

DEPARTMENT OF HIGHWAYS, ONTARIO

GEOGRCS No:
30114-17

SOIL CONDITIONS

PROPOSED WELLAND CANAL TUNNEL

WELLAND

ONTARIO

WP. 150-61

GOLDER & ASSOCIATES

GEOCRES No:
30L14-17

Mr. A. M. Toye,
Bridge Engineer.

December 20, 1960.

FOUNDATION INVESTIGATION REPORT

Materials and Research Section. By: H. Q. Golder & Associates, Ltd.

Attention: Mr. S. McCombie.

Re: Proposed Welland Canal Tunnel,
Welland, Ontario, District #4.

Submitted herewith, for your information, is the report on soil conditions at the above noted tunnel location.

The details presented in this report have been discussed with the Consultants, H. Q. Golder & Associates, and we are in agreement with the facts presented.

The Consultants retained to study the feasibility of the tunnel at this location, Sir Alexander Gibb & Partners, have discussed these test results on soil conditions in detail, with Dr. Golder & Associates, and have based their preliminary studies on the soil conditions presented in this report.

LGS/MdeF
Attach.

L. G. Soderman
L. G. Soderman,
PRINCIPAL FOUNDATION ENGINEER

cc: Messrs. A. M. Toye (2)
H. A. Tregaskes
D. G. Ramsay
I. C. Campbell
R. E. Richardson
T. J. Kovich

Foundations Office
Gen. Files.

H. Q. GOLDER & ASSOCIATES LTD.

CONSULTING CIVIL ENGINEERS

H. Q. GOLDER
V. MILLIGAN

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REPORT
TO
DEPARTMENT OF HIGHWAYS, ONTARIO
ON
PROPOSED WELLAND CANAL TUNNEL
WELLAND, ONTARIO

Distribution:

- 10 copies - Department of Highways, Ontario,
Toronto, Ontario.
- 2 copies - H. Q. Golder & Associates Ltd.,
Toronto, Ontario.

December, 1960

6022

ABSTRACT

The results of a preliminary investigation, the purpose of which was to determine soil conditions at the site of a proposed tunnel in Welland, Ontario, are reported. It was found that, following minor thicknesses of topsoil and fill, the site was underlain by about 80 to 90 feet of hard to firm silty clay followed by a thin layer of glacial till and then dolomite bedrock. The hard portion of the silty clay stratum is in the upper 20 to 30 feet, where undrained shear strengths range up to about 6,000 pounds per square foot; below this the shear strengths are relatively constant with an average of about 750 pounds per square foot. Groundwater levels established at the borehole locations ranged from 3 to 7 feet above normal canal level.

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INTRODUCTION

1.

H. Q. Golder and Associates Ltd. have been retained by the Department of Highways, Ontario under the terms of a letter of authorization dated October 7th, 1960 to carry out a preliminary investigation at the site of a proposed tunnel in Welland, Ontario. The purpose of the investigation was to determine the soil and groundwater conditions at the site.

PROCEDURE

The field work for the investigation was commenced on October 11th, and was completed on October 28th, 1960. Three boreholes were put down in BX size to depths of 93 to 123 feet using a standard skid-mounted machine drillrig. Soil samples were taken with standard 2-inch drive open and thin-walled samplers, and bed-rock was cored in AX size in two holes. Piezometers for the determination of groundwater conditions were installed successfully in two boreholes, but one was destroyed by children before observations could be recorded. The locations of the boreholes together with the inferred soil stratigraphy at the site are shown on Drawing 1. Detailed logs of each borehole are given on the Records of Boreholes.

Following the field work, the soil samples were returned to the laboratory for testing. The results of the testing are plotted on the Records of Boreholes and on the enclosed figures. Samples remaining after testing will be stored until May 1st, 1961 at which time you will be notified regarding their disposal.

GOLDER & ASSOCIATES

All elevations used in the report were supplied by the City of Welland and are referred to the Welland Canal Datum.

SITE TOPOGRAPHY AND GEOLOGY

The site is located in the physiographic region known as the Haldimand Clay Plain, which is, in this area, relatively flat. The area is known to be underlain by stratified silt and clay deposits of glacial Lake Warren which are of the order of 100 feet thick. The silt and clay are underlain by a thin layer of glacial drift followed by shales and dolomites of the Paleozoic era.

SOIL CONDITIONS

The following soil strata have been determined from the results of the investigation:

Fill

A stratum of brown to reddish-brown fill was encountered in Borehole 3 on the east bank of the canal beneath a thin layer of topsoil. This fill, which may have been placed during the construction of the canal, was about 17 feet thick and was composed primarily of silty clay with some sand, gravel and organic matter. Two water contents of about 20 per cent were measured on samples from the stratum.

Penetration of the stratum was difficult with standard

Fill (continued)

penetration resistances ranging from 15 to greater than 100 blows per foot. Based on these and visual observation of the samples, the consistency of the stratum is estimated to be hard.

A thin layer of cinder fill was also encountered in Borehole 2.

Silty Clay

Beneath the topsoil in Borehole 1 and immediately underlying the fill in Boreholes 2 and 3, was a stratum of brown to reddish-brown silty clay extending to depths of 92 to 96 feet. Included in the matrix of the silty clay throughout its depth were small amounts of granular material ranging in size from sand to sub-angular pebbles of $1\frac{1}{2}$ inch diameter.

In the majority of samples only faint indications of stratification were apparent, implying that the individual layers are of very similar composition. However, occasional zones of definitely layered material were encountered, usually in the lower half of the stratum. In addition to the brown to reddish silty clay, which forms the bulk of the stratum, these layers, which ranged from $1/16$ to 1 inch in thickness, were composed of red or grey silty clay. Occasional thin seams of silty sand were also encountered; their thickness never exceeded $\frac{1}{8}$ inch and was usually less than $1/16$.

Silty Clay (continued)

Samples from the upper 20 to 30 feet of the stratum frequently exhibited thin fissures containing grey silt which is indicative of weathering and/or desiccation.

A total of 50 sets of Atterberg limits were carried out on samples from this stratum. The liquid limits ranged from about 20 to 60 with an average of 36, and plasticity indices ranged from about 3 to 33, with an average of about 16. The higher liquid limits of the order of 50 to 60 with plasticity indices of the order of 30 are generally representative of the red and grey layers discussed above. The liquid limits of the order of 30 to 40 are representative of the brown silty clay, with the limits from 40 to 50 indicative of thinly layered samples where it was not practical to separate the layers.

