

NOTE :

NORTH RAISIN RIVER BRIDGE HWY 138
W.P. 39-66-02 CONTR. NO. 68-112

SOMETIME IN THE PAST GERRY WROONG AND MYSELF LOOKED INTO THE SETTLEMENT PROBLEMS AND APPARENTLY DECIDED TO RECOMMEND SURCHARGING (5 FT.) & SETTLEMENT PLATES. AT THE REGIONAL CONTRACT REVIEW MEETING J. CRICKSHANK BROUGHT UP THE QUESTION OF STABILITY AND PHONED TO CHECK.

STABILITY ANALYSES WITH A 5 FT SURCHARGE WERE CARRIED OUT AND SHOWED THE LONGITUDINAL PROFILE TO BE UNSTABLE. IT WAS THEREFORE DECIDED THAT NO SURCHARGING BE ASKED FOR. THE RISKS ARE GREATER THAN THE BENEFITS THAT COULD BE DERIVED FROM THIS MEASURE.

G. WROONG ADVISED BY PHONE JIM CRICKSHANK ON OCT. 2. 1968 TO WRITE TO THE DISTRICT & ADVISE THEM TO TAKE THE SURCHARGE ITEM OUT OF THE CONTRACT.

SETTLEMENT PLATE ARE ALREADY IN PLACE SO NO CHANGE IN THIS REQUIREMENT.

OCT 2. 1968.

A. G. Wroong

Mr. C. S. Grebski,
Bridge Design Engineer,
Bridge Division,
Admin. Bldg.

Foundation Section,
Materials & Testing Div.,
Room 107, Lab. Bldg.

July 21, 1967

North Raisin River -- South Bridge
3.4 Miles North of St. Andrews
W.P. 39-66-02 -- Site No. 31-198
Highway 138, District No. 9 (Ottawa)

We have reviewed your Preliminary Bridge Plan Drawing C-6216-P for the above-named structure, and wish to make the following comments:

The pile length required will only be 8'6" long to reach bedrock at approx. elev. 287.0. It may be more economical to excavate down to bedrock and use mass concrete up to the required footing elevation.

MD/MdeP

R. Devata
R. Devata,
SUPERVISING FOUNDATION ENGR.
For:
A. G. Stermac,
PRINCIPAL FOUNDATION ENGR.

cc: Messrs. S. McCombie
G. Scott

Foundations Files
Gen. Files

Department of Highways Ontario

Copy for the information of

Mr. A. Stermac

Mr. G. Scott,
Reg. Bridge Location Engineer,
Kingston Regional Office,
Kingston, Ontario

Bridge Division,
Downsview, Ontario

July 12, 1967

North Raisin River - South Bridge
5.4 Miles North of St. Andrews
W.P. 39-66-02, Site No. 31-108
Highway 138, District No. 9

Attached herewith are prints of the Preliminary Bridge
Plan Drawing D-6216-F for the above-mentioned structure.

The estimated cost of the proposed structure is \$36,000.
This cost includes term., materials, engineering and sundry
construction.

Any comments or revisions you may have should be submitted
within three weeks.

CSG:rd

G.S. Grebski,
Bridge Design Engineer

Attach.

c.c. S. McCombie
A. Stermac
R. Forrest
E. Cross

Mr. E. H. Davis,
Bridge Engineer,
Bridge Division, Admin. Bldg.

Foundation Section,
Materials & Testing Div.,
Rm. 107, Lab. Bldg.

Attention: Mr. S. McLambie

March 30, 1967

MAR 30 1967

FOUNDATION INVESTIGATION REPORT FOR D.H.O.
BY: H. G. GOLDSER & ASSOCIATES LIMITED --
Proposed North Main River Bridge, South
Crossing of North Branch, Proposed Hwy. 138,
Montclair, Ontario, District No. 9 (Ottawa).
H.F. 39-36-2

Attached, please find the report for the above mentioned site, prepared and submitted by the consultant, H. G. Goldser & Associates Ltd.

We have reviewed the report and have found the factual information adequate and well presented.

The consultant mentions various alternatives for the foundations of the structure. He also suggests the lowering of the grade for 3 ft., if possible. At this stage, we find it difficult to comment on the various schemes and would, therefore, suggest that you contact this office after having studied the report, and if you wish to discuss any aspects of it. It is our opinion that the final choice of the foundation or structure scheme will be largely governed by economic considerations.

AGB/EdF

Attach.

cc: Messrs. E. H. Davis (2)

A. A. Tregaskes

D. A. Farren

C. J. Markiewicz

C. B. Robertson

G. Scott

J. W. Gruszyer

B. A. Singh

Foundations Files ✓

Gen. Files

A. G. Stern

A. G. Stern

PRINCIPAL FOUNDATION ENGINEER

H. Q. GOLDER & ASSOCIATES LTD.

CONSULTING CIVIL ENGINEERS
HEAD OFFICE - TORONTO, ONTARIO

H. Q. GOLDER
V. MILLIGAN
L. G. SODERMAN
J. L. SEYCHUK

196 BRONSON AVENUE
OTTAWA 4, ONTARIO
235-9698

F. J. HEFFERNAN (OTTAWA)

March 29, 1967.

Department of Highways, Ontario,
Materials and Testing Division,
Hwy. 401 & Keele Street,
DOWNSVIEW, Ontario.

Attention: Mr. A.G. Stermac, P.Eng.,
Principal Foundation Engineer.

RE: W.P.39-66-2,
FOUNDATION INVESTIGATION,
PROPOSED NORTH RAISIN RIVER BRIDGE,
SOUTH CROSSING OF NORTH BRANCH,
MONKLAND, ONTARIO.

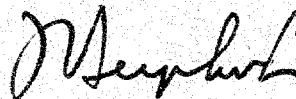
Dear Sirs:

Eleven copies of our report presenting the results of the above investigation were delivered to you today by messenger. Also included with the report shipment was a Cronaflex copy of Figure 1.

Should you have any questions regarding our report, please call us.

Yours truly,

H. Q. GOLDER & ASSOCIATES LTD.,



J. L. Seychuk, P.Eng.

JLS:hdg
67752

May. 401 & Leslie Sts.,
Donmewick, Ontario.

Tel. No. 243-3282

Materials and Testing Division

February 16, 1967

H. G. Collier and Associates Ltd.,
2044 Bloor Street West,
Toronto, Ontario.

Attention: Mr. J. L. Satchuk

Re: Foundation Investigations -- letter of authority

- (1) M.T. 39-64-2 - North Branch of E. Mainia River,
South Crossing.
- (2) M.T. 39-64-3 - North Branch of E. Mainia River,
North Crossing.

Proposed Hwy. #135, District No. 3 (Ottawa).

Dear Sir:

Please consider this your authority to carry out the necessary foundation investigations at the above mentioned sites.

The necessary plans were given to your representative on February 13, 1967, at which time, all the problems were also discussed.

You are to commence the investigations as soon as possible and submit eleven (11) copies of each of the final reports to the Department by not later than March 28, 1967.

Should you encounter any problems regarding locations and/or alignments, please contact Mr. G. Scott, Regional Bridge Location Engineer, Kingston - Tel. No. 944-2223 - (Area Code 613). Problems regarding subsoil conditions should be taken up, if necessary, with our Foundation Section.

Be understood that this investigation will be undertaken out of your Service office.

cc: Mr. /2 ...

M. S. Golder & Assoc. Ltd.
Attn: Mr. J. L. Seyebur

- 2 -

February 16, 1967

The field work should, at all times, be supervised by a qualified soils engineer. Any deviation from this agreement has to meet our prior approval.

Previous requirements as to preliminary borehole information and laboratory testing program, should be followed.

Since the drawings accompanying the foundation reports, showing the location of borings, the inferred subsoil conditions, etc., are to become contract drawings, you are requested to prepare them in accordance with the A.S.C. Standards. To enable you to do this, we are supplying you with a sample drawing with all the necessary explanations, together with linen sheets for your drawings. You are also requested to provide us with Cronoflex copies of the drawings.

Charges for the work performed will be in accordance with your Schedule of Rates, dated October 1, 1965, and invoices to be addressed to the attention of the undersigned.

Yours very truly,

A. Rutta

A. Rutta

MATERIALS & TESTING ENGINEER

AGS/edw
attach.

cc: Messrs. E. McCombie
S. J. Sarkiewicz
C. R. Robertson
C. Scott
J. E. Crispier
E. Honings
Mrs. I. Steinberg
A. Crowley
M. Szymanski (2) ✓
Foundations Office
Gen. Files (2)

Mr. C. R. Robertson,
District Engineer,
District No. 9 (Ottawa)

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

Mr. K. Westerby,
Construction Engineer

January 13, 1969

Contract 68-112, Hwy. 138,
St. Andrew's N. Limits N'y.,
District No. 9 (Ottawa)

This is to confirm our telephone conversation of
January 10, 1969, regarding the above subject.

It was decided some time ago (letter of October 3,
1968, by Mr. J. A. Cruickshank to you) that no surcharge will
be placed on the approach fills. If the surcharge would have
been placed, a waiting period of about 3 to 4 months would
have been required between the grading and bridge construction.

However, since there will be no surcharging, the
entire contract can proceed without any delays - i.e., waiting
periods. The benefit that could be derived from having the
fill sit there for about three months would be more than upset
by the hardship and difficulties the Contractor would have to
cope with because of such scheduling.

AGS/HdeF

A. G. Stermac
A. G. Stermac
PRINCIPAL FOUNDATION ENGINEER

cc: Mr. J. E. Cruspier

Foundations Files ✓
Gen. Files

MEMORANDUM

file 280

To: Mr. C. R. Robertson,
District Engineer,
Ottawa, Ontario.

FROM: Materials & Testing Division,
Kingston, Ontario.

Attention: Mr. K. Westerby.

DATE: October 3rd, 1968.

OUR FILE REF.

IN REPLY TO

SUBJECT:

Re: Contract 68-112, Hwy. 138,
St. Andrew's N. Limits N'ly.,
District 9, Ottawa.

*W.P. 4000/67
39-66-1, 2 & 3
92-67-2*

(a) Muskeg Excavation

After removal of the buildings in the vicinity of Station 140⁺ on the above project, additional investigation was carried out, to determine the subsoil conditions within the surrounding landscaped area. As a result of this investigation, it is now apparent that the frame garage was "floating" on the underlying muskeg, and that landscaping had been carried out with topsoil placed directly over this muskeg.

In view of the above, it is recommended that the muskeg excavation presently required from Station 134⁺ to Station 139⁺ be extended to Station 141⁺, in order to remove the organic material in the landscaped area, and provide uniform subgrade support throughout this section.

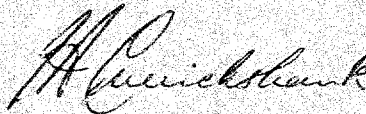
(b) North Raisin River Bridge Approaches

Following the Head Office review of this project, a special provision was included covering the placing of a surcharge at the approaches to the structure crossing the south branch of the North Raisin River. Further study and analysis, by Materials and Testing, of the conditions at the structure approaches has indicated a potential stability problem if the surcharge is placed as indicated in the contract documents.

In view of the above, the surcharge should not be applied.

Cont'd.....

Although the surcharge will not be placed, Materials and Testing have installed settlement plates at both structure approaches in order to record the rate and amount of settlement under the approach fills. The last paragraph of the Special Provision, dealing with prevention of damage to these plates, should, therefore, still apply.



J. A. Truickshank

for J. E. Gruspier,
Regional Materials Engineer.

