

64-F-261M

PHILLIP'S BRIDGE

CAISTOR IND

B.A. 1353

H. Q. GOLDER & ASSOCIATES LTD.  
CONSULTING CIVIL ENGINEERS

H. Q. GOLDER  
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767-9201  
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STRUCTURE SITE No. 12-121

October 8, 1964.

J. M. Tomlinson & Associates Ltd.,  
593 Brant Street,  
Burlington, Ontario.

64-F-261M

Attention: Mr. D. J. S. Tefft, P.Eng.

RE: SOIL INVESTIGATION,  
PROPOSED PHILLIP'S BRIDGE,  
CAISTOR TOWNSHIP,  
LINCOLN COUNTY, ONTARIO.

Dear Sirs:

This letter reports the results of a soil investigation carried out at the above site. The purpose of this investigation was to determine the subsoil conditions and to provide information for the foundation design of the proposed bridge replacement.

PROCEDURE

The field work was carried out on September 29 and 30, 1964. Two boreholes were put down using a mobile power auger supplied and operated by the F.E. Johnston Drilling Co. Ltd. These borings were carried down until refusal to augering was encountered at about 45 foot depth.

A detailed log for each boring is given on the Records of Boreholes following the text of this report. The locations of the borings together with a section of the inferred soil stratigraphy across the site are shown on Figure 1.

The elevations given in this report are referred to a local bench mark, the elevation of which is given as 92.46 on drawing 64.8.1 Prel. 1. The bench mark consists of a tack on the south side of a tree and is located near the northwest wing wall of the existing bridge.

#### SITE AND GEOLOGY

The site of the proposed bridge over the upper reaches of the Welland River is located at the first river crossing east of Lincoln County Road #46 in Caistor Township. The new bridge will be located on the road between Lots 15 and 16 in the south part of Concession 2 at about the same location as the existing Phillip's bridge.

The topography of the surrounding area is generally level to gently rolling. There is no distinct valley of the Welland River at this location. There is in general, however, about a 20 foot bank on the outside curves of the river and about a 5 foot bank followed by gently sloping land elsewhere along

the river. The river bottom is mainly covered by numerous boulders up to about 2 feet in size.

From available geological information it is known that the area lies within the "Haldimand Clay Plain" which is a complex intermixture of tills and glacial Lake Warren clays and silts. The underlying bedrock consists of dolomites or shales of Paleozoic Age.

#### SOIL CONDITIONS

The borings put down in this investigation, at the proposed abutment locations, show that the roadway approaches to the existing bridge consist of fill some 5 feet thick. The upper two feet of the fill consists of brown sand and gravel while the lower portion of the fill below the sand and gravel consists of brown silty clay with some sand and gravel.

The fill is underlain by an extensive deposit of silty clay till which is the significant foundation stratum at the site. The till was encountered at about elevation 90 and extends to a depth of about 35 feet. The upper portion of the till stratum to a depth of about 17 feet below ground level, is desiccated and brown in colour. The lower unweathered portion of the till is grey. The till is essentially comprised of silty clay with a trace to some sand and gravel dispersed throughout.

A grain size distribution curve obtained on a sample from this stratum is shown on Figure 2. Although not obtained in the sampler due to its limited size (1½ inches I.D.) the till may contain random cobbles and boulders.

The results of Atterberg limits carried out on samples of the grey silty clay till gave liquid limits of 28 and 20 and plasticity indices of 13 and 8. The corresponding natural water contents are some 3 to 6 per cent above the plastic limit.

Triaxial compression tests carried out on samples of the lower till gave undrained shear strengths of about 600 lb/sq. ft. It is considered that these values are too low, due to disturbance during sampling resulting from the presence of gravel sizes, and are not representative of the overall shear strength of the grey till.

Based on "N" values ranging from 19 to 58 blows per foot, the consistency of the upper desiccated portion of the stratum is generally hard. In the lower grey portion of the till stratum, the "N" values range from 11 to 18 blows per foot indicating a generally stiff consistency.

The gravel content in the till decreases with depth until at about elevation 62 the material becomes essentially silty

clay with only a trace on gravel. The silty clay was penetrated for a depth of about 12 feet where the augers met refusal on what is assumed to be bedrock at about elevation 46.

