

W.D. 70-11119

March 10, 1971

1 of 4

Embankment FailureBrant County Road No 8 (White Swan Road)  
1 mile of Hwy. # 53.Effective Stress Stability Analyses

Bishop and Morgenstern Stability Numbers Method

Assumptions:Angle Between <sup>original</sup> Natural Slope and As Constructed Slope -  $11^\circ (5:1)$ Angle Between As Constructed Slope and Horizontal -  $26^\circ (2:1)$ PARAMETERS:FILL AND TOPSOIL -  $\gamma = 0$ 

$$C' = 0 \quad \therefore c'/\gamma H = 0$$

$$D = 1.0$$

The variable

$$\tau_u = M_0 + \bar{B} \quad \text{where } M_0 \text{ is negligible}$$

CASE A'

Assume the Fill-Topsoil combination is both a  $c'$  (cohesive) as well as  $\phi'$  (frictional) material.

$$\frac{c'}{8H} = 0.025$$

$$\therefore c' = 0.025 \times 8H = 0.025 \times 120 \times 13 = 39 \text{ p.s.f.}$$

assume  $\phi' = 15^\circ$

$$\text{If } r_u = 0.4,$$

$$b = 1.0$$

$$F = m - n r_u \quad (m = 1.85 \quad n = 1.5)$$

$$F = 1.85 - 0.4 \times 1.5$$

$$= \underline{\underline{1.25}}$$

Conclusion:

If the fill-topsoil has cohesive then the slope should have been stable.

CASE 'B'

Assume the Fill-topsoil is a friction material only ( $c' = 0$ )  $\frac{c'}{\gamma H} = 0$

Slope - 5:1 (Angle between As constructed section and original side hill slope).

$D = 1.0$

$\phi'$  variable.

$$F.S. = (m - n \times r_u)$$

STABILITY FACTORS  
MORGENTHAU & BISHOP

$\phi'$	m	n	F.S. $r_u = 0$	F.S. $r_u = 0.2$	F.S. $r_u = 0.4$	F.S. $r_u = 0.5$
15°	1.35	1.40	1.35	1.07	0.79	0.65
20°	1.80	1.90	1.80	1.42	1.04	0.85
22½°	2.05	2.15	2.05	1.62	1.19	0.98
17½°	1.55	1.65	1.55	1.22	0.89	0.73

Referring to Figure #1

Most Likely combination of Failure:

- $\phi'$  somewhere between 17° and 19°.
- $r_u$  " " 0.35 and 0.40.

CASE 'C'

WHAT OVERALL SLOPE IS REQUIRED TO ~~BE~~ INCREASE THE FACTOR OF SAFETY WITH RESPECT TO STABILITY TO 1.3.

Assuming

$$D = 1.0$$

$$r_{u, \text{design}} = 0.4$$

$$\phi'_{\text{design}} = 19^\circ$$

TRIAL 'A'

$$\phi' = 17\frac{1}{2}^\circ$$

$$\cot \beta = 7:1$$

$$\phi' = 20^\circ$$

$$r_u = 0.4$$

$$r_u = 0.4$$

$$m = 2.20 \quad n = 2.20$$

$$m = 2.55 \quad n = 2.55$$

$$F.S. = \underline{\underline{1.32}}$$

$$F.S. = 1.53$$

$$\begin{aligned} \text{Weight Average for } \phi' = 19^\circ &= 1.53 - \frac{1}{2.5} \times 0.21 \\ &= \underline{\underline{1.45}} \end{aligned}$$

TRIAL 'B'

$$\phi' = 17\frac{1}{2}^\circ$$

$$\cot \beta = 6\frac{1}{2}:1$$

$$\phi' = 20^\circ$$

$$r_u = 0.4$$

$$r_u = 0.4$$

$$m = 2.05 \quad n = 2.05$$

$$m = 2.4 \quad n = 2.4$$

$$F.S. = 1.23$$

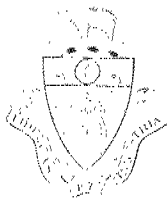
$$F.S. = 1.44$$

$$\begin{aligned} \text{Weighted Average} &= 1.44 - \frac{1}{2.5} \times 0.21 = \underline{\underline{1.36}} \\ \text{for } \phi' = 19^\circ &= \underline{\underline{1.36}} \end{aligned}$$

### CONCLUSIONS

- 1) The side slope should be stable if the overall slope is  $6\frac{1}{2}:1$ . A mid-height berm 10' wide would be a satisfactory ARRANGEMENT. 2) SURFICIAL DRAINAGE MEASURES SHOULD

C. GEORGE SPENCER  
P. ENG.  
COUNTY ENGINEER AND  
ROAD SUPERINTENDENT



COUNTY OF BRANT  
ROADS DEPT.

