | PM           | 570         |                                |  |  |  |  |  |  |           | 0 0 23 77                          |         |
|              |   |             | 18      | TW   | PM           |             |                                |  |  |  |  |  |  |           |                                    |         |
|              | Grey  |             | 19      | TW   | PM           |             |                                |  |  |  |  |  |  |           |                                    |         |
|              |   |             | 20      | TW   | PM           | 560         |                                |  |  |  |  |  |  |           |                                    |         |
| 552.8        | Stiff   |             | 21      | TW   | PM           |             |                                |  |  |  |  |  |  |           |                                    |         |
| 76.5         | End of Borehole   |             |         |      |              | 550         |                                |  |  |  |  |  |  |           |                                    |         |

DEPARTMENT OF HIGHWAYS- ONTARIO  
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 2

FOUNDATION SECTION

JOB 70-11070 LOCATION Thunder Bay Expressway & Hwy. 11 & 17 ORIGINATED BY BTD  
W.P. 59-69 BORING DATE August 6, 1970 COMPILED BY BTD  
DATUM Geodetic BOREHOLE TYPE Auger-Washboring-NX Casing CHECKED BY [Signature]

| SOIL PROFILE |  |             | SAMPLES |      |              | ELEV. SCALE   | DYNAMIC PENETRATION RESISTANCE |  |  |  |  | LIQUID LIMIT — $w_L$<br>PLASTIC LIMIT — $w_p$<br>WATER CONTENT — $w$ |  |  | BULK DENSITY<br>$\gamma$<br>P.C.F. | REMARKS |
|--------------|--|-------------|---------|------|--------------|---|--------------------------------|--|--|--|--|--|--|--|------------------------------------|---------|
| ELEV. DEPTH  | DESCRIPTION  | STRAT. PLOT | NUMBER  | TYPE | BLOWS / FOOT |   | SHEAR STRENGTH P.S.F.          |  |  |  |  | $w_p$ — $w$ — $w_L$<br>WATER CONTENT %                               |  |  |                                    |         |
|              |  |             |         |      |              | ○ UNCONFINED + FIELD VANE<br>● QUICK TRIAXIAL x LAB. VANE<br>400 800 1200 1600 2000 |                                |  |  |  |  |  |  |  |                                    |         |
| 629.2        | Ground Level   |             |         |      |              |   |                                |  |  |  |  |  |  |  |                                    |         |
|              | Topsoil  |             |         |      |              |   |                                |  |  |  |  |  |  |  |                                    |         |
|              | Silty fine sand (occ. seams of silty clay up to 1/4" thick)  |             | 1       | SS   | 16           |   |                                |  |  |  |  |  |  |  |                                    |         |
|              | Brown to Grey  |             |         |      |              | 620   |                                |  |  |  |  |  |  |  |                                    |         |
| 616.2        | Compact  |             | 2       | SS   | 15           |   |                                |  |  |  |  |  |  |  |                                    |         |
| 13.0         | Silt, with some sand & trace of organic matter - sea shells, root fibre, etc. (numerous clayey silt layers up to 3/4" thick) |             | 3       | SS   | 3            |   |                                |  |  |  |  |  |  |  |                                    |         |
|              |  |             | 4       | AS   | -            | 610   |                                |  |  |  |  |  |  |  |                                    |         |
|              |  |             | 5       | SS   | 2            |   |                                |  |  |  |  |  |  |  |                                    |         |
| 605.2        | Very Loose   |             |         |      |              |   |                                |  |  |  |  |  |  |  |                                    |         |
| 24.0         | Silty sand (strat.)  |             | 6       | SS   | 11           |   |                                |  |  |  |  |  |  |  |                                    |         |
| 600.2        | Grey Compact   |             |         |      |              | 600   |                                |  |  |  |  |  |  |  |                                    |         |
| 29.0         | Silty sand, silt & clayey silt (layered-irregular thickness)   |             | 7       | SS   | 2            |   |                                |  |  |  |  |  |  |  |                                    |         |
|              | Grey   |             | 8       | TW   | PM           |   |                                |  |  |  |  |  |  |  |                                    |         |
| 590.7        | Very Loose   |             |         |      |              | 590   |                                |  |  |  |  |  |  |  |                                    |         |
| 38.5         | Silty Fine Sand to sandy silt (faintly strat.)   |             | 9       | SS   | 8            |   |                                |  |  |  |  |  |  |  |                                    |         |
| 585.2        | Loose  |             | 10      | SS   | 9            |   |                                |  |  |  |  |  |  |  |                                    |         |
| 44.0         | End of Borehole  |             |         |      |              | 580   |                                |  |  |  |  |  |  |  |                                    |         |