The limits are plotted, together with natural water contents, on the Records of Boreholes. These show that in the upper 20 to 30 feet of the stratum, the natural moisture contents are very close to the plastic limit, and that below these depths there is a definite trend of increase in moisture content. This is illustrated more graphically by a plot of liquidity index versus elevation for Borehole 1, given as Figure 1. Also, in the lower part of the stratum, the average liquidity index is about 0.6. Based on accumulated experience

Silty Clay (continued)

with the clays of Southern Ontario, it is considered that this may be indicative of a slight over-consolidation in the stratum.

Another observation which is confirmed by the plotted limits and water contents is that in the lower 10 to 15 feet of the stratum, the material becomes very silty. This is indicated by the low limits and the sharp reduction in the natural water contents.

A total of 46 wet unit weights were measured on samples from this stratum. These ranged from 107 to 134 pounds per cubic foot with an average of 125 pounds per cubic foot.

Grain size distributions were determined on samples of the clay and are shown on Figures 2, 3 and 4. These indicate the clay to be generally very silty. In some cases, particularly where these curves were obtained for relatively highly plastic materials, it is considered that the high silt percentage may be due to flocculation; during testing, dispersion of some samples was found to be difficult, probably due to the presence of iron oxides as cementing agents.

A total of 47 undrained triaxial compression tests were carried out on samples of the clay. The results of these are plotted on the Records of Boreholes, and are summarized on Figure 6, which is a plot of undrained shear strength versus

Silty Clay (continued)

elevation. Typical stress-strain curves are shown on Figure 5. Again, the influence of desiccation or weathering in the upper portion of the stratum is indicated by the fact that above elevation 550 the shear strengths are generally high, ranging up to about 6,000 pounds per square foot. Below elevation 550 the shear strengths average about 750 pounds per square foot with no appreciable increase with depth. About 10 strengths lower than 750 pounds per square foot were recorded, but it is considered that most of these samples were disturbed.

From the results of the strength tests, the consistency of the clay stratum varies from hard at the top to firm below elevation 550.

Clayey Silt, Sand, and Gravel

A stratum of brown clayey silt, sand, and gravel, which is probably a glacial till, was found to underlie the silty clay in Boreholes 1 and 3. A boulder of about 1 foot diameter was also encountered within the stratum in Borehole 1. The thickness of the stratum was about 11 feet in Borehole 1 and 5 feet in Borehole 3.

One liquid limit of 16 and a corresponding plastic limit of 12 were obtained from a sample in this stratum. A grain size distribution curve is shown on Figure 4 (BH1, Sa48).

Clayey Silt, Sand, and Gravel (continued)

Two wet unit weights of 136 and 148 pounds per square foot were measured.

Two triaxial compression tests were carried out and shear strengths of 1,150 and 5,190 pounds per square foot were obtained.

The consistency of the till, based on the above shear strengths and the difficulty encountered in penetrating the stratum, is estimated to be hard.


Dolomite Bedrock


Bedrock was proven for 10 feet in Borehole 1 and about 22 feet in Borehole 3. It was found to be composed of a dark grey dolomite of the Guelph formation.

Groundwater Conditions

Water levels were measured in the boreholes at the time of the investigation, and these together with observations made in a piezometer installed in Borehole 3 are considered to be a valid indication of groundwater conditions at the site. These observations indicate that groundwater levels ranged from about 572 at Boreholes 1 and 3 on the banks of the canal to about 576 at Borehole 2. Canal level was at 569.5 during the investigation.

AAG:IMB
6022
December, 1960


A. A. Gass, P. Eng.


V. Milligan, P. Eng.


GOLDER & ASSOCIATES

LIST OF STANDARD ABBREVIATIONS

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

SAMPLE TYPES

A.S. - Auger Sample	R.C. - Rock Core
C.S. - Chunk Sample	S.T. - Slotted Tube
D.O. - Drive Open	T.O. - Thin-walled, Open
D.S. - Denison Type Sample	T.P. - Thin-walled, Piston
F.S. - Foil Sample	W.S. - Wash Sample

PENETRATION RESISTANCES

Dynamic Penetration Resistance - The energy required to drive a 2 inch diameter, 60 degree cone attached to the end of the drilling rods into the ground: expressed in blows per foot, where each blow represents 4,200 inch-pounds of energy.

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 into the ground.

Sampler advanced by static weight	- weight, hammer	- Wh
Sampler advanced by pressure	- pressure, hydraulic	- Ph
Sampler advanced by pressure	- pressure, manual	- Pm

SOIL DESCRIPTION

The standard terminology for the descriptions of the relative density of cohesionless soils and the consistency of cohesive soils is as follows:

<u>Relative Density</u>	<u>N, Blows/ft.</u>	<u>Consistency</u>	<u>c, lb/sq. ft.</u>
Very Loose	0 to 4	Very Soft	Less than 250
Loose	4 to 10	Soft	250 to 500
Compact	10 to 30	Firm	500 to 1,000
Dense	30 to 50	Stiff	1,000 to 2,000
Very Dense	over 50	Very Stiff	2,000 to 4,000
		Hard	over 4,000

SOIL TESTS

C - Consolidation Test	Q - Undrained Triaxial
H - Hydrometer Analysis	Qc - Consolidated Undrained Triaxial
M - Sieve Analysis	S - Drained Triaxial
MH - Combined Analysis, Sieve and Hydrometer	U - Unconfined Compression
	V - Field Vane Test

