DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

REPT.BK.NO. 85/51
STABILITY ASSESSMENT OF REHABILITATION AREA, READYMIX-FARLEY QUARTZITE QUARRY (RIVERVIEW HIGHBURY).

GEOLOGICAL SURVEY

by

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GROUNDWATER & ENGINEERING

OCTOBER, 1985

DME.427/75

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DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

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STABILITY ASSESSMENT OF REHABILITATION AREA, READYMIX - FARLEY QUARTZITE QUARRY (RIVERVIEW), HIGHBURY

ABSTRACT

A slope stability analysis carried out at the Readymix - Farley Riverview quartzite quarry on a rehabilitated slope shows the slope to be unstable when saturated and marginally stable when dry. The lower section of the slope may be rendered stable for the saturated condition by the placement of toe-fill.

A maximum Factor of Safety of 1.3 was calculated.

Recommendations are to cease placement of fill and allow slope to stabilize prior to vegetation.

INTRODUCTION

Waste rockfill from quarrying operations at the Readymix - Farley Riverview Quarry is being used to rehabilitate exposed quarry faces (Figure 1. Plates 1 to 8). This rehabilitation is costed to the Extractive Areas Rehabilitation Fund which is administered by the Dept. for the Environment and Planning who rely upon the Department of Mines and Energy for project recommendations.

Rehabilitation in one area of the quarry is considered by the Mining Branch of this Department to be near completion.

The Chief Inspector of Mines has requested through the Chief Government Geologist that this area be inspected in relation to the following points:

1. The slope stability of the filled portion of the quarry in its present state.
2. The effect on slope stability of additional volumes of the fill.
3. The effect of moisture in the fill.
4. Any means of increasing the slope stability.

METHOD OF ASSESSMENT

Plans, cross-sections and surveyed traverses (Figure 2) of the face under investigation were supplied by Readymix - Farley and formed the basis of profiles (Figures 3 to 6) used in the slope - stability analyses.

Three analyses were used. A quick analysis described by Hoek and Bray. ('Rock slope Engineering' p. 247 - 253) and a more detailed analysis. [Janbu's non-circular failure analysis.]

There have been no field tests carried out and assumed parameter values are based upon commonly accepted values for the situation under discussion.

The third analysis was carried out using the STABL computer programme available to the Department through the South Australian Institute of Technology at The Levels.

All three methods arrive at a value for the Factor of Safety for the rehabilitated slope as it currently stands and after it has been modified with the placement of additional volumes of quarry waste as toe-fill.

THE FACTOR OF SAFETY (F.O.S)

Theoretically any F.O.S. greater than one indicates that a slope is more stable than unstable. For long term stability a minimum F.O.S. of 1.5 is thought to be required at this site although an F.O.S. as low as 1.3 may be considered acceptable for the following reasons:

- Very large volumes of fill are not involved and costs of clean up operations resulting from a failure will only be minor, although re-vegetation of the slope may need to be carried out.

- Failure is not considered likely to interfere either with the course of the Torrens River or the Gorge Road, although failure may temporarily cut-off the lower quarry access road.

PARAMETER VALUES

Waste-fill slope angle:	35° measured from profiles constructed from client data. (A mean slope angle of 30° has been used for calculations incorporating a toe-fill).
Density of fill:	Material as tipped taken to be 13 kN/m^3 to 19.5 kN/m^3. For the toe-fill a 10% increase of density from vehicle compaction was assumed.
Density of in situ rock:	Taken to be 25 kN/m^3.
Cohesion:	Although there are isolated patches of silt-clay, the quarry waste is truck-dumped and a cohesion value of nil has been assigned to the fill. For the STABL analysis a cohesion value of 10 000 kPa has been assigned to the in situ rock.
Coefficient of internal friction	33°. (A value of 35° was assigned to the toe-fill assuming some compaction).
Profile of quarry floor and quarry face:	The floor is taken as horizontal and the quarry face, in part, as 65° for the non-circular slip analysis. Quarry profiles from Readymix Survey Plans RVQ3 and RVQ1 did not tie-in neatly with fill-slope calculated from plan supplied by SURTECH PTY.

LTD. and some adjustment was necessary to the cross-sections on RVQ3 and RVQ1 to make the SURTECH data fit to a sensible profile.

Water-table: Because it is possible for fines to be washed out of the quarry waste and to infill bedrock fractures it is considered necessary, although the fill is in the main free-draining, to assume that a perched water-table may result following prolonged wet periods.

Of at least equal importance to fill-stability as the presence of a water-table is the saturation of the fill by direct precipitation. In pockets of fill having a relatively high silt/clay content the water is retained thus increasing the weight of the fill with no compensating increase in fill cohesion.

RESULTS

The Quick-Analysis

Table 1, Appendix 1, summarizes results of the quick-analysis for wet and dry slopes for varying slope angles.

A F.O.S. of 1.63 was obtained, based on dry fill, a slope of 25° and a friction angle of 38°. The dry condition is unrealistic and the low slope angle is considered to be economically undesirable.

The minimum F.O.S. (0.56) was obtained for a partially saturated fill, a slope of 35° and a high friction angle of 40°. An even lower F.O.S. would have resulted had a lower, more realistic friction angle been used and the slope fully saturated.

Slope angle is considered to be more important to the stable - unstable condition of the rehabilitated slope than expected values of cohesion or saturation. The relationship between slope angle and the F.O.S. is shown in Charts 1 and 2, Appendix 1 for dry and partially saturated slopes.

The accepted F.O.S. for this analysis for the current rehabilitated slope is:

for partly saturated fill :0.6
for dry fill :1.1

The Janbu non-circular slip analysis

Tables 2, 3 and 4, Appendix 1, show calculations using the non-circular slip analysis where it is assumed that to some extent the failure surface will coincide with the quarry face. Results of the calculations are summarized in Appendix 1 and tabulated below:

Table 2:	Dry fill; c = 0; Ø = 35°; slope angle = 35°	F.O.S. = 1.12
Table 3:	Toe Saturated to water-table, level A. (Figure 4)	F.O.S. = 1.06
Table 3:	Toe saturated to water-table, level B. (Figure 4)	F.O.S. = 0.9
Table 4:	Toe-fill to water-table, level B. (Figure 5)	F.O.S. = 1.3
Table 5:	Toe-fill with compaction and water table at level B. (Figure 6)	F.O.S. = 1.5

From this analysis it can be concluded that maximum slope stability for failures passing through the toe can be achieved by placing a free-draining toe to approximately EL 164 with some compaction of the toe-fill.

The STABL Analysis

The programme repeatedly locates slip-failure surfaces and identifies the slip-circle associated with the minimum F.O.S. which in the cases examined range from 0.956 to 0.984, again underlining the unstable nature of the waste-fill. The slip circles in question are located above both water-table and toe-fill.

DISCUSSION

The analyses show that the placement of a toe-fill at the base of the rehabilitated slope will increase the existing F.O.S. of approx 1.0 to a maximum F.O.S. of 1.4 for failures passing through the toe of the slope. For higher seated failures a F.O.S. of approximately 1.0 prevails for both the wet and dry condition.

The continued tipping of quarry waste onto the existing slope will increase slope steepness and decrease slope stability. Should there be further disposal of waste this must be placed as free-draining toe-fill at an angle (approx. 25°) which will reduce the over-all slope from approximately 35° to 30°.

Toe-fill should be placed in maximum 1.0 metre thick lifts and preferably in 500 mm to 600 mm lifts. The lifts should be compacted by laden quarry trucks ensuring that the trucks traverse the full area of the lift surface and do not limit their movement to rut-routes.

CONCLUSIONS

It is advised that placement of further quarry-waste onto the rehabilitated slope in the area under discussion cease and that the existing slope be allowed to stabilize prior to vegetating. A standing period of two wet seasons is suggested. During this period measures should be taken to drain storm water away from the rehabilitated slope.

A toe-fill of free draining material having a slope angle no greater than 25° and a height to approximately EL 165 m could be placed along the foot of the rehabilitated slope but because this is not considered essential from a rehabilitation viewpoint use of rehabilitation funds cannot be recommended.

Reasons why placement of further quarry-waste should not be considered may be summarized:

1. Failure along slip-surfaces indicated by the stability analyses do not involve sufficiently large volumes of fill to threaten disruption of the River Torrens or the Gorge Road. It is not therefore essential to design a failure-free slope.

2. By keeping the access berm which runs along the foot of the rehabilitated slope, free of further fill, a narrow safety bench is preserved onto which failed slope material may slide.
3. The STABL analysis indicates slope instability at levels higher than what is considered practicable to take a toe-fill. That is, some failure is considered inevitable and should therefore be allowed to take place.
4. Although not the opinion of this Department, the steep, exposed quarry faces which rise above the rehabilitated slope may be considered by some to warrant treatment of some kind. Further placement of fill to cover these faces is not possible as this would lead to very unstable, oversteep slopes. Such faces will need to be treated, if at all, in some other way (eg. spray seeding with lichen, moss etc.)

   If the Department for the Environment and Planning consider rehabilitation of the steep quarry faces desirable then Rehabilitation Funds could perhaps be sought to research a suitable process for treating these steep faces, rather than be used for the unwarranted placement of further quarry waste.

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J.C. BEAL
SENIOR GEOLOGIST

REFERENCES

HOEK, E.; BRAY, J.W. 'Rock Slope Engineering' p. 247-253 1977. Inst. Min. Metall. LONDON ISBN 0 900488 36 0.

SIEGEL, R.A. 'STABL-Computer Analysis of General Slope Stability Problems'. Purdue University, West Lafayette, Indiana, June, 1975.