10-11119  
COUNTY COURT HOUSE,  
MARKET STREET,  
BRANTFORD, ONT.

TELEPHONE  
AREA CODE 519  
752-5232

February 16, 1971

Mr. A.G. Stermac, P. Eng.,  
Principal Foundation Engineer,  
Ontario Department of Highways,  
Downsview, Ontario.


Attention - Mr. M. Devata.

Re: Embankment Instability  
White Swan Road, Brant County  
Road No. 8

Dear Sir:

Confirming our recent telephone conversation, please be advised that the County hereby approves and authorizes your Department to carry out a bore hole investigation at the above noted site of road embankment failure. In order that I may clear with the property owner and obtain permission to enter for your equipment and men, I would appreciate being advised as soon as possible in advance of when you think they will be in to do the work in order that I may make the necessary arrangements with Mr. Lloyd Hunter, the owner.

Yours truly,

  
C.G. Spencer, P. Eng.,  
County Engineer.

CGS/mw.

## MEMORANDUM

TO: Mr. A. G. Stermac  
Principal Foundation Engineer  
Downsview, Ontario

FROM: B. H. Newington  
District Municipal Engineer  
Hamilton, Ontario

ATTENTION: M. Devata

DATE: February 11, 1971

OUR FILE REF.

IN REPLY TO

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SUBJECT:

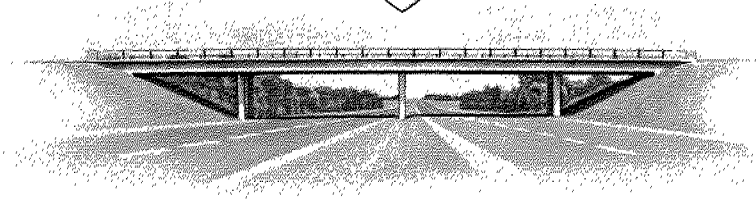
Embankment Instability  
White Swan Road  
Brant County Road No. 8

Further to recent correspondence in this matter, as well as conversations between ourselves and County Engineer, C. G. Spencer, I would request that your section carry out a bore hole investigation in order to more precisely determine the cause of the failure on this road and thus provide a better solution. I trust that the necessary arrangements can be made with Mr. Spencer and that he will be made aware of the approximate cost of the work.

BHN:lo

*B. H. Newington*  
B. H. Newington  
District Municipal Engineer

c.c. C. G. Spencer



DEPARTMENT OF HIGHWAYS

Box 279, Burlington  
January 21, 1971

MEMORANDUM TO:

Mr. M. Devata  
Supvg. Foundation Eng.  
Foundation Section  
Materials & Testing Office  
Room 107, Lab. Building  
Downsview, Ontario

Re: Embankment Instability - Brant County  
Road No. 8 - White Swan Road

Forwarded herewith are two sets of drawings showing the proposed repairs and a copy of the covering explanatory letter as submitted by Mr. C. G. Spencer, County Engineer, for your approval please.

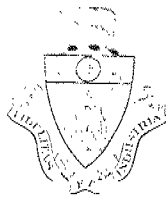
It would be appreciated if at least one set of the drawings could be returned to this office with your comments.

It will be noted that the proposed repairs differ somewhat to your proposal as set out in your memo of December 11, 1970.

Att.  
AEP:sas

  
A. E. Pettigrew  
Asst. to Municipal Eng.

C. GEORGE SPENCER  
B.S.C., P.ENG.  
COUNTY ENGINEER AND  
ROAD SUPERINTENDENT



COUNTY OF BRANT  
ROADS DEPT.