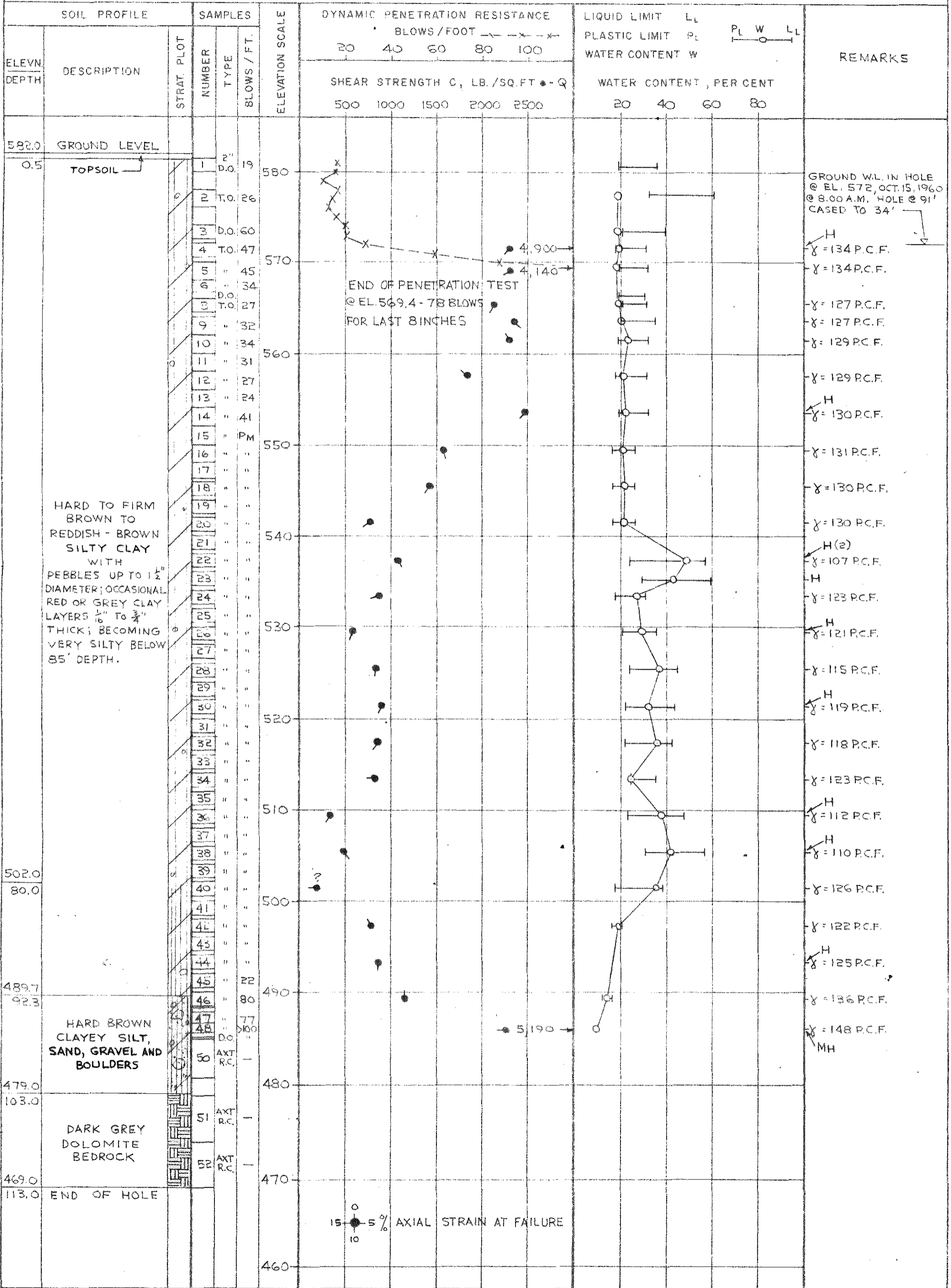
Note: Undrained triaxial tests in which pore pressures are measured are shown as Q' or Q'c.

SOIL PROPERTIES

γ - Total Unit Weight	K - Coefficient of Permeability
γ_d - Dry Unit Weight	c - Undrained Shear Strength (1/2 Compressive Strength)
γ_b - Submerged Unit Weight	St - Sensitivity
L _L - Liquid Limit	ϕ' - Effective Angle of Shearing Resistance
P _L - Plastic Limit	c' - Effective Cohesion Intercept
W - Natural Water Content	Cc - Compression Index
G - Specific Gravity	Cv - Coefficient of Consolidation
e - Void Ratio	