PLATES 1 to 8

Plate 1. Neg. No. 34467

General view looking North

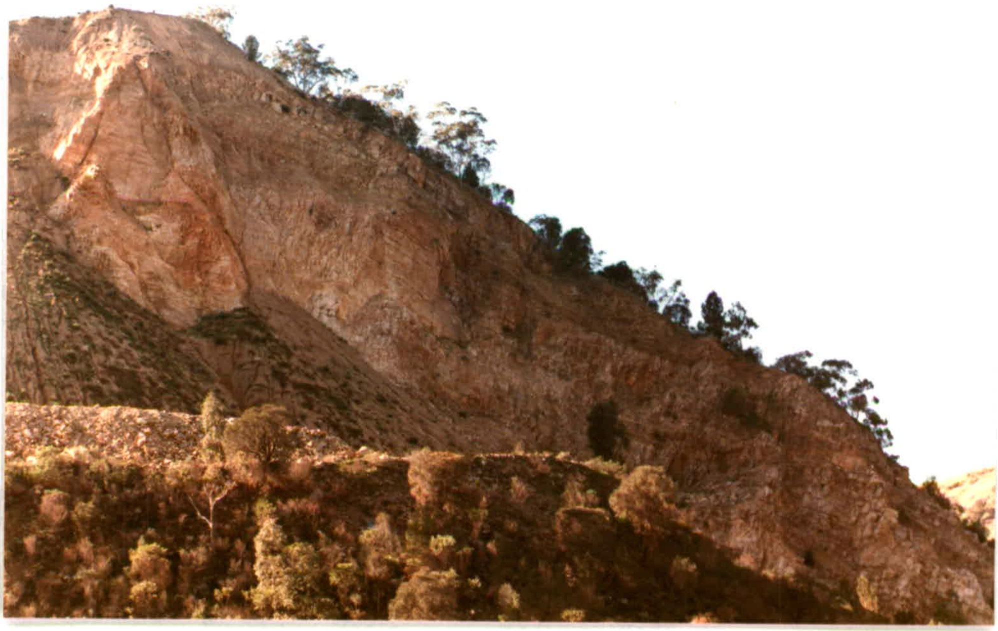


Plate 2 Neg. NO. 34468

General view looking north-east

Plate 3 Neg. No. 34469

Berm at EL 164

Plate 4 Neg. NO. 34470

Berm at EL 198

Plate 5 Neg. No. 24471

Berm at EL 250

Plate 6 Neg. No. 34472

Above berm EL 198

Plate 7 Neg. No. 34473

West of rehabilitated slope

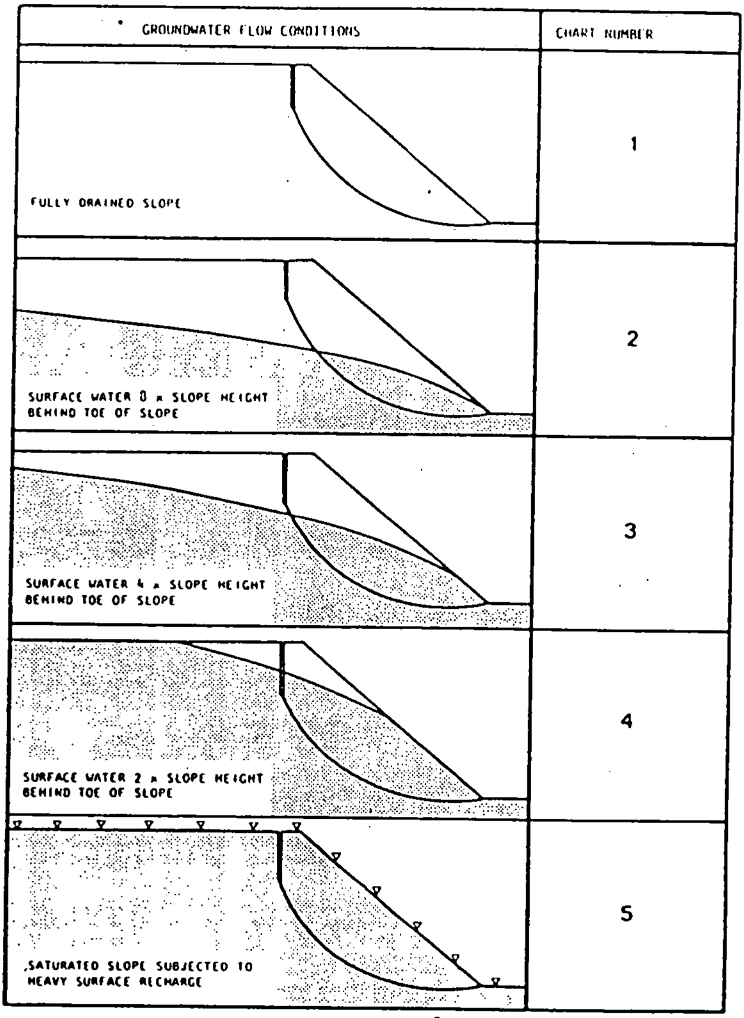
Plate 8 Neg. No. 34474

East of rehabilitated slope

APPENDIX 1

SLOPE STABILITY CALCULATIONS AFTER HOEK AND BRAY

CIRCULAR FAILURE



(Taken from Hoek and Bray)

The five degrees of groundwater conditions shown in the above figure indicate which of five circular failure charts given in 'Rock Slope Engineering' by E. Hoek and J.W. Bray to choose when using their 'Quick-Analysis' for calculating the factor of safety of a soil mass. Particular care is needed for Chart 2 and Chart 3 when calculating values for $\frac{\tan \emptyset}{F}$ for cohesionless soils.

CHART NUMBER 1

(FOR DRY SLOPES)

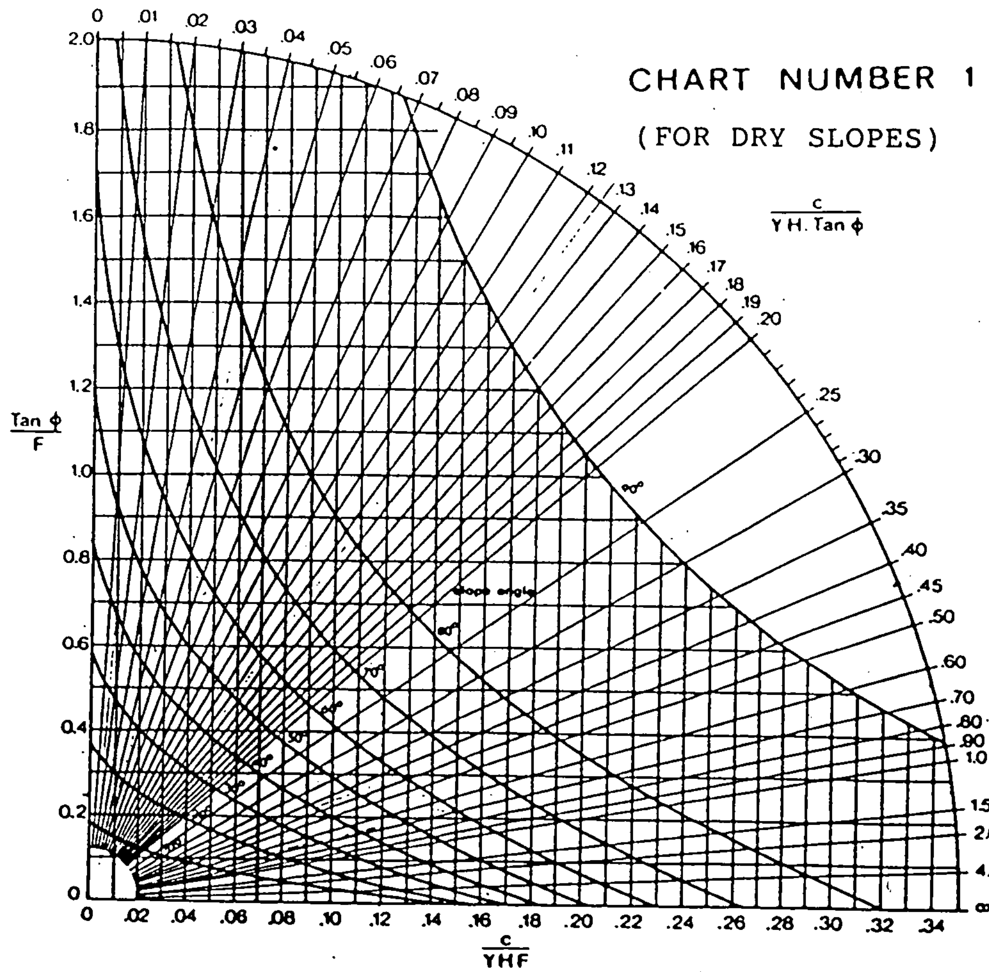
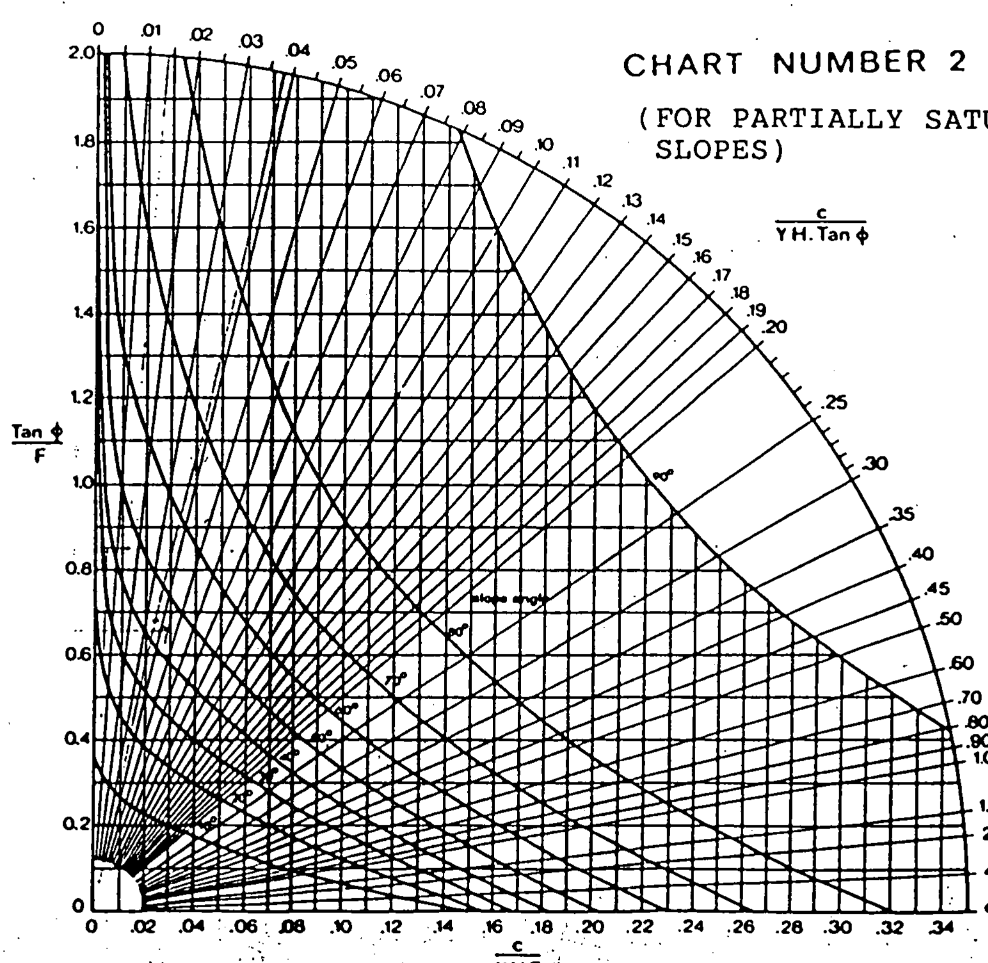


CHART NUMBER 2

(FOR PARTIALLY SATURATED SLOPES)



