

G E O C O N      L T D.

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TORONTO, Ontario.  
May 15th, 1956.

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TORONTO, Ontario.  
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Ontario Department of Highways,  
Room 1422  
Parliament Buildings,  
Toronto, Ontario.

Attention: Mr. F. C. Brownridge, P. Eng.,  
Materials and Research Engineer.

Re: Soil Investigation and Engineering Study,  
Proposed Embankment, Queen Elizabeth Way,  
Burlington, Ontario.

Dear Sirs:

This letter accompanies our detailed report covering the above soil investigation and engineering study. The object of the work was to determine the most suitable treatment for the proposed embankment.

The borings put down during this investigation encountered about 10 feet of loose sand overlying up to 60 feet of firm organic silty clay followed by stiff till. Information available from previous work carried out by the Ontario Department of Highways, shows that a similar stratigraphy is generally present elsewhere over the area under consideration, but that the surface of the till is highly irregular.

Stability computations show that, for a factor of safety of 1.3, the proposed embankment and Ramp "A" generally require side slopes of 1 vertical to 3 horizontal, except where flatter slopes are necessary as noted in the report. The expected total settlements at a number of locations are also given. The times to reach any given degree of consolidation would vary greatly and a number of estimated values are given in the report.

We trust that this report contains all the information required by you. If we can be of any further assistance, we would be pleased if you would call us.

Yours very truly,

GEOCON LTD.

James Morgan, P. Eng.,  
Chief Engineer

JM:IMS  
OS6239

REPORT  
TO  
ONTARIO DEPARTMENT OF HIGHWAYS  
ON  
SOIL CONDITIONS AND ENGINEERING STUDY  
PROPOSED EMBANKMENT  
QUEEN ELIZABETH WAY  
BURLINGTON, ONTARIO

Distribution:

- 3 copies - Ontario Department of Highways,  
Toronto, Ontario.
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May 15th, 1956

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## INTRODUCTION

Geocon Ltd. has been retained by the Ontario Department of Highways (proposal dated March 28, 1956 and Official Work Order - No. 5-6224 dated March 29th, 1956) to investigate and report on the soil conditions at the site of the proposed embankment of the Queen Elizabeth Way between the King's Highway No. 2 and the Burlington Skyway, Burlington, Ontario. The object of this investigation was to determine how the bank could be founded here.

## PROCEDURE

The field work was carried out between April 4th, 1956 and April 23rd, 1956 inclusive. Three boreholes with dynamic penetration tests and one additional penetration test were put down using a skid-mounted drillrig. In all boreholes, in-situ shear strength measurements were made employing vane testing apparatus.

Drawing OS6239-1 bound at the rear of this report gives the locations of the exploratory borings and dynamic penetration test and also the location of some boreholes of previous investigations by the Ontario Department of Highways. This drawing also shows the soil stratigraphy inferred from all these borings. Some differences in terminology were encountered in correlating this data. A detailed log of each hole put down in this investigation is given on the Office Reports on Soil Exploration in Appendix I. Drawing OS6239-2 at the rear of the report gives a summary of the stability calculations.

The soil testing was carried out in the Toronto Soil Mechanics Laboratory of Geocon Ltd., and the results are plotted on the Office Reports and on the Figures of Appendix II. The samples remaining after testing will be stored until November 15th, 1956 and then destroyed unless other instructions are received.

Elevations are referred to Geodetic datum and were supplied by the Ontario Department of Highways.

## SITE AND GEOLOGY

Most of the site is a marsh area adjacent to Hamilton Bay with the average elevation of the ground surface at about 248. A small stream which flows through the marsh comes within about 100 yards of the present highway.

Following the last glaciation the lake level was at one time considerably lower than at present. The organic clay which overlies the glacial till and sand was probably deposited in shallow water at the mouth of the stream, and accumulated as the lake rose to its present level.

## SOIL CONDITIONS:

The principal soil strata encountered by the borings are as follows:

Very Loose Grey-brown Sand

The uppermost stratum consists of 7 to 11 feet of grey-brown sand which contains pieces of wood, roots, and shells. The sand is generally of medium grain size and contains pebble gravel. In borehole 4 the sand became coarser with depth. At borehole 2, which was put down near a buried Hydro cable, some pieces of brick and concrete were found, but there was no further evidence that the stratum is fill material.

Standard penetration resistance or "N" values of up to 9 blows per foot and generally less than 4 were obtained indicating that the sand is of very loose relative density.

For design the sand may be assumed to have saturated and submerged unit weights of 120 and 58 pounds per cubic foot respectively. The angle of repose, determined on an oven dried sample of the sand, was  $32^{\circ}$ ; in the saturated state, the angle of internal friction is estimated to be  $30^{\circ}$ .

Firm Brown Organic Silty Clay

A stratum of organic silty clay from 13 to 61 feet thick underlies the loose sand. The clay is generally brown in colour and varies from yellowish-brown to reddish-brown to very dark brown depending on the character and the amount of organic material. Horizontal stratification is exhibited both by colour variations and by the delineation of the organic particles throughout the whole stratum. A layer of reddish-brown organic clay up to 4 feet thick was encountered at the top of the stratum in the boreholes. Similar layers were also occasionally encountered at greater depths. Sand layers varying in thickness from a few grains up to  $1\frac{1}{2}$  inches were found within the reddish-brown clay layers. No continuous sand seams, which would lead to spreading type failures due to excess hydrostatic pressures, were found in this stratum. The stratum contains throughout organic material such as wood and leaves, and also small white shells and subrounded pebble gravel. In borehole 2 a piece of wood was bored through for four feet at elevation 205. One grain size curve plotted on Figure 1 shows that the clay has a high percentage of silt size particles, however the clay content is sufficient to give the stratum the characteristics of a clay. The natural water contents obtained ranged between 19 and 236 percent and were generally in excess of 80 percent. Five Atterberg Limit tests gave liquid limits varying between 50 and 157 percent with plasticity indices of 22 and 49 percent respectively. The corresponding moisture contents were within or below the plastic range. Air drying decreased the liquid limit of one sample from 92 to 70 percent. These tests identify the stratum as an organic clay. One test on a sample with a natural water content of 173 percent gave an organic content equal to 45 percent of the total dry weight. Wet unit weights of 74 to 117 pounds per cubic foot with a general value of 95 pounds per cubic foot were obtained.

Firm Brown Organic Silty Clay (continued)

The shear strengths obtained from in-situ vane shear tests and triaxial quick compression tests are plotted on the Office Reports. Figure 2 gives a plot of shear strength versus elevation. The vane shear strengths range between .26 and .55 tons per square foot with a few higher values near the bottom of borehole 1. The shear strengths as determined from the compression tests are generally lower than those obtained with the vane apparatus. The average shear strength line used for stability calculations is given on Figure 2. By comparing remoulded strengths with natural strengths as determined with the vane tester the sensitivity of the clay was found to be about 3 to 4. Typical stress-strain curves for the compression tests are plotted on Figure 3 and for the vane tests on Figures 4, 5 and 6.

The pressure void ratio curves for four consolidation tests are given on Figures 7 and 8 and indicate that the clay is normally loaded or very slightly precompressed. Compression indices obtained from these curves ranged from 0.47 to 1.16. The time curves gave coefficients of consolidation for loads in the range of 0.5 to 1.0 tons per square foot of 0.009 to 0.032 with an average value of 0.019 square inches per minute.

Stiff Reddish-brown Till

Reddish-brown clayey till underlies the organic clay in all boreholes and was penetrated for a maximum distance of 30 feet. The till contains all sizes of soil grains and boulders over 4 feet thick were core drilled in several holes. In borehole 4 a layer of reddish-grey sand was encountered in the till between elevations 213 and 198. Natural moisture contents ranged from 8 to 28 percent in the till stratum.