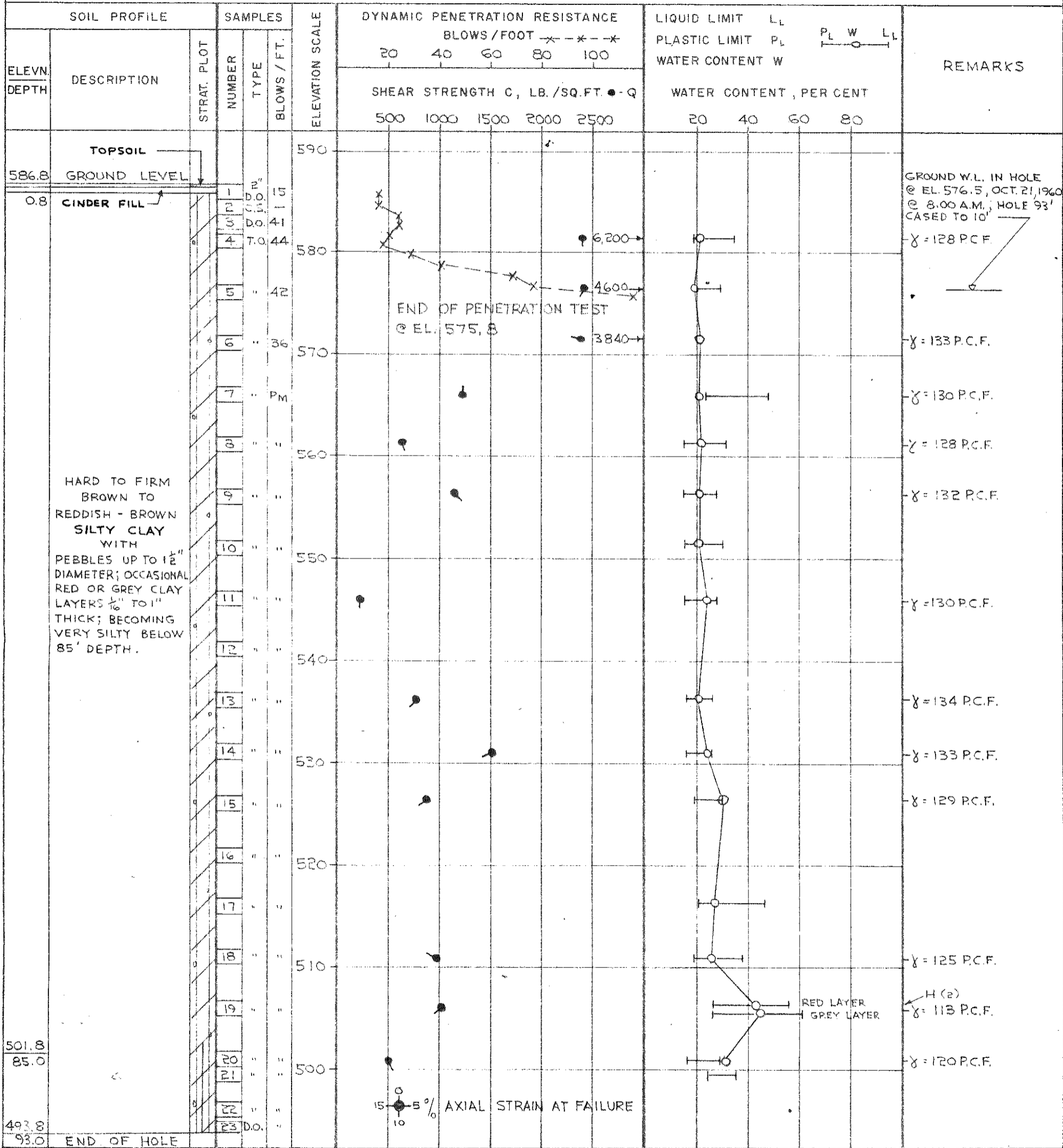
RECORD OF BOREHOLE 1

LOCATION SEE DRWG. No. 1 BORING DATE OCT. 11-17, 1960 DATUM WELLAND CANAL
BOREHOLE TYPE WASH BORING BOREHOLE DIAMETER BX CASING
SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



RECORD OF BOREHOLE 2

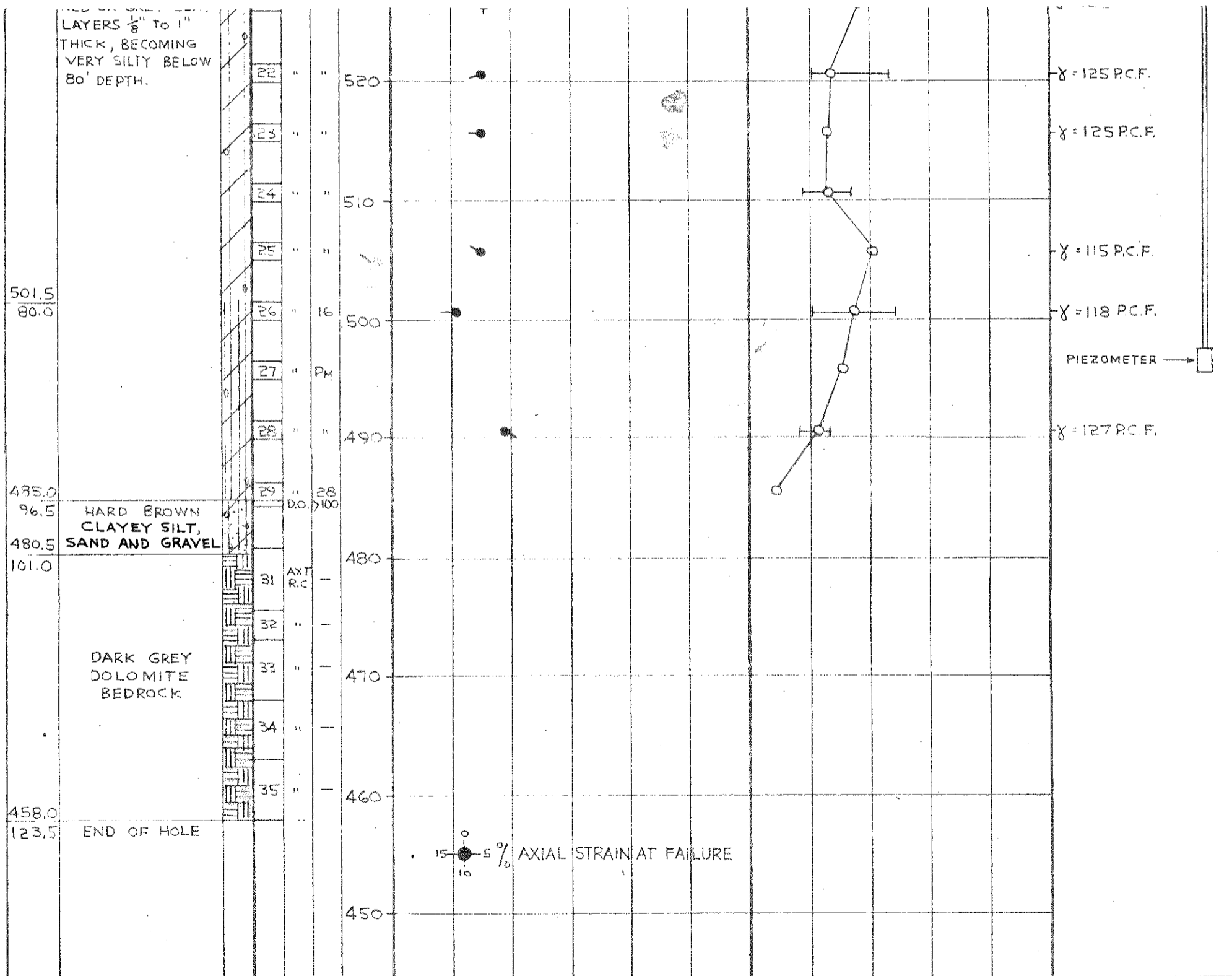
LOCATION SEE DRWG. N° 1 BORING DATE OCT. 18 - 21, 1960 DATUM WELLAND CANAL
BOREHOLE TYPE WASH BORING BOREHOLE DIAMETER BX CASING
SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