3869

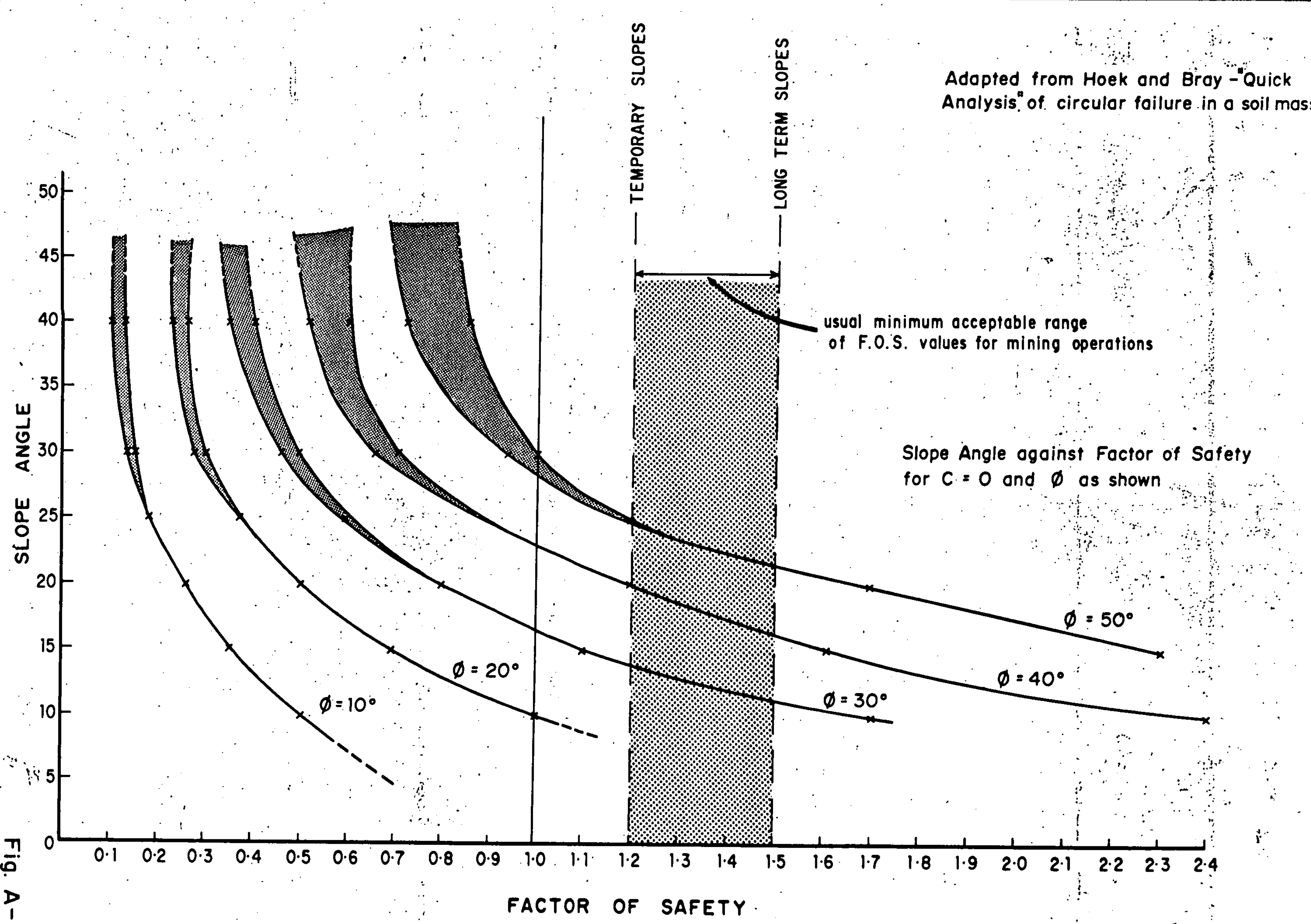


Fig. A-1

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RIVERVIEW QUARRY - REHABILITATED SLOPE STABILITY ANALYSIS

SEC. 5394 HD. YATALA

CHART FOR PARTIALLY SATURATED SLOPES

COMPILED J.B.	C.D.O.	18.11.85 DATE
DRAWN M.B.	SCALE	
DATE Sept '85	PLAN NUMBER	
CHECKED	S18381	

3869

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

RIVERVIEW QUARRY - REHABILITATED SLOPE STABILITY ANALYSIS

SEC. 5394 HD. YATALA

CHART FOR DRY SLOPES

COMPILED J. B.	C.D.O. 18.11.85 DATE
DRAWN M. B.	SCALE
DATE Sept '85 CHECKED	PLAN NUMBER S18382

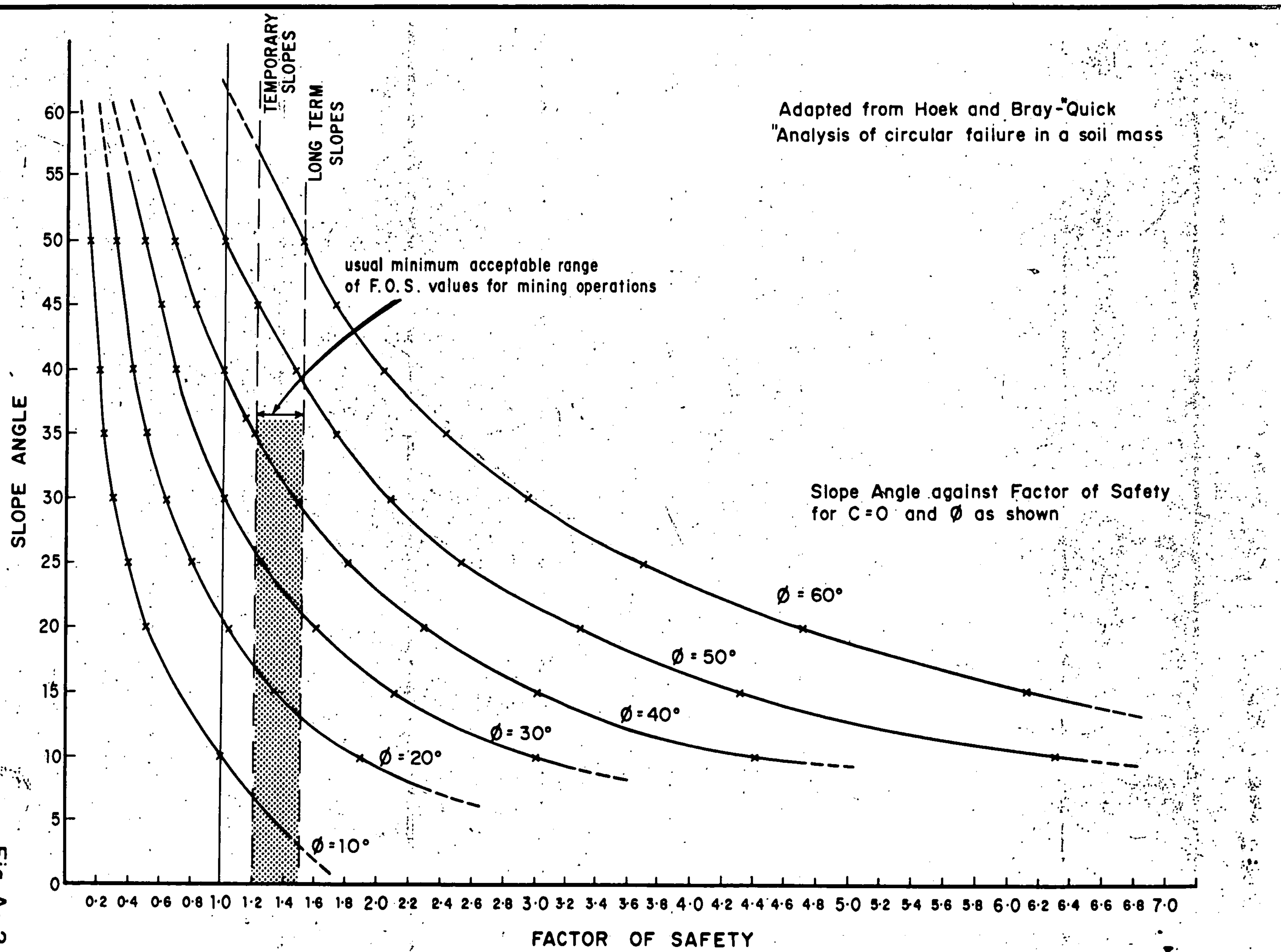


Fig. A-2

TABLE 1 QUICK ANALYSIS BY HOEK & BRAY

	CHART	SLOPE ANGLE	TAN Ø	C	γ	H	C / γ.H.TAN Ø	TAN Ø / F	F
1	2 (Partially Saturated)	35°	40°=0.84	Nil				1.5	<1
2	2	33°	35°=0.7	Nil				1.2	<1
3	2	35°	38°=0.78	Nil				1.3	<1
4	2	30°	40°=0.84	Nil				1.4	<1
5	2	25°	38°=0.78	Nil				1.0	<1
6	2	25°	40°=0.84	Nil				0.84	1.0
7	2	23°	38°=0.78	Nil				0.78	1.0
8	1 (Dry)	33°	35°=0.7	Nil				0.7	1.0
9	1	35°	38°=0.78	Nil				0.7	1.1
10	1	30°	40°=0.84	Nil				0.7	1.2
11	2	30°	38°=0.78	(50lb/ft^2) 2.5 KPa	(100lb/ft^3) 16 KN/M^3	(60ft) 20m	0.010	0.53	
12	1	30°	38°=0.78	2.5 KPa	(80lb/ft^3)	20m	0.012	0.50	
13	1	25°	38°=0.78	Nil				0.48	

Co-ordinates for centre of
critical circle: $x = 0.1H = 2M$
$y = 1.5H = 30M$

APPENDIX 2

SLOPE STABILITY CALCULATIONS USING STABL

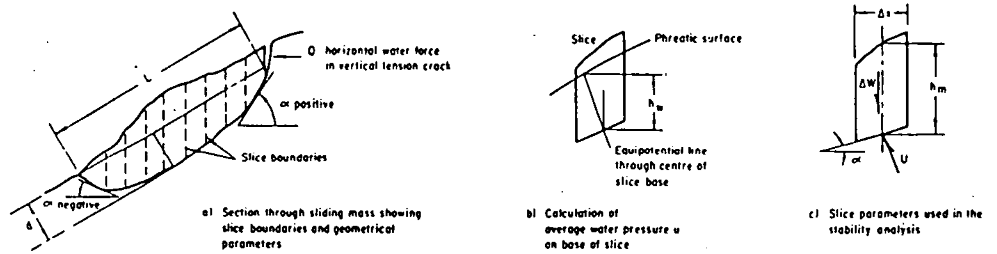
DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA
GROUNDWATER AND ENGINEERING BRANCH