JAC/jtk

c.c. H. A. Tregaskes
S. J. Markiewicz
G. Scott
H. B. McKay
A. Stermac ✓
G. A. Wrong

NOTE:

CONTR. NO 68-112

TELEPHONE CONVERSATION WITH J. CRICKSHANK

- STAGE CONSTRUCTION - (GRADING - PAVING) WAS NOT DONE. CONSEQUENTLY THERE WILL BE ONLY A SHORT PERIOD OF TIME BEFORE PAVING.
- BOULDERY FILL WILL BE USED
- IT WAS DECIDED THAT ONLY 2 (TWO) SETTLEMENT PLATES ON ONE SIDE BE PUT IN. THEY SHOULD BE UNDER THE SHOULDER SO READINGS CAN BE CONTINUED AFTER PAVING.
- 4 FT LONG PIPES WILL BE ADDED DURING CONSTRUCTION IN ORDER TO DISPENSE WITH DRILLING THROUGH BOULDERY FILL
- CARE SHOULD BE TAKEN TO PREVENT DAMAGE TO PIPES
- IT IS OUR OPINION THAT APPROACH SLABS SHOULD BE BUILT TO TAKE CARE OF THE BUMP THAT WILL DEVELOP AT ABUTMENTS.
THE DISTRICT WILL TAKE THIS UP WITH THE BRIDGE OFFICE.

Aes

H. Q. GOLDER & ASSOCIATES LTD.

CONSULTING CIVIL ENGINEERS
HEAD OFFICE - TORONTO, ONTARIO

H. Q. GOLDER
V. MILLIGAN
L. G. SODERMAN
J. L. SEYCHUK

196 BRONSON AVENUE
OTTAWA 4, ONTARIO
235-9698

F. J. HEFFERNAN (OTTAWA)

W.P. 39-66-2

REPORT

TO

DEPARTMENT OF HIGHWAYS, ONTARIO

ON

SOIL CONDITIONS AND FOUNDATIONS

PROPOSED NORTH RAISIN RIVER BRIDGE

SOUTH CROSSING OF NORTH BRANCH

PROPOSED HIGHWAY 138

MONKLAND

ONTARIO

Distribution:

11 copies - Department of Highways, Ontario,
Toronto, Ontario

2 copies - H. Q. Golder & Associates Ltd.,
Ottawa, Ontario

March, 1967

67752

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ABSTRACT

The results of an investigation to determine the sub-soil conditions at the proposed south crossing of the north branch of the North Raisin River by Highway 138 near Monkland, Ontario, are reported.

It was found that below a surficial cover of sandy top-soil and alluvium, the site is underlain by firm sensitive silty clay becoming soft with depth. This deposit is underlain directly by sound flat-lying limestone bedrock at a depth of about 15 ft. below the existing ground surface. The groundwater level in the boreholes was observed to be slightly above river level.

To ensure the stability of the approach embankments with side slopes of 2 horizontal to 1 vertical on the underlying soft sensitive clay it is recommended that the desired embankment height of 13 ft. be reduced to 10 ft. or from elevation 314 to 311. If the profile grade cannot be reduced it is suggested that the bridge be replaced by a flexible multi-plate culvert or culverts.

A rigid frame structure, if used, should be founded on the limestone bedrock.

The embankment fills should be placed well in advance of paving operations.

INTRODUCTION

H. Q. Golder & Associates Ltd. have been retained by the Department of Highways, Ontario, to carry out a subsurface investigation at the site of the south crossing of the north branch of the North Raisin River by the proposed Highway 138 (Line A) near McMillan Corners in Stormont County. The purpose of this investigation was to determine the subsurface conditions across the site and to provide information for the foundation design and construction of the proposed structure and associated roadway approach embankments.

PROCEDURE

The field work for the investigation was carried out between February 24 and 27, 1967. During this period 2 boreholes with adjacent dynamic penetration tests and 2 additional dynamic penetration tests were put down with a machine drillrig supplied and operated by the F. E. Johnston Drilling Co. Ltd. of Ottawa, Ontario. Bedrock was cored in AXT size in each of the boreholes for a depth of about 10 ft. A piezometer was installed in each borehole for groundwater level observations. The field work was supervised throughout by an engineer from our staff.

The locations of borings, together with a stratigraphic section across the site is shown on Fig. 1. A detailed log of each boring is shown on the Record of Borehole sheets following the text of this report.

All soil samples and rock core, obtained during the investigation, were brought to our laboratory for examination and testing. The results of the testing are shown on the Record of Borehole sheets and on Figs. 2 and 3.

The borehole locations and ground surface elevations at the boreholes were obtained by the Department of Highways, Ontario. Elevations are understood to be referred to geodetic datum.

SITE AND GEOLOGY

The site is located in Roxborough Township, Stormont County at McMillan Corners, some 100 yards east of the existing county road running from Cornwall to Monkland Station. The proposed structure will be the south crossing of the proposed Highway 138 (Line A) over the north branch of the North Raisin River. At this site the river is some 10 ft. wide at normal water level and runs in a northeasterly direction through a meadow. The surrounding countryside is farmland with occasional wooded areas.

The site is in the physiographic region known as the Glengarry till plain. It has an undulating surface consisting of well formed drumlins together with intervening clay flats and swamps. The till is very bouldery and has a high proportion of limestone. Over much of the area the overburden is known to be less than 25 ft. deep to bedrock. The bedrock underlying the site is known, from

existing geological information to be the Ottawa formation of the Trenton and Black River groups. It is grey, flat-lying limestone with occasional shaly partings and is of Ordovician Age.

SOIL AND BEDROCK CONDITIONS

General

At this site firm to soft sensitive clay overlies sound limestone bedrock at a depth of 15 ft. below the existing ground surface. The detailed stratigraphy encountered in each boring is on the Record of Borehole sheets and a section of the inferred stratigraphy across the site is on Fig. 1.

Surficial Deposits

The surficial material across the site is about 1 ft. of sandy topsoil. This overlies a further 1 to 2 ft. of alluvial sand and gravel which contains shells. This material was probably deposited by the meandering Raisin River as it moved back and forth across the valley bottom.

Sensitive Silty Clay

Underlying the surficial deposits, at about elevation 300, is a sensitive silty clay which extends down to bedrock at about elevation 287. The upper 3 to 5 ft. of this sensitive clay is desiccated and forms a highly fissured, firm brownish grey crust with occasional root fibres. Two grain size distribution curves are on Fig. 3.

The stratum becomes softer, grey and less desiccated with depth. A summary of the engineering properties is on Fig. 2. The natural moisture content of the stratum ranges between 54 and 74 per cent. The liquid limit, from two determinations is 61 and 79 with corresponding plastic limits of 20 and 23. Four in situ vane shear tests were carried out in the silty clay below the crust. These gave undrained shear strengths ranging between 320 and 680 lb/sq.ft., the lower strengths being measured near the bottom of the stratum. Corresponding remoulded in situ vane shear tests gave remoulded undrained shear strengths varying between 50 and 140 lb/sq.ft. Based on the vane test results the sensitivity of the clay (the ratio of the in situ to remoulded undrained shear strength) was found to be about 7. Four undrained triaxial compression tests on relatively undisturbed samples gave undrained shear strengths between 130 and 670 lb/sq.ft. However, the tests carried out in borehole 1 gave extremely low strengths of 130 and 340 lb/sq.ft. and are considered to be due to disturbance of the samples since the corresponding strength from in situ vane tests in the same borehole gave undrained shear strengths between 480 and 680 lb/sq.ft. Generally, therefore, the undrained shear strength for the part of the stratum below the crust decreases with depth from 700 to 300 lb/sq.ft.

In borehole 2 the bottom 2 ft. of the silty clay stratum becomes interbedded with thin layers of silty sand and occasional gravel

Bedrock

The bedrock underlying the site, at a depth below ground surface of about 15 ft. is very level at about elevation 287. It is sound grey, generally horizontally bedded, limestone with occasional fine shaly partings.

GROUNDWATER CONDITIONS

Piezometers were installed in both boreholes following completion of the borings to determine the groundwater level. Details of these installations are given on the Record of Borehole sheets. The water levels recorded in this report were taken on March 7, 1967 one week after the field investigation was completed. On this date the water level across the site was found to be at about elevation 300. This may not be the stabilized water level because of the time lag for the water to stabilize in the relatively impermeable silty clay into which the piezometers were sealed.

PROPOSED BRIDGE STRUCTURE

General

It is understood that the south crossing of the north branch of the North Raisin River by the proposed Highway 138 is to be by a single span rigid frame structure some 30 ft. long and 42 ft. wide (Ref. Fig. 1). The desired grade is to be at elevation 314 or some 13 ft. above the existing ground surface.

Approach Embankments

For an embankment 13 ft. high, with side slopes of 2 horizontal to 1 vertical, the factor of safety, F , of the side slopes against failure in the sensitive clay, will be marginal. Based on a total stress ($\phi = 0$) analysis and using the undrained shear strength distribution shown in Fig. 4, the factor of safety was found to be about 1.3 (Fig. 4a). Considering the stress strain characteristics of the sensitive clay, it is recommended that for design, F , ($\phi = 0$ analysis) should be at least 1.5.

The stability of a 13 ft. embankment along the bridge abutment face was also checked and the minimum total stress factor of safety against failure was found to be less than 1.2 (Ref. Fig. 4b). The factor of safety could be slightly increased to allow for embankment end effects but it would still be marginal. Consideration was also given to a 2 span structure with spill through abutments but this arrangement only slightly increased the total stress factor of safety. Consequently, it is recommended that the embankment height be reduced by 3 ft. to a level of 10 ft. above the existing ground surface. For an embankment of 10 ft. (elevation 311) at the bridge abutment, F is computed to be 1.5 (Fig. 4c). Standard side slopes of 2 horizontal to 1 vertical for the approach embankment will have a slightly higher factor of safety.

If the grade cannot be reduced below elevation 314 (13 ft.

embankment), then consideration should be given to a different type of structure such as a flexible multi-plate culvert or culverts. It is recommended that at least 3 ft. of bedding material, consisting of free-draining sand and gravel, well compacted in 9 to 12 in. lifts, be placed beneath the culvert. During placement, care should be taken to prevent disturbance of the sensitive clay.

Bridge Foundations

Due to the low shear strength of the silty clay subsoil, together with the relatively shallow depth to bedrock, it will be necessary to found the abutments for the bridge (if this type of structure is used) on bedrock. This could be achieved by local timbered or sheeted excavations or by using a large diameter auger and a steel lining to prevent caving of the sensitive clay. Provided that the bedrock surface is clean (and this should be checked by inspection) a bearing pressure of 20 tons/sq.ft. may be used for the limestone in the design of piers or pier footings. No bellling out at the base of such excavations is recommended in this case because of possible sloughing of the sensitive clay overburden.*

Closed end abutments should be backfilled for a distance of at least 5 ft. horizontally with a well compacted free-draining

*Alternatively, low displacement piles such as H-section, driven to refusal on bedrock could be used, but their economic use for this site is doubtful.

and non-frost susceptible granular material. Provision should be made for drainage from the backfill to prevent hydrostatic or ice pressure build-up behind the abutment walls. With full effective drainage of the backfill, a coefficient of lateral earth pressure at rest, K_0 , = 0.4 and a total unit weight, γ , = 135 lb/cu.ft. should be used for the compacted granular backfill in the design of the abutment walls.

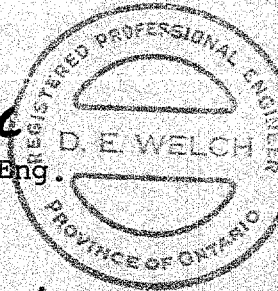
The embankment fill, adjacent to the pile supported bridge structure should be placed and compacted well in advance of final paving operations since consolidation settlement of the clay will take place.

Settlement of Approach Embankments

Settlement of the roadway embankment and culvert, if used, will take place due to consolidation of the clay stratum underlying the site. Based on consolidation characteristics of similar local deposits, it is estimated that the total settlement at the centre of a 10 ft. high embankment would be of the order of 9 ins. and that for a 13 ft. high embankment could be greater than 12 ins. To accommodate such settlement which would be differential from the edges of the embankment to the centre, it is recommended that the culvert be placed with an 8 in. camber in the middle and if the embankment is raised to 13 ft. the camber should be increased

to 12 ins. For approach fills to a bridge structure paving should be delayed as long as possible after the fill is placed. Further, it is recommended that approach slabs (DHO Std DD-514-F) 20 ft. in length be constructed to minimize differential movement at the edges of the bridge deck.

for *RA Macaul*
D. E. Welch, P.Eng.