A triaxial compression test on a sample of the clay gave an undrained shear strength of 600 lb/sq. ft. Based on the above results together with the standard penetration values, which range from 8 to 10 blows per foot, the consistency of the clay is generally firm.

#### WATER CONDITIONS

At the time of the investigation, the water level in the Welland River was at about elevation 85. From local information it is understood that extreme high water level in the river is at about elevation 95.

The standpipes installed in the borings following their completion was 8 to 12 feet below ground level or at about elevation 86 some 10 days after the field work. The water levels in the borings appear to closely reflect the river water level.

#### DISCUSSION

##### General

It is understood that the existing 60 foot single span Phillip's bridge will be replaced by either a single or double

span bridge some 80 to 90 feet in total length. It is also understood that the existing roadway grade will be raised by several feet.

#### Foundation Design

It is recommended that the abutments and the centre pier of the proposed bridge be founded on spread footings placed in the silty clay till underlying the site. To provide adequate frost protection, the footings should be taken down at least 4 feet below the creek bed. This would also provide some scour protection for the footings. The foundation level will therefore be no higher than about elevation 80, which is at about the surface of the stiff grey silty clay till.

For footings founded in the till as discussed above, an allowable bearing pressure of 3000 lb/sq. ft. may be used in design. If a central pier is provided for the bridge, the footing should be taken down below any recent river deposits covering river bottom to undisturbed till. The total settlement of the bridge pier and abutments using the above bearing value should be less than 1 inch, provided precautions are taken during construction to prevent softening of the silty clay till at and below foundation grade.

In the computation of sliding resistance between a rough concrete footing base and the undisturbed silty clay till, a value of 1000 lb/sq. ft. may be used.

It is recommended that free draining granular backfill, compacted in horizontal lifts of about 9 inches, be placed behind the bridge abutments. The granular backfill should be non-frost susceptible and should extend horizontally from the back face of the abutment walls a minimum distance of 4 feet. Provision for drainage from this backfill material should be made.

In the design of the abutment and wing walls, it is recommended that an "at-rest" earth pressure coefficient,  $K_0$ , of 0.5 be used for the compacted granular backfill.

No steep slopes exist at the site at this time. There should be no stability problem with the approach embankments, which are to be raised several feet above the present level, provided they are constructed of properly compacted suitable material using side slopes of 2 horizontal to 1 vertical. Prior to placement of embankment fill, all topsoil and any organic pockets overlying the glacial till should be removed under the proposed embankments. Rip rap should be placed on the river banks and embankment side slopes in the vicinity of the bridge to prevent



scour behind the abutments. The rip rap should be placed on a clean granular fill bed about 2 feet in thickness and the rip rap should extend for a height of 2 feet above the maximum high water level.

#### Construction Problems

No major construction problems are envisaged for the bridge abutments to be founded in the relatively impervious silty clay till. Any water inflow into foundation excavations should be minor and readily handled by pumping from sumps. The foundation excavation for the central pier could be carried out within braced closed sheeting driven several feet below footing level or a perimeter clay dyke. The sheeting or dyke should be constructed to a sufficient height to prevent flooding of the excavation during a flash run off period. If a dyke is employed all pervious deposits covering the river bed should be removed prior to its construction.

To prevent softening of the till due to surface water or construction operations, it is recommended that the base of footing excavations, once foundation grade is reached, be inspected for any local soft spots and immediately covered by a mud mat of lean concrete. If any soft spots are encountered at

foundation grade they should be removed and replaced by lean concrete or highly compacted granular fill.

We trust that the above information is sufficient to enable you to proceed with the design of the proposed bridge structure. Should you require any additional information or if we can be of any further service to you, please call us.

Yours faithfully,

H. Q. GOLDER & ASSOCIATES LTD.



*for* F. J. Heffernan, P.Eng.