PROJECT : READYMIX RIVERVIEW QUARRY REHABILITATION SLOPE	
CALCULATED : J. BEAL	DATE : JULY '85

SLOPE STABILITY ASSESSMENT USING JANBU'S NON-CIRCULAR FAILURE ANALYSIS

(Taken from 'ROCK SLOPE ENGINEERING' ; E Hoek , J W Bray , p247-253)

L	80
d	12·5
d/L	0·156
f_0 from chart	1·041
γ material 1 DRY	13 kN/m³
γ material 2 SAT	16 kN/m³
γ_w	9·82 kN/m³



a) Section through sliding mass showing slice boundaries and geometrical parameters

b) Calculation of average water pressure u on base of slice

c) Slice parameters used in the stability analysis

SYMBOLS

- f_0 correction factor
- n geometrical functions
- c cohesive strength
- ϕ angle of friction
- p average weight per unit width of slice
- u average water pressure on base of slice
- L chord length of failure surface
- d depth of failure surface

Calculation of FACTOR OF SAFETY

$$F = f_0 \frac{\sum \frac{(c+(p-u)\tan\phi)\Delta x}{n_\alpha}}{\sum \Delta W \tan\alpha + Q}$$

If Q is zero and Δx is constant

$$F = f_0 \frac{\sum \frac{(c+(p-u)\tan\phi)}{n_\alpha}}{\sum p.\tan\alpha}$$

$$F.O.S = \frac{f_0 \sum \frac{X}{n}}{\sum \Delta W.\tan\alpha}$$

DESCRIPTION OF MATERIAL & SLOPE : Slope angle = 35° ; c = 0 ; φ = 35°
Quarry waste

Note : 1 lb/ft³ = 0·16 kN/m³ , 1 psi = 6·89 kPa , 1 lbf/ft² = 0·04788 kPa

SLICE	α	Tan α	h_m	h_w	u ($u = h_w \gamma_w$)	γ_m	p ($p = \gamma_m h_m$)	Δx	ΔW ($\Delta W = p\Delta x$)	p − u	ΔW.Tan α	c	φ	Tan φ	X ($X = (c+(p-u)\tan\phi)\Delta x$)	TRIAL 1 (F = 1) n_α use chart	TRIAL 1 $\frac{X}{n_\alpha}$	TRIAL 2 (F =) n_α	TRIAL 2 $\frac{X}{n_\alpha}$	TRIAL 3 (F =) n_α	TRIAL 3 $\frac{X}{n_\alpha}$	
1	65°	2·14	3	DRY		13		5	39	DRY	417·3	0	35°	0·7	(5×0·7) × 39 = 136·5	0·46	297					
2	50°	1·19	4		"	"		"	52	"	309·4	"	"	"	3·5 × 52 = 182	0·75	243					
3	50°	1·19	5		"	"		"	65	"	386·8	"	"	"	" × p 228	0·75	304					
4	50°	1·19	6		"	"		"	78	"	464·1	"	"	"	" 273	0·75	205					
5	40°	0·84	6·5		"	"		"	84·5	"	354·9	"	"	"	" 296	0·93	318					
6	30°	0·58	5·8		"	"		"	75·4	"	218·7	"	"	"	" 264	1·05	251					
7	22°	0·40	5·4		"	"		"	70·2	"	140·4	"	"	"	" 246	1·1	224					
8	15°	0·27	4·6		"	"		"	59·8	"	80·7	"	"	"	" 209	1·1	190					
9	18°	0·32	4·2		"	"		"	54·6	"	87·36	"	"	"	" 191	1·1	174					
10	7°	0·31	3·5		"	"		"	45·5	"	70·5	"	"	"	" 159	1·1	145					
11	10°	0·18	3		"	"		"	39	"	35·1	"	"	"	" 137	1·08	127					
12	6°	0·11	2·7		"	"		"	35·1	"	19·3	"	"	"	" 123	1·07	115	Modified for Water Table (A)		Modified for water Table (B)		For details of calculations for water tables (A) + (B) see working file No. 85/7
13	4°	0·07	1·7	water table (A)	"	"		"	22·1	"	7·7	"	"	"	" 77	1·05	73					
14	−30°	0·58	1·2	water table (B)	"	"		"	15·6	"	45·2	"	"	"	" 55	0·44	125					
											Σ ΔW.Tan α = 2592				$\Sigma \frac{X}{n_\alpha}$		2791 × f_0		2650 × f_0		2492 × f_0	

TRIAL	1	2 (A)	3 (B)
$\frac{\tan\phi}{F}$	0·7	0·7	0·7
F. O. S.	1·12	1·06	0·99

Final FACTOR OF SAFETY : 1·0

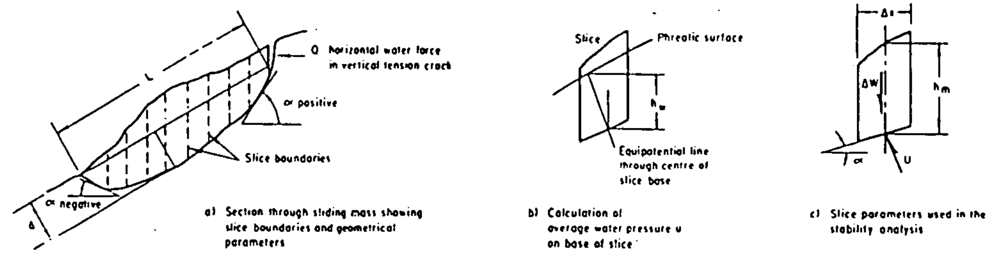
PROJECT: READYMIX RIVERVIEW QU.
REHABILITATION SLOPE
CALCULATED: J. BEAL   DATE: JULY '85

GROUNDWATER AND ENGINEERING BRANCH

SLOPE STABILITY ASSESSMENT USING JANBU'S NON-CIRCULAR FAILURE ANALYSIS

(Taken from 'ROCK SLOPE ENGINEERING'; E Hoek, J W Bray, p247-253)

L	88
d	14
$\frac{d}{L}$	0.159
f_0 from chart	1.046
γ DRY material 1	15 kN/m³
γ WET material 2	19.5
γ_w	9.82 kN/m³



a) Section through sliding mass showing slice boundaries and geometrical parameters

b) Calculation of average water pressure u on base of slice

c) Slice parameters used in the stability analysis

SYMBOLS

- f_0 correction factor
- n_α geometrical functions
- c cohesive strength
- ϕ angle of friction
- p average weight per unit width of slice
- u average water pressure on base of slice
- L chord length of failure surface
- d depth of failure surface

Calculation of FACTOR OF SAFETY

$$F = f_0 \frac{\sum \frac{(c + (p-u)\tan\phi)\Delta x}{n_\alpha}}{\sum \Delta W \tan\alpha + Q}$$

If Q is zero and Δx is constant

$$F = f_0 \frac{\sum \frac{(c + (p-u)\tan\phi)}{n_\alpha}}{\sum p.\tan\alpha}$$

$$\boxed{F.S. = \frac{f_0 \sum \frac{X}{n}}{\sum \Delta W.\tan\alpha}}$$

DESCRIPTION OF MATERIAL & SLOPE: Slope angle taken as 30°; ϕ = 33°; c = 0.
Quarry waste of quartzite, metasiltstone / sandstone. Minor silt/clay content
Truck-dumped down face of excavation.

Note: 1 lb/ft³ = 0.16 kN/m³

SLICE	α	Tan α	h_m	h_w	u ($u = h_w \gamma_w$)	γ_m	p ($p = \gamma_m h_m$)	Δx	ΔW ($\Delta W = p\Delta x$)	p − u	ΔW.Tan α	c	φ	Tan φ	X ($X = (c + (p-u)\tan\phi)\Delta x$)	TRIAL 1 (F = 1) n_α use chart	TRIAL 1 $\frac{X}{n_\alpha}$	TRIAL 2 (F = 1.3) n_α	TRIAL 2 $\frac{X}{n_\alpha}$	TRIAL 3 (F =) n_α	TRIAL 3 $\frac{X}{n_\alpha}$
1	65°	2.14	8			15	120	5	600	120	1284	0	33°	0.65	(0.65 × 5) × 120 = 390	0.42	929				
2	50°	1.19	10			15	150	5	750	150	893	0	"	"	3.25 × 150 = 488	0.72	678				
3	50°	1.19	12.5			15	127.5	5	938	127.5	1116	0	"	"	" × 128 = 611	0.72	849				
4	50°	1.19	16			15	240	5	1200	240	1428	0	"	"	" × 240 = 780	0.72	1083				
5	40°	0.84	16.3			15	245	5	1223	245	1027	0	"	"	" × 245 = 796	0.90	884				
6	30°	0.58	15			15	225	5	1125	225	653	0	"	"	" × 225 = 731	1.02	717				
7	22°	0.40	14			15	210	5	1050	210	420	0	"	"	" × 210 = 683	1.08	632				
8	15°	0.27	12	0.5	4.9	15	180	5	900	175	243	0	"	"	" × 175 = 569	1.09	522				
9	12°	0.32	10	1.3	12.8	15	150	5	750	137	240	0	"	"	" × 137 = 445	1.09	408				
10	17°	0.31	10	3.0	29.5	16	160	5	800	131	248	0	"	"	" × 131 = 426	1.09	391				
11	10°	0.18	11	3.5	34.4	16	176	5	880	142	158	0	"	"	" × 142 = 462	1.07	432				
12	6°	0.11	12.5	4.0	39.3	16	200	5	1000	161	110	0	"	"	" × 161 = 523	1.06	493				
13	2°	0.03	12.5	3.8	37.3	16	200	5	1000	163	30	0	"	"	" × 163 = 530	1.02	520				
14	−4°	0.07	10	3.5	34.4	17	170	5	850	136	60	0	"	"	" × 136 = 442	0.94	470				
15	−14°	0.25	7	2.5	24.6	17	119	5	595	94	149	0	"	"	" × 94 = 306	0.79	387				
16	−25°	0.47	2.5	0.8	7.9	16	40	5	200	32	94	0	"	"	" × 32 = 104	0.58	179				

From chart using F = 1.3

Trial F.O.S. = calc. F.O.S. ∴ no further trials required

8153 ⇐ Σ ΔW.Tan α

$\Sigma \frac{X}{n_\alpha}$ ⇒ 9514 × f_0 ⇒ 10131 × f_0 ⇒

TRIAL	1	2	3
$\frac{\tan\phi}{F}$	0.65	0.5	
F. O. S.	1.23	1.3	

Final FACTOR OF SAFETY: 1.3

SHEET 2

RV1. DAT

```
PROFILE     READYMIX SLOPE STABILITY ANALYSIS
12 7
47.0 0.0 90.0 66.0 1
90.0 66.0 115.0 62.0 2
115.0 62.0 188.0 103.0 3
188.0 103.0 250.0 103.0 3
250.0 103.0 452.0 248.0 2
452.0 248.0 486.0 267.0 1
486.0 267.0 600.0 267.0 1
315.0 52.0 452.0 248.0 1
200.0 69.0 250.0 103.0 2
115.0 62.0 200.0 69.0 2
90.0 66.0 112.0 52.0 1
112.0 52.0 315.0 52.0 1
* SOIL
3
25.0 26.0 10000.0 60.0 0.0 0.0 1
13.0 17.5 0.0 33.0 0.0 0.0 1
14.5 18.5 0.0 33.0 0.0 0.0 1
WATER
1 9.8
3
47.0 0.0
85.0 59.0
600.0 150.0
CIRCLE
3 5 85.0 250.0 315.0 600.0 0.0 30.0 0.0 0.0
```

SOIL TYPE	moist wt kN/m³	Saturt. wt	c	φ	pore pressure param.	pore pressure const.	piezometric surface no.
1	25	26	0	60	—	—	1
2	13	17.5	0	33	—	—	1
3	14.5	18.5	0	33	—	—	1

RVT (Example)

FOLLOWING ARE DISPLAYED THE TEN MOST CRITICAL OF THE TRIAL FAILURE SURFACES EXAMINED. THEY ARE ORDERED - MOST CRITICAL FIRST.