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

DEW:IMB
67752
March 27, 1967

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.

<i>WH</i>	sampler advanced by static weight—weight, hammer
<i>PH</i>	sampler advanced by pressure—pressure, hydraulic
<i>PM</i>	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_u, 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 ¹
<i>Q</i>	undrained triaxial ²
<i>R</i>	consolidated undrained triaxial ²
<i>S</i>	drained triaxial
<i>U</i>	unconfined compression
<i>V</i>	field vane test

NOTES:

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

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

LIST OF SYMBOLS

I. GENERAL

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

II. STRESS AND STRAIN

u	pore pressure
σ	normal stress
σ'	normal effective stress ($\bar{\sigma}$ is also used)
τ	shear stress
ϵ	linear strain
ϵ_{xy}	shear strain
ν	Poisson's ratio (μ is also used)
E	modulus of linear deformation (Young's modulus)
G	modulus of shear deformation
K	modulus of compressibility
η	coefficient of viscosity

III. SOIL PROPERTIES

(a) Unit weight

γ	unit weight of soil (bulk density)
γ_s	unit weight of solid particles
γ_w	unit weight of water
γ_d	unit dry weight of soil (dry density)
γ'	unit weight of submerged soil
G_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_s	coefficient of consolidation
T_v	time factor = cd^2/d^2 (d , drainage path)
U	degree of consolidation

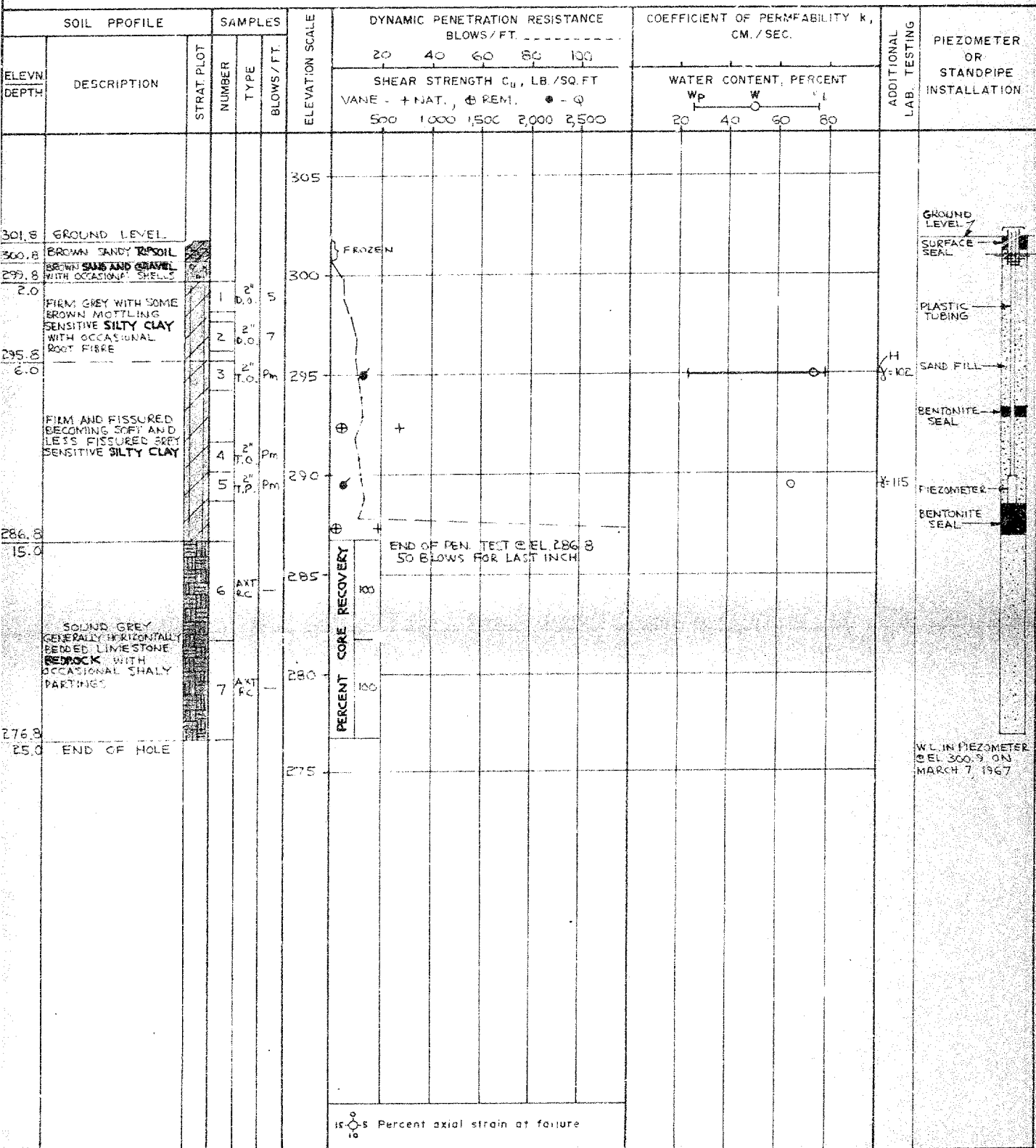
(e) Shear strength

τ_f	shear strength
c'	effective cohesion
ϕ'	effective angle of shearing resistance, or friction
c_u	apparent cohesion*
ϕ_u	apparent angle of shearing resistance, or friction
μ	coefficient of friction
S_i	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 !

LOCATION S-2 Figure 1 BORING DATE FEB. 24, 1967 DATUM GEODETIC
 BOREHOLE TYPE WASH BORING BOREHOLE DIAMETER NX CASING
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



VERTICAL SCALE
1 INCH TO 5'-0"

GOLDER & ASSOCIATES

DRAWN J.A.
CHECKED +7

RECORD OF BOREHOLE L

LOCATION See Figure 1

BORING DATE FEB. 24 & 27, 1967

DATUM

GEODETIC

BOREHOLE TYPE

WASH BORING

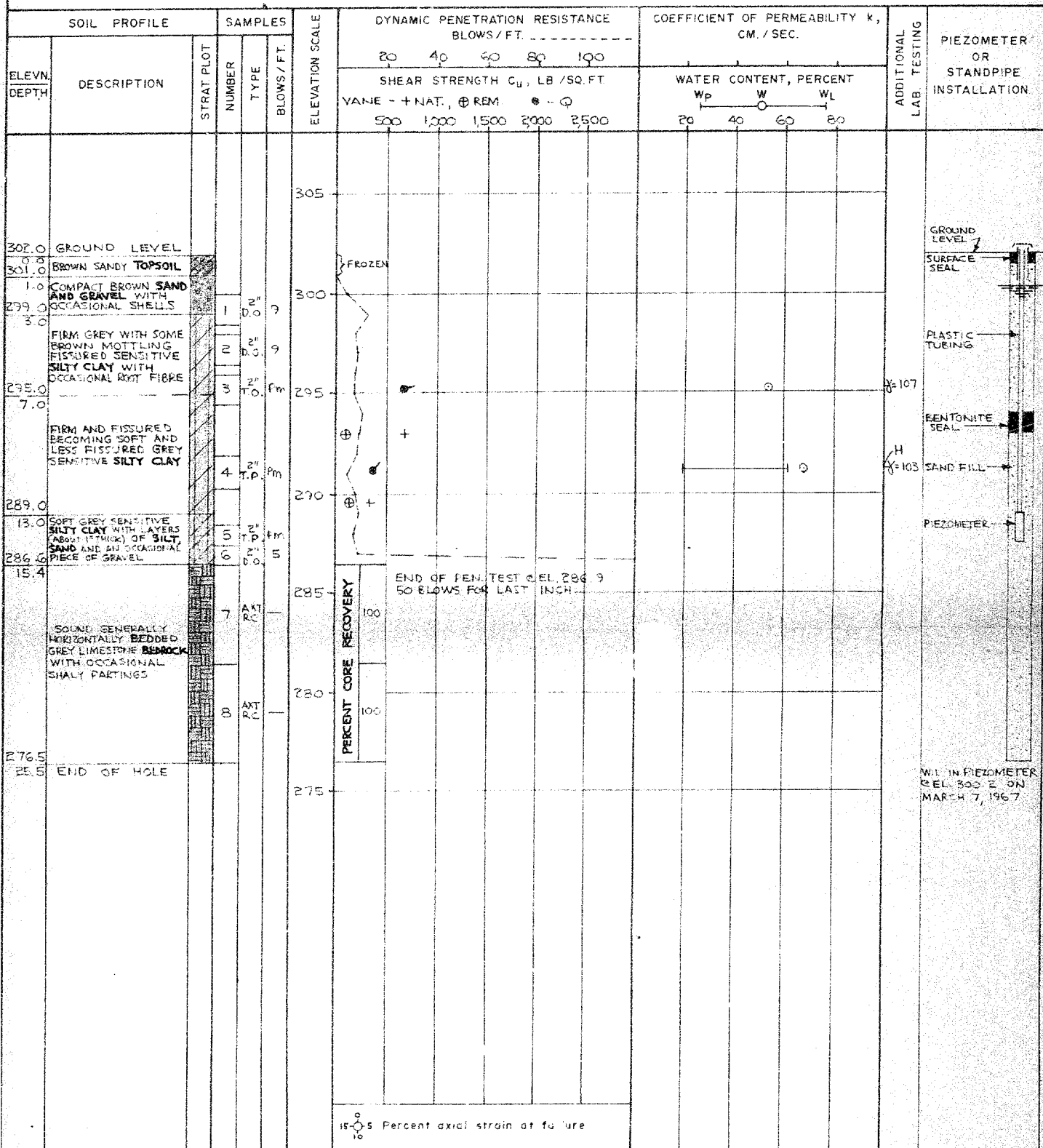
BOREHOLE DIAMETER

NX CASING

SAMPLER HAMMER WEIGHT 140 LB

DROP 30 INCHES

PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



VERTICAL SCALE

1 INCH TO 5'-0"

GOLDER & ASSOCIATES

DRAWN J.A.