Standard penetration resistances of 7 to over 100 blows per foot were obtained in the till and it is estimated that the till is of stiff consistency.

Bedrock

Previous investigations by the Ontario Department of Highways show that bedrock underlies the till. Bedrock is reported to be a soft reddish-brown shale.

WATER CONDITIONS

The ground level over most of the site was only about 1 foot above the level of Lake Ontario at the time of the investigation. Field observations indicated that the groundwater table at the holes was about 9 inches below ground level.

## EMBANKMENT

4.

The proposed embankment and the connecting ramps are to consist of compacted granular fill. The elevation of the finished road surface varies from 278 at the overpass to 255 at station 13/50; the maximum height of embankment overlying the organic clay is about 28 feet.

Stability computations have been carried out for a number of representative cross-sections of the embankment and a connecting ramp. The design data used and the results obtained are given on drawing OS6239-2. The computations show that for a minimum desirable factor of safety of 1.3 side slopes of 1 vertical to 3 horizontal are required except on the right hand slope of the embankment north of chainage 5/20. At chainage 3/20 the slope should be reduced to 1 vertical to 4 horizontal and between chainages 3/20 and 5/20 a gradual transition may be made. Ramp "A" is in itself stable and also provides a stabilizing effect as a berm to the main embankment; this stabilizing effect has been taken into account in the computations. The ramp and the main embankment should therefore be constructed simultaneously. The left shoulder of ramp "A" should be continued at ramp elevation to its intersection with the slope of the main embankment. Although the creek to the south of the embankment does not, in its present location, endanger the stability, it should not be allowed to approach the ramp, as erosion at the toe of the slope may then result.

Because of the wide variation in the depth to a firm stratum it is suggested that the behaviour of the embankment during construction should be watched for signs of local failures.

The organic clay stratum is highly compressible and also of irregular thickness and therefore large total and differential settlements must be expected. Settlement calculations give the values tabulated below:

Chainage Along Line B	<u>Total Settlement in Inches</u>			Ramp A Centre Line
	<u>Main Embankment</u>			
	<u>Left Outside Edge</u>	<u>Centre Line</u>	<u>Right Outside Edge</u>	
3 / 20		7		15
5 / 20	15	15	28	18
8 / 20	9	26	30	18
12 / 00		15		9

Because of the large variation in the thickness of the organic clay stratum the time to reach any given degree of consolidation will vary greatly. For the embankment the times for 50 percent consolidation range

between  $\frac{1}{2}$  month and  $1\frac{1}{2}$  years. For 90 percent consolidation the time ranges between  $\frac{1}{2}$  year and 15 years. For Ramp "A" the corresponding time intervals are 1 year to 4 years and 4 years to 20 years. The above times, for the thicker parts of the stratum in particular, may be considerably reduced by the installation of vertical sand drains beneath the proposed embankment location.

CONCLUSIONS AND RECOMMENDATIONS:

1. The uppermost stratum at the site is a very loose sand which is underlain by 13 to 61 feet of firm organic clay and then stiff till.
2. At the time of the investigation the groundwater table was encountered about 9 inches below the ground surface.
3. The embankment may be constructed with side slopes of 3 horizontal to 1 vertical except in one location where a flatter slope is required as discussed.
4. The expected total settlements of the embankment at several locations are given in the report.
5. Estimated times for various degrees of consolidation are also given.

PERSONNEL

The field work was carried out under the direction of Messrs. A. Prior and G. C. Morgan with driller Hocken. The report was written by Mr. Prior, checked by Mr. D. J. L. Kennedy, and reviewed by Mr. N. A. J. Matich.

AP:IMB

A. PRIOR, P. Eng.



## OFFICE REPORT ON SOIL EXPLORATION

### SAMPLE CONDITION

## SAMPLE TYPES

## ABBREVIATIONS

	DISTURBED
	FAIR
	GOOD
	LOST

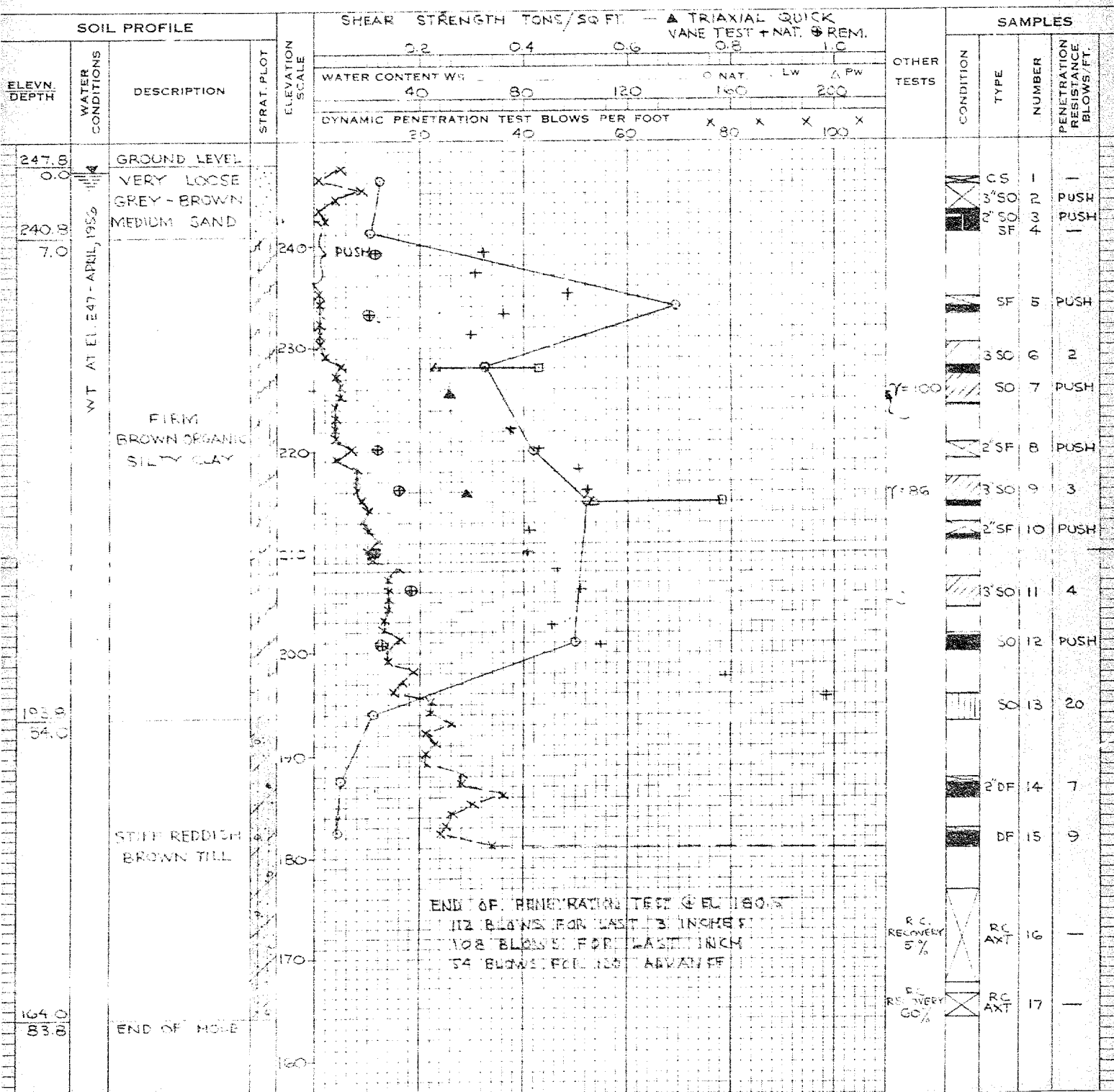
A.S. - AUGER SAMPLE  
S.T. - SLOTTED TUBE  
W.S. - WASHED SAMPLE  
D.O. - DRIVE-OPEN  
D.F. - DRIVE-FOOT VALVE  
CS - CHUNK SAMPLE