COUNTY COURT HOUSE  
MARKET STREET  
BRANTFORD, ONT

TELEPHONE  
AREA CODE 519  
752-5232

January 18, 1971

Mr. C.R. Robertson,  
District Engineer,  
Department of Highways,  
Burlington, Ontario.

Attention - Mr. B.H. Newington,  
District Municipal Engineer.

Re: Embankment Instability, Brant County Road No. 8,  
White Swan Road

Dear Sir:

With reference to Mr. M. Devata's submission to you under date of December 11th, 1970, relative to the above noted embankment stability problem on Brant County Road #8, the White Swan Road, please find enclosed for your consideration, two sets each of the following for your consideration and approval:

- (a) Cross-sections from Stations 93+50 to 98+50 on which we have shown the proposed method of slope treatment based on Mr. Devata's comments.

The cross-sections show a typical section for the treatment of the slope and a typical section showing the proposed counterfort drain construction. The construction steps for slope stabilization would be as follows:

- 1- To remove softened <sup>material</sup> on slope to a minimum depth of two feet and place it outside of the construction area at the bottom of the slope to be reused.
- 2- Excavate for and place a 4' granular pad at the toe of the slope in the area of the slope extension.
- 3- Construct four counterfort drains through the failure zone having a minimum trench bottom width of 4 feet, this being the width of a dragline bucket, backfilling the counterfort drains with a free draining granular pit run material.
- 4- Rebuild the slope to a 2 1/2 to 1 slope with acceptable fill material preferably of a granular non-frost susceptible material.
- 5- Place the previously excavated material along the toe of the new slope to further flatten the slope



Mr. B.H. Newington

January 18, 1971.

5- and act as a berm.

Also shown on the cross-sections is the proposed 6" perforated pipe sub-drain construction to be placed in the west ditch through the fill area.

(b) Plan & Profile.

The plan and profile shows the following information:

- 1- The additional right-of-way required which will be an additional 50 feet.
- 2- The limits of the new 2 1/2 to 1 fill slope.
- 3- The location of the proposed four counter fort drains.
- 4- The 6" perforated pipe sub-drain system.
- 5- The removal of the existing 24" diameter corrugated iron pipe which has pulled apart due to the movement of the embankment.
- 6- The placing of a new 12" diameter corrugated iron pipe culvert and ditch inlet. The 6" perforated pipe sub-drain will be taken into the inlet at Sta. 98+00 and the drainage will then be carried through the 12" corrugated iron pipe culvert across the road to the east. The culvert has been relocated to Sta. 98+00 from Sta. 97+11 in the hopes that it will be in a location which will no longer be subject to movement, should any further future embankment movements take place. In this way it is hoped that the drainage of the area can be maintained and that we will not be faced with a situation which presently exists where the present 24" diameter culvert has pulled apart and is blocked.

Since the first cracks appeared on this embankment, the settlement of the failure area has amounted in total to 13 feet. When the settlement had reached a level of 7 feet, the County placed pit run granular material to bring it up to the design road grade. Subsequent to that a further settlement of 4 feet took place. Again the County placed pit run granular material up to road grade and a further 2 feet of settlement has once more taken place.

With the movement of the material in the failure zone, the existing fence has moved eastward away from the fill and also upwards. In other words, a vertical

Mr. B.H. Newington.


January 18, 1971

movement has taken place also. With the last settlement a definite peak or heave has occurred immediately outside of the present railway fence which would to me indicate that the failure has changed into a more deep seated one than the original surficial type of failure that was believed to have taken place.

The estimated cost of this slope and sub-drain construction is \$20,000.00. It is proposed to carry out the work in the spring as soon as weather conditions permit. In the meantime material will be added to the top of the failure zone as required in order to protect the remaining embankment and to permit traffic to use the County road.

Your Department's approval of this proposed slope treatment is requested.

Yours truly,

  
C.G. Spencer, P. Eng.  
County Engineer.

CGS/mw.  
Encl.

JAN 18<sup>TH</sup>/71  
OVERCAST & MILD.