CHECKED 7

PEN. TEST RECORD OF BOREHOLE 3

LOCATION See Figure 1

BORING DATE FEB. 24, 1967

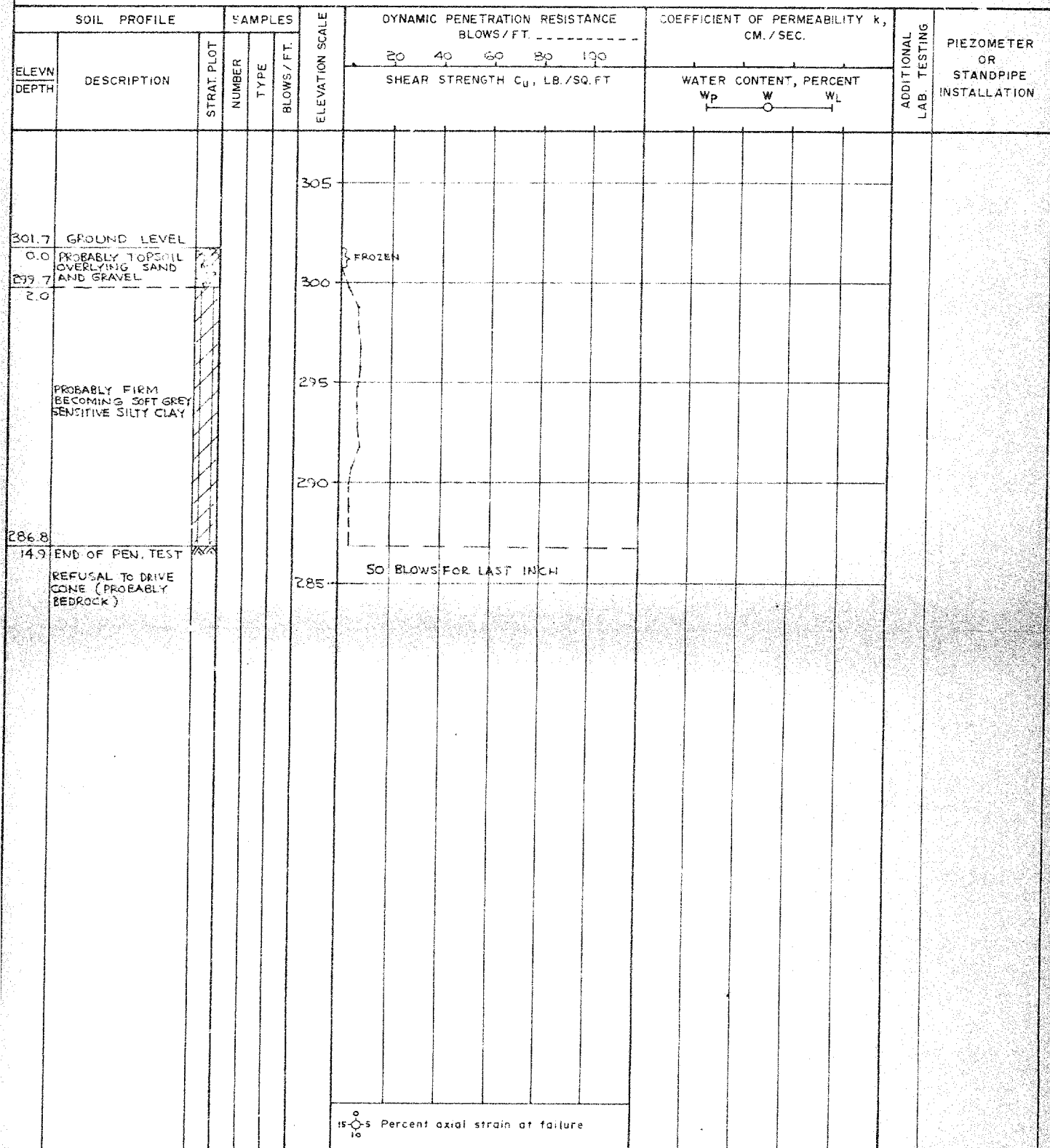
DATUM GEODETIC

BOREHOLE TYPE PENETRATION TEST

BOREHOLE DIAMETER --

SAMPLER HAMMER WEIGHT -- LB. DROP -- INCHES

PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES


 VERTICAL SCALE
 1 INCH TO 5'-0"

GOLDER & ASSOCIATES

 DRAWN J. A.
 CHECKED 17

PROJECT NO. 2-10-2-1-1

PROJECT NO. 2-10-2-1-1

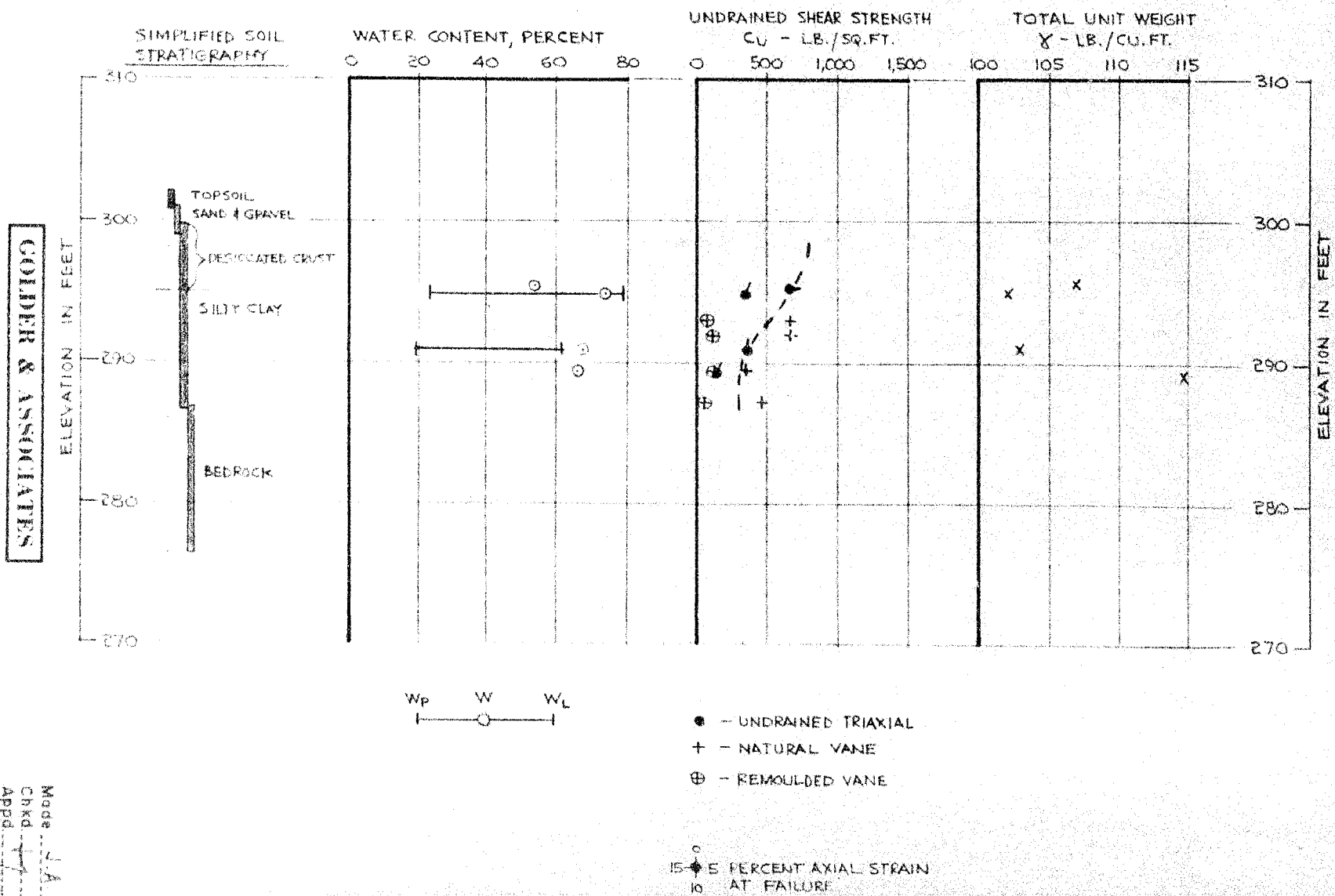
PROJECT NO. 2-10-2-1-1

DRAWN J. A.
CHECKED H

GOLDER & ASSOCIATES

SUMMARY OF ENGINEERING PROPERTIES SENSITIVE SILTY CLAY STRATUM

FIGURE 2



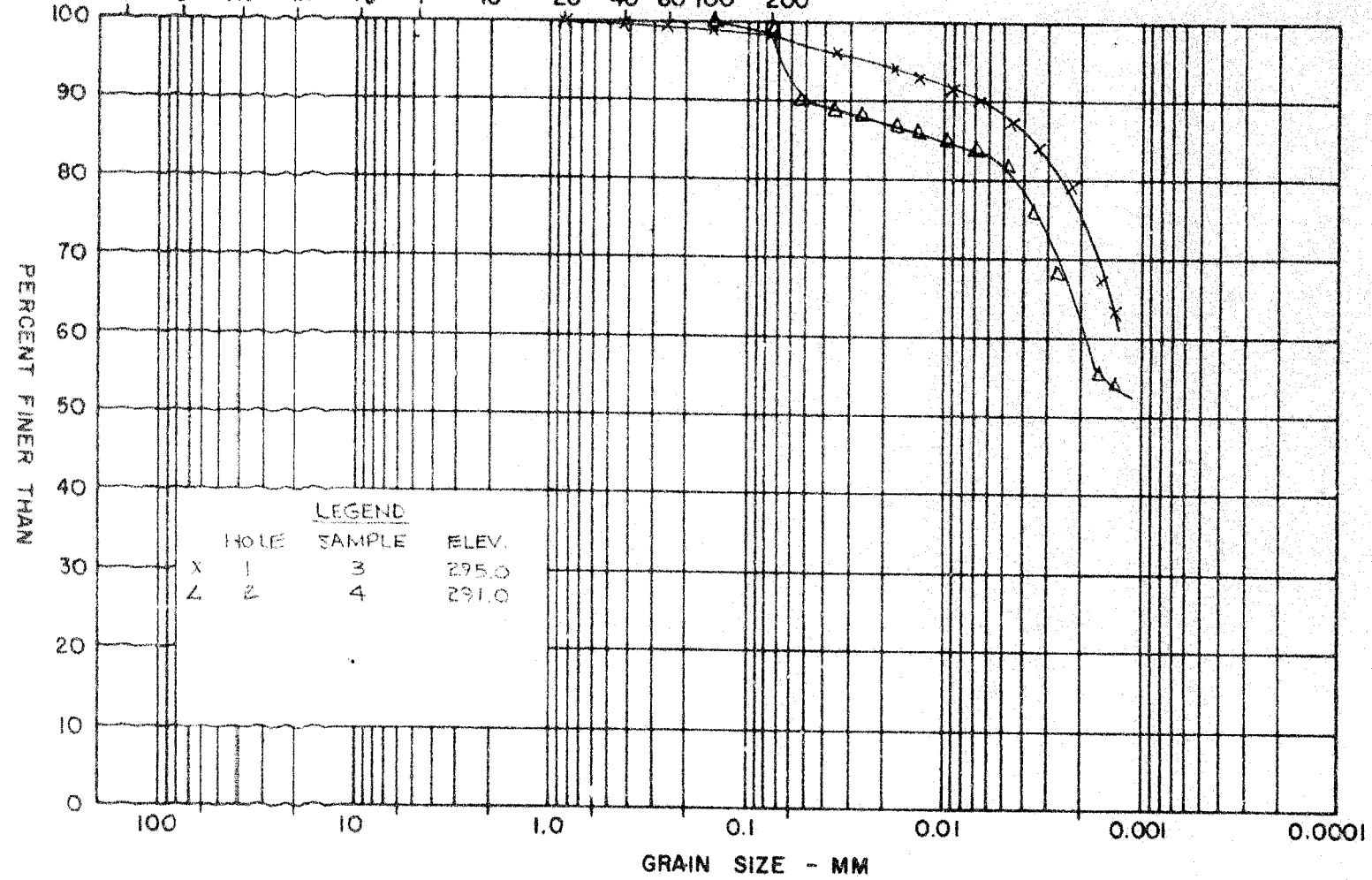
GOLDER & ASSOCIATES

Made J.A.
Chkd.
Appd.