F.S. - FOIL SAMPLE  
S.O. - SLEEVE-OPEN  
S.F. - SLEEVE-FOOT VALVE  
T.O. - THIN WALLED OPEN  
R.C. - ROCK CORE

V - IN-SITU VANE TEST  
M - MECHANICAL ANALYSIS  
U - UNCONFINED COMPRESSION  
QC - TRIAXIAL CONSOLIDATED QUICK  
Q - TRIAXIAL QUICK  
S - TRIAXIAL SLOW

- W - WET UNIT WEIGHT
- K - PERMEABILITY
- C - CONSOLIDATION

WL - WATER LEVEL IN CASING  
WT - WATER TABLE IN SOIL



## GEOCON

## OFFICE REPORT ON SOIL EXPLORATION

CONTRACT 056239 BORING # 2 DATUM GEODETIC CASING 4" Bx  
 BORING DATE APRIL 11, 1956 REPORT DATE APRIL 16, 1956 COMPILED BY J. A. CHECKED BY J. J.  
 SAMPLER HAMMER WT. 380 LBS. DROP 12 INCHES (PENETRATION RESISTANCES CONVERTED TO BLOWS OF 4200 IN. LBS. ENERGY)

## SAMPLE CONDITION



## SAMPLE TYPES

A.S. - AUGER SAMPLE  
 S.T. - SLOTTED TUBE  
 W.S. - WASHED SAMPLE  
 D.O. - DRIVE-OPEN  
 D.F. - DRIVE-FOOT VALVE  
 C.S. - CHUNK SAMPLE  
 F.S. - FOIL SAMPLE  
 S.O. - SLEEVE-OPEN  
 S.F. - SLEEVE-FOOT VALVE  
 T.O. - THIN WALLED OPEN  
 R.C. - ROCK CORE

## ABBREVIATIONS

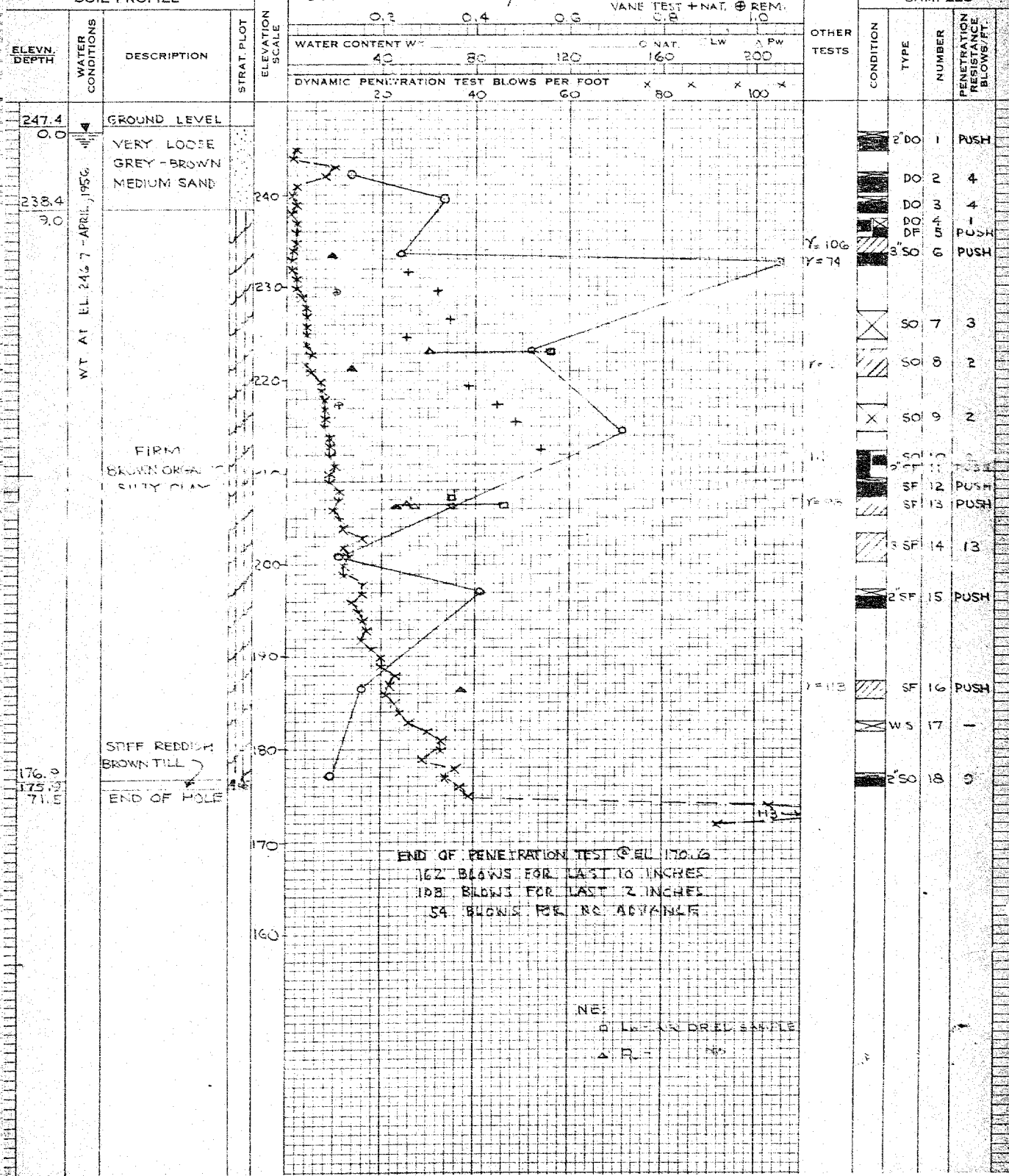
V - IN-SITU VANE TEST  
 M - MECHANICAL ANALYSIS  
 U - UNCONFINED COMPRESSION  
 Q - TRIAXIAL CONSOLIDATED QUICK  
 Q - TRIAXIAL QUICK  
 S - TRIAXIAL SLOW  
 γ - WET UNIT WEIGHT  
 K - PERMEABILITY  
 C - CONSOLIDATION  
 WL - WATER LEVEL IN CASING  
 WT - WATER TABLE IN SOIL

## SOIL PROFILE

## SHEAR STRENGTH TONS/50 FT. — ▲ TRIAXIAL QUICK

VANE TEST + NAT. REM.  
 C.S. 1.0

## SAMPLES



# GEOCON

## OFFICE REPORT ON SOIL EXPLORATION

CONTRACT OS G 239 PENETRATION TEST 3 DATUM GEODETIC CASING         
 BORING DATE APRIL 16, 1956 REPORT DATE APRIL 17, 1956 COMPILED BY        CHECKED BY         
 SAMPLER HAMMER WT. 380 LBS. DROP 12 INCHES (PENETRATION RESISTANCES CONVERTED TO BLOWS OF 4200 IN - LBS. ENERGY)