CROSS SECTION TAKEN OVER SLOPE FAILURE ON JAN 6<sup>TH</sup>/71

BIANT COUNTY ENG. - C.G. SPENCER

FIELD SURVEY PARTY - D. GILLAW

R. FOXALL

J. ISAACS

701.9	701.6	698.4	698.9	694.5	694.2	693.0	688.3	686.7	686.4	684.0	680.7	673.5	673.2	670.8	669.2	668.7	667.8	666.6	666.1	664.6
±	7	7	17	28	29	37	50	51	52	57	67	75	80	85	89	92	95 FL	101	102	104 EDGE OF BACK WASH.
				664.2																
				664.3																
				664.7																
				665.3																
				664.3																
				662.8																
				664.4																
				664.7																
±	116	125 EDGE OF BACK WASH	133	153	161 EDGE OF STREAM	177 ± STREAM	196 EDGE OF STREAM	200												

TEST HOLE #1 3' LT OF STA 96+50 ELEVATION 701.85

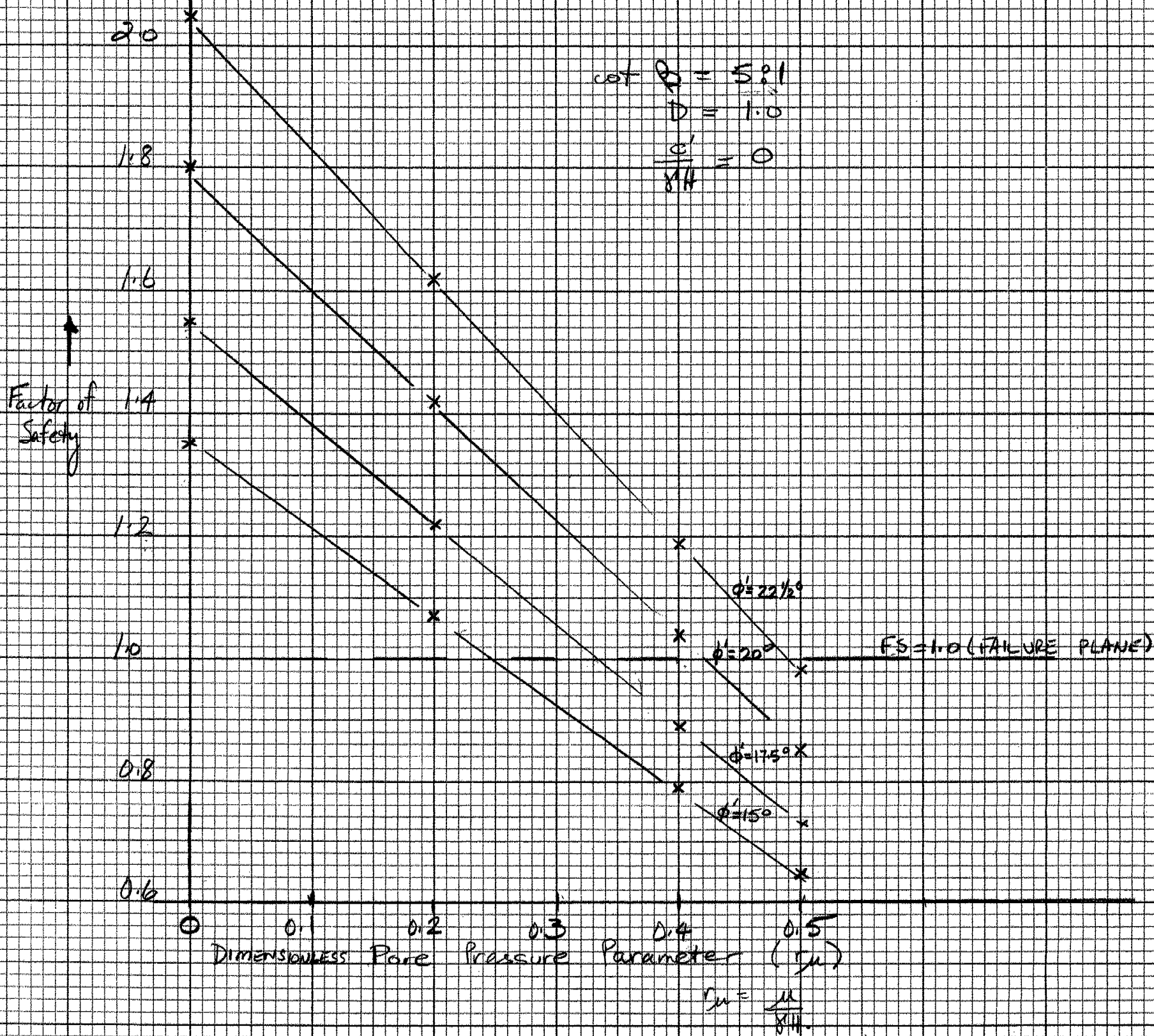
TEST HOLE #2 34' RT OF STA 96+50 ELEVATION 693.11