FJH/nb  
64120

## LIST OF ABBREVIATIONS

The abbreviations commonly employed on each "Record of Borehole," on the figures and in the text of the report, are as follows:

### I. SAMPLE TYPES

<i>AS</i>	auger sample
<i>CS</i>	chunk sample
<i>DO</i>	drive open
<i>DS</i>	Denison type sample
<i>FS</i>	foil sample
<i>RC</i>	rock core
<i>ST</i>	slotted tube
<i>TO</i>	thin-walled, open
<i>TP</i>	thin-walled, piston
<i>WS</i>	wash sample

### II. PENETRATION RESISTANCES

**Dynamic Penetration Resistance:** The number of blows by a 140-pound hammer dropped 30 inches required to drive a 2-inch diameter, 60 degree cone one foot, where the cone is attached to 'A' size drill rods and casing is not used.

**Standard Penetration Resistance, *N*:** The number of blows by a 140-pound hammer dropped 30 inches required to drive a 2-inch drive open sampler one foot.

*WH* sampler advanced by static weight—weight, hammer

*PH* sampler advanced by pressure—pressure, hydraulic

*PM* sampler advanced by pressure—pressure, manual

### III. SOIL DESCRIPTION

#### (a) *Cohesionless Soils*

<i>Relative Density</i>	<i>N, blows/ft.</i>
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

#### (b) *Cohesive Soils*

<i>Consistency</i>	<i>c<sub>u</sub>, lb./sq. ft.</i>
Very soft	Less than 250
Soft	250 to 500
Firm	500 to 1,000
Stiff	1,000 to 2,000
Very stiff	2,000 to 4,000
Hard	over 4,000

### IV. SOIL TESTS

<i>C</i>	consolidation test
<i>H</i>	hydrometer analysis
<i>M</i>	sieve analysis
<i>MH</i>	combined analysis, sieve and hydrometer <sup>1</sup>
<i>Q</i>	undrained triaxial <sup>2</sup>
<i>R</i>	consolidated undrained triaxial <sup>2</sup>
<i>S</i>	drained triaxial
<i>U</i>	unconfined compression
<i>V</i>	field vane test

#### NOTES:

<sup>1</sup>Combined analyses when 5 to 95 per cent of the material passes the No. 200 sieve.

<sup>2</sup>Undrained triaxial tests in which pore pressures are measured are shown as  $\bar{Q}$  or  $\bar{R}$ .

## LIST OF SYMBOLS

### I. GENERAL

$\pi$	= 3.1416
$e$	= base of natural logarithms 2.7183
$\log_e a$ or $\ln a$ ,	natural logarithm of $a$
$\log_{10} a$ or $\log a$ ,	logarithm of $a$ to base 10
$t$	time
$g$	acceleration due to gravity
$V$	volume
$W$	weight
$M$	moment
$F$	factor of safety

### II. STRESS AND STRAIN

$u$	pore pressure
$\sigma$	normal stress
$\sigma'$	normal effective stress ( $\bar{\sigma}$ is also used)
$\tau$	shear stress
$\epsilon$	linear strain
$\epsilon_{xy}$	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

### III. SOIL PROPERTIES

#### (a) Unit weight

$\gamma$	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
$G_s$	specific gravity of solid particles $G_s = \gamma_s / \gamma_w$
$e$	void ratio
$n$	porosity
$w$	water content
$S_r$	degree of saturation

#### (b) Consistency

$w_L$	liquid limit
$w_P$	plastic limit
$I_P$	plasticity index
$w_S$	shrinkage limit
$I_L$	liquidity index = $(w - w_P) / I_P$
$I_c$	consistency index = $(w_L - w) / I_P$
$e_{max}$	void ratio in loosest state
$e_{min}$	void ratio in densest state
$D_r$	relative density = $(e_{max} - e) / (e_{max} - e_{min})$

#### (c) Permeability

$h$	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

#### (d) Consolidation (one-dimensional)

$m_v$	coefficient of volume change = $-\Delta e / (1+e) \Delta \sigma'$
$C_c$	compression index = $-\Delta e / \Delta \log_{10} \sigma'$
$c_c$	coefficient of consolidation
$T_v$	time factor = $c_d / d^2$ ( $d$ , drainage path)
$U$	degree of consolidation

#### (e) Shear strength

$\tau_f$	shear strength
$c'$	effective cohesion
$\phi'$	effective angle of shearing resistance, or friction
$c_u$	apparent cohesion*
$\phi_u$	apparent angle of shearing resistance, or friction
$\mu$	coefficient of friction
$S_r$	sensitivity

\*For the case of a saturated cohesive soil,  $\phi_u = 0$  and the undrained shear strength  $\tau_f = c_u$  is taken as half the undrained compressive strength.