FAILURE SURFACE SPECIFIED BY 6 COORDINATE POINTS

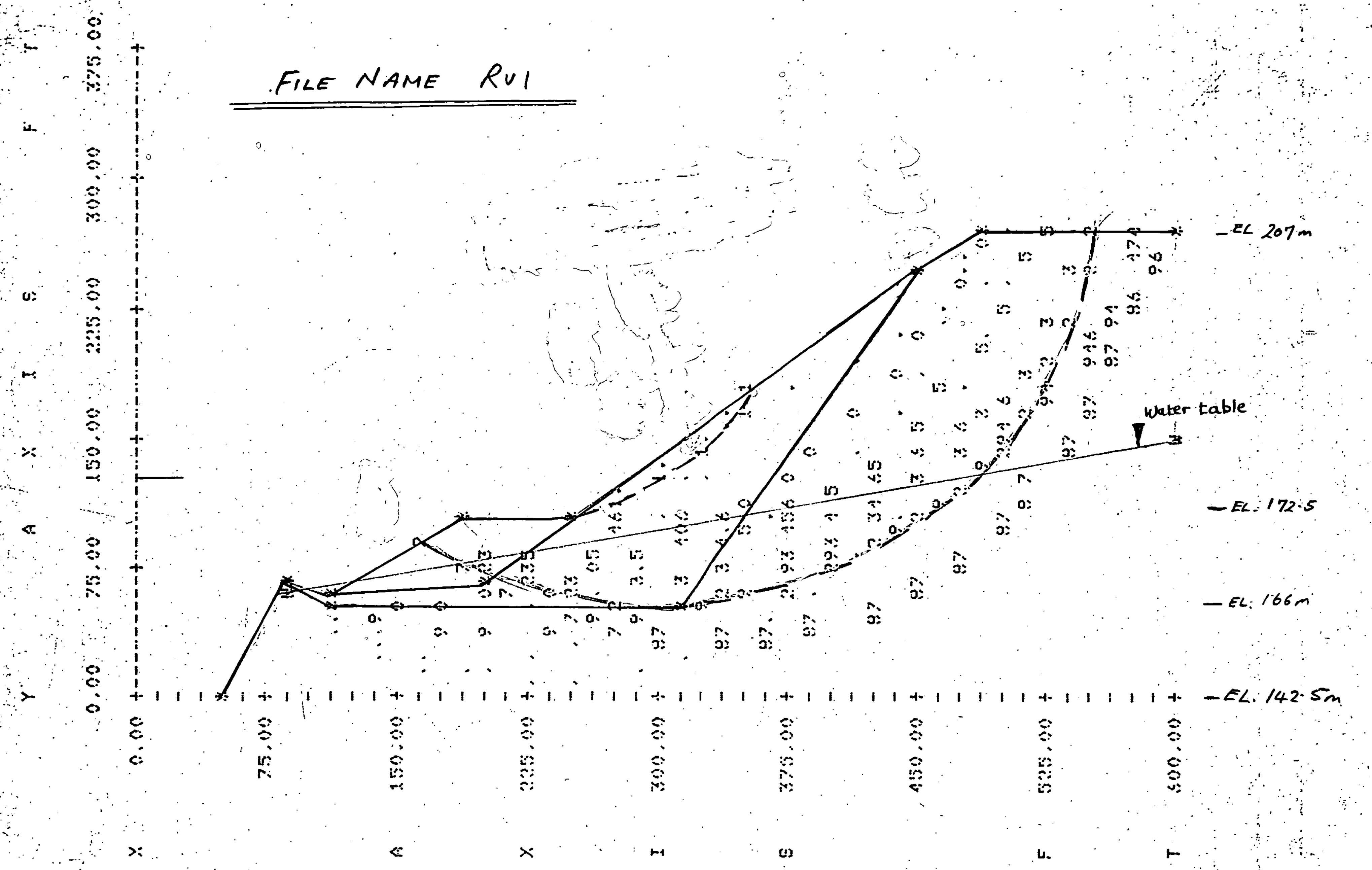
POINT NO.	X-SURF (M.)	Y-SURF (M.)
1	250.00	103.00
2	278.65	111.91
3	305.15	125.96
4	328.60	144.68
5	348.17	167.41
6	354.18	177.78

*** 0.956 *** [circle described by 1 on plot]

FAILURE SURFACE SPECIFIED BY 18 COORDINATE POINTS

POINT NO.	X-SURF (M.)	Y-SURF (M.)
1	167.50	91.49
2	193.96	77.36
3	221.91	66.44
4	250.94	58.88
5	280.66	54.79
6	310.65	54.23
7	340.51	57.19
8	369.81	63.64
9	398.14	73.80
10	425.12	86.61
11	450.37	102.81
12	473.54	121.87
13	494.31	143.52
14	512.39	167.46
15	527.53	193.36
16	539.52	220.86
17	548.19	249.58
18	551.27	267.00

*** 15.099 *** [circle described by 2 on plot.]


FILE NAME RV1
EL 207m
Water table
EL. 172.5
EL. 166m
EL. 142.5m
0.00
75.00
150.00
225.00
300.00
375.00
450.00
525.00
600.00
Y AXIS FT
X AXIS FT

RV2. DAT

```
PROFILE
READYMIX SLOPE STABILITY ANALYSIS
9 6
47.0 0.0 90.0 66.0 1
90.0 66.0 115.0 62.0 2
115.0 62.0 200.0 69.0 2
200.0 69.0 452.0 248.0 2
452.0 248.0 486.0 267.0 1
486.0 267.0 600.0 267.0 1
315.0 52.0 452.0 248.0 1
90.0 66.0 112.0 52.0 1
112.0 52.0 315.0 52.0 1
SOIL
3
25.0 26.0 10000.0 60.0 0.0 0.0 1
13.0 17.5 0.0 33.0 0.0 0.0 1
14.5 18.5 0.0 33.0 0.0 0.0 1
WATER
1 9.8
3
47.0 0.0
85.0 60.0
600.0 108.0
CIRCLE
3 5 115.0 280.0 250.0 460.0 0.0 30.0 0.0 0.0
```

SOIL TYPE	moist wt kN/m³	sat. wt	c	φ	pore pressure param.	pore pressure constant	piezometric surface number
1	25	26	0	60	–	–	1
2	13	17.5	0	33	–	–	1
3	14.5	18.5	0	33	–	–	1

RV2 (Example)

FOLLOWING ARE DISPLAYED THE TEN MOST CRITICAL OF THE TRIAL FAILURE SURFACES EXAMINED. THEY ARE ORDERED - MOST CRITICAL FIRST.

FAILURE SURFACE SPECIFIED BY 8 COORDINATE POINTS

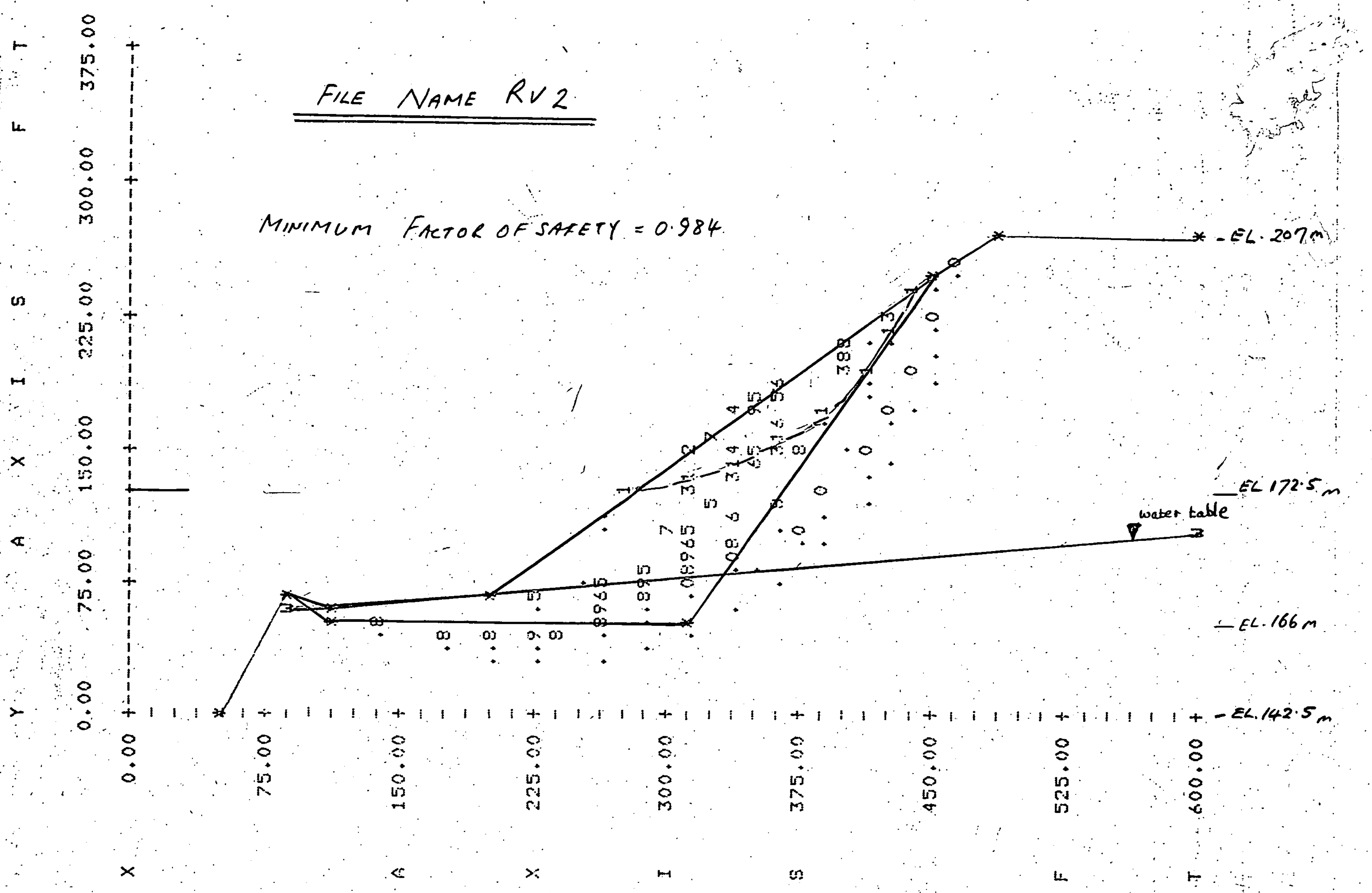
POINT NO.	X-SURF (M.)	Y-SURF (M.)
1	280.00	125.83
2	309.39	131.85
3	337.61	142.03
4	364.08	156.15
5	388.24	173.93
6	409.61	194.98
7	427.74	218.89
8	438.54	238.44