VERTICAL SCALE
1 INCH TO 10 FEET

GOLDER & ASSOCIATES

DRAWN J.A.
CHECKED AB



Dynamic penetration resistance converted to 4200 inch lb. energy

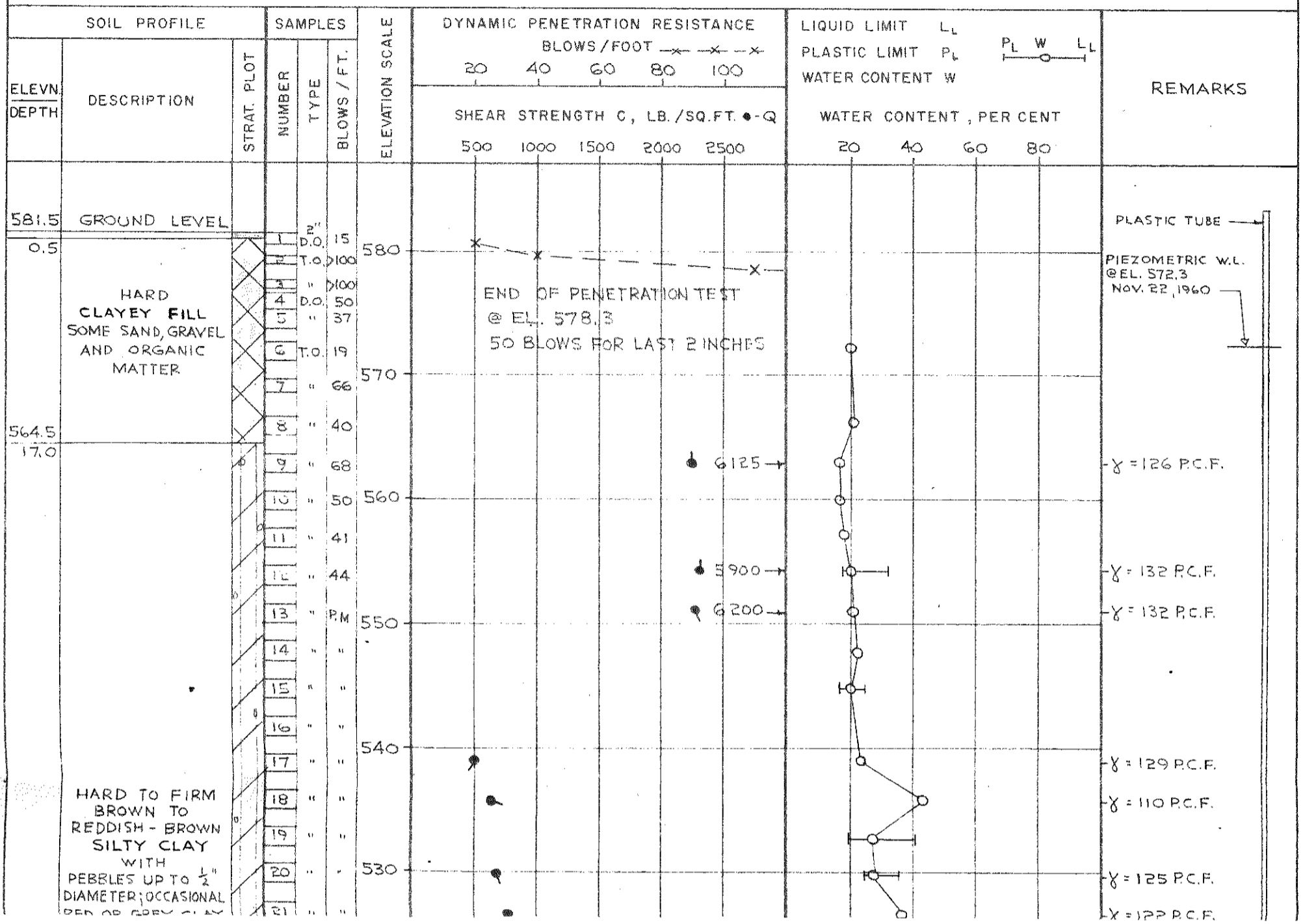
VERTICAL SCALE
1 INCH TO 10 FEET

GOLDER & ASSOCIATES

DRAWN J.A.
CHECKED *216*

RECORD OF BOREHOLE 3

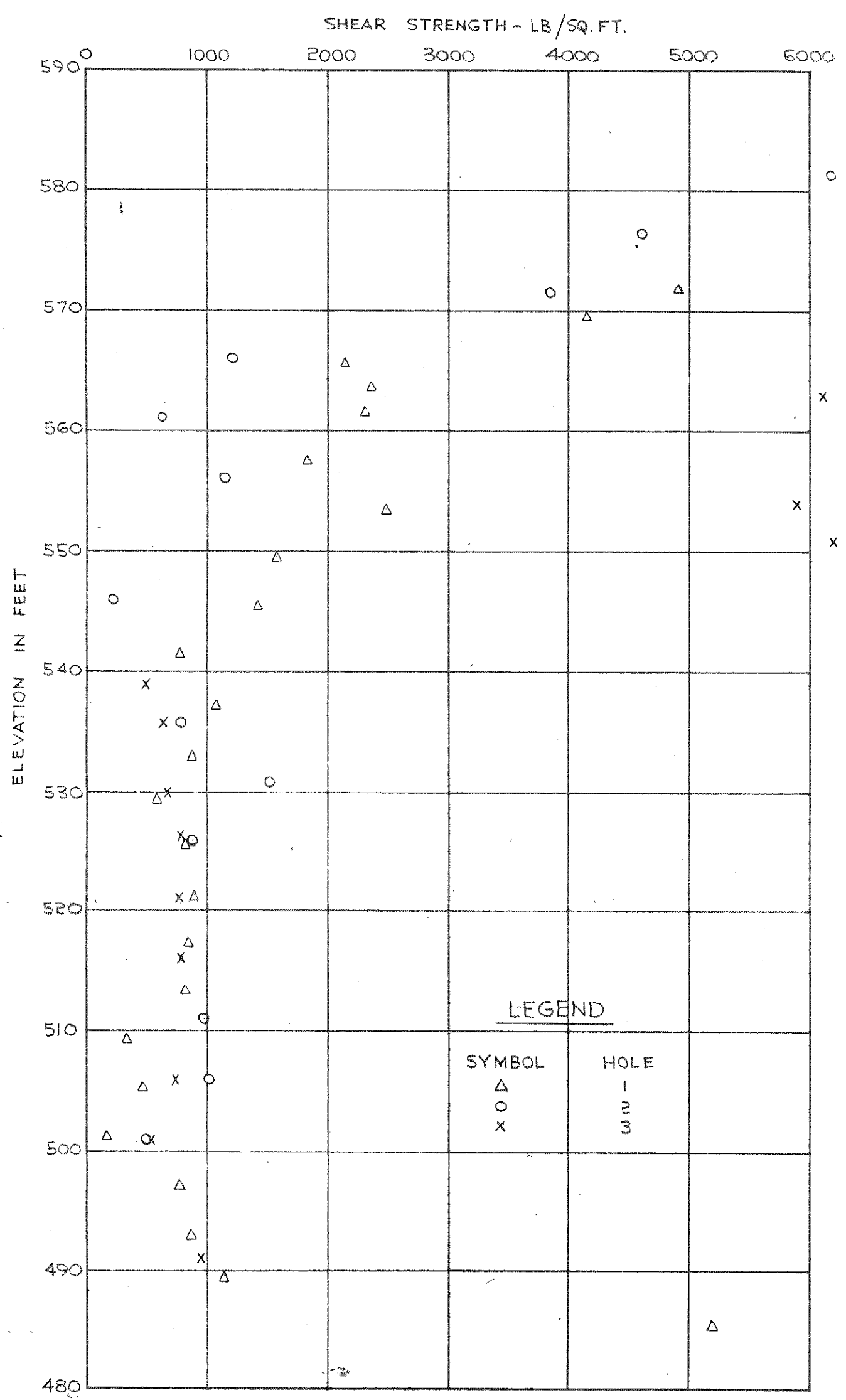
LOCATION SEE DRWG. No 1 BORING DATE OCT. 21-27, 1960 DATUM WELLAND CANAL
 BOREHOLE TYPE WASH BORING BOREHOLE DIAMETER BX CASING
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