### SAMPLE CONDITION



A.S. - AUGER SAMPLE  
 S.T. - SLOTTED TUBE  
 W.S. - WASHED SAMPLE  
 D.O. - DRIVE-OPEN  
 D.F. - DRIVE-FOOT VALVE  
 C.S. - CHUNK SAMPLE

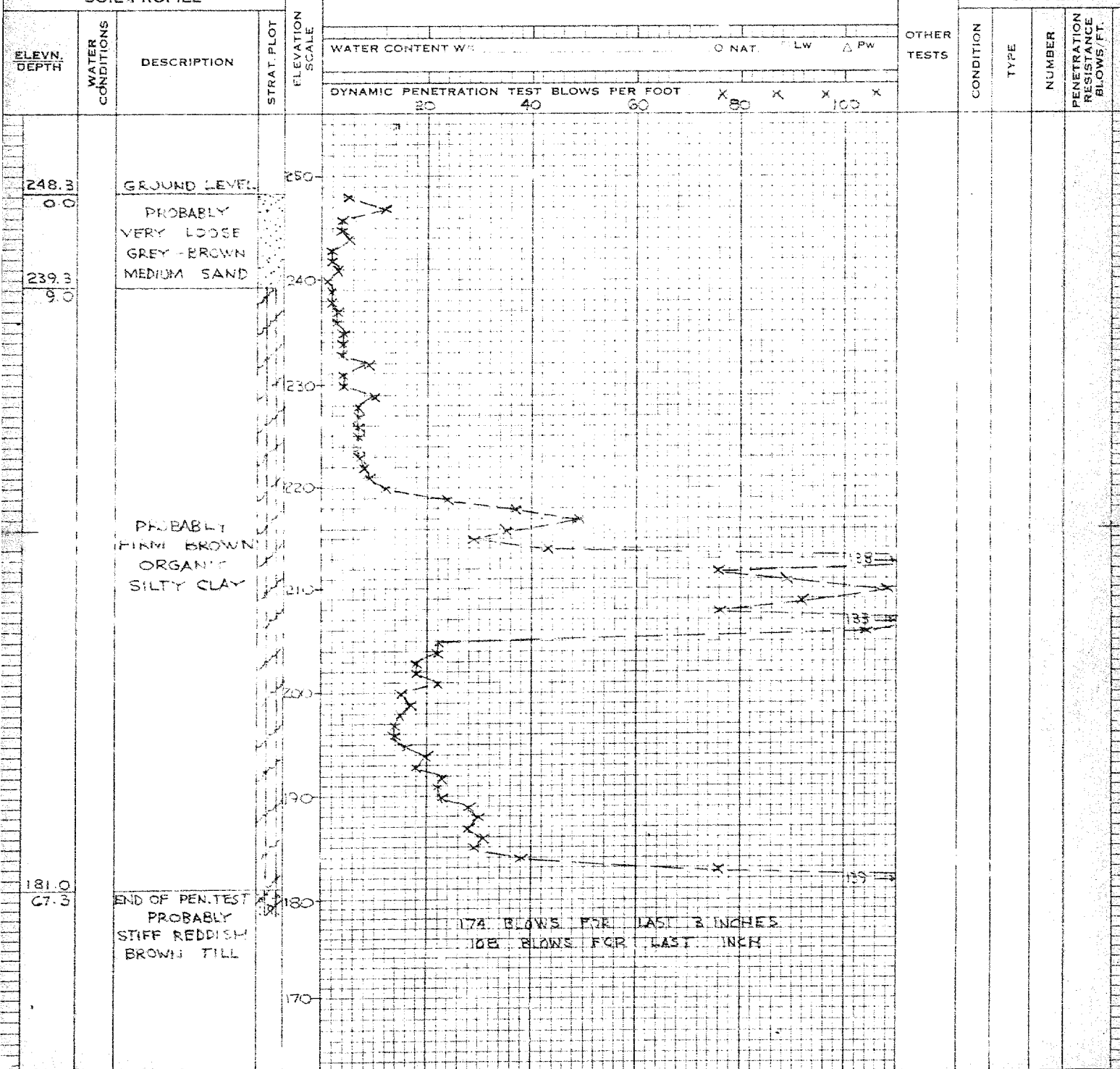
### SAMPLE TYPES

F.S. - FOIL SAMPLE  
 S.O. - SLEEVE-OPEN  
 S.F. - SLEEVE-FOOT VALVE  
 T.O. - THIN WALLED OPEN  
 R.C. - ROCK CORE

### ABBREVIATIONS

V - IN-SITU VANE TEST  
 M - MECHANICAL ANALYSIS  
 U - UNCONFINED COMPRESSION  
 OC - TRIAXIAL CONSOLIDATED QUICK  
 Q - TRIAXIAL QUICK  
 S - TRIAXIAL SLOW  
 γ - WET UNIT WEIGHT  
 K - PERMEABILITY  
 C - CONSOLIDATION  
 WL - WATER LEVEL IN CASIN  
 WT - WATER TABLE IN SOIL

### SOIL PROFILE



# GEOCON

## OFFICE REPORT ON SOIL EXPLORATION

CONTRACT OS 6239 BORING # 4 DATUM GEODETIC CASING 4" BX  
 BORING DATE APRIL 19, 1956 REPORT DATE APRIL 23, 1956 COMPILED BY J.A. CHECKED BY 770  
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### SAMPLE CONDITION



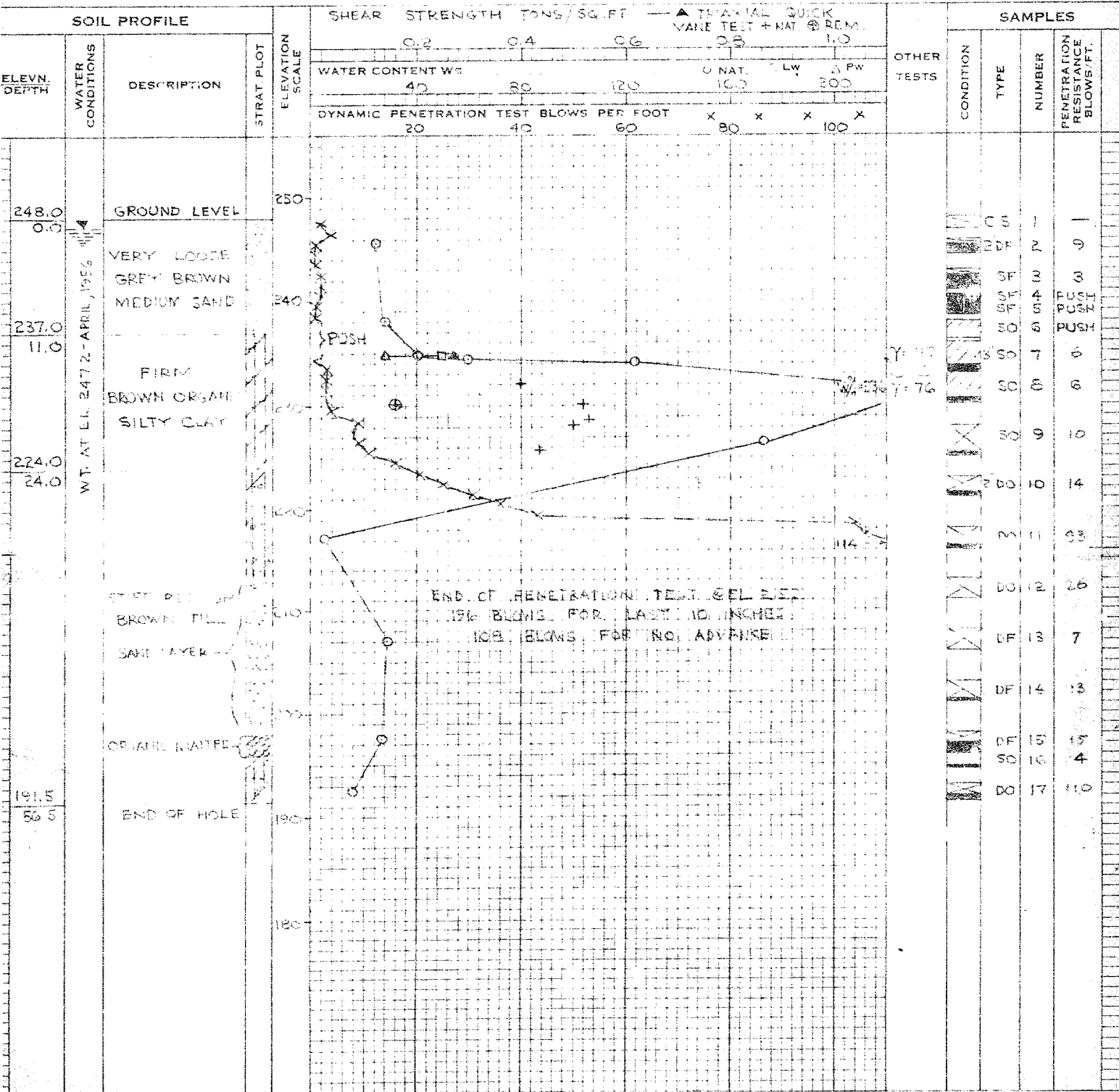
A.S. - AUGER SAMPLE  
 S.T. - SLOTTED TUBE  
 W.S. - WASHED SAMPLE  
 D.O. - DRIVE-OPEN  
 D.F. - DRIVE-FOOT VALVE  
 C.S. - CHUNK SAMPLE