*** 0.984 *** [circle described by 1 on plot]

FAILURE SURFACE SPECIFIED BY 3 COORDINATE POINTS

POINT NO.	X-SURF (M.)	Y-SURF (M.)
1	280.00	125.83
2	307.19	138.50
3	317.23	152.27

*** 1.000 *** [circle described by 2 on plot]



FILE NAME RV2
MINIMUM FACTOR OF SAFETY = 0.984
EL. 207m
EL 172.5 m
water table
EL. 166 m
EL. 142.5 m
Y AXIS FT
X AXIS FT
0.00
75.00
150.00
225.00
300.00
375.00
450.00
525.00
600.00

RV3.DAT

```
PROFILE
READYMIX SLOPE STABILITY ANALYSIS
9 6
47.0 0.0 90.0 66.0 1
90.0 66.0 115.0 62.0 2
115.0 62.0 200.0 69.0 2
200.0 69.0 452.0 248.0 2
452.0 248.0 486.0 267.0 1
486.0 267.0 600.0 267.0 1
315.0 52.0 452.0 248.0 1
90.0 66.0 112.0 52.0 1
112.0 52.0 315.0 52.0 1
* SOIL
3
25.0 26.0 10000.0 60.0 0.0 0.0 1
13.0 17.5 0.0 33.0 0.0 0.0 1
14.5 18.5 0.0 33.0 0.0 0.0 1
CIRCLE
3 5 115.0 280.0 250.0 460.0 0.0 30.0 0.0 0.0
```

*

Soil type	Moist Wt. KN/m3	Sat. wt.	c.	φ	Pore press	Pore const.	Piez surface No.
1	25	26	0	60	–	–	1
2	13	17·5	0	33	–	–	1
3	14·5	18·5	0	33	–	–	1

RV3 (Example)

FOLLOWING ARE DISPLAYED THE TEN MOST CRITICAL OF THE TRIAL FAILURE SURFACES EXAMINED. THEY ARE ORDERED - MOST CRITICAL FIRST.

FAILURE SURFACE SPECIFIED BY 8 COORDINATE POINTS

POINT NO.	X-SURF (M.)	Y-SURF (M.)
1	280.00	125.83
2	309.39	131.85
3	337.61	142.03
4	364.08	156.15
5	388.24	173.93
6	409.61	194.98
7	427.74	218.89
8	438.54	238.44

*** 0.984 ***

FAILURE SURFACE SPECIFIED BY 3 COORDINATE POINTS

POINT NO.	X-SURF (M.)	Y-SURF (M.)
1	280.00	125.83
2	307.19	138.50
3	317.23	152.27

*** 1.000 ***

PROJECT : READYMIX RIVERVIEW QUARRY REHABILITATION SLOPE

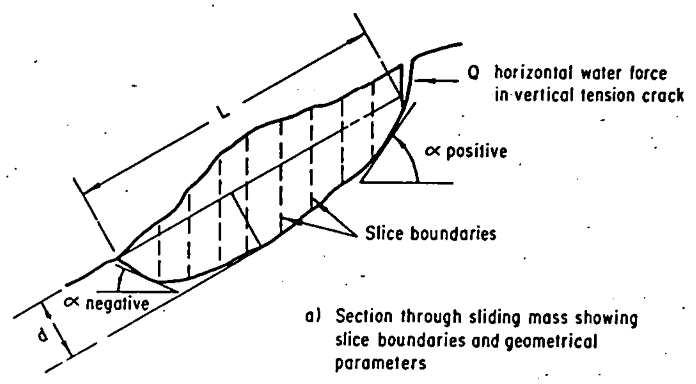
CALCULATED : J. BEAL DATE : JULY '85

DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA
GROUNDWATER AND ENGINEERING BRANCH

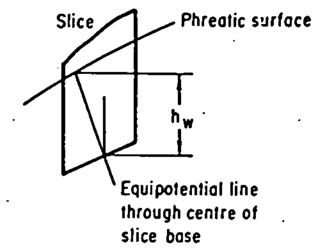
SLOPE STABILITY ASSESSMENT USING JANBU'S NON-CIRCULAR FAILURE ANALYSIS

(Taken from 'ROCK SLOPE ENGINEERING'; E Hoek, J W Bray, p247-253)

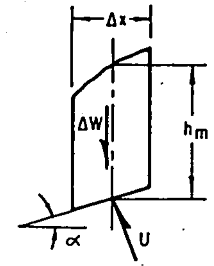
L	80
d	12·5
$\frac{d}{L}$	0·156
f_o from chart	1·041
$\gamma_{material\ 1}$ DRY	13 kN/m³
$\gamma_{material\ 2}$ SAT	16 kN/m³
γ_w	9·82 kN/m³



a) Section through sliding mass showing slice boundaries and geometrical parameters



b) Calculation of average water pressure u on base of slice



c) Slice parameters used in the stability analysis

SYMBOLS

- f_o correction factor
- n geometrical functions
- c cohesive strength
- ϕ angle of friction
- p average weight per unit width of slice
- u average water pressure on base of slice
- L chord length of failure surface
- d depth of failure surface

Calculation of FACTOR OF SAFETY

$$F = f_o \frac{\sum \frac{(c+(p-u)\tan\phi)\Delta x}{n_\alpha}}{\sum \Delta W \tan\alpha + Q}$$

If Q is zero and Δx is constant

$$F = f_o \frac{\sum \frac{(c+(p-u)\tan\phi)}{n_\alpha}}{\sum p . \tan\alpha}$$

$$\boxed{F.O.S. = \frac{f_o \sum \frac{X}{n}}{\sum \Delta W . \tan\alpha}}$$

DESCRIPTION OF MATERIAL & SLOPE : Slope angle = 35° ; c = 0 ; Ø = 35°
Quarry waste

Note : 1 lb/ft³ = 0·16 kN/m³ , 1 psi = 6·89 kPa , 1 lb f/ft² = 0·04788 kPa

SLICE	α	Tan α	h_m	h_w	u $u = h_w \gamma_w$	γ_m	p $p = \gamma_m h_m$	Δx	ΔW ΔW = p Δx	p − u	ΔW. Tan α	c	ϕ	Tan ϕ	X X = (c+(p−u)Tanϕ)Δx	TRIAL 1 (F = 1) n_α use chart	TRIAL 1 $\frac{X}{n_\alpha}$	TRIAL 2 (F=) n_α	TRIAL 2 $\frac{X}{n_\alpha}$	TRIAL 3 (F=) n_α	TRIAL 3 $\frac{X}{n_\alpha}$
1	65°	2·14	3	DRY		13		5	39	DRY	417·3	0	35°	0·7	(5×0·7) × 39 = 136·5	0·46	297				
2	50°	1·19	4		"	"		"	52	"	309·4	"	"	"	3·5 × 52 = 182	0·75	243				
3	50°	1·19	5		"	"		"	65	"	386·8	"	"	"	" × p 228	0·75	304				
4	50°	1·19	6		"	"		"	78	"	464·1	"	"	"	" " 273	0·75	205				
5	40°	0·84	6·5		"	"		"	84·5	"	354·9	"	"	"	" " 296	0·93	318				
6	30°	0·58	5·8		"	"		"	75·4	"	218·7	"	"	"	" " 264	1·05	251				
7	22°	0·40	5·4		"	"		"	70·2	"	140·4	"	"	"	" " 246	1·1	224				
8	15°	0·27	4·6		"	"		"	59·8	"	80·7	"	"	"	" " 209	1·1	190				
9	18°	0·32	4·2		"	"		"	54·6	"	87·36	"	"	"	" " 191	1·1	174				
10	17°	0·31	3·5		"	"		"	45·5	"	70·5	"	"	"	" " 159	1·1	145				
11	10°	0·18	3		"	"		"	39	"	35·1	"	"	"	" " 137	1·08	127				
12	6°	0·11	2·7		"	"		"	35·1	"	19·3	"	"	"	" " 123	1·07	115				
13	4°	0·07	1·7		"	"		"	22·1	"	7·7	"	"	"	" " 77	1·05	73				
14	-30°	0·58	1·2		"	"		"	15·6	"	45·2	"	"	"	" " 55	0·44	125				

water table (A)
water table (B)

Modified for Water Table (A)

Modified for water Table (B)

For details of calculations for water tables (A) + (B) see working file No: 85/7

2592 ⇐ Σ ΔW. Tan α

$\sum \frac{X}{n_\alpha}$ ⇒ 2791 × f_o ⇒ 2650 × f_o ⇒ 2492 × f_o

TRIAL	1	2 (A)	3 (B)
$\frac{\tan\phi}{F}$	0·7	0·7	0·7
F. O. S.	1·12	1·06	0·99

Final FACTOR OF SAFETY : 1·0

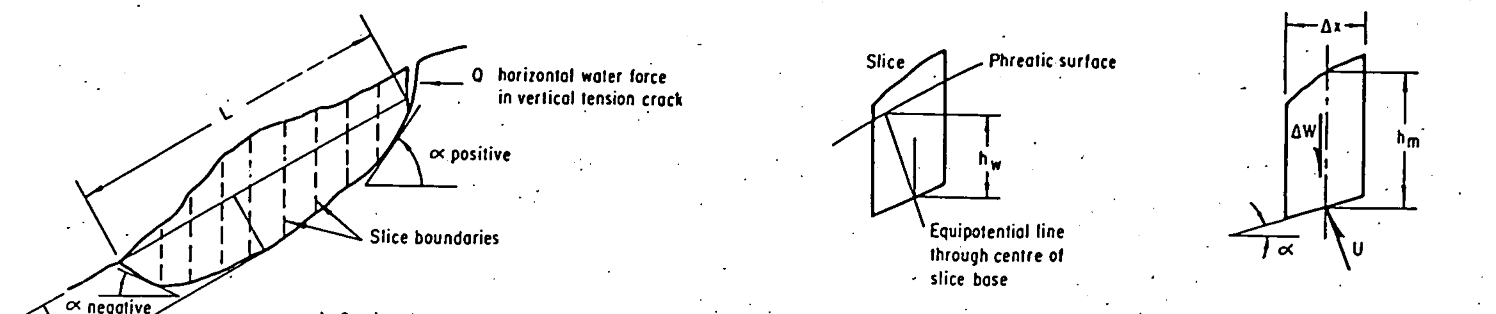
PROJECT :	READYMIX RIVERVIEW QU. REHABILITATION SLOPE
CALCULATED : J. BEAL	DATE : JULY '85