## RECORD OF BOREHOLE 1

LOCATION See Figure 1

BORING DATE SEPT 23, 1964

DATUM LOCAL

BOREHOLE TYPE


POWER AUGER BORING

BOREHOLE DIAMETER 4.5"

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES

PEN. TEST HAMMER WEIGHT — LB. DROP — INCHES

SOIL PROFILE			SAMPLES			ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS/FT. -----		COEFFICIENT OF PERMEABILITY k, CM./SEC.		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	BLOWS/FT.		SHEAR STRENGTH $C_u$ , LB./SQ. FT.		WATER CONTENT, PERCENT $W_p$ $W$ $W_L$			
97.5	GROUND LEVEL											
95.0	SAND AND GRAVEL (FILL)											
92.5	HARD BROWN SILTY CLAY SOME SAND (FILL)		1	"	35							
92.3			2	"								
52			3	"	30							
			4	"	58							
			5	"	54							
81.5	HARD BROWN SILTY CLAY SOME SAND AND GRAVEL (SILTY CLAY TILL)		6	"	31							
16.0			7	"	5							
			8	"	13							
	STIFF GREY SILTY CLAY SOME SAND AND GRAVEL (SILTY CLAY TILL)		9	"	15							
			10	"	11							
62.0												
35.5			11	"	8							
	FIRM GREY SILTY CLAY TRACE OF GRAVEL		12	"	10							
49.1												
48.4	END OF HOLE REFUSAL TO AUGERING PROBABLY BEDROCK											


 5 Percent axial strain at failure

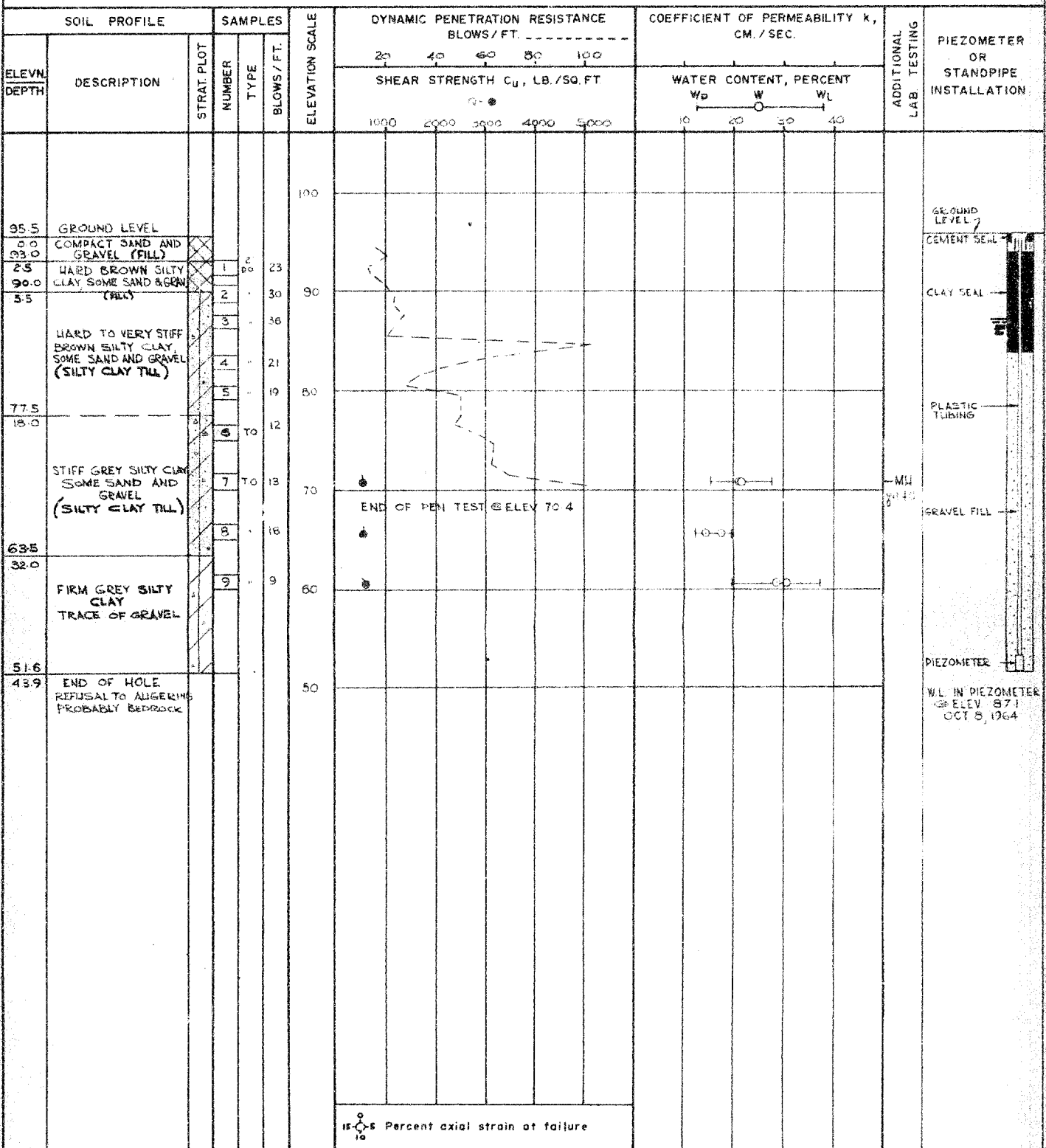
 VERTICAL SCALE  
 1 INCH TO 10'-0"