TEST HOLE #3 112' RT OF STA 96+50 ELEVATION 664.78

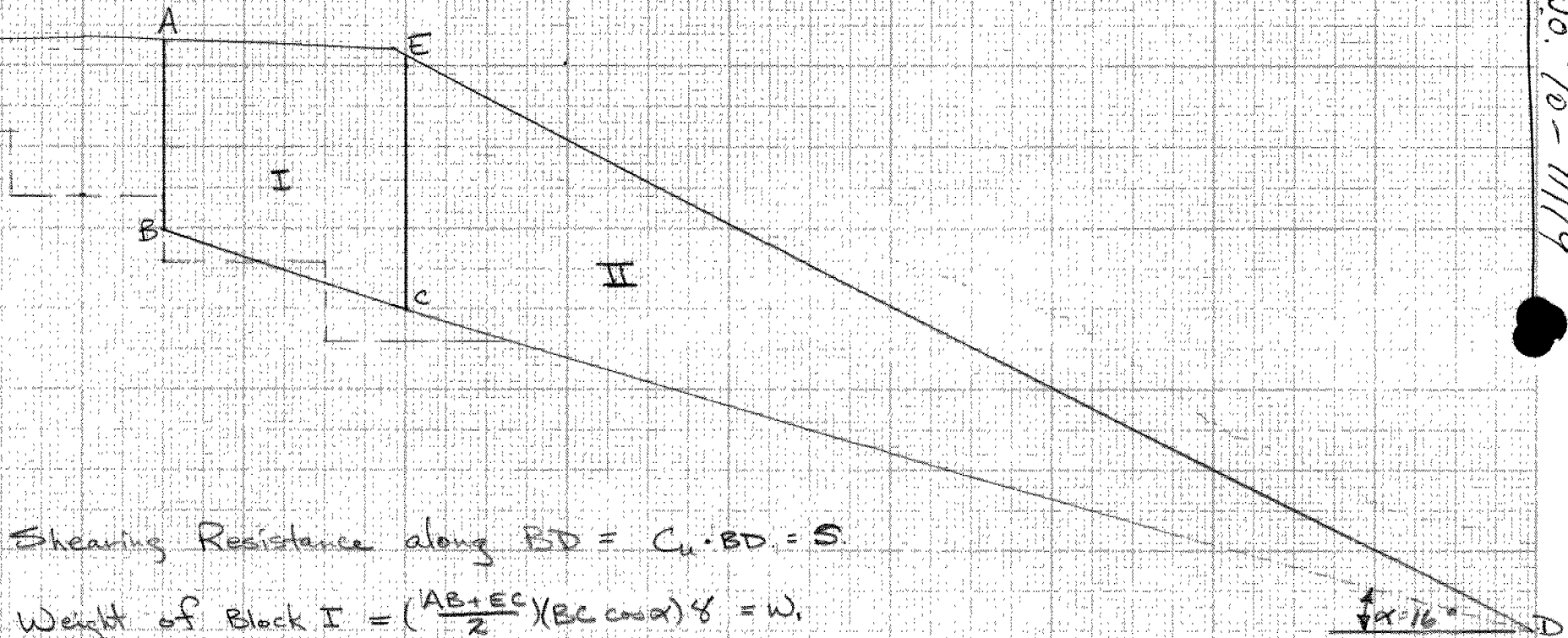
D. Gillow

70-1119

FIGURE NO 1.