### SAMPLE TYPES

F.S. - FOIL SAMPLE  
 S.O. - SLEEVE-OPEN  
 S.F. - SLEEVE-FOOT VALVE  
 T.O. - THIN WALLED OPEN  
 R.C. - ROCK CORE

### ABBREVIATIONS

V. - IN SITU VANE TEST  
 M. - MECHANICAL ANALYSIS  
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 S. - TRIAXIAL SLOW  
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 K. - PERMEABILITY  
 C. - CONSOLIDATION  
 WL. - WATER LEVEL IN CASING  
 WT. - WATER TABLE IN SOIL



PROJECT OS 6239



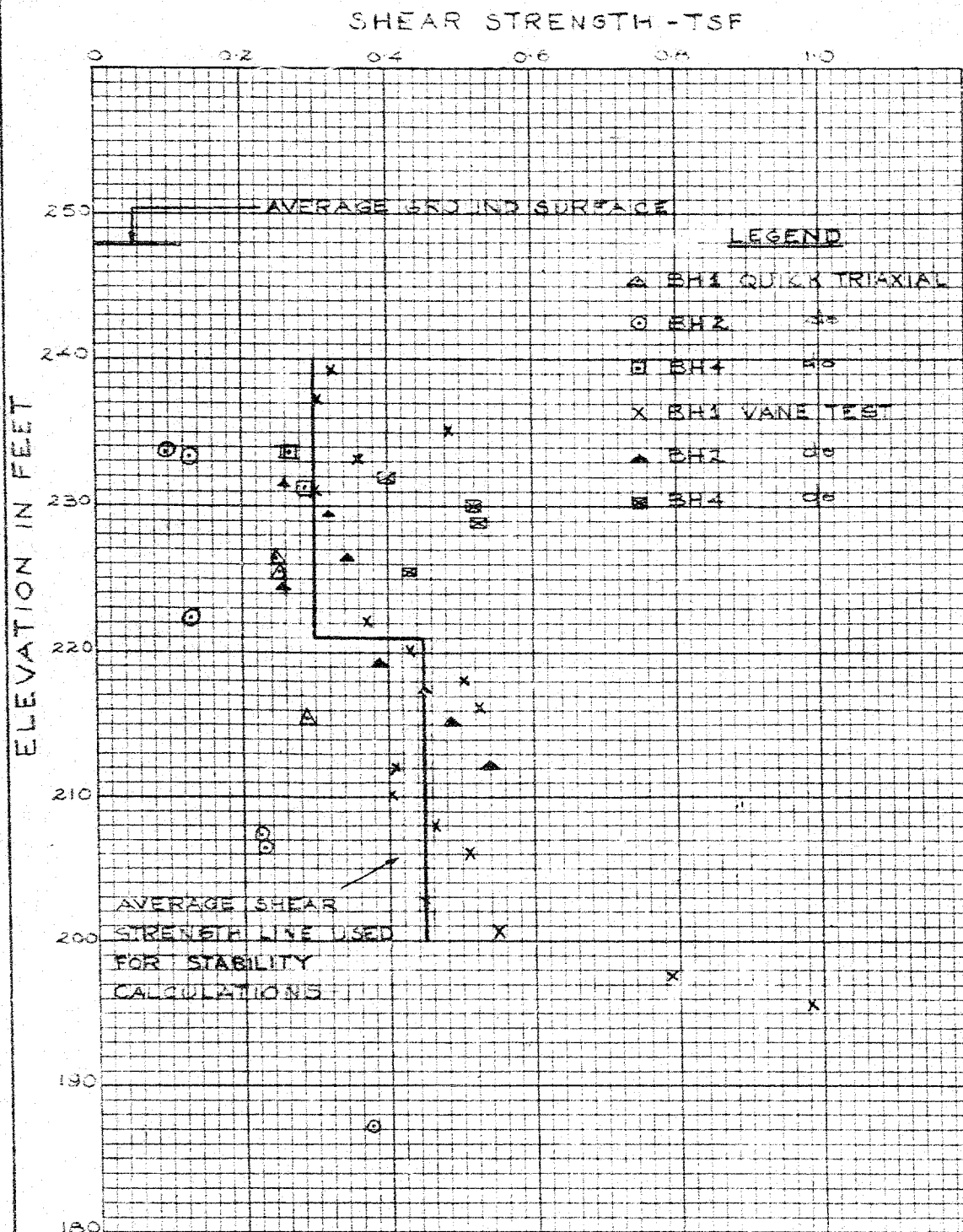
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# SHEAR STRENGTH vs ELEVATION