M.I.T. GRAIN SIZE SCALE

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

6" 3" 1 1/2" 3/4" 3/8" 4 10 20 40 60 100 200



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

GRAIN SIZE DISTRIBUTION
SENSITIVE SILTY CLAY

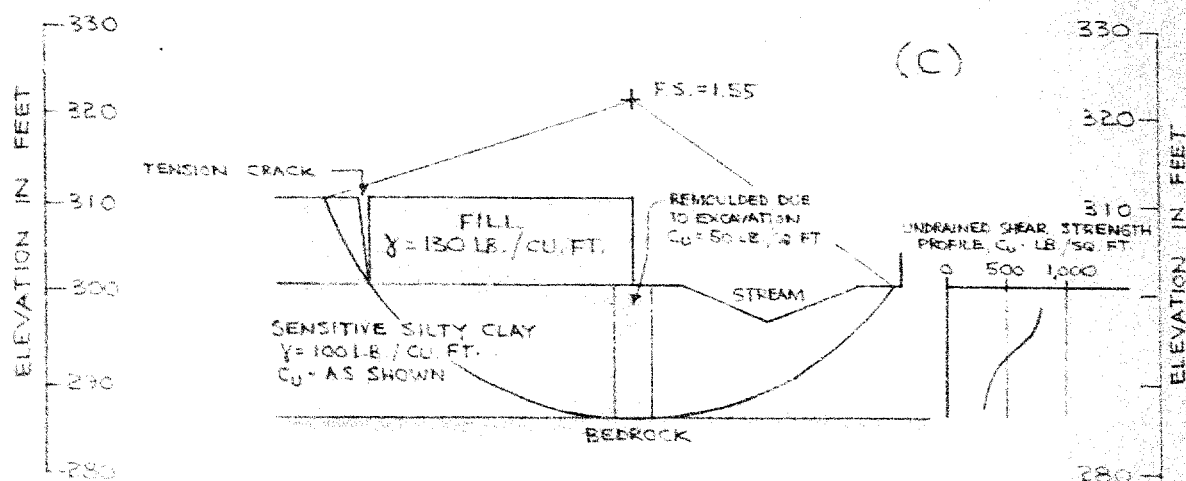
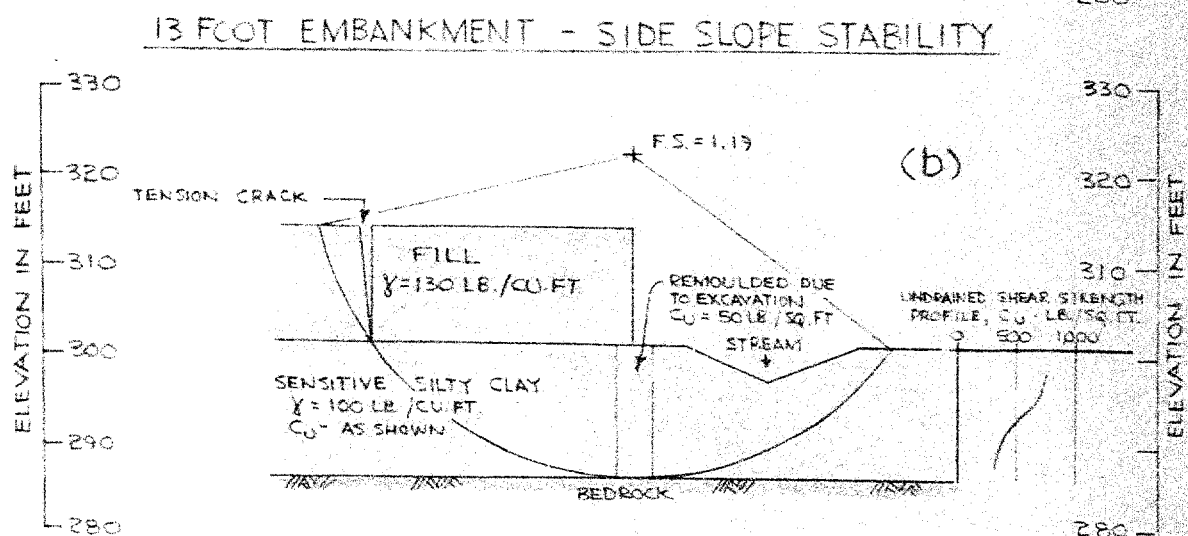
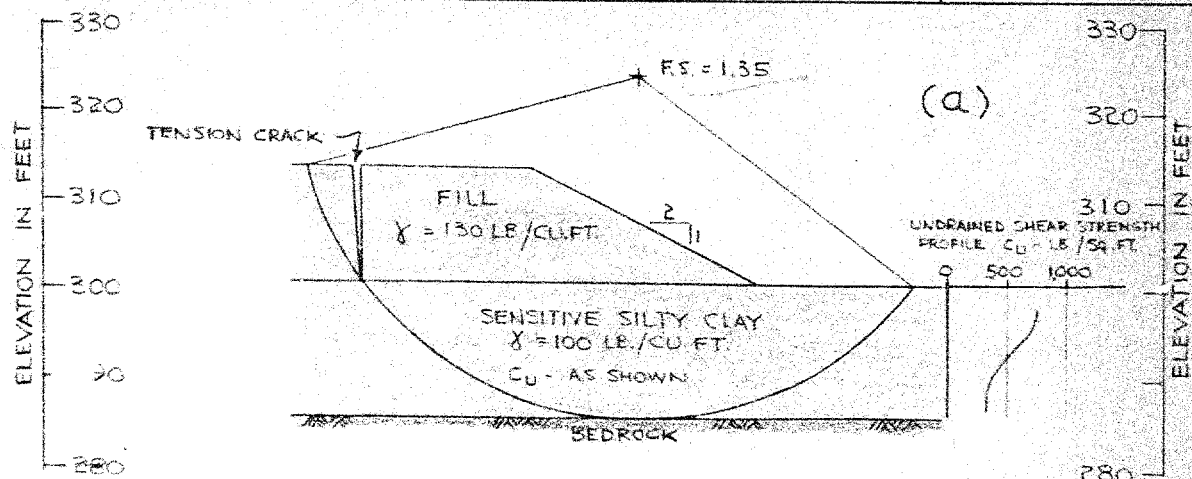
FIGURE 3

GOLDER & ASSOCIATES

PROJECT No. 67752

SUMMARY OF RESULTS TOTAL STRESS STABILITY ANALYSES

FIGURE 4



SCALE: 1" TO 20'

GOLDER & ASSOCIATES

Made J.A.
Chkd
Appd

SLICES	X-INIT.	Y-INIT.	DELX	DELY	TANG. R.L.	INCR.	NO. R	TENSION CRACK	NO. PTS.%-X<	NO. PTS.%&X<	CUT-OFF%-X<	CUT-OFF%&X<
25	30	-9	5.0	5.0	17.0	2.0	8	0.0	1	3	-100.0	98.0

X COORD	Y COORD	X COORD	Y COORD	X COORD	Y COORD	X COORD	Y COORD	X COORD	Y COORD	X COORD	Y COORD
-100.00	0.0	40.00	20.00	58.00	20.00	98.00	0.0				

SECTIONAL DETAILS

SECTION	X COORD	SOIL TYPE	Y COORD	WATER TABLE
1	-100.00	1	0.0	19.00
1		2	5.00	
1		3	16.00	
1		4	19.00	
1		5	25.00	
2	98.00	1	0.0	19.00
2		2	5.00	
2		3	16.00	
2		4	19.00	
2		5	25.00	

SOIL PROPERTIES

SOIL TYPE	COHESION	PHI	BULK DENSITY	SUBMERGED DENSITY
1	0.0	0.0	130.0	70.0
2	0.0	30.0	130.0	70.0
3	760.	0.0	100.0	38.0
4	450.	0.0	38.0	38.0
5	350.	0.0	38.0	38.0

	RADIUS	XC	YC	F. OF S.
1	51.00	5.00	-34.00	2.634
2	53.00	5.00	-34.00	2.380
3	55.00	5.00	-34.00	1.821
4	57.00	5.00	-34.00	1.668
5	59.00	5.00	-34.00	1.491
6	61.00	5.00	-34.00	1.253
7	63.00	5.00	-34.00	1.112
8	65.00	5.00	-34.00	1.054
9	51.00	10.00	-34.00	2.391
10	53.00	10.00	-34.00	2.162
11	55.00	10.00	-34.00	1.732
12	57.00	10.00	-34.00	1.514
13	59.00	10.00	-34.00	1.326
14	61.00	10.00	-34.00	1.119
15	63.00	10.00	-34.00	1.058
16	65.00	10.00	-34.00	0.998
17	51.00	15.00	-34.00	2.191
18	53.00	15.00	-34.00	2.095
19	55.00	15.00	-34.00	1.540
20	57.00	15.00	-34.00	1.330
21	59.00	15.00	-34.00	1.246
22	61.00	15.00	-34.00	1.065
23	63.00	15.00	-34.00	1.023
24	65.00	15.00	-34.00	0.969
25	51.00	20.00	-34.00	2.062
26	53.00	20.00	-34.00	2.008
27	55.00	20.00	-34.00	1.456
28	57.00	20.00	-34.00	1.279
29	59.00	20.00	-34.00	1.222
30	61.00	20.00	-34.00	1.057
31	63.00	20.00	-34.00	1.017
32	65.00	20.00	-34.00	0.964
33	51.00	25.00	-34.00	2.022
34	53.00	25.00	-34.00	1.930
35	55.00	25.00	-34.00	1.445
36	57.00	25.00	-34.00	1.294
37	59.00	25.00	-34.00	1.255
38	61.00	25.00	-34.00	1.081
39	63.00	25.00	-34.00	1.037
40	65.00	25.00	-34.00	1.121
41	51.00	30.00	-34.00	1.909
42	53.00	30.00	-34.00	1.923
43	55.00	30.00	-34.00	1.452
44	57.00	30.00	-34.00	1.395
45	59.00	30.00	-34.00	1.338
46	61.00	30.00	-34.00	1.210
47	63.00	30.00	-34.00	1.229
48	65.00	30.00	-34.00	1.249
49	51.00	35.00	-34.00	1.847
50	53.00	35.00	-34.00	1.960

51	55.00	35.00	-34.00	1.641
52	57.00	35.00	-34.00	1.560
53	59.00	35.00	-34.00	1.743
54	61.00	35.00	-34.00	1.537
55	63.00	35.00	-34.00	1.542
56	65.00	35.00	-34.00	1.569
58	53.00	40.00	-34.00	2.234
59	55.00	40.00	-34.00	2.034
60	57.00	40.00	-34.00	2.292
61	59.00	40.00	-34.00	2.211
62	61.00	40.00	-34.00	2.139
63	63.00	40.00	-34.00	2.237
64	65.00	40.00	-34.00	2.308
68	57.00	45.00	-34.00	4.564
69	59.00	45.00	-34.00	4.482
70	61.00	45.00	-34.00	4.430
89	46.00	5.00	-29.00	2.576
90	48.00	5.00	-29.00	2.351
91	50.00	5.00	-29.00	1.805
92	52.00	5.00	-29.00	1.659
93	54.00	5.00	-29.00	1.485
94	56.00	5.00	-29.00	1.281
95	58.00	5.00	-29.00	1.111
96	60.00	5.00	-29.00	1.045
97	46.00	10.00	-29.00	2.233
98	48.00	10.00	-29.00	2.124
99	50.00	10.00	-29.00	1.708
100	52.00	10.00	-29.00	1.498
101	54.00	10.00	-29.00	1.324
102	56.00	10.00	-29.00	1.109
103	58.00	10.00	-29.00	1.012
104	60.00	10.00	-29.00	0.981
105	46.00	15.00	-29.00	2.131
106	48.00	15.00	-29.00	2.055
107	50.00	15.00	-29.00	1.521
108	52.00	15.00	-29.00	1.363
109	54.00	15.00	-29.00	1.201
110	56.00	15.00	-29.00	1.040
111	58.00	15.00	-29.00	0.975
112	60.00	15.00	-29.00	0.950
113	46.00	20.00	-29.00	1.998
114	48.00	20.00	-29.00	1.931
115	50.00	20.00	-29.00	1.425
116	52.00	20.00	-29.00	1.232
117	54.00	20.00	-29.00	1.191
118	56.00	20.00	-29.00	1.032
119	58.00	20.00	-29.00	0.968
120	60.00	20.00	-29.00	0.944
121	46.00	25.00	-29.00	1.962
122	48.00	25.00	-29.00	1.889