# TOTAL STRESS ANALYSIS.



Shearing Resistance along BD =  $C_u \cdot BD = S$

Weight of Block I =  $\left(\frac{AB+EC}{2}\right)(BC \cos \alpha) \gamma = W_1$

" " " II =  $\frac{1}{2} EC \cdot CD \cos \alpha \cdot \gamma = W_2$

$$\frac{S}{F} = (W_1 + W_2) \sin \alpha \quad (\text{Assume } F=1)$$

$$\therefore C_u \cdot BD = \gamma \sin \alpha \cos \alpha \left( \frac{AB+EC}{2} \cdot BC + \frac{1}{2} EC \cdot CD \right) \quad (\text{Note } \sin 2\alpha = 2 \sin \alpha \cos \alpha)$$

$$C_u = \frac{\gamma}{4} \sin 2\alpha \left( \frac{AB+EC}{2} \cdot BC + \frac{1}{2} EC \cdot CD \right) \left( \frac{1}{BD} \right)$$

$$= \frac{125}{4} \times .53 \left( \frac{11.5+15.5}{2} \cdot 15.5 + \frac{15.5 \times 12.5}{2} \right) \left( \frac{1}{28} \right) = 16.6 (209.5 + 962.5) \frac{1}{28}$$

$$= 146 \text{ psf}$$

wo. 70-1119

CONSTRUCTION OF ROAD #8 FILL

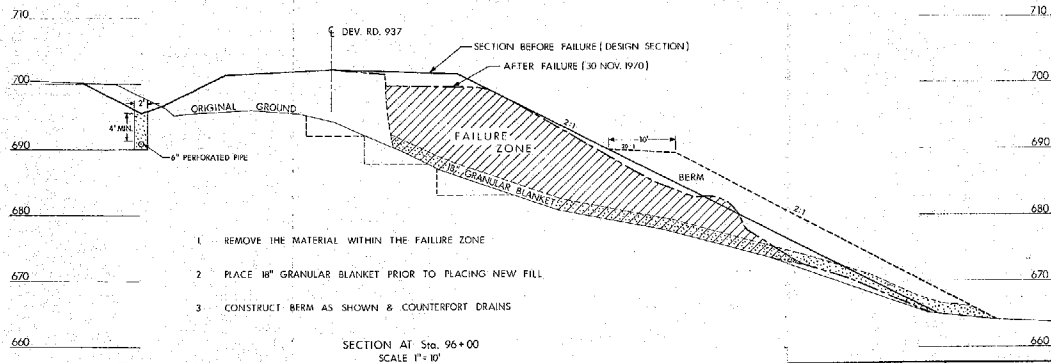
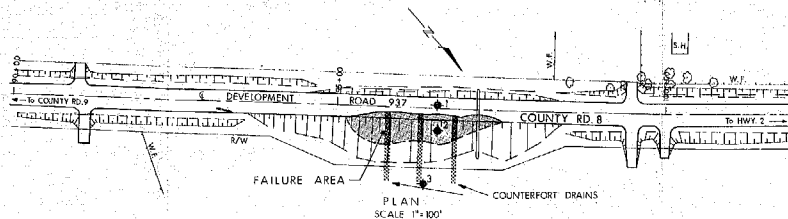
October 15/69 - Start of Construction - Sunny & Mild  
" 16/69 - - Cloudy, Showers - A.M.  
" 17/69 - - Cloudy, Showers - P.M.  
" 18/69 - -  
" 19/69 - -  
" 20/69 - - Cloudy, Rain 8:00-5:00  
" 21/69 - - Cloudy, Showers - A.M.  
" 22/69 - - Cloudy, Cool  
" 23/69 - - Sunny, Cool  
October 24/69 - End of Construction - Sunny, Cool

X-sections were originally done in May of 1967, by McCormick, Rankin & Associates.


X-sections were re-done in October of 1969.

Construction of Fill took place in October of 1969.

Settlement occurred starting November 16 of 1970.



1. REMOVE THE MATERIAL WITHIN THE FAILURE ZONE
2. PLACE 18" GRANULAR BLANKET PRIOR TO PLACING NEW FILL
3. CONSTRUCT BERM AS SHOWN & COUNTERFORT DRAINS

 DEPARTMENT OF HIGHWAYS MATERIALS and TESTING OFFICE ONTARIO	COUNTY ROAD 8 - SLOPE FAILURE REMEDIAL MEASURES	
	COUNTY OF BRANT	TOWNSHIP OF BRANTFORD
DATE DECEMBER 14, 1970	CONT. NO. D.R. 937-1	DRAWING NO. 70-11119 A