621.  
in open BH  
Aug. 6/70



DEPARTMENT OF HIGHWAYS- ONTARIO  
MATERIALS & TESTING OFFICE

## RECORD OF BOREHOLE No. 3

FOUNDATION SECTION

JOB 70-11070

LOCATION Thunder Bay Expressway &amp; Hwy. 11 &amp; 17

ORIGINATED BY BTB

W.P. 59-69

BORING DATE August 8, 1970

COMPILED BY BTB

DATUM Geodetic

BOREHOLE TYPE Auger - Washboring-NX Casing

CHECKED BY

| SOIL PROFILE |  |             | SAMPLES |      |              | ELEV. SCALE | DYNAMIC PENETRATION RESISTANCE |  |  |  |  | LIQUID LIMIT — $w_L$<br>PLASTIC LIMIT — $w_p$<br>WATER CONTENT — $w$ |  |  | BULK DENSITY<br>$\gamma$<br>P.C.F. | REMARKS                         |
|--------------|--|-------------|---------|------|--------------|-------------|--------------------------------|--|--|--|--|--|--|--|------------------------------------|---------------------------------|
| ELEV. DEPTH  | DESCRIPTION  | STRAT. PLOT | NUMBER  | TYPE | BLOWS / FOOT |             | SHEAR STRENGTH P.S.F.          |  |  |  |  | $w_p$ — $w$ — $w_L$<br>WATER CONTENT %<br>20 40 60                   |  |  |                                    |                                 |
| 629.4        | Ground Level   |             |         |      |              |             |                                |  |  |  |  |  |  |  |                                    |                                 |
| 0.5          | Silty fine sand<br>(Brown to Grey)   |             | 1       | SS   | 12           | 620         |                                |  |  |  |  |  |  |  |                                    | 624.<br>In open BH<br>Aug. 8/70 |
| 616.4        | Loose to Compact   |             | 2       | SS   | 7            |             |                                |  |  |  |  |  |  |  |                                    |                                 |
| 13.0         | Silt, with some sand &<br>trace of organic<br>matter-sea shells, root<br>fibre etc.<br>(numerous clayey silt<br>layers up to 3/4" thick) |             | 3       | SS   | 3            | 610         |                                |  |  |  |  |  |  |  |                                    | 119.5 Orgs. 0.8%                |
| 603.1        | Very Loose to Loose  |             | 4       | TW   | PM           |             |                                |  |  |  |  |  |  |  |                                    |                                 |
| 26.3         | Silty sand (strat.)<br>Grey  |             | 5       | TW   | PM           | 600         |                                |  |  |  |  |  |  |  |                                    | 121.5                           |
| 596.4        | Loose  |             | 6       | SS   | 9            |             |                                |  |  |  |  |  |  |  |                                    |                                 |
| 33.0         | Silty sand, silt &<br>clayey silt (layered-<br>irregular thickness)<br>Grey. Very loose to Loose   |             | 7       | TW   | PM           | 590         |                                |  |  |  |  |  |  |  |                                    |                                 |
| 588.4        |  |             | 8       | SS   | 2            |             |                                |  |  |  |  |  |  |  |                                    |                                 |
| 41.0         | Silty fine sand.   |             | 9       | SS   | 12           | 580         |                                |  |  |  |  |  |  |  |                                    |                                 |
| 585.4        | Grey Compact   |             |         |      |              |             |                                |  |  |  |  |  |  |  |                                    |                                 |
| 44.0         | End of Borehole  |             |         |      |              |             |                                |  |  |  |  |  |  |  |                                    |                                 |

DEPARTMENT OF HIGHWAYS- ONTARIO  
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 4

FOUNDATION SECTION

JOB 70-11070 LOCATION Thunder Bay Expressway & Hwy. 11 & 17 ORIGINATED BY LTD

W.P. 59-69 BORING DATE August 7 & 8, 1970 COMPILED BY LTD

DATUM Geodetic BOREHOLE TYPE Auger-Washboring-NX Casing CHECKED BY

| SOIL PROFILE |   |             | SAMPLES |      |              | ELEV. SCALE | DYNAMIC PENETRATION RESISTANCE |     |      |      |      | LIQUID LIMIT — $w_L$<br>PLASTIC LIMIT — $w_P$<br>WATER CONTENT — $w$ |  |  | BULK DENSITY<br>$\gamma$<br>P.C.F. | REMARKS |
|--------------|---|-------------|---------|------|--------------|-------------|--------------------------------|-----|------|------|------|--|--|--|------------------------------------|---------|
| ELEV. DEPTH  | DESCRIPTION   | STRAT. PLOT | NUMBER  | TYPE | BLOWS / FOOT |             | SHEAR STRENGTH P.S.F.          |     |      |      |      | WATER CONTENT %  |  |  |                                    |         |
|              |   |             |         |      |              |             |                                |     |      |      |      | $w_P$ — $w$ — $w_L$  |  |  |                                    |         |
|              |   |             |         |      |              |             | 400                            | 800 | 1200 | 1600 | 2000 |  |  |  |                                    |         |
| 629.1        | Ground Level  |             |         |      |              |             |                                |     |      |      |      |  |  |  |                                    |         |
| 0.5          | Topsoil   |             |         |      |              |             |                                |     |      |      |      |  |  |  |                                    |         |
|              | Silty fine sand<br>(occ. seams of silty clay up to 1/4" thick)<br>(Brown to Grey)   |             | 1       | SS   | 15           |             |                                |     |      |      |      |  |  |  |                                    |         |
| 618.1        | Compact   |             | 2       | SS   | 12           | 620         |                                |     |      |      |      |  |  |  |                                    |         |
| 11.0         | Silt with some sand & a trace of organic matter-sea shells, root fibre etc)<br>(numerous clayey silt layers up to 3/4" thick, particularly below el. 604)<br>(Grey & Black) |             | 3       | SS   | 2            |             |                                |     |      |      |      |  |  |  |                                    |         |
|              |   |             | 4       | TW   | PM           | 610         |                                |     |      |      |      |  |  |  |                                    |         |
|              |   |             | 5       | TW   | PM           |             |                                |     |      |      |      |  |  |  |                                    |         |
| 597.8        | Very Loose to Loose   |             | 6       | TW   | PM           | 600         |                                |     |      |      |      |  |  |  |                                    |         |
| 31.3         | Silty fine sand (strat) Grey  |             | 7       | SS   | 19           |             |                                |     |      |      |      |  |  |  |                                    |         |
| 592.1        | Compact   |             | 8       | TW   | PM           | 590         |                                |     |      |      |      |  |  |  |                                    |         |
| 37.0         | Silty sand, silt and clayey silt (layered-layers of irregular thickness)<br>Grey  |             | 9       | SS   | 2            |             |                                |     |      |      |      |  |  |  |                                    |         |
| 580.6        | Very Loose to Loose   |             | 10      | SS   | 10           | 580         |                                |     |      |      |      |  |  |  |                                    |         |
| 48.5         | Silty fine sand. Grey   |             |         |      |              |             |                                |     |      |      |      |  |  |  |                                    |         |
| 577.6        | Compact   |             |         |      |              |             |                                |     |      |      |      |  |  |  |                                    |         |
| 51.5         | End of Borehole   |             |         |      |              | 570         |                                |     |      |      |      |  |  |  |                                    |         |