123	50.00	25.00	-29.00	1.393
124	52.00	25.00	-29.00	1.267
125	54.00	25.00	-29.00	1.228
126	56.00	25.00	-29.00	1.058
127	58.00	25.00	-29.00	0.989
128	60.00	25.00	-29.00	1.011
129	46.00	30.00	-29.00	1.873
130	48.00	30.00	-29.00	1.895
131	50.00	30.00	-29.00	1.423
132	52.00	30.00	-29.00	1.372
133	54.00	30.00	-29.00	1.320
134	56.00	30.00	-29.00	1.126
135	58.00	30.00	-29.00	1.210
136	60.00	30.00	-29.00	1.167
137	46.00	35.00	-29.00	1.921
138	48.00	35.00	-29.00	1.988
139	50.00	35.00	-29.00	1.638
140	52.00	35.00	-29.00	1.553
141	54.00	35.00	-29.00	1.474
142	56.00	35.00	-29.00	1.502
143	58.00	35.00	-29.00	1.432
144	60.00	35.00	-29.00	1.433
147	50.00	40.00	-29.00	2.156
148	52.00	40.00	-29.00	1.909
149	54.00	40.00	-29.00	2.211
150	56.00	40.00	-29.00	2.107
151	58.00	40.00	-29.00	2.058
152	60.00	40.00	-29.00	2.012
157	54.00	45.00	-29.00	4.512
158	56.00	45.00	-29.00	4.178
159	58.00	45.00	-29.00	4.217
160	60.00	45.00	-29.00	4.508
177	41.00	5.00	-24.00	2.535
178	43.00	5.00	-24.00	2.326
179	45.00	5.00	-24.00	1.826
180	47.00	5.00	-24.00	1.689
181	49.00	5.00	-24.00	1.517
182	51.00	5.00	-24.00	1.258
183	53.00	5.00	-24.00	1.124
184	55.00	5.00	-24.00	1.047
185	41.00	10.00	-24.00	2.184
186	43.00	10.00	-24.00	2.018
187	45.00	10.00	-24.00	1.819
188	47.00	10.00	-24.00	1.452
189	49.00	10.00	-24.00	1.313
190	51.00	10.00	-24.00	1.112
191	53.00	10.00	-24.00	0.999
192	55.00	10.00	-24.00	0.956
193	41.00	15.00	-24.00	2.009
194	43.00	15.00	-24.00	2.017

195	45.00	15.00	-24.00	1.497
196	47.00	15.00	-24.00	1.321
197	49.00	15.00	-24.00	1.173
198	51.00	15.00	-24.00	1.018
199	53.00	15.00	-24.00	0.955
200	55.00	15.00	-24.00	0.922
201	41.00	20.00	-24.00	1.969
202	43.00	20.00	-24.00	1.890
203	45.00	20.00	-24.00	1.377
204	47.00	20.00	-24.00	1.236
205	49.00	20.00	-24.00	1.136
206	51.00	20.00	-24.00	1.008
207	53.00	20.00	-24.00	0.948
208	55.00	20.00	-24.00	0.915
209	41.00	25.00	-24.00	1.909
210	43.00	25.00	-24.00	1.850
211	45.00	25.00	-24.00	1.369
212	47.00	25.00	-24.00	1.213
213	49.00	25.00	-24.00	1.175
214	51.00	25.00	-24.00	1.037
215	53.00	25.00	-24.00	0.971
216	55.00	25.00	-24.00	0.936
217	41.00	30.00	-24.00	1.916
218	43.00	30.00	-24.00	1.881
219	45.00	30.00	-24.00	1.409
220	47.00	30.00	-24.00	1.321
221	49.00	30.00	-24.00	1.273
222	51.00	30.00	-24.00	1.113
223	53.00	30.00	-24.00	1.124
224	55.00	30.00	-24.00	1.055
226	43.00	35.00	-24.00	2.087
227	45.00	35.00	-24.00	1.657
228	47.00	35.00	-24.00	1.521
229	49.00	35.00	-24.00	1.438
230	51.00	35.00	-24.00	1.514
231	53.00	35.00	-24.00	1.391
232	55.00	35.00	-24.00	1.296
236	47.00	40.00	-24.00	1.974
237	49.00	40.00	-24.00	2.209
238	51.00	40.00	-24.00	1.919
239	53.00	40.00	-24.00	1.978
240	55.00	40.00	-24.00	1.957
246	51.00	45.00	-24.00	4.026
247	53.00	45.00	-24.00	3.986
248	55.00	45.00	-24.00	4.033
265	36.00	5.00	-19.00	2.426
266	38.00	5.00	-19.00	2.201
267	40.00	5.00	-19.00	1.822
268	42.00	5.00	-19.00	1.598
269	44.00	5.00	-19.00	1.524

270	46.00	5.00	-19.00	1.274
271	48.00	5.00	-19.00	1.121
272	50.00	5.00	-19.00	1.035
273	36.00	10.00	-19.00	2.134
274	38.00	10.00	-19.00	1.986
275	40.00	10.00	-19.00	1.576
276	42.00	10.00	-19.00	1.442
277	44.00	10.00	-19.00	1.307
278	46.00	10.00	-19.00	1.097
279	48.00	10.00	-19.00	0.997
280	50.00	10.00	-19.00	0.927
281	36.00	15.00	-19.00	1.947
282	38.00	15.00	-19.00	1.858
283	40.00	15.00	-19.00	1.500
284	42.00	15.00	-19.00	1.269
285	44.00	15.00	-19.00	1.162
286	46.00	15.00	-19.00	1.002
287	48.00	15.00	-19.00	0.937
288	50.00	15.00	-19.00	0.889
289	36.00	20.00	-19.00	1.903
290	38.00	20.00	-19.00	1.851
291	40.00	20.00	-19.00	1.585
292	42.00	20.00	-19.00	1.206
293	44.00	20.00	-19.00	1.102
294	46.00	20.00	-19.00	0.986
295	48.00	20.00	-19.00	0.929
296	50.00	20.00	-19.00	0.882
297	36.00	25.00	-19.00	1.903
298	38.00	25.00	-19.00	1.818
299	40.00	25.00	-19.00	1.339
300	42.00	25.00	-19.00	1.211
301	44.00	25.00	-19.00	1.146
302	46.00	25.00	-19.00	1.020
303	48.00	25.00	-19.00	0.956
304	50.00	25.00	-19.00	0.905
305	36.00	30.00	-19.00	1.983
306	38.00	30.00	-19.00	1.919
307	40.00	30.00	-19.00	1.404
308	42.00	30.00	-19.00	1.330
309	44.00	30.00	-19.00	1.260
310	46.00	30.00	-19.00	1.106
311	48.00	30.00	-19.00	1.025
312	50.00	30.00	-19.00	1.091
315	40.00	35.00	-19.00	1.727
316	42.00	35.00	-19.00	1.579
317	44.00	35.00	-19.00	1.471
318	46.00	35.00	-19.00	1.395
319	48.00	35.00	-19.00	1.319
320	50.00	35.00	-19.00	1.322
326	46.00	40.00	-19.00	2.012

327	48.00	40.00	-19.00	1.838
328	50.00	40.00	-19.00	1.818
336	50.00	45.00	-19.00	3.940
353	31.00	5.00	-14.00	2.401
354	33.00	5.00	-14.00	2.224
355	35.00	5.00	-14.00	1.752
356	37.00	5.00	-14.00	1.596
357	39.00	5.00	-14.00	1.509
358	41.00	5.00	-14.00	1.271
359	43.00	5.00	-14.00	1.163
360	45.00	5.00	-14.00	1.053
361	31.00	10.00	-14.00	2.039
362	33.00	10.00	-14.00	1.922
363	35.00	10.00	-14.00	1.567
364	37.00	10.00	-14.00	1.440
365	39.00	10.00	-14.00	1.278
366	41.00	10.00	-14.00	1.130
367	43.00	10.00	-14.00	1.002
368	45.00	10.00	-14.00	0.925
369	31.00	15.00	-14.00	1.864
370	33.00	15.00	-14.00	1.832
371	35.00	15.00	-14.00	1.458
372	37.00	15.00	-14.00	1.259
373	39.00	15.00	-14.00	1.155
374	41.00	15.00	-14.00	0.991
375	43.00	15.00	-14.00	0.914
376	45.00	15.00	-14.00	0.878
377	31.00	20.00	-14.00	1.777
378	33.00	20.00	-14.00	1.806
379	35.00	20.00	-14.00	1.375
380	37.00	20.00	-14.00	1.172
381	39.00	20.00	-14.00	1.091
382	41.00	20.00	-14.00	0.971
383	43.00	20.00	-14.00	0.905
384	45.00	20.00	-14.00	0.870
385	31.00	25.00	-14.00	1.921
386	33.00	25.00	-14.00	1.811
387	35.00	25.00	-14.00	1.301
388	37.00	25.00	-14.00	1.194
389	39.00	25.00	-14.00	1.134
390	41.00	25.00	-14.00	1.011
391	43.00	25.00	-14.00	0.935
392	45.00	25.00	-14.00	0.895
395	35.00	30.00	-14.00	1.416
396	37.00	30.00	-14.00	1.342
397	39.00	30.00	-14.00	1.262
398	41.00	30.00	-14.00	1.113
399	43.00	30.00	-14.00	1.016
400	45.00	30.00	-14.00	1.005
405	39.00	35.00	-14.00	1.523

406	41.00	35.00	-14.00	1.305
407	43.00	35.00	-14.00	1.360
408	45.00	35.00	-14.00	1.243
415	43.00	40.00	-14.00	1.891
416	45.00	40.00	-14.00	1.842
441	26.00	5.00	-9.00	2.325
442	28.00	5.00	-9.00	2.240
443	30.00	5.00	-9.00	1.749
444	32.00	5.00	-9.00	1.593
445	34.00	5.00	-9.00	1.451
446	36.00	5.00	-9.00	1.297
447	38.00	5.00	-9.00	1.182
448	40.00	5.00	-9.00	1.108
449	26.00	10.00	-9.00	1.976
450	28.00	10.00	-9.00	1.940
451	30.00	10.00	-9.00	1.522
452	32.00	10.00	-9.00	1.444
453	34.00	10.00	-9.00	1.328
454	36.00	10.00	-9.00	1.117
455	38.00	10.00	-9.00	1.005
456	40.00	10.00	-9.00	0.949
457	26.00	15.00	-9.00	1.770
458	28.00	15.00	-9.00	1.815
459	30.00	15.00	-9.00	1.460
460	32.00	15.00	-9.00	1.295
461	34.00	15.00	-9.00	1.160
462	36.00	15.00	-9.00	0.978
463	38.00	15.00	-9.00	0.930
464	40.00	15.00	-9.00	0.872
465	26.00	20.00	-9.00	1.748
466	28.00	20.00	-9.00	1.817
467	30.00	20.00	-9.00	1.357
468	32.00	20.00	-9.00	1.205
469	34.00	20.00	-9.00	1.095
470	36.00	20.00	-9.00	0.926
471	38.00	20.00	-9.00	0.916
472	40.00	20.00	-9.00	0.863
474	28.00	25.00	-9.00	1.851
475	30.00	25.00	-9.00	1.372
476	32.00	25.00	-9.00	1.178
477	34.00	25.00	-9.00	1.131
478	36.00	25.00	-9.00	0.972
479	38.00	25.00	-9.00	0.954
480	40.00	25.00	-9.00	0.893
484	32.00	30.00	-9.00	1.379
485	34.00	30.00	-9.00	1.284
486	36.00	30.00	-9.00	1.089
487	38.00	30.00	-9.00	1.055
488	40.00	30.00	-9.00	0.975
495	38.00	35.00	-9.00	1.280

496	40.00	35.00	-9.00	1.296
529	21.00	5.00	-4.00	2.411
530	23.00	5.00	-4.00	2.224
531	25.00	5.00	-4.00	1.785
532	27.00	5.00	-4.00	1.715
533	29.00	5.00	-4.00	1.483
534	31.00	5.00	-4.00	1.407
535	33.00	5.00	-4.00	1.270
536	35.00	5.00	-4.00	1.182
537	21.00	10.00	-4.00	1.963
538	23.00	10.00	-4.00	1.883
539	25.00	10.00	-4.00	1.516
540	27.00	10.00	-4.00	1.396
541	29.00	10.00	-4.00	1.374
542	31.00	10.00	-4.00	1.189
543	33.00	10.00	-4.00	1.071
544	35.00	10.00	-4.00	0.995
545	21.00	15.00	-4.00	1.765
546	23.00	15.00	-4.00	1.765
547	25.00	15.00	-4.00	1.482
548	27.00	15.00	-4.00	1.297
549	29.00	15.00	-4.00	1.183
550	31.00	15.00	-4.00	1.017
551	33.00	15.00	-4.00	0.930
552	35.00	15.00	-4.00	0.847
553	21.00	20.00	-4.00	1.755
554	23.00	20.00	-4.00	1.867
555	25.00	20.00	-4.00	1.420
556	27.00	20.00	-4.00	1.211
557	29.00	20.00	-4.00	1.107
558	31.00	20.00	-4.00	0.962
559	33.00	20.00	-4.00	0.899
560	35.00	20.00	-4.00	0.835
564	27.00	25.00	-4.00	1.246
565	29.00	25.00	-4.00	1.145
566	31.00	25.00	-4.00	0.990
567	33.00	25.00	-4.00	0.947
568	35.00	25.00	-4.00	0.872
574	31.00	30.00	-4.00	1.140
575	33.00	30.00	-4.00	1.073
576	35.00	30.00	-4.00	0.971
617	16.00	5.00	1.00	2.634
618	18.00	5.00	1.00	2.458
619	20.00	5.00	1.00	1.956
620	22.00	5.00	1.00	1.778
621	24.00	5.00	1.00	1.736
622	26.00	5.00	1.00	1.486
623	28.00	5.00	1.00	1.418
624	30.00	5.00	1.00	1.322
625	16.00	10.00	1.00	2.058