APPENDIX II

FIGURE 2

PROJECT OS 6239



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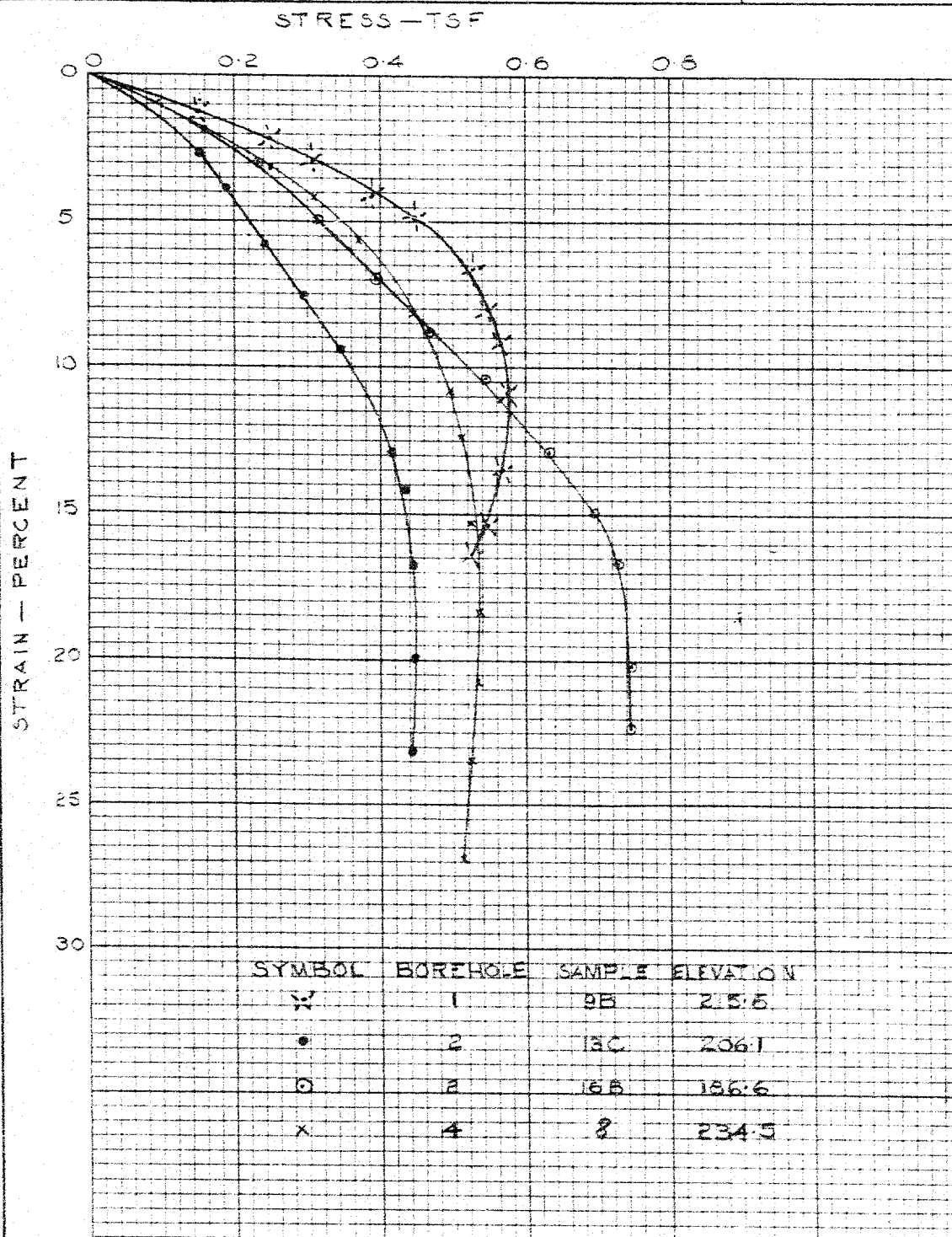
# QUICK TRIAXIAL COMPRESSION TESTS

## STRESS-STRAIN CURVES

APPENDIX II

FIGURE 3

PROJECT OS 6239



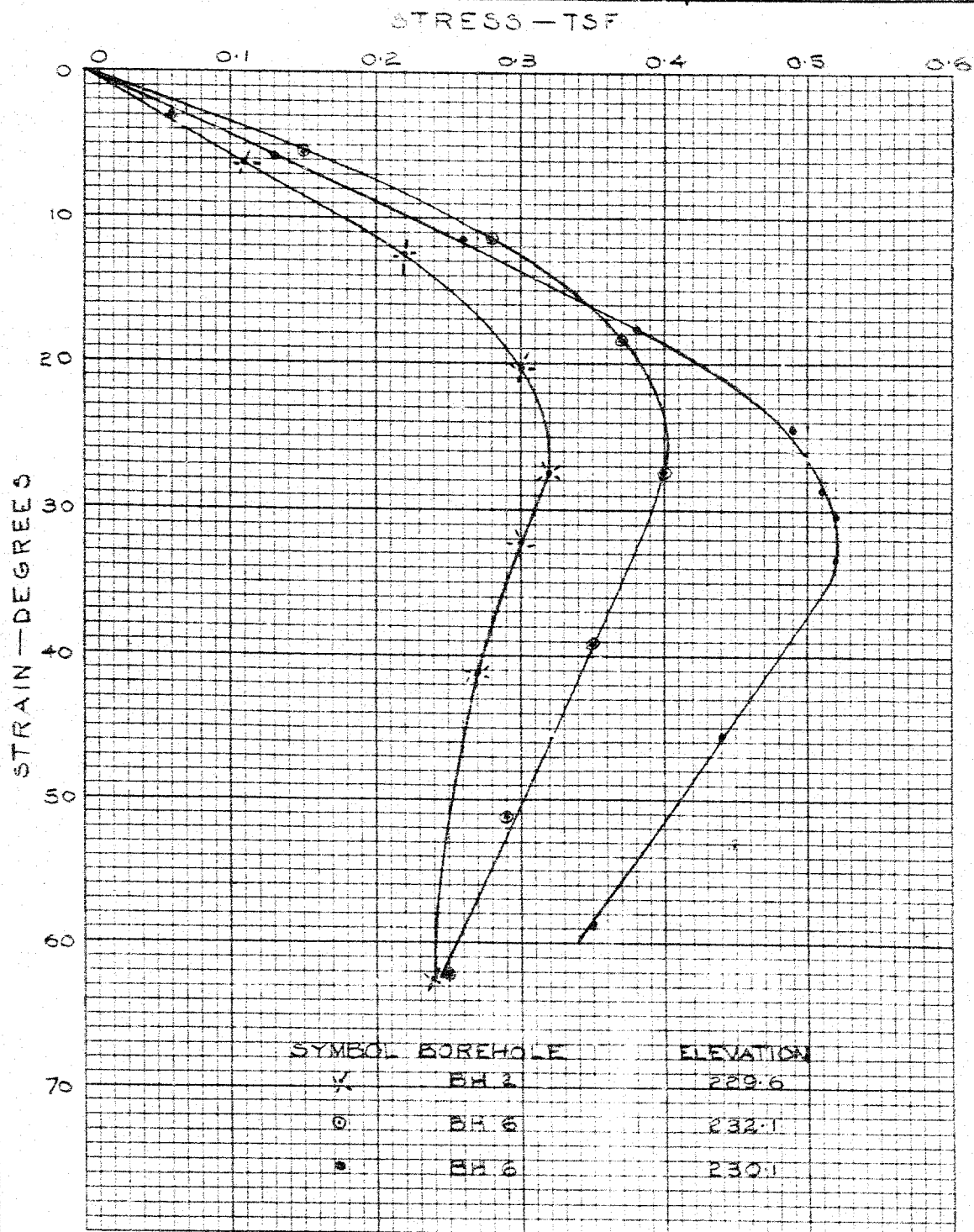
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# IN-SITU VANE TESTS