DEPARTMENT OF HIGHWAYS- ONTARIO  
MATERIALS & TESTING OFFICE

## RECORD OF BOREHOLE No. 5

FOUNDATION SECTION

JOB 70-11070

LOCATION

Thunder Bay Expressway &amp; Hwy. 11 &amp; 17

ORIGINATED BY BTD

W.P. 59-69

BORING DATE

August 6 and 7, 1970

COMPILED BY BTDDATUM Geodetic

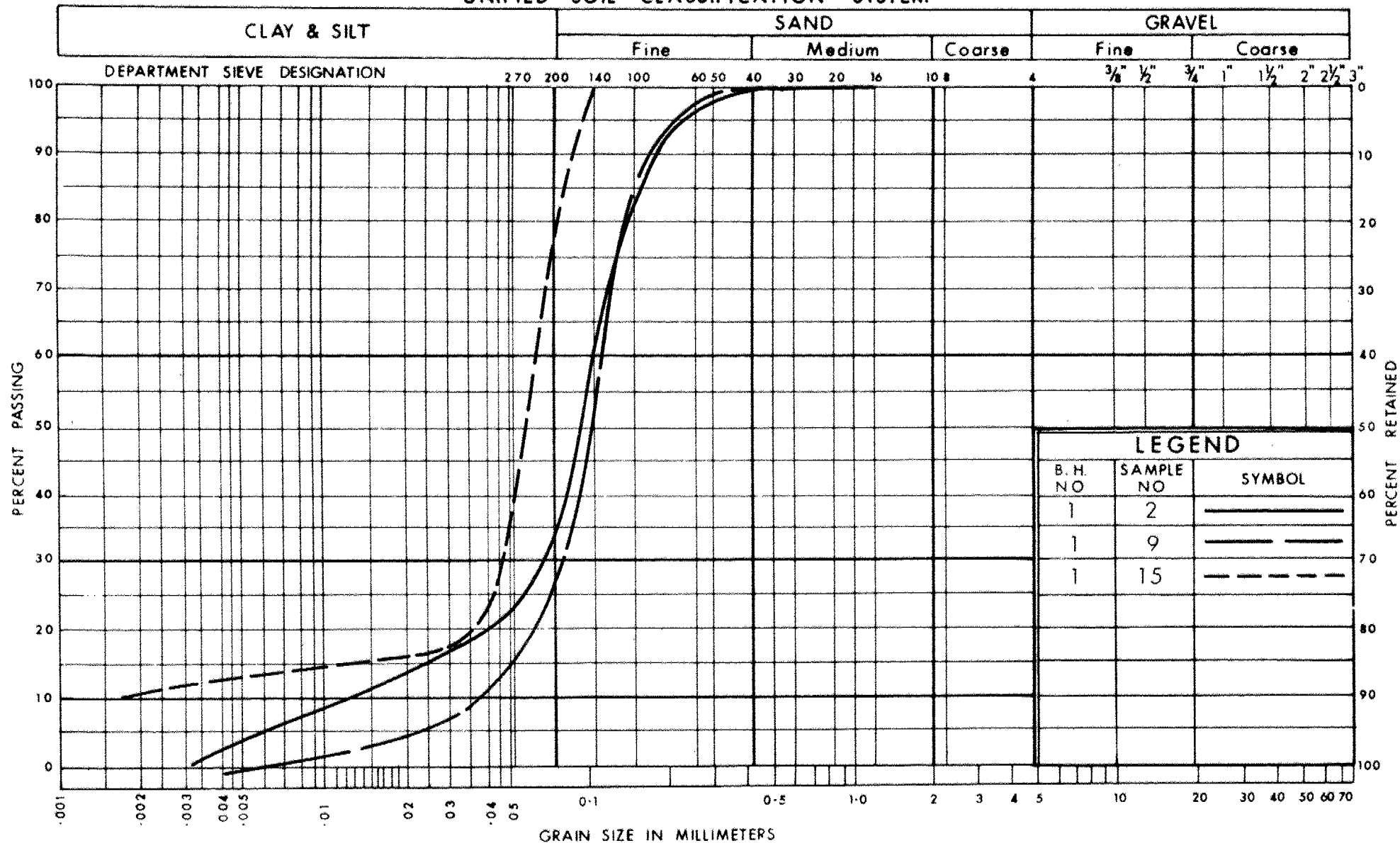
BOREHOLE TYPE

Auger-Washboring-NX Casing

CHECKED BY SK

| SOIL PROFILE |   |             | SAMPLES |      |              | ELEV. SCALE | DYNAMIC PENETRATION RESISTANCE |  |  |  |  | LIQUID LIMIT — $w_L$<br>PLASTIC LIMIT — $w_p$<br>WATER CONTENT — $w$ |  |  | BULK DENSITY<br>$\gamma$<br>P.C.F. | REMARKS |
|--------------|---|-------------|---------|------|--------------|-------------|--------------------------------|--|--|--|--|--|--|--|------------------------------------|---------|
| ELEV. DEPTH  | DESCRIPTION   | STRAT. PLOT | NUMBER  | TYPE | BLOWS / FOOT |             | SHEAR STRENGTH P.S.F.          |  |  |  |  | WATER CONTENT %  |  |  |                                    |         |
|              |   |             |         |      |              |             |                                |  |  |  |  | $w_p$ — $w$ — $w_L$  |  |  |                                    |         |
| 628.3        | Ground Level  |             |         |      |              |             |                                |  |  |  |  |  |  |  |                                    |         |
| 0.5          | Silty fine sand<br>(Brown to Grey)  |             |         |      |              |             |                                |  |  |  |  |  |  |  |                                    |         |
| 619.8        | Compact   |             | 1       | SS   | 15           |             |                                |  |  |  |  |  |  |  |                                    |         |
| 8.5          | Silt, with some sand &<br>trace of organic<br>matter-sea shells,<br>foot fibre etc.<br>(numerous clayey silt<br>layers up to 2" thick<br>particularly below<br>el. 610)<br>Grey and Black |             | 2       | SS   | 3            |             |                                |  |  |  |  |  |  |  |                                    |         |
|              |   |             | 3       | SS   | 2            |             |                                |  |  |  |  |  |  |  |                                    |         |
|              |   |             | 4       | TW   | PM           |             |                                |  |  |  |  |  |  |  |                                    |         |
| 601.3        | Very Loose to Loose   |             | 5       | TW   | PM           |             |                                |  |  |  |  |  |  |  |                                    |         |
| 27.0         | Silty fine sand (strat.)<br>Grey  |             |         |      |              |             |                                |  |  |  |  |  |  |  |                                    |         |
| 596.3        | Compact   |             | 6       | SS   | 19           |             |                                |  |  |  |  |  |  |  |                                    |         |
| 32.0         | Silty sand, silt and<br>clayey silt (layered<br>irregular thickness)<br>Grey  |             | 7       | TW   | PM           |             |                                |  |  |  |  |  |  |  |                                    |         |
| 587.8        | Very Loose to Loose   |             |         |      |              |             |                                |  |  |  |  |  |  |  |                                    |         |
| 40.5         | Silty fine sand   |             | 8       | SS   | 6            |             |                                |  |  |  |  |  |  |  |                                    |         |
| 584.8        | Grey Compact  |             | 9       | SS   | 11           |             |                                |  |  |  |  |  |  |  |                                    |         |
| 43.5         | End of Borehole   |             |         |      |              |             |                                |  |  |  |  |  |  |  |                                    |         |