626	18.00	10.00	1.00	2.036
627	20.00	10.00	1.00	1.619
628	22.00	10.00	1.00	1.503
629	24.00	10.00	1.00	1.389
630	26.00	10.00	1.00	1.248
631	28.00	10.00	1.00	1.165
632	30.00	10.00	1.00	1.055
633	16.00	15.00	1.00	1.867
634	18.00	15.00	1.00	1.911
635	20.00	15.00	1.00	1.498
636	22.00	15.00	1.00	1.396
637	24.00	15.00	1.00	1.287
638	26.00	15.00	1.00	1.095
639	28.00	15.00	1.00	1.004
640	30.00	15.00	1.00	0.947
644	22.00	20.00	1.00	1.306
645	24.00	20.00	1.00	1.202
646	26.00	20.00	1.00	1.005
647	28.00	20.00	1.00	0.942
648	30.00	20.00	1.00	0.907
654	26.00	25.00	1.00	1.057
655	28.00	25.00	1.00	1.012
656	30.00	25.00	1.00	0.963
705	11.00	5.00	6.00	7.124
706	13.00	5.00	6.00	4.876
707	15.00	5.00	6.00	3.277
708	17.00	5.00	6.00	2.683
709	19.00	5.00	6.00	2.533
710	21.00	5.00	6.00	1.982
711	23.00	5.00	6.00	1.746
712	25.00	5.00	6.00	1.731
714	13.00	10.00	6.00	3.482
715	15.00	10.00	6.00	2.514
716	17.00	10.00	6.00	2.155
717	19.00	10.00	6.00	1.878
718	21.00	10.00	6.00	1.708
719	23.00	10.00	6.00	1.486
720	25.00	10.00	6.00	1.336
724	17.00	15.00	6.00	1.846
725	19.00	15.00	6.00	1.768
726	21.00	15.00	6.00	1.398
727	23.00	15.00	6.00	1.255
728	25.00	15.00	6.00	1.117
734	21.00	20.00	6.00	1.297
735	23.00	20.00	6.00	1.155
736	25.00	20.00	6.00	1.042
799	18.00	5.00	11.00	16.787
800	20.00	5.00	11.00	7.670
806	16.00	10.00	11.00	29.010
807	18.00	10.00	11.00	7.292

808	20.00	10.00	11.00	4.396
816	20.00	15.00	11.00	3.322

12
11
10
9
8
7
6
5
4
3

CRITICAL CIRCLE

RADIUS	XC	YC	F. OF S.
35.00	20.00	-4.00	0.835
35.00	15.00	-4.00	0.847
40.00	20.00	-9.00	0.863
45.00	20.00	-14.00	0.870
35.00	25.00	-4.00	0.872
40.00	15.00	-9.00	0.872
45.00	15.00	-14.00	0.878
50.00	20.00	-19.00	0.882
50.00	15.00	-19.00	0.889
40.00	25.00	-9.00	0.893

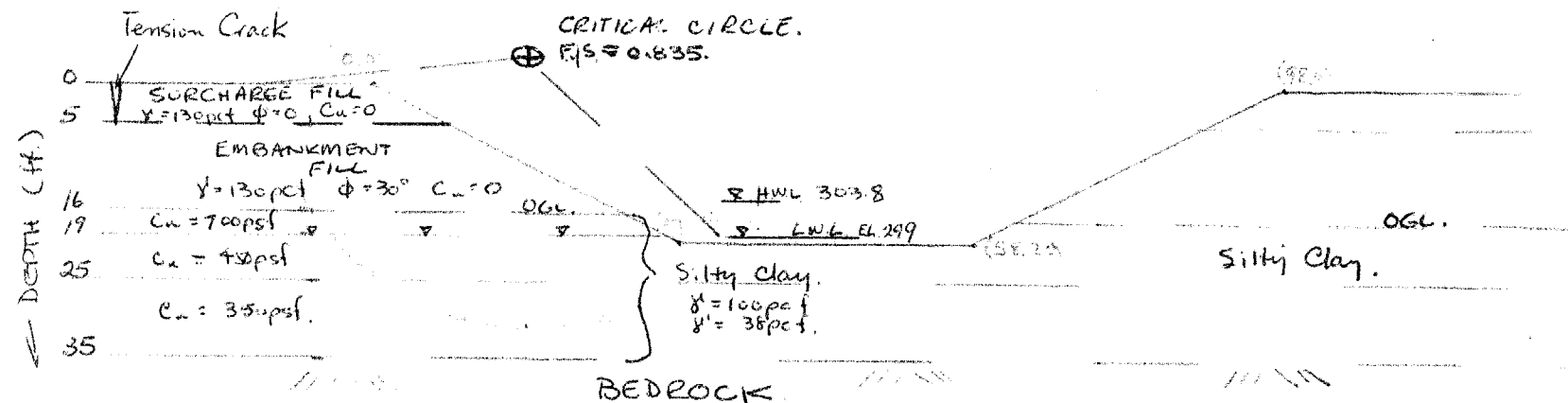
THIS JOB COMPLETED. RUNNING DATE OCT 01, 1968 TIME ELAPSED # 47 SECONDS

NORTH RAISIN RIVER

HWY. 138.

W.P. 39-66-2.

SUMMARIZED RESULTS OF
TOTAL STRESS STABILITY
ANALYSES



DEPARTMENT OF HIGHWAYS
ONTARIO

930012

PRODUCTION REQUEST

TO - SCHEDULING OFFICER

ELECTRONIC COMPUTING BRANCH

REFERENCE NO. 39-66-2REQUIRED FOR Foundation SectionAUTHORIZED BY M. DevataSHIPPING ADDRESS Room 107, Lab BldgTITLE Supervising Fndn EngLOCATION CODE 06-8-06-1-02-00DATE Sept 30/68JOB TITLE Rasin River Hwy 138REQUIRED DATE Oct. 1/68NO. OF COPIES OF OUTPUT 1

DESCRIPTION

Slope Stability Analysis - Total StressOne program is identical to ECB No 925013 except for one change marked in red.

SYSTEMS TO BE USED

Name Slope Stability Analysis
Total Stress 033No. 0051Units 2

FOR ELECTRONIC COMPUTING BRANCH USE ONLY

E.C.B. NO. 930012TECHNICIAN NO. 186

DATE REC'D _____

PRIORITY NO. _____

DATE COMPLETED _____

APPROVED _____

STABILITY ANALYSIS (COMPLEX SLOPE)

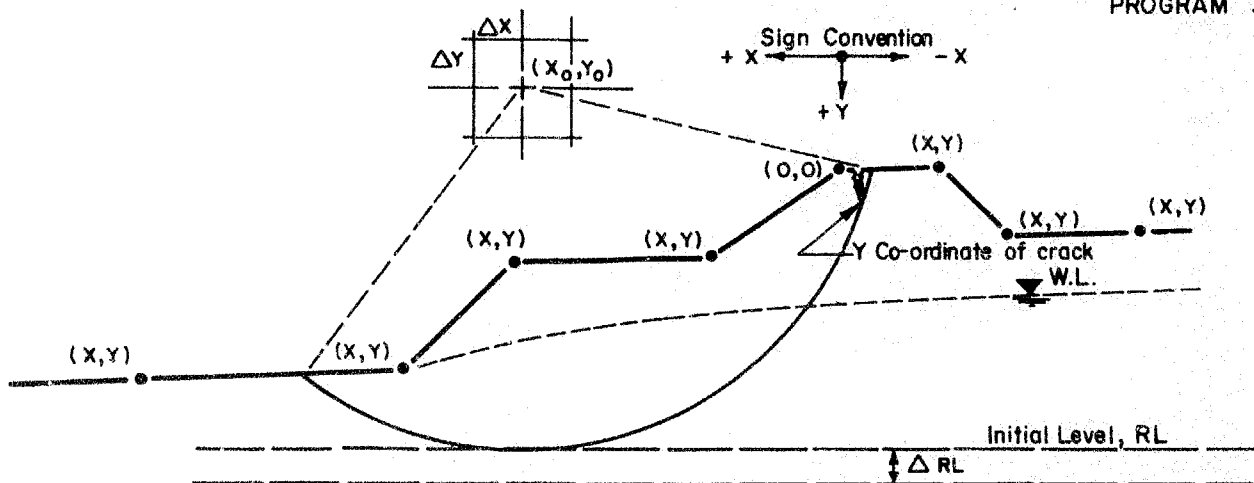
MADE BY: S. G. WILSON

DATE SEPT. 24/68

JOB NO. 39-66-2

PROGRAM 32 (C-B-D and Vars)

PROGRAM 33 ($\emptyset = 0$ analysis)



9	15	48	59	70
PROG. NO.	JOB TITLE	DATE	JOB NO.	
33	RASIN RIVER HWY 138 HT 1175	SEPT 24/68	39-66-2	

GEOMETRY OF SLOPE & INITIAL TRIAL CIRCLE

[illegible]

SOIL PROPERTIES

REMARKS

[illegible]

Slice No.	OVERTURNING MOMENT							RESISTING MOMENT								$M_r = ② + ③$	
	γ or γ'	b	h	Area	W = Weight	r	① $M_o = \Sigma \pm W_r$	c	L	R	② c L R	$\tan \phi$	β	$\cos \beta$	③ $\pm WR \cos \beta / \tan \phi$		
1	130	3.5	8	28	3640	33	120,000	0		440		.577	85°	.989	83200	83200	
2	130	2.5	11	27.5	3580	30	107,000	700	5.92	400	166,000						
	100	2.5	1	2.5	250	30	7500										
3	130	7.5	11	82.5	10900	25	268,000	450	11.88	40.0	88,000						
	100	7.5	3	22.5	2250	25	56,300										
	38	7.5	3	22.5	856	25	21,400										
4	130	6.5	11	71.5	9300	18	167,000	350	44.6	40.0	625,000						
	100	6.5	3	19.5	1950	18	35,100										
	38	6.5	6	39	1480	18	26,600	450	8.39	10.0	151,000						
	38	6.5	2	13	494	18	8,900										
5	130	15	7	105	13650	7.5	103,000										
	100	15	3	45	4500	7.5	33,800										

$\Sigma ① =$

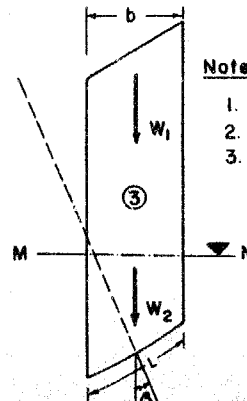
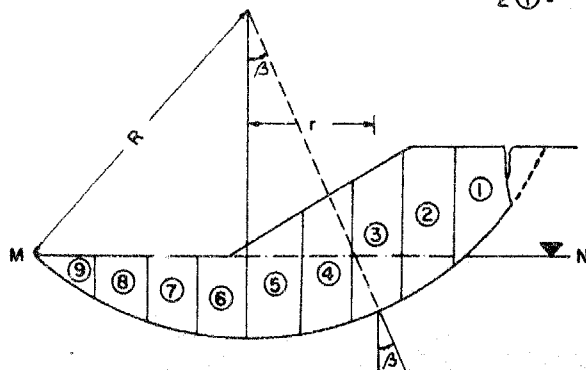
$\Sigma ② + ③ = 1,113,200$

$$F = \frac{\Sigma ② + ③}{\Sigma ①} =$$

Notes:-

1. $W = W_1 + W_2$
2. W_1 Weight of Slice above MN, computed from Bulk density
3. W_2 Weight of Slice above MN, computed from Submerged density