MF 164

SLOPE STABILITY ASSESSMENT USING JANBU'S NON-CIRCULAR FAILURE ANALYSIS

(Taken from 'ROCK SLOPE ENGINEERING'; E. Hoek, J W Bray, p247-253)

L	88
d	14
d / L	0.159
f_0 from chart	1.046
γ DRY material 1	15 kN/m³
γ WET material 2	19.5
γ_w	9.82 kN/m³



a) Section through sliding mass showing slice boundaries and geometrical parameters

b) Calculation of average water pressure u on base of slice

c) Slice parameters used in the stability analysis

SYMBOLS

- f_0 correction factor
- n geometrical functions
- c cohesive strength
- ϕ angle of friction
- p average weight per unit width of slice
- u average water pressure on base of slice
- L chord length of failure surface
- d depth of failure surface

Calculation of FACTOR OF SAFETY

$$F = f_0 \frac{\sum \frac{(c+(p-u)\tan\phi)\Delta x}{n_\alpha}}{\sum \Delta W \tan\alpha + Q}$$

If Q is zero and Δx is constant

$$F = f_0 \frac{\sum \frac{(c+(p-u)\tan\phi)}{n_\alpha}}{\sum p . \tan\alpha}$$

$$F.o.S. = \frac{f_0 \sum \frac{X}{n}}{\sum \Delta W . \tan\alpha}$$

DESCRIPTION OF MATERIAL & SLOPE : Slope angle taken as 30°; ϕ = 33°; c = 0.
Quarry waste of quartzite, metasiltstone / sandstone. Minor silt / clay content
Truck-dumped down face of excavation.

Note : 1 lb/ft³ = 0.16 kN/m³

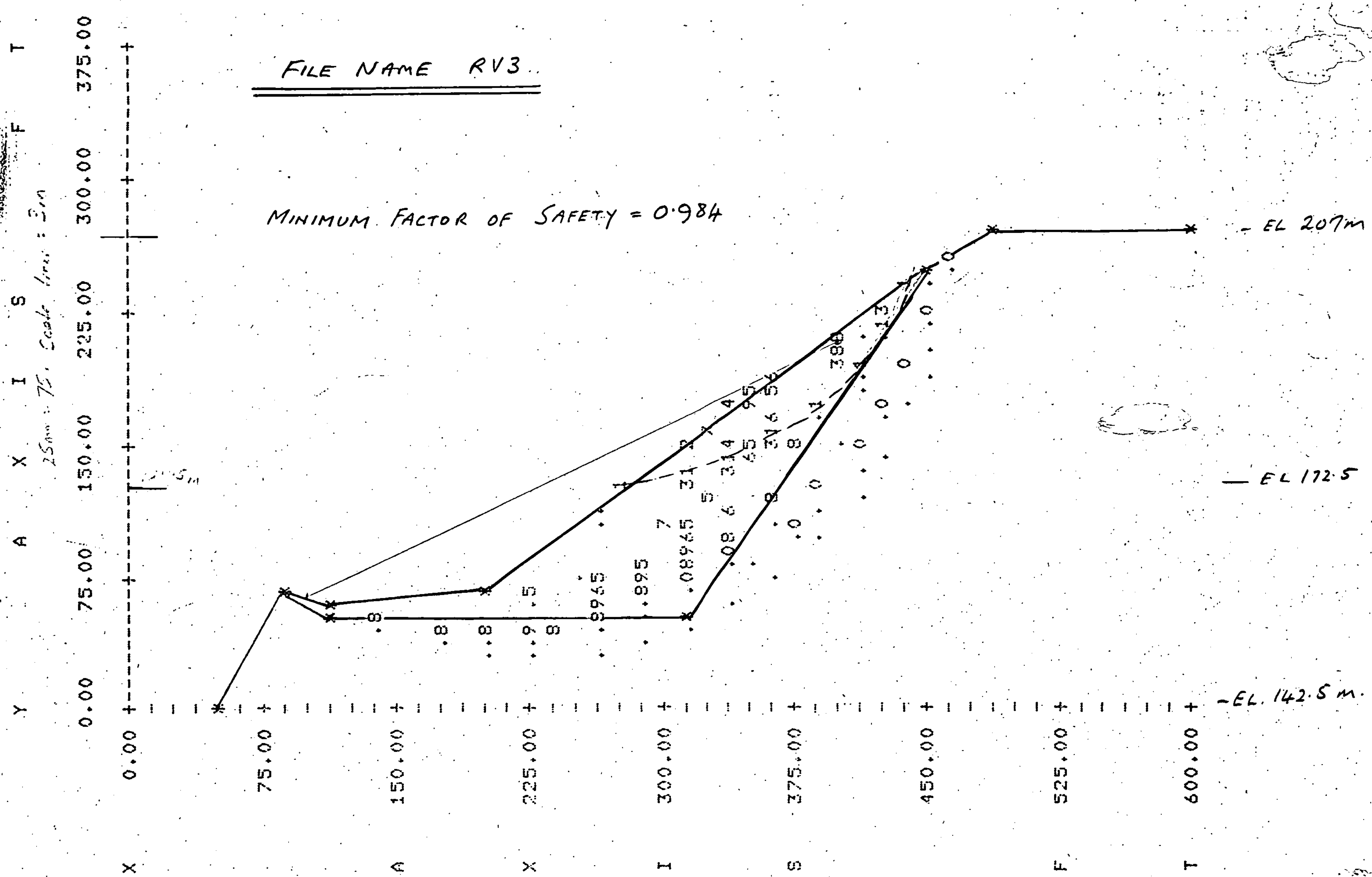
SLICE	α	Tan α	h_m	h_w	u ($u = h_w \gamma_w$)	γ_m	p ($p = \gamma_m h_m$)	Δx	ΔW ($\Delta W = p \Delta x$)	p − u	ΔW. Tan α	c	ϕ	Tan ϕ	X ($X = (c+(p-u)\tan\phi)\Delta x$)	TRIAL 1 (F = 1) n_α use chart	TRIAL 1 X/n_α	TRIAL 2 (F = 1.3) n_α	TRIAL 2 X/n_α	TRIAL 3 (F =) n_α	TRIAL 3 X/n_α
1	65°	2.14	8			15	120	5	600	120	1284	0	33°	0.65	(0.65 × 5) × 120 = 390	0.42	929				
2	50°	1.19	10			15	150	5	750	150	893	0	"	"	3.25 × 150 = 488	0.72	678				
3	50°	1.19	12.5			15	187.5	5	938	187.5	1116	0	"	"	" × 188 = 611	0.72	849				
4	50°	1.19	16			15	240	5	1200	240	1428	0	"	"	" × 240 = 780	0.72	1083				
5	40°	0.84	16.3			15	245	5	1223	245	1027	0	"	"	" × 245 = 796	0.90	884				
6	30°	0.58	15			15	225	5	1125	225	653	0	"	"	" × 225 = 731	1.02	717				
7	22°	0.40	14			15	210	5	1050	210	420	0	"	"	" × 210 = 683	1.08	632				
8	15°	0.27	12	0.5	4.9	15	180	5	900	175	243	0	"	"	" × 175 = 569	1.09	522				
9	18°	0.32	10	1.3	12.8	15	150	5	750	137	240	0	"	"	" × 137 = 445	1.09	408				
10	17°	0.31	10	3.0	29.5	16	160	5	800	131	248	0	"	"	" × 131 = 426	1.09	391				
11	10°	0.18	11	3.5	34.4	16	176	5	880	142	158	0	"	"	" × 142 = 462	1.07	432				
12	6°	0.11	12.5	4.0	39.3	16	200	5	1000	161	110	0	"	"	" × 161 = 523	1.06	493				
13	2°	0.03	12.5	3.8	37.3	16	200	5	1000	163	30	0	"	"	" × 163 = 530	1.02	520				
14	−4°	0.07	10	3.5	34.4	17	170	5	850	136	60	0	"	"	" × 136 = 442	0.94	470				
15	−14°	0.25	7	2.5	24.6	17	119	5	595	94	149	0	"	"	" × 94 = 306	0.79	387				
16	−25°	0.47	2.5	0.8	7.9	16	40	5	200	32	94	0	"	"	" × 32 = 104	0.58	179				
											8153 ← Σ ΔW. Tan α				$\Sigma \frac{X}{n_\alpha}$ →		9514 × f_0		10131 × f_0		