## STRESS - STRAIN CURVES

APPENDIX II  
FIGURE 4  
PROJECT OS 6239



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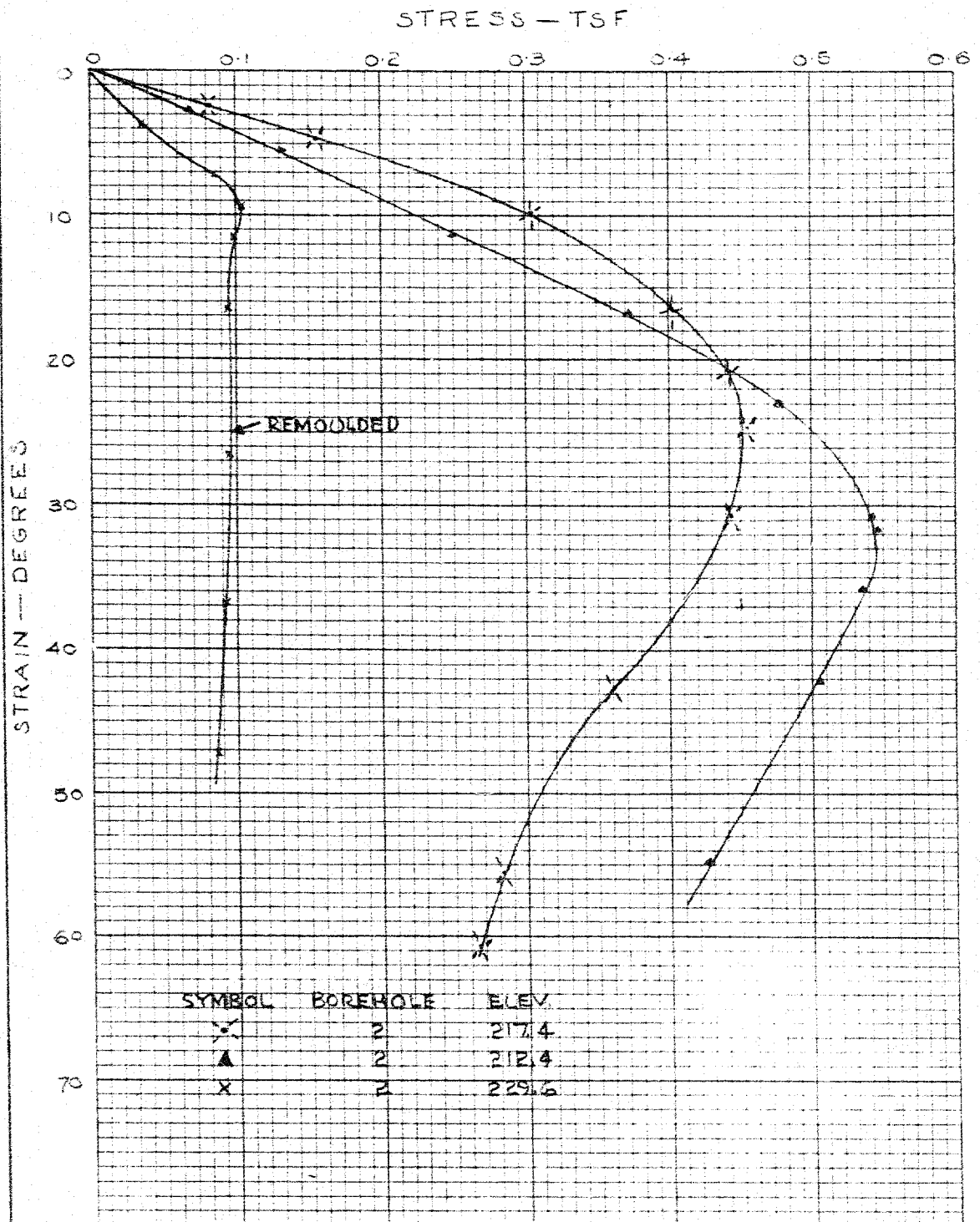
# IN-SITU VANE TESTS