PROJECT No. 6022

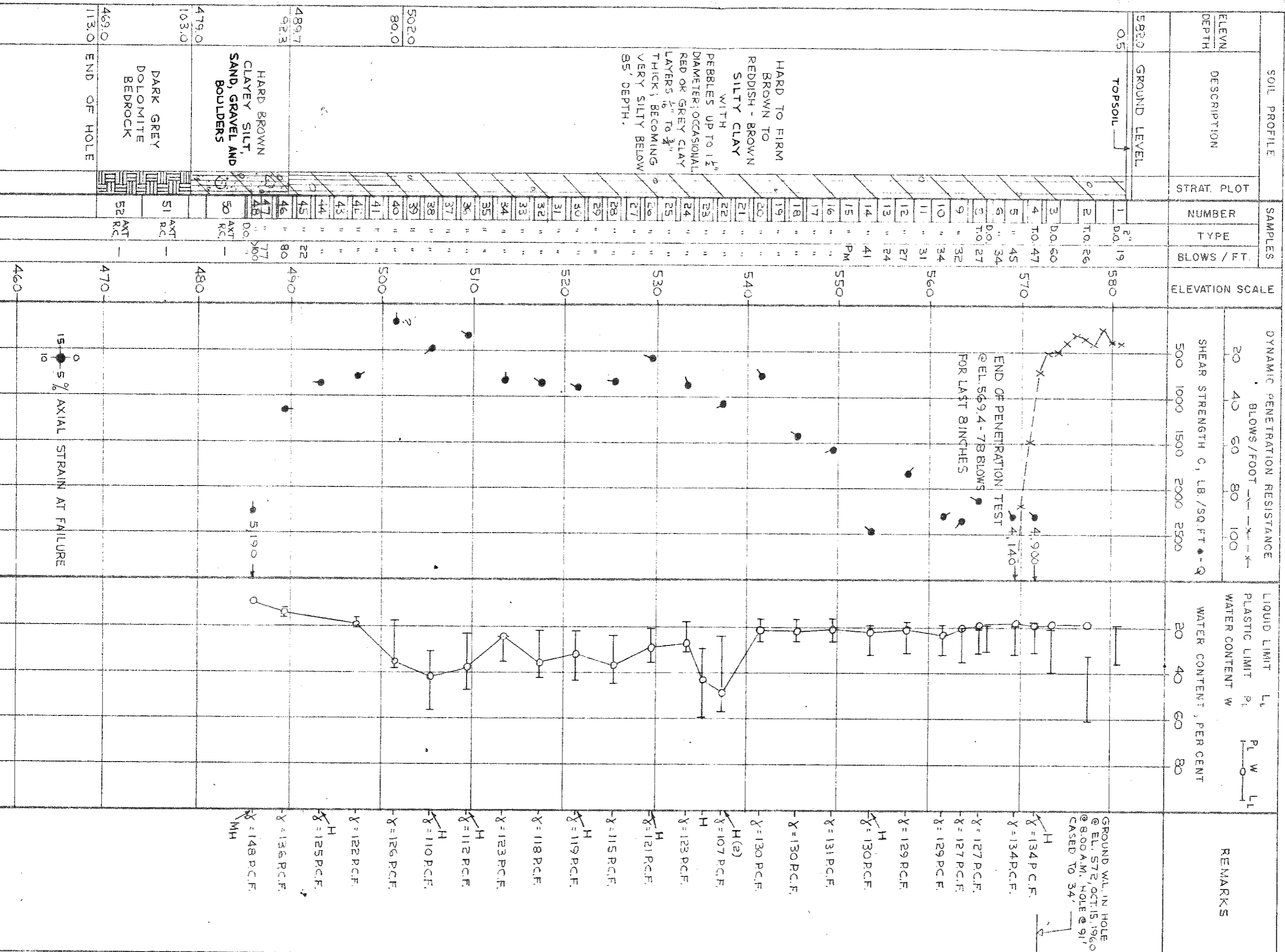
UNDRAINED TRIAXIAL COMPRESSION TESTS SHEAR STRENGTH VS ELEVATION