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 DRAWN BH  
 CHECKED F.J.H.

# RECORD OF BOREHOLE 2

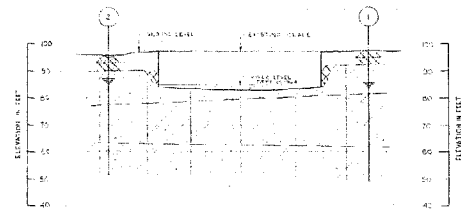
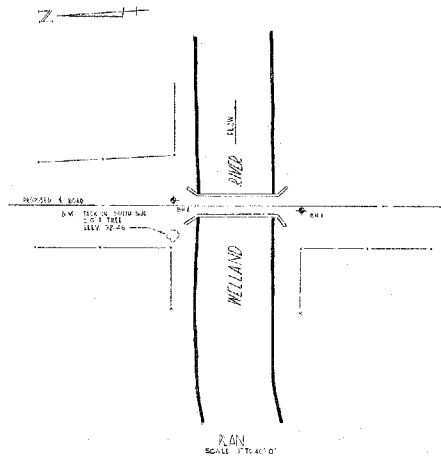
LOCATION See Figure 1 BORING DATE SEPT 20 30, 1964 DATUM LOCAL  
 BOREHOLE TYPE POWER AUGER BORING BOREHOLE DIAMETER 4.5"  
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



VERTICAL SCALE  
 1 INCH TO 10'-0"

GOLDER & ASSOCIATES

DRAWN RH  
 CHECKED E.M.

SCHEMATIC SECTION ALONG CENTURINE DEPOSED BRIDGE  
SCALE 1"=20'-0"

UGN.

## STENOGRAPHY

- $P^2 \in \mathbb{R}^{n \times n}$  is a symmetric positive semidefinite matrix

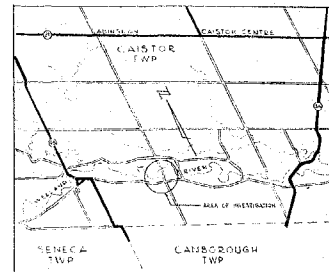
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- EAST. AND SOUTH. SIDE OF THE MAIN CLAY (FILL)

- MADE OF LIME ROCKS TO GREY SILTY CLAY, FINE SAND AND GRAVEL  
(SILTY CLAY TILL)