# UNIFIED SOIL CLASSIFICATION SYSTEM



DEPARTMENT OF HIGHWAYS  
**MATERIALS and  
TESTING  
DIVISION**

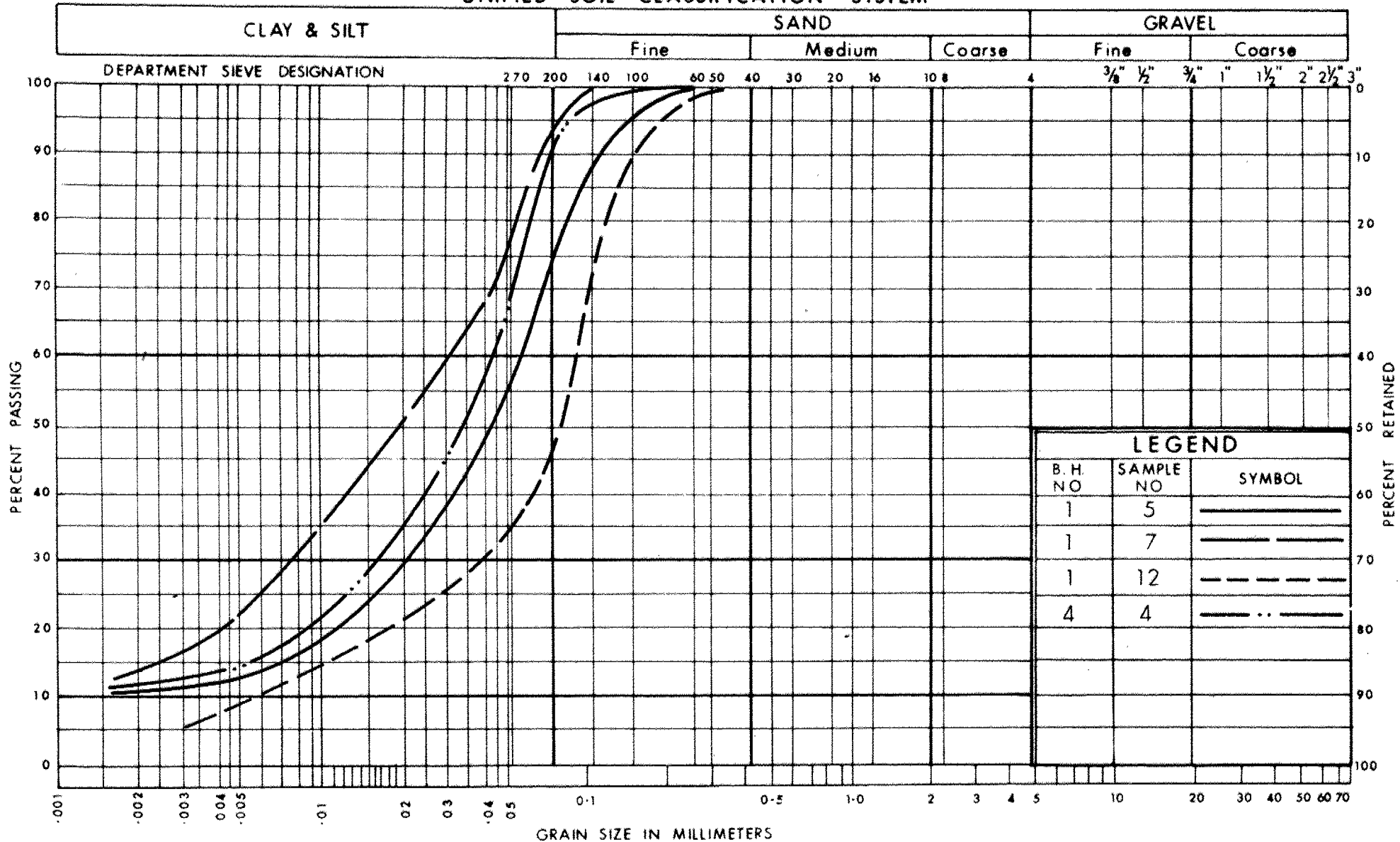
## GRAIN SIZE DISTRIBUTION SILTY SAND

W.P. No. 59-69

JOB No. 70-11070

Fig. No 1

# UNIFIED SOIL CLASSIFICATION SYSTEM



DEPARTMENT OF HIGHWAYS  
MATERIALS and  
TESTING  
DIVISION

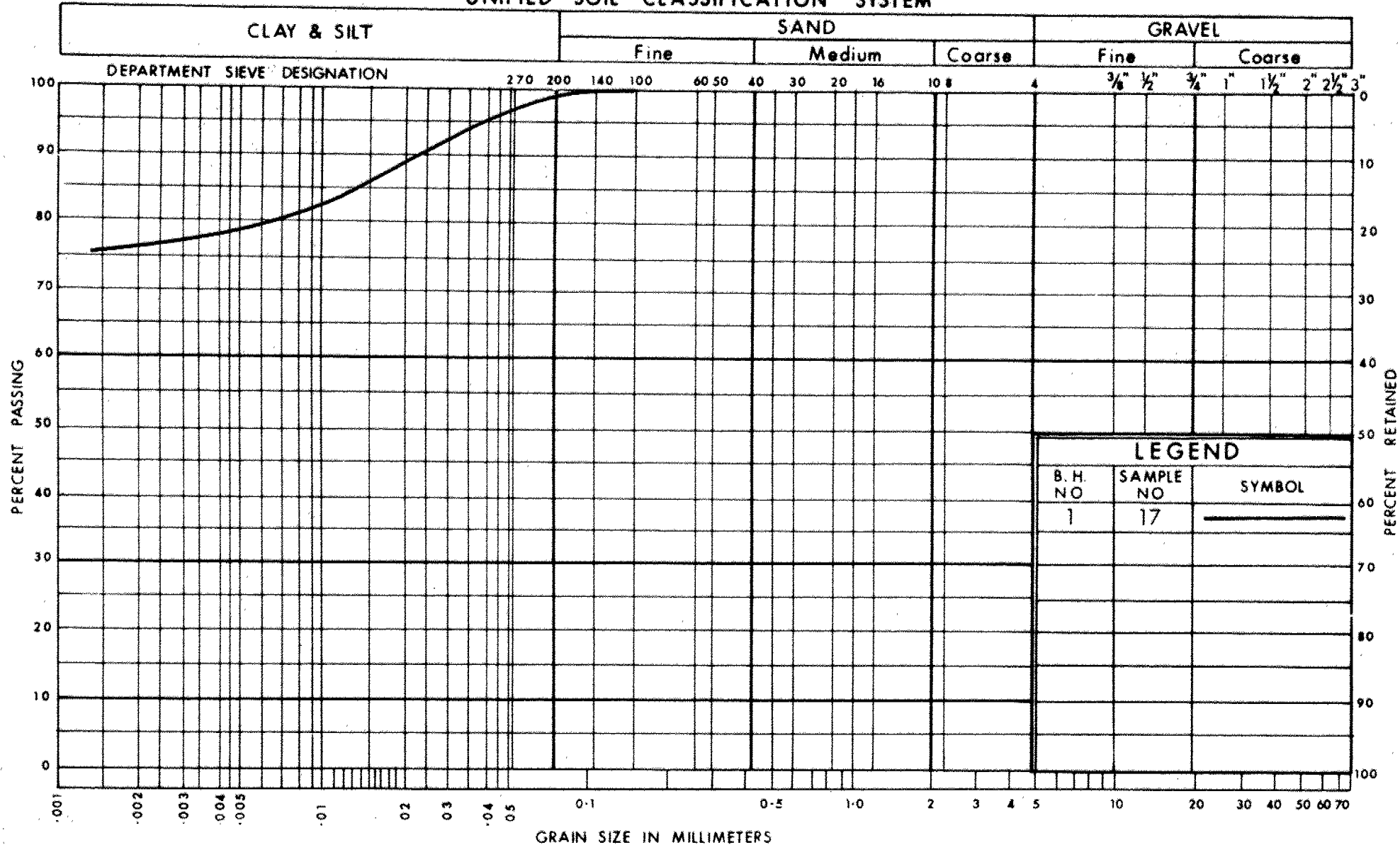
**GRAIN SIZE DISTRIBUTION**  
**SILT**  
SOME SAND, TRACE OF ORGANIC MATTER