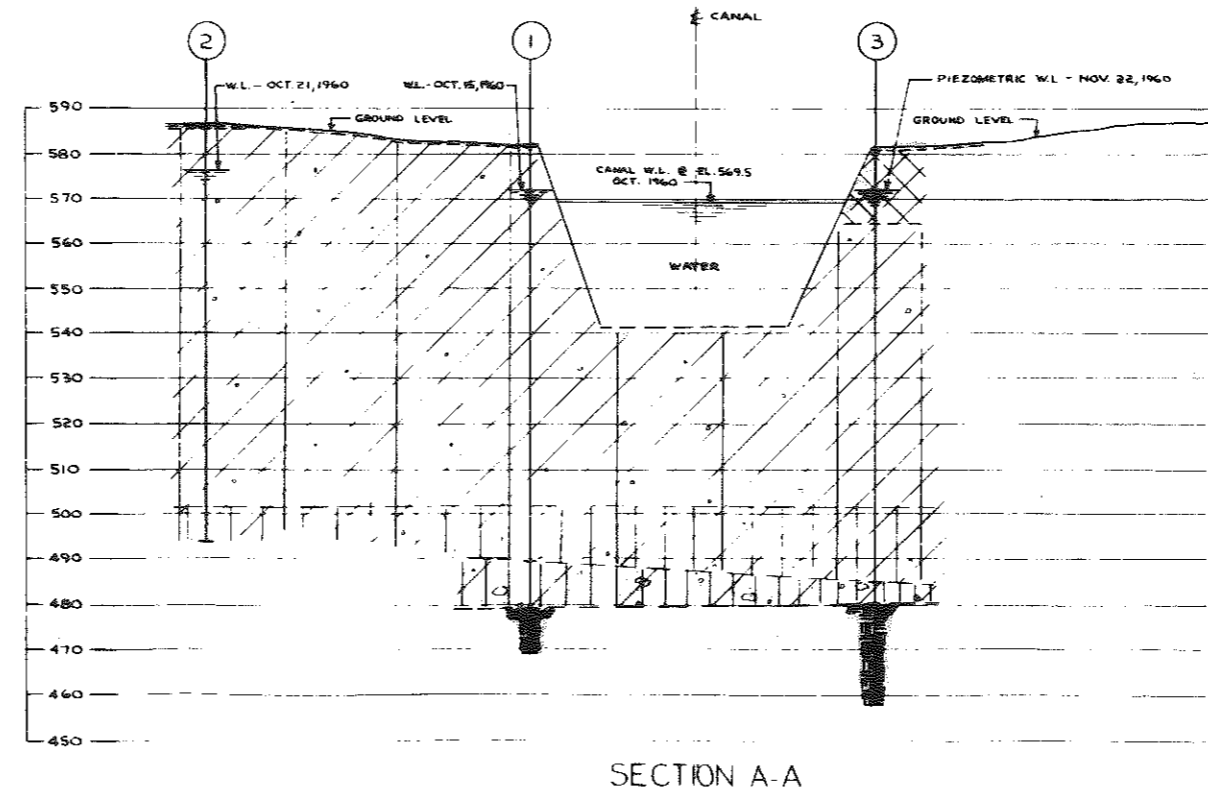
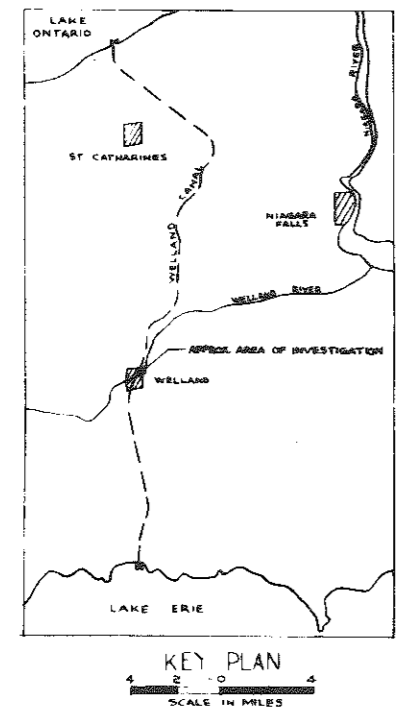
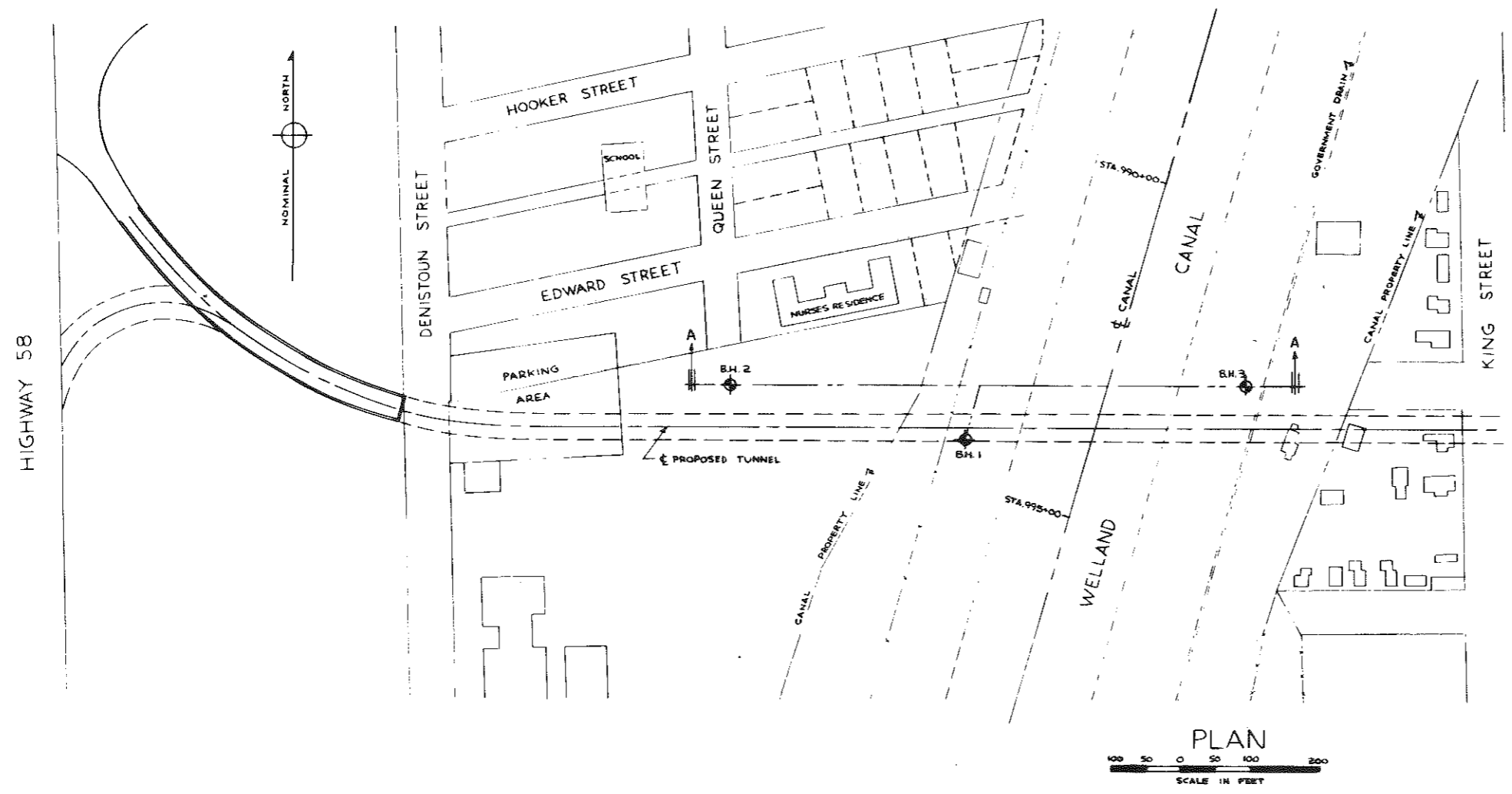
FIGURE 6