STRESS - STRAIN CURVES

APPENDIX II

FIGURE 5

PROJECT OS 6230



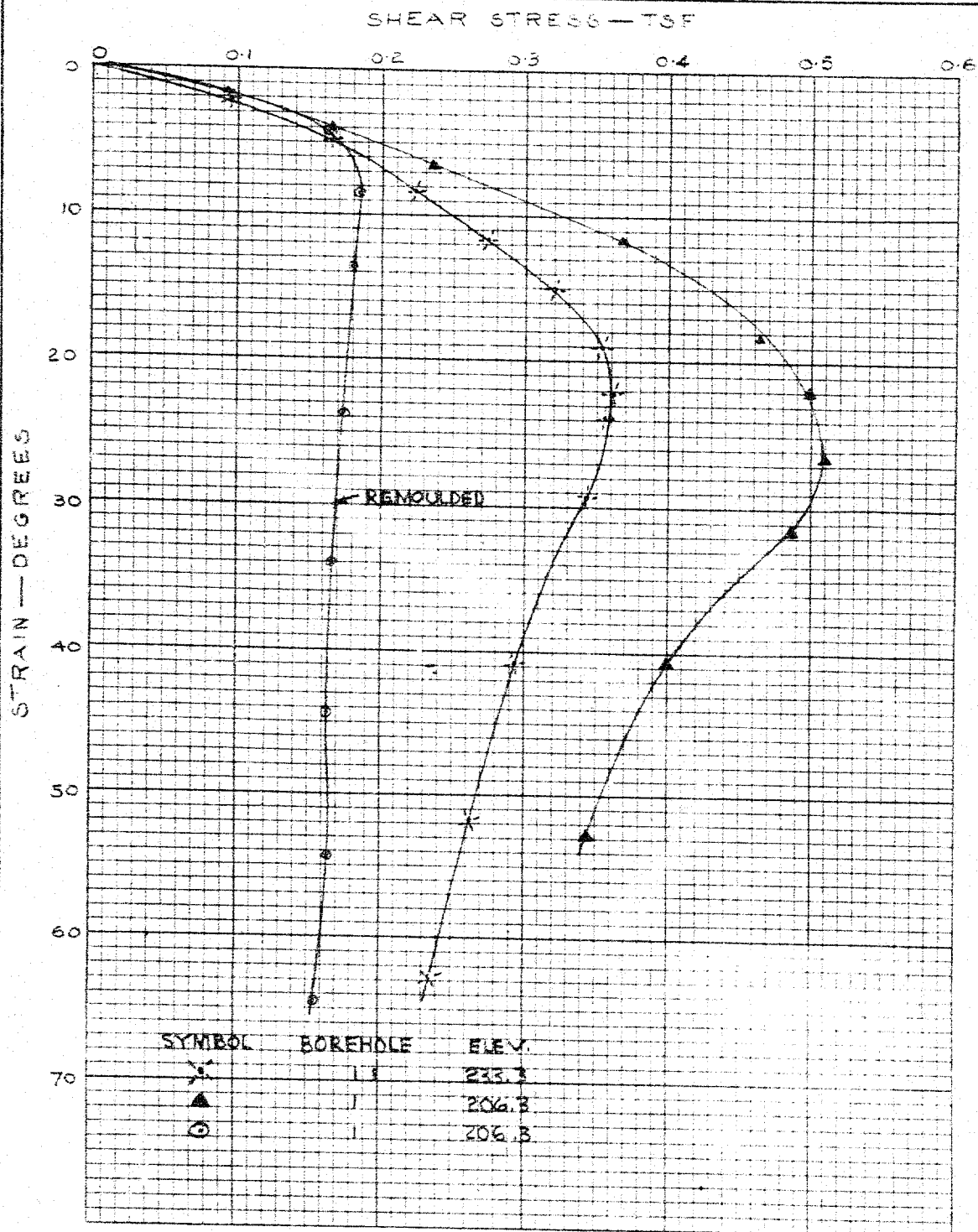
# IN-SITU VANE TESTS

STRESS - STRAIN CURVES

APPENDIX II

FIGURE 6

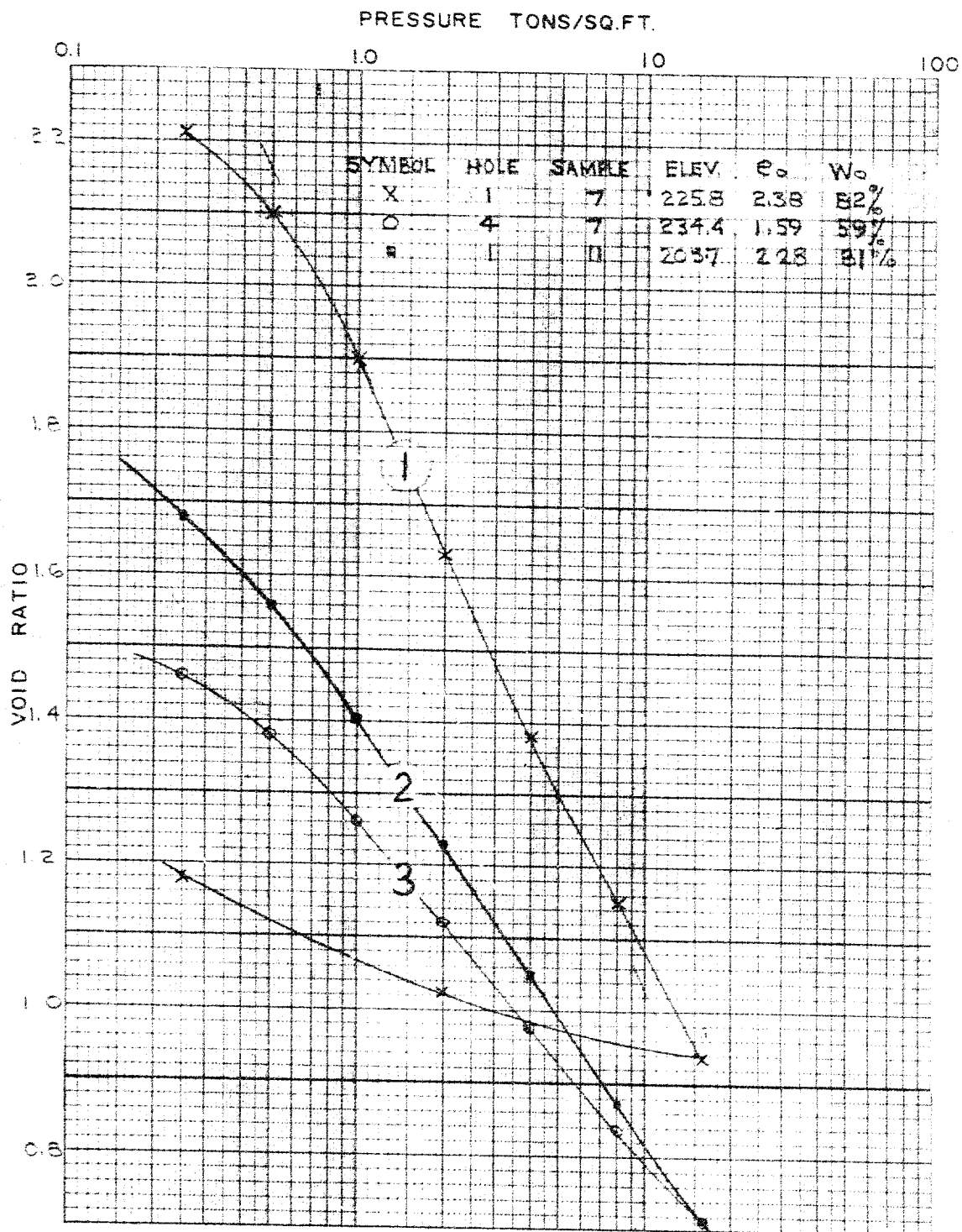
PROJECT OS 6239



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# VOID RATIO-PRESSURE CURVES CONSOLIDATION TEST

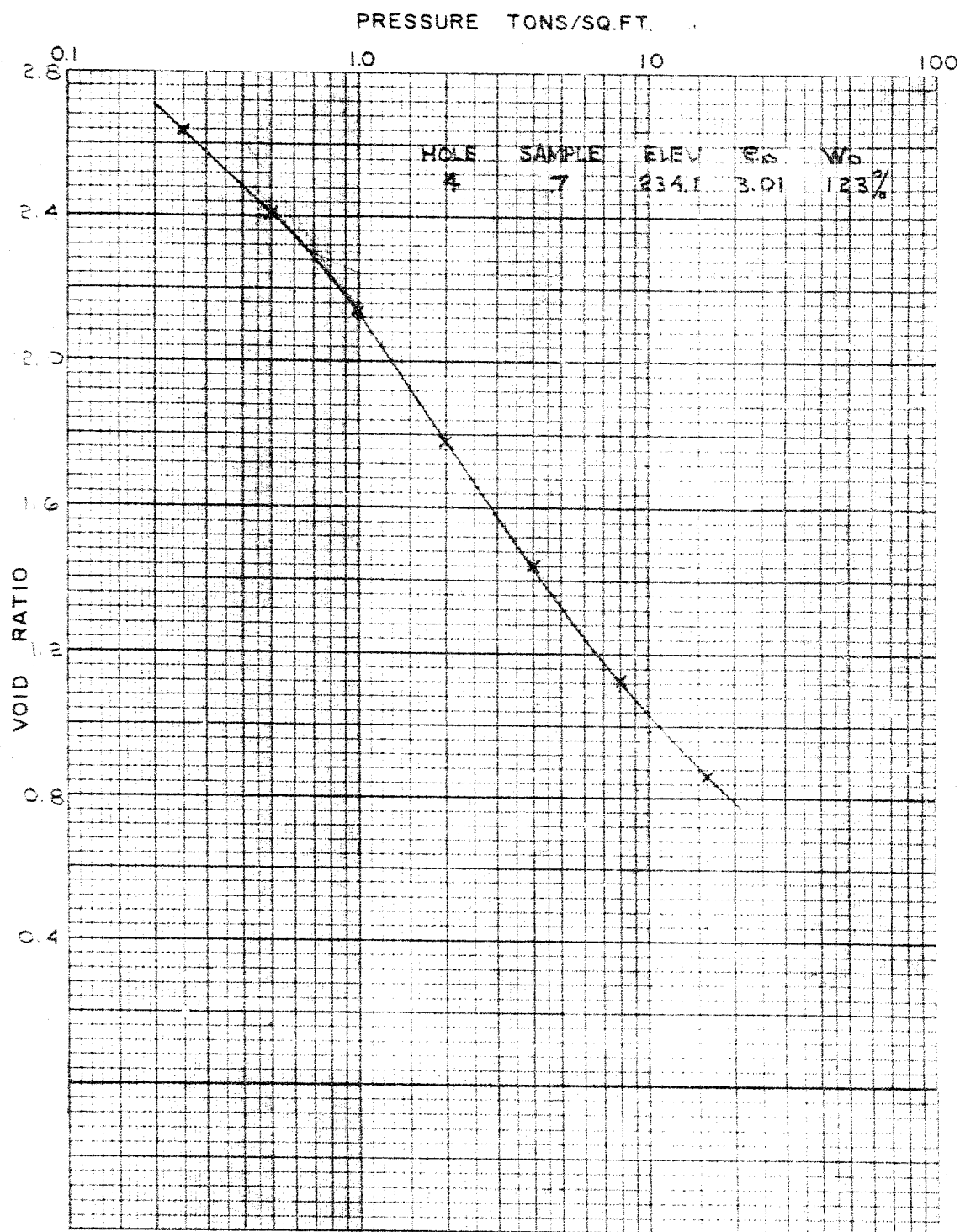
APPENDIX ☐  
FIGURE 7  
PROJECT OS 6239



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# VOID RATIO-PRESSURE CURVES CONSOLIDATION TEST

APPENDIX II  
FIGURE 8  
PROJECT OS6239



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#56F-201C

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QEW. & Hwy #2

INTERCHANGE