SOIL PROPERTIES				
TYPE	γ	γ'	c	ϕ
1	130			30°
2	120		700	0
3		38	450	0
4		38	350	0



DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

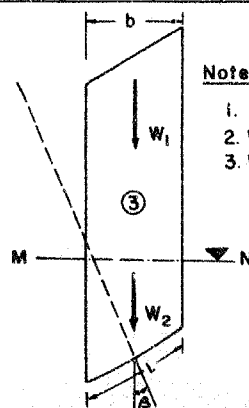
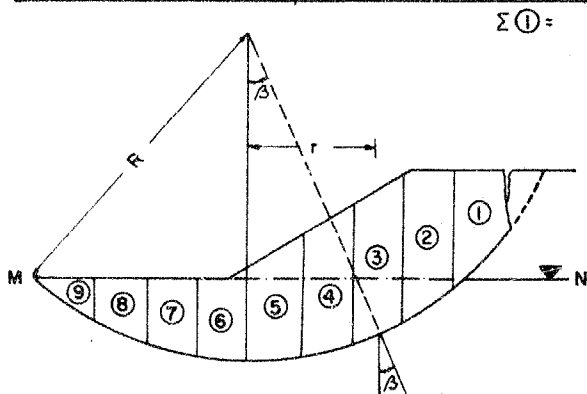
TOTAL STRESS ANALYSIS

MADE BY: S. G. WILSON
LOCATION: NO. 128
CHECKED:
CIRCLE LOCATION:
DATE: OCT 1/68

CIRCLE NO.:
RADIUS:
JOB NO.:
SHEET NO.: 1

MADE BY: <u>S. G. COLLISON</u> LOCATION: _____ CHECKED: _____ CIRCLE LOCATION: _____ DATE: _____	DEPARTMENT OF HIGHWAYS - ONTARIO MATERIALS & TESTING DIVISION TOTAL STRESS ANALYSIS	CIRCLE NO. _____ RADIUS _____ JOB NO. _____ SHEET NO. <u>2</u>
--------------------------------------------------------------------------------------------------------------	--------------------------------------------------------------------------------------------------	-------------------------------------------------------------------------

Slice No.	OVERTURNING MOMENT							RESISTING MOMENT								
	γ or γ'	b	h	Area	W = Weight	r	① $M_o = \Sigma \pm W_r$	c	L	R	② c L R	$\tan \phi$	β	$\cos \beta$	③ $\pm W R \cos \beta / \tan \phi$	$M_r = ② + ③$
5	38	15	6	90	3420	7.5	25,600									
	38	15	5.5	825	3140	7.5	23,500									
6	130	6	2	12	1560	3	4,680									
	100	6	3	18	1800	3	5,400									
	38	6	6	36	1370	3	4,110									
	38	6	6	36	1370	3	4,110									
7	100	7	2	14	1400	9.5	13,300									
	38	7	6	42	1600	9.5	15,200									
	38	7	5	35	1330	9.5	12,600									
8	38	2	5.5	11	418	14	5,850									
	38	2	3.5	7	266	14	3,720									
9	38	6	5	30	1140	18	20,500									
	38	6	2	12	456	18	8,200									



Notes:-

1. $W = W_1 + W_2$
2. W_1 Weight of Slice above MN, computed from Bulk density
3. W_2 Weight of Slice above MN, computed from Submerged density

SOIL PROPERTIES				
TYPE	γ	γ'	c	ϕ

$$\Sigma ② + ③ =$$

$$F = \frac{\Sigma ② + ③}{\Sigma ①} =$$

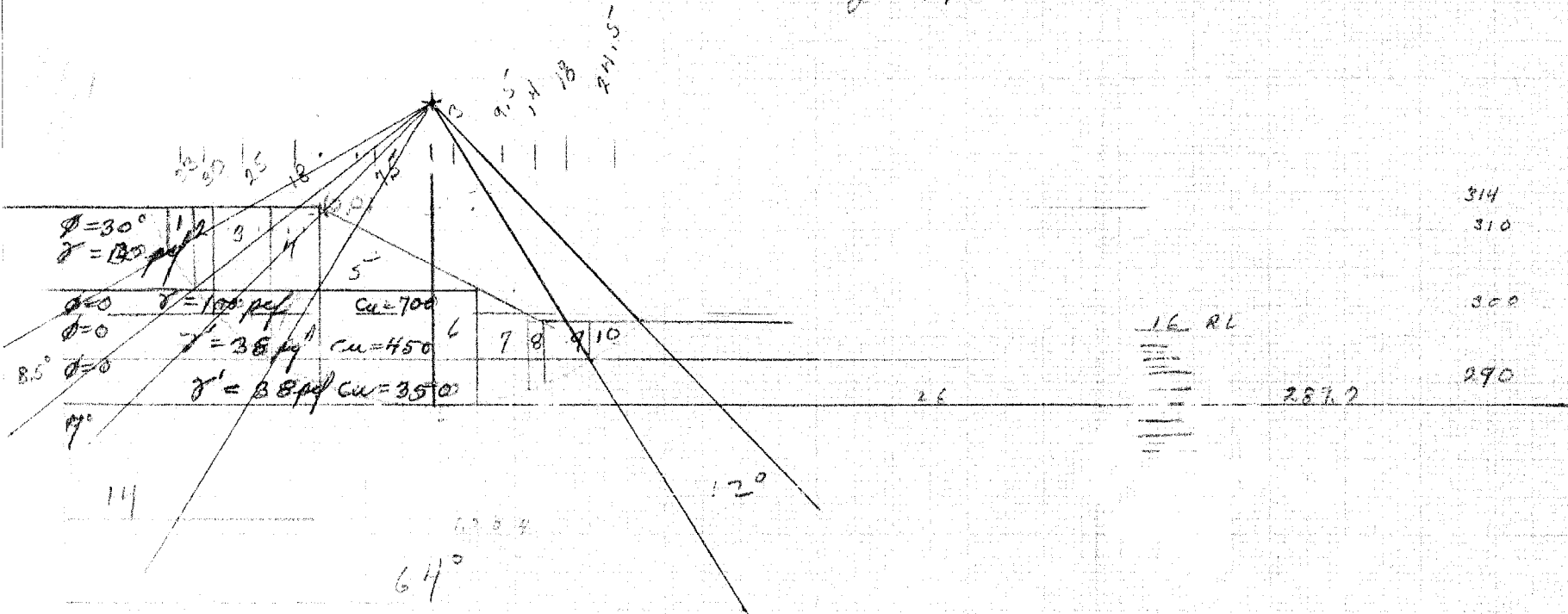
180

$$\phi = 30^\circ$$

$$R = 40.0$$

$$x = 15$$

$$y = -14.0$$



RAISIN RIVER-HWY138 -NO SUR. OCT 2,68 39-66-2

RUN DATE OCT 04, 1968

SLICES	X-INIT.	Y-INIT.	DELX	DELY	TANG. R.L.	INCR.	NO. R	TENSION CRACK	NO. PTS.%-X<	NO. PTS.%EX<	CUT-OFF%-X<	CUT-OFF%-EX<
25	20	-9	5.0	5.0	16.0	2.0	8	5.00	1	3	-100.0	74.0

X COORD	Y COORD	X COORD	Y COORD	X COORD	Y COORD	X COORD	Y COORD	X COORD	Y COORD	X COORD	Y COORD
-100.00	0.0	28.00	14.00	46.00	14.00	74.00	0.0				

SECTIONAL DETAILS

SECTION	X COORD	SOIL TYPE	Y COORD	WATER TABLE
1	-100.00	1	0.0	14.00
1		2	11.00	
1		3	14.00	
1		4	20.00	
2	74.00	1	0.0	14.00
2		2	11.00	
2		3	14.00	
2		4	20.00	

SOIL PROPERTIES

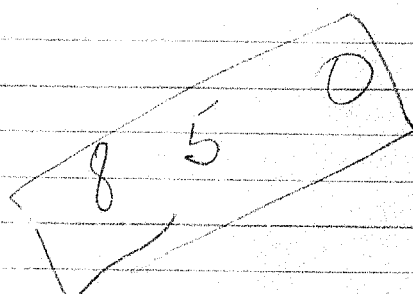
SOIL TYPE	COHESION	PHI	BULK DENSITY	SUBMERGED DENSITY
1	0.0	30.0	130.0	70.0
2	700.	0.0	100.0	38.0
3	450.	0.0	38.0	38.0
4	350.	0.0	38.0	38.0

CRITICAL CIRCLE

RADIUS	XC	YC	F. OF S.
29.00	15.00	1.00	1.168 ✓
29.00	10.00	1.00	1.183 ✓
34.00	15.00	-4.00	1.206 ✓
37.00	15.00	-9.00	1.207 ✓
39.00	15.00	-8.00	1.209 ✓
39.00	10.00	-9.00	1.210 ✓
32.00	15.00	-4.00	1.212 ✓
44.00	10.00	-14.00	1.215 ✓
37.00	10.00	-9.00	1.218 ✓
34.00	10.00	-4.00	1.218 ✓

THIS JOB COMPLETED. RUNNING DATE OCT 04, 1968 TIME ELAPSED # 48 SECONDS

X	Y
15	1
10	1
15	-4
15	-9
10	-9
10	-14
10	-4



37-
28 44
28 14

CRITICAL CIRCLE

390	40.0	15.00	-14.0	1.238 ✓
478	35.0	15.00	-9.00	1.243
566	30.0	15.00	-4.00	1.248
332	40.0	10.00	-14.00	1.249

RAISIN RIVER HWY 138 HT11&8 SEPT24/68 39-66-2

RUN DATE OCT 01, 1968

SLICES	X-INIT.	Y-INIT.	DELX	DELY	TANG. R.L.	INCR.	NO. R	TENSION CRACK	NO. PTS. -X	NO. PTS. &X	CUT-OFF -X	CUT-OFF &X
25	40	-9	5.0	5.0	17.0	2.0	8	0.0	1	3	-100.0	110.0

X COORD	Y COORD	X COORD	Y COORD	X COORD	Y COORD	X COORD	Y COORD	X COORD	Y COORD	X COORD	Y COORD
-100.00	0.0	40.00	20.00	58.00	20.00	98.00	0.0				

SECTIONAL DETAILS

SECTION	X COORD	SOIL TYPE	Y COORD	WATER TABLE
1	-100.00	1	0.0	19.00
1		2	5.00	
1		3	11.00	
1		4	19.00	
1		5	25.00	
2	110.00	1	0.0	19.00
2		2	5.00	
2		3	16.00	
2		4	19.00	
2		5	25.00	

SOIL PROPERTIES

SOIL TYPE	COHESION	PHI	BULK DENSITY	SUBMERGED DENSITY
1	0.0	0.0	130.0	70.0
2	0.0	30.0	130.0	70.0
3	700.	0.0	100.0	38.0
4	450.	0.0	38.0	38.0
5	350.	0.0	38.0	38.0

-100

1	0
2	11
3	14
4	20

46
28
74

31 26

35 30

17
14
31

30
10
16

CRITICAL CIRCLE

RADIUS	XC	YC	F. OF S.
35.00	20.00	-4.00	<u>0.835</u>
35.00	15.00	-4.00	0.847
40.00	20.00	-9.00	0.863
45.00	20.00	-14.00	0.870
35.00	25.00	-4.00	0.872
40.00	15.00	-9.00	0.872
45.00	15.00	-14.00	0.878
50.00	20.00	-19.00	0.882
50.00	15.00	-19.00	0.889
40.00	25.00	-9.00	0.893

THIS JOB COMPLETED. RUNNING DATE OCT 01, 1968 TIME ELAPSED 30 SECONDS

#67-F-209
W.P. #39-66-02
HWY #138
NORTH RAISIN
RIVER