W.P. No. 59-69

JOB No: 70-11070

FIG. NO. 2

# UNIFIED SOIL CLASSIFICATION SYSTEM



DEPARTMENT OF HIGHWAYS  
MATERIALS and  
TESTING  
DIVISION

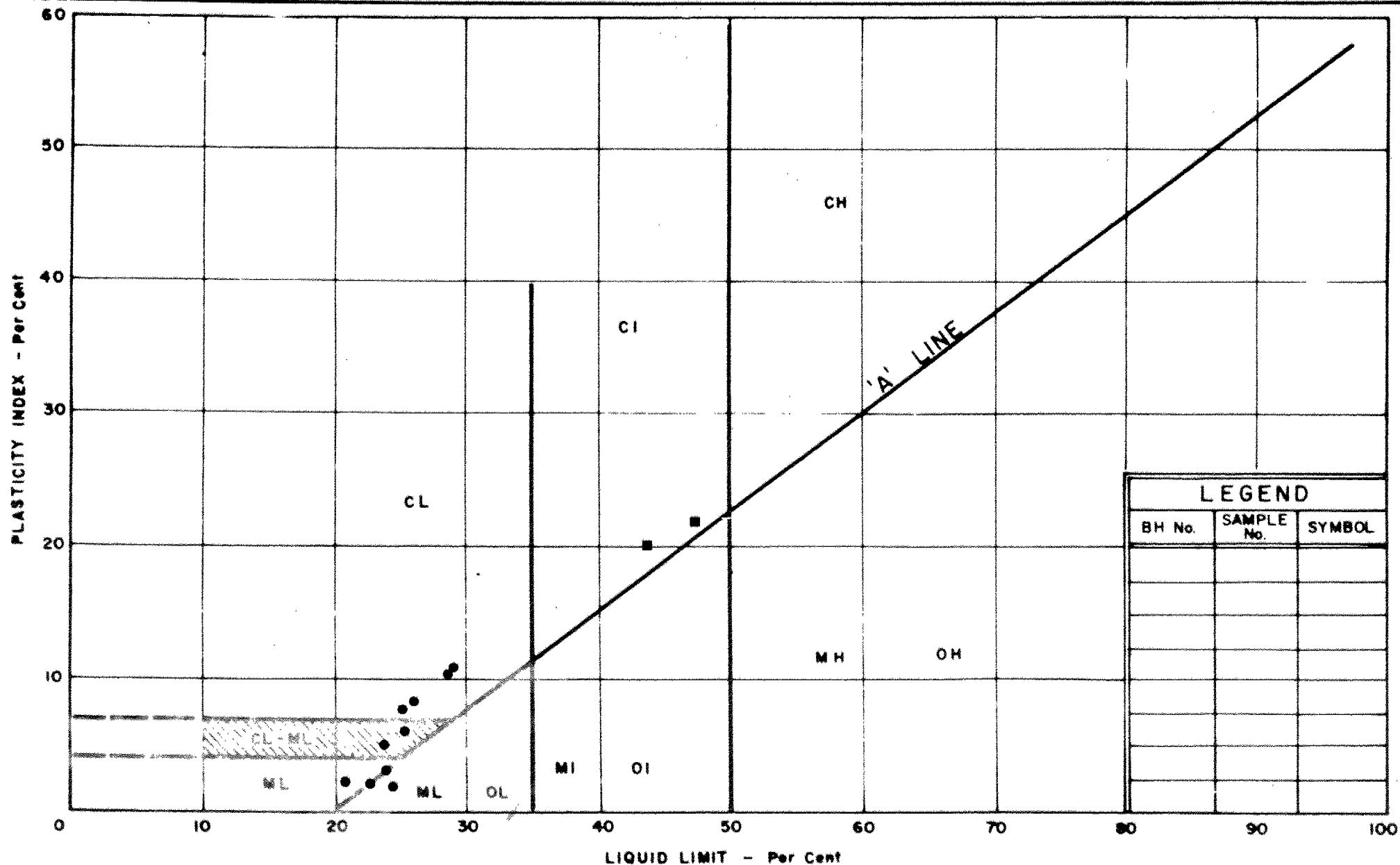
## GRAIN SIZE DISTRIBUTION

SILTY CLAY

W.P. No. 59-69

JOB No. 70-11070

FIG. NO. 3



# VOID RATIO vs PRESSURE

$W_L = 47\%$   
 $W_p = 25\%$   
 $W = 43\%$   
 $C_c = 0.54$

BORE HOLE 1  
SAMPLE 17  
DEPTH 58'-3"  
ELEV. 571.0

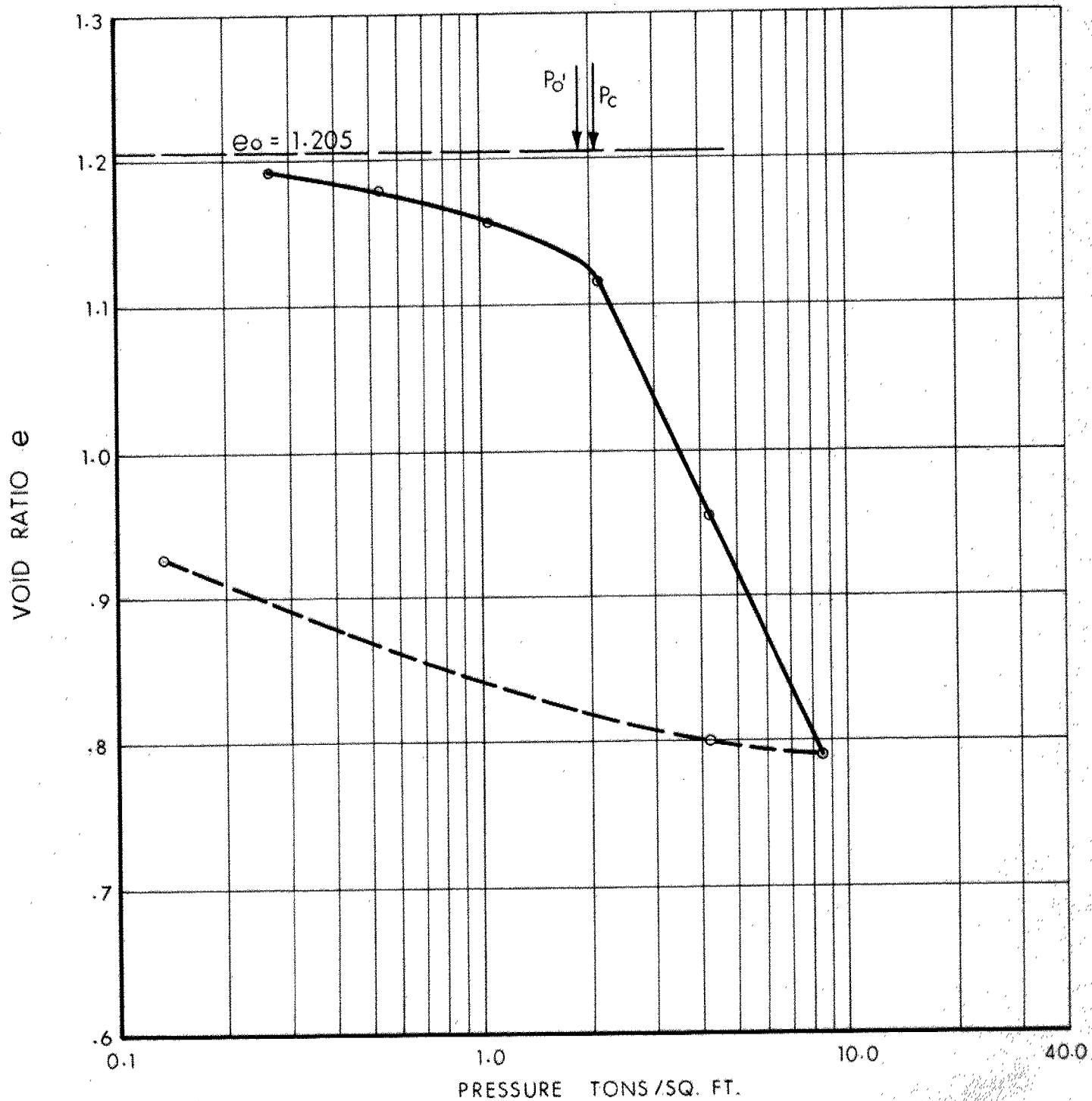


Fig. 5

Job 70-11070



## 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     |
| W.S. | 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 INTERCEPT   |
| $\phi'$    | EFFECTIVE ANGLE OF SHEARING RESISTANCE, OR FRICTION                  |
| $c_u$      | APPARENT COHESION  |
| $\phi_u$   | APPARENT ANGLE OF SHEARING RESISTANCE, OR FRICTION                   |
| $\mu$      | COEFFICIENT OF FRICTION  |
| $S_t$      | SENSITIVITY  |