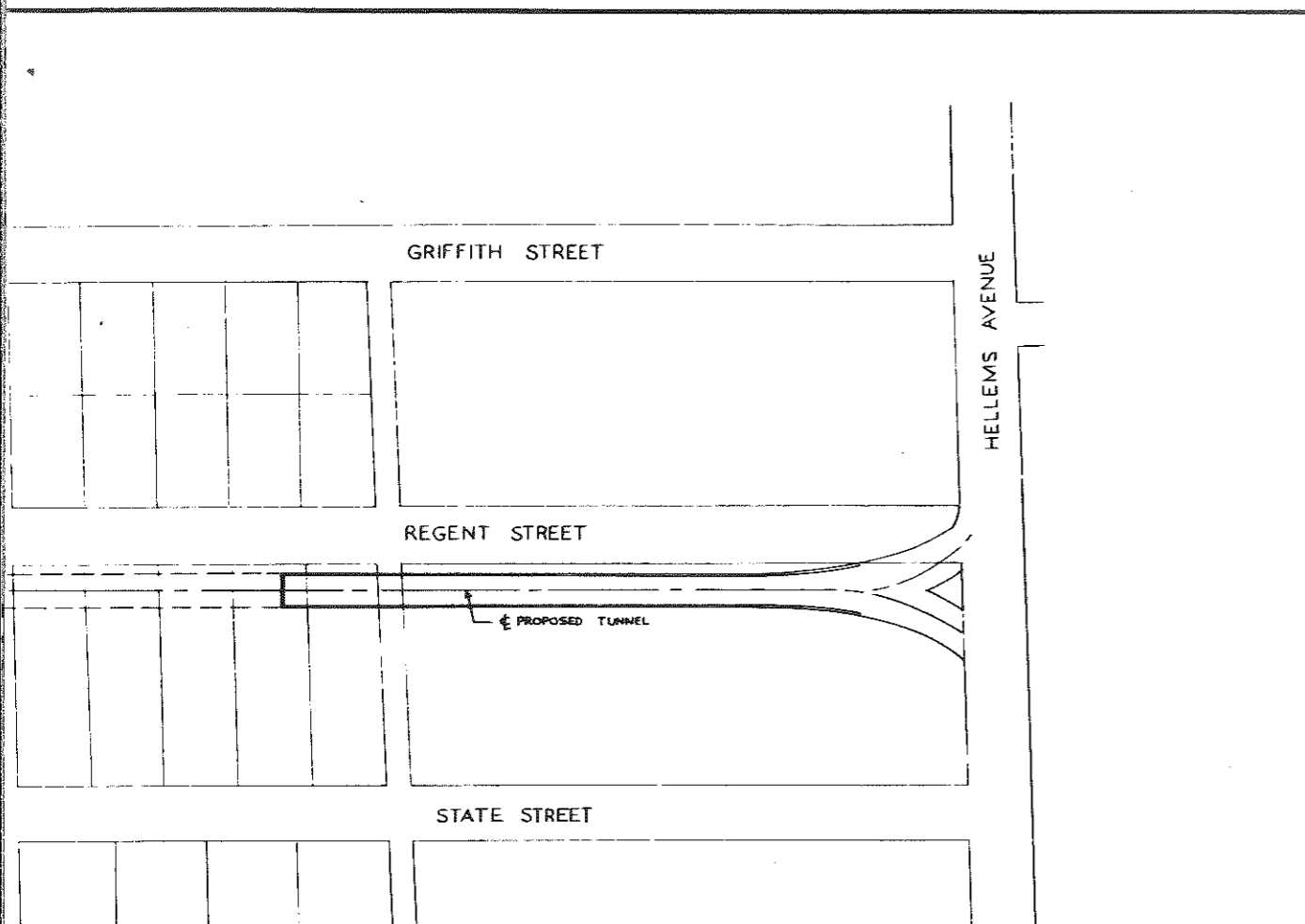


RECORD OF BOREHOLE 1



LOCATION SEE DRWG. No. 1 BORING DATE OCT. 11-17, 1960 DATUM WELLAND CANAL
BOREHOLE TYPE WASH BORING BOREHOLE DIAMETER BX CASING
SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES












LEGEND

-  BOREHOLE WITH PENETRATION TEST IN PLAN
-  BOREHOLE IN ELEVATION

STRATIGRAPHY

-  TOPSOIL
-  HARD CLAYEY FILL
-  HARD TO FIRM BROWN TO REDDISH-BROWN SILTY CLAY
-  HARD BROWN CLAYEY SILT, SAND, GRAVEL AND BOULDERS
-  DARK GREY DOLOMITE BEDROCK

SPECIAL NOTE: DATA CONCERNING THE VARIOUS STRATA HAVE BEEN OBTAINED AT BOREHOLE LOCATIONS ONLY. THE SOIL STRATIGRAPHY BETWEEN BOREHOLES HAS BEEN INFERRED FROM GEOLOGICAL EVIDENCE AND SO MAY VARY FROM THAT SHOWN.

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REFERENCE		DEPARTMENT OF HIGHWAYS, ONTARIO		GOLDER & ASSOCIATES	
DRWG. NO.	DESCRIPTION	TORONTO	ONTARIO	CONSULTING CIVIL ENGINEERS	
—	PLAN AND SECTION - WELLAND CANAL TUNNEL, SUPPLIED BY GIBB, UNDERWOOD, McCLELLAN LTD.	PROPOSED WELLAND CANAL TUNNEL		DATE: NOV. 29, 1960	SCALE: AS SHOWN
		BORING PLAN AND SOIL STRATIGRAPHY		DATE: J.A. / 1960	DRWG. NO. 1