- 51 FINE GRAY SILTY CLAY, TRACE OF GRAVEL

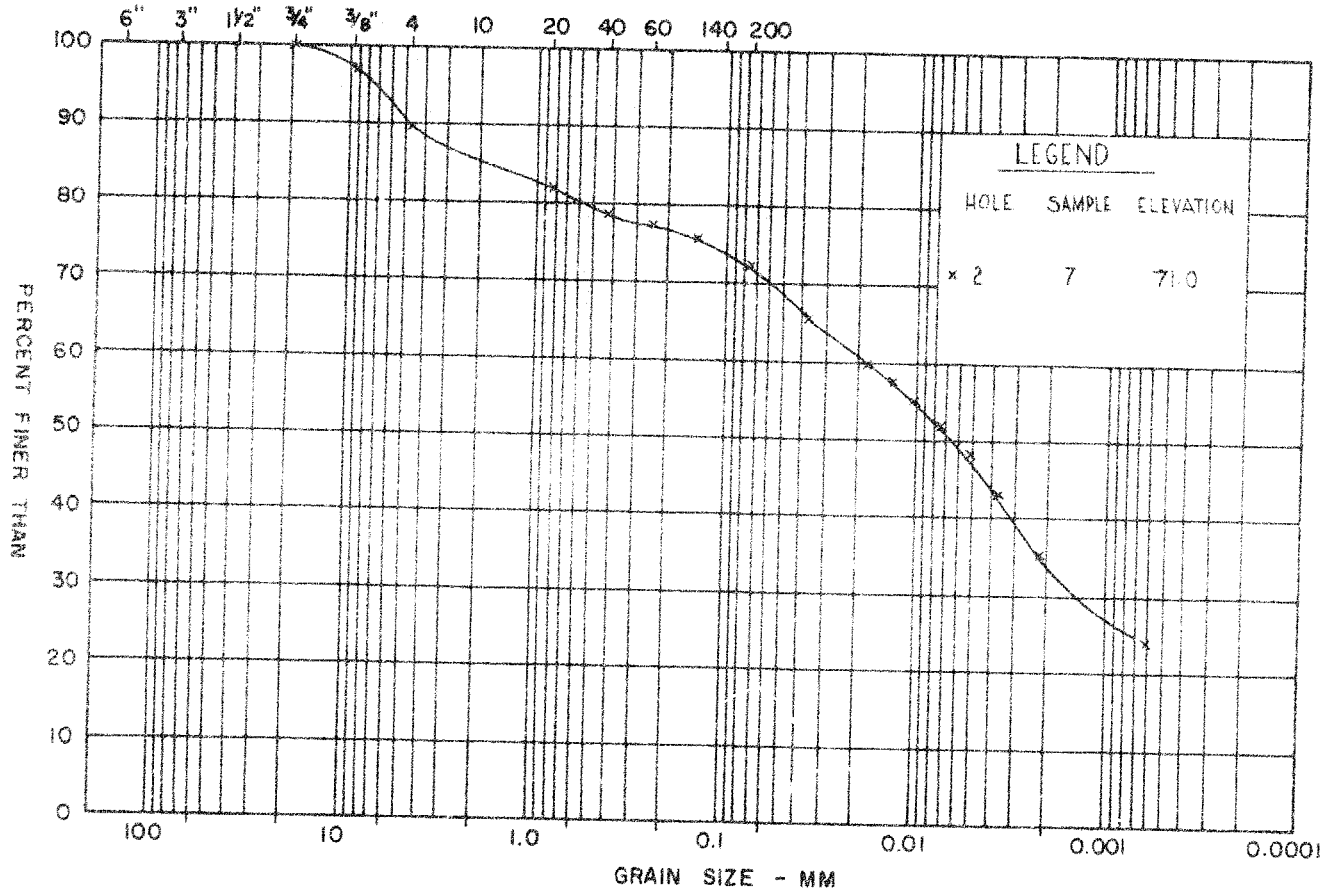


REFERENCE: J.M. TOMLINSON & ASSOCIATES LTD. DRAWING 64-01 PUEL I  
BUILDING EIGHT SITE PLAN, TOWNSHIP OF CAISTON, DATED SEPT. 1964

[illegible]

## M.I.T. GRAIN SIZE SCALE

SIZE OF OPENING - INS. U.S.S. SIEVE SIZE - MESHES / IN.



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GRAIN SIZE DISTRIBUTION  
SILT/CLAY TILL

FIGURE 2

COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE		CLAY SIZE	
	GRAVEL SIZE			SAND SIZE			FINE GRAINED			