### GENERAL

|                                     |                                   |
|-------------------------------------|-----------------------------------|
| $\pi$                               | = 3.1416                          |
| e                                   | BASE OF NATURAL LOGARITHMS 2.7183 |
| $\log_e \sigma$ OR $\ln \sigma$     | NATURAL LOGARITHM OF $\sigma$     |
| $\log_{10} \sigma$ OR $\log \sigma$ | LOGARITHM OF $\sigma$ 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  |
| $\sigma'$  | 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

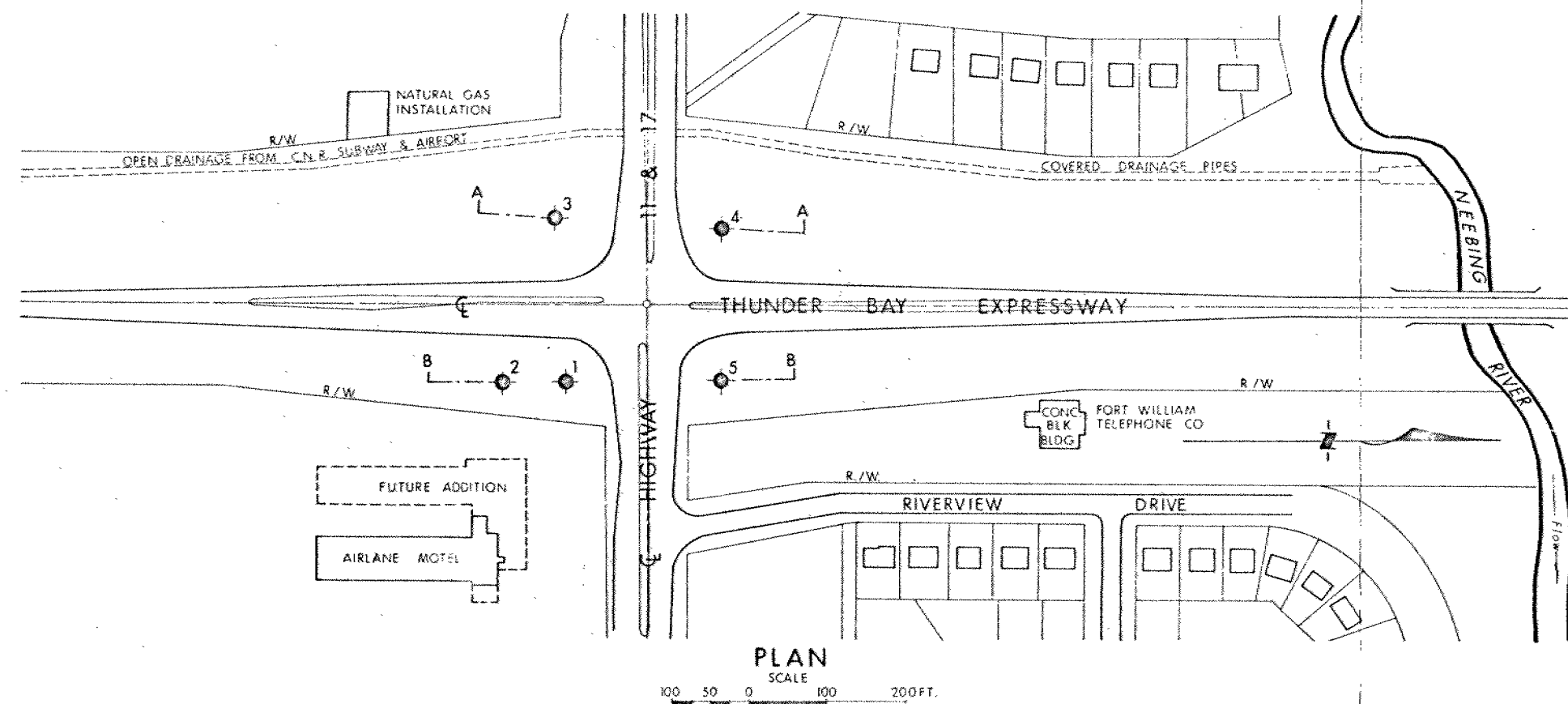
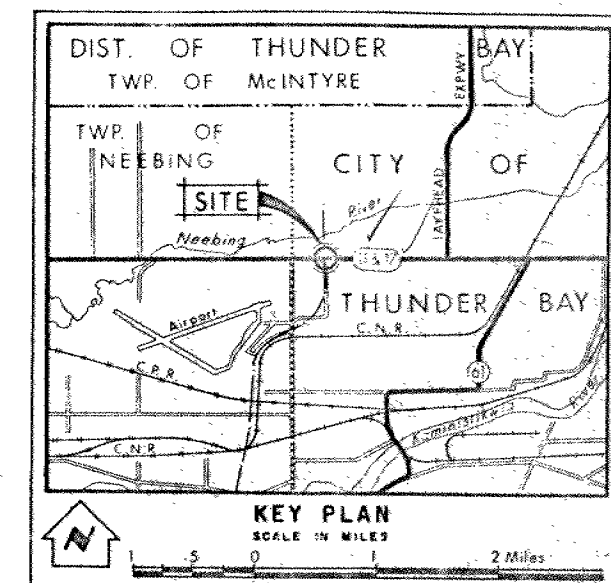
|          |   |
|----------|---|
| d        | DISTANCE FROM TOP OF WALL TO POINT OF APPLICATION OF PRESSURE   |
| $\delta$ | ANGLE OF WALL FRICTION  |
| K        | DIMENSIONLESS COEFFICIENT TO BE USED WITH VARIOUS SUFFIXES IN EXPRESSIONS REFERRING TO NORMAL STRESS ON WALLS |
| $K_0$    | COEFFICIENT 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 FOR BEARING CAPACITY |
| $k_s$ | MODULUS OF SUBGRADE REACTION   |

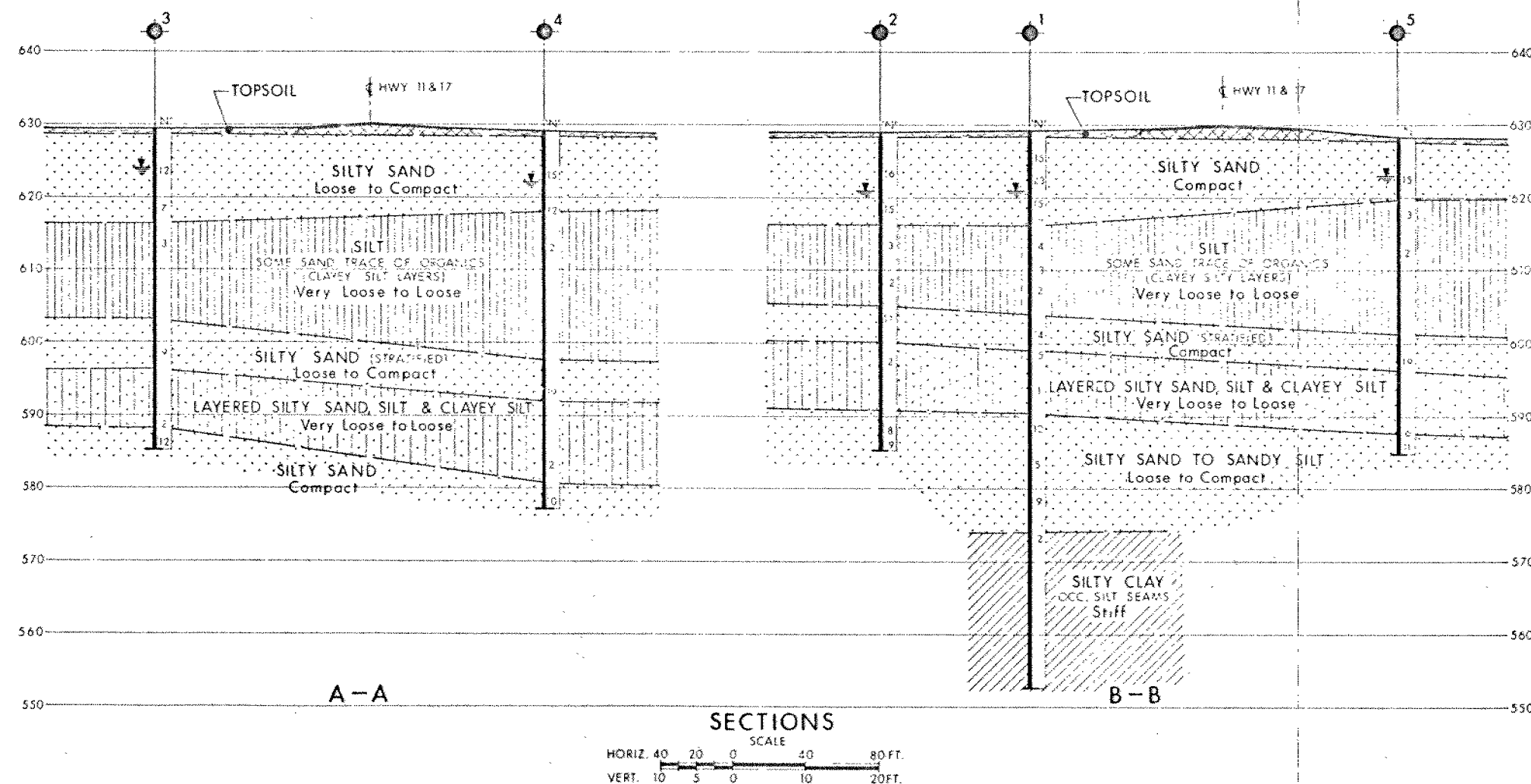
### SLOPES

|         |  |
|---------|--|
| 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, Aug. 1970 |  |  |

| NO. | ELEVATION | STATION | OFFSET |
|-----|-----------|---------|--------|
| 1   | 629.3     | As      | Shown  |
| 2   | 629.2     | "       | "      |
| 3   | 629.4     | "       | "      |
| 4   | 629.1     | "       | "      |
| 5   | 628.3     | "       | "      |



**NOTE**

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

| DATE | BY | DESCRIPTION |
|------|----|-------------|
|      |    |             |
|      |    |             |
|      |    |             |

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

**THUNDER BAY EXPRESSWAY**

KING'S HIGHWAY NO. 11 & 17 DIST. NO. 19  
DIST. THUNDER BAY City of THUNDER BAY  
TWP. LOT CON.

**BORE HOLE LOCATIONS & SOIL STRATA**

|                                   |           |                  |                    |
|-----------------------------------|-----------|------------------|--------------------|
| SUBNO. B.T.D.                     | CHECKED   | WP. NO. 59-69    | M.B.T. DRAWING NO. |
| DRAWN G.P.                        | CHECKED   | JOB NO. 70-11070 | 70-11070A          |
| DATE Sept. 28, 1970               | SITE NO.  |                  | BRIDGE DRAWING NO. |
| APPROVED <i>A. J. [Signature]</i> | CONT. NO. |                  |                    |