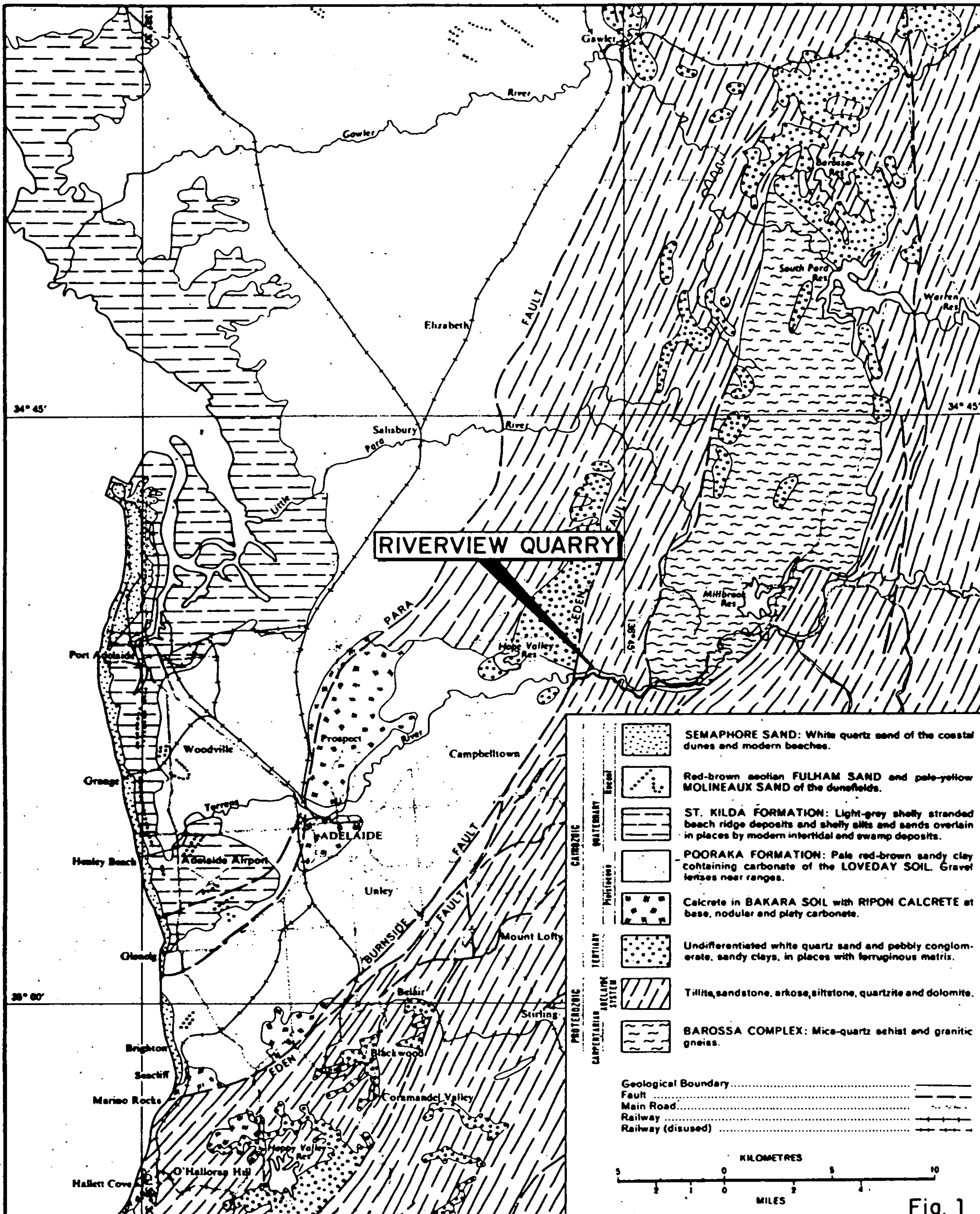
From chart using F = 1.3

Trial F.O.S. = calc. F.O.S. ∴ no further trials required

TRIAL	1	2	3
Tan ϕ / F	0.65	0.5	
F. O. S.	1.23	1.3	

Final FACTOR OF SAFETY : 1.3


FILE NAME RV3
MINIMUM FACTOR OF SAFETY = 0·984
EL 207m
EL 172·5
EL. 142·5 m.
AXIS FT
0.00
75.00
150.00
225.00
300.00
375.00
450.00
525.00
600.00
X AXIS FT
Y



DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

COMPILED J.B.	CDO DATE
DRAWN M.B.	SCALE 1:250 000
DATE July '85	PLAN NUMBER
CHECKED	S18289

RIVERVIEW QUARRY – REHABILITATED SLOPE STABILITY ANALYSIS

SEC. 5394 HD. YATALA

LOCATION AND REGIONAL GEOLOGY

3869

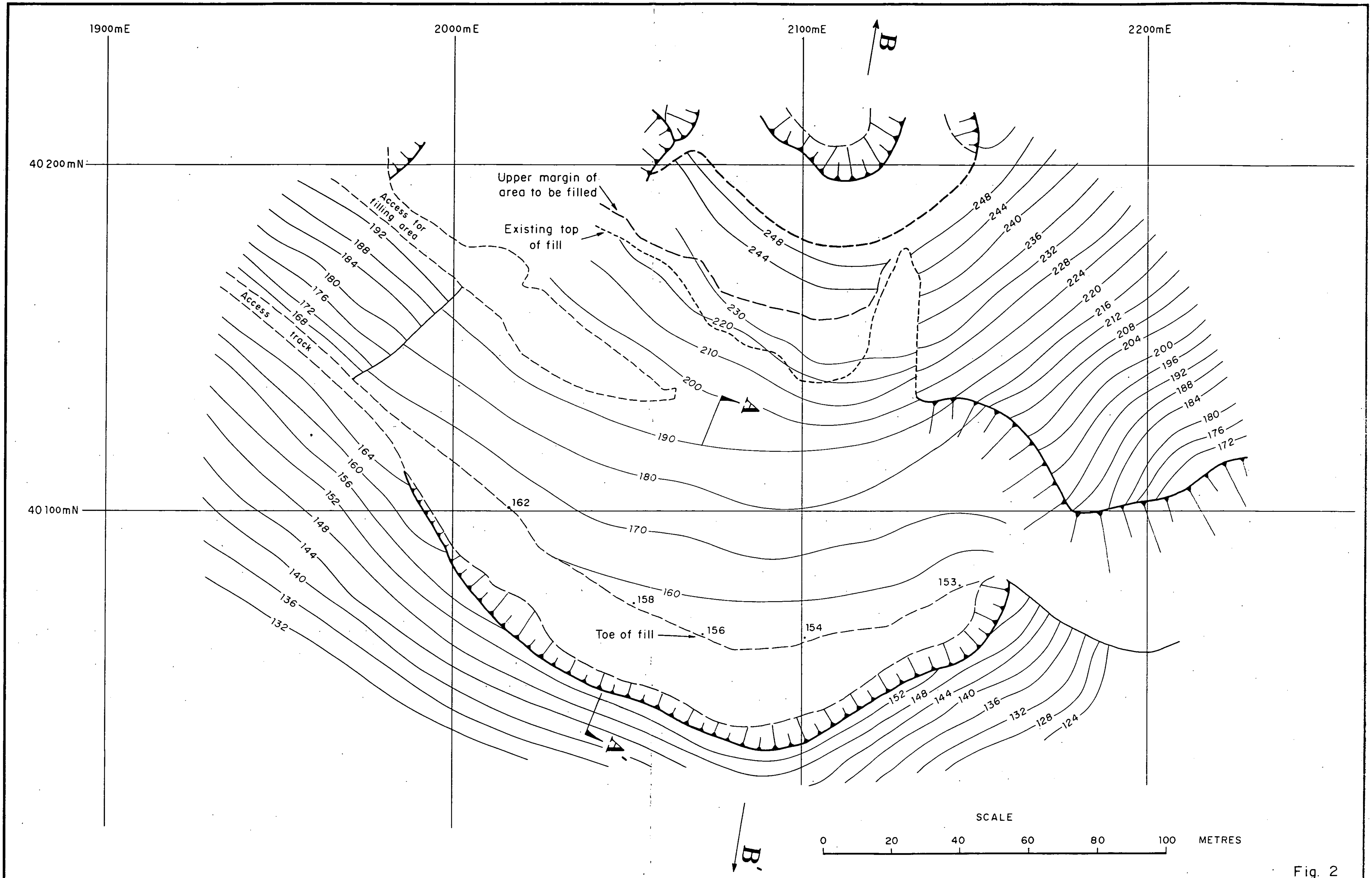
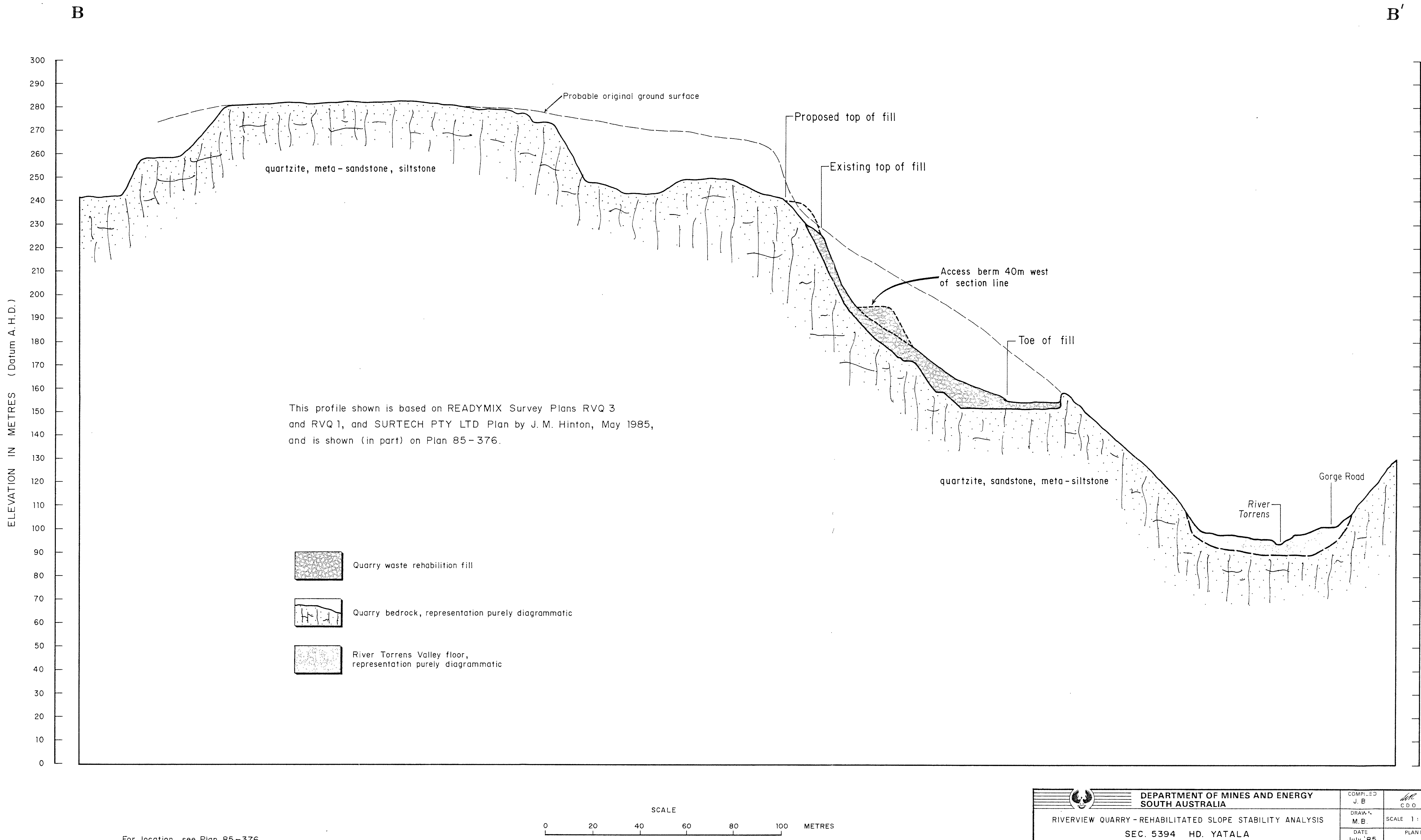


Fig. 2

For Sections, see Plans 85-377, 85-378

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED J. B.	C.D.O.	DATE 18.11.85
RIVERVIEW QUARRY - REHABILITATED SLOPE STABILITY ANALYSIS	DRAWN M. B.	SCALE 1 : 1000	
SEC. 5394 HD. YATALA	DATE July '85	PLAN NUMBER	
CONTOUR PLAN BASED ON SURTECH PTY LTD PLAN	CHECKED	85-376	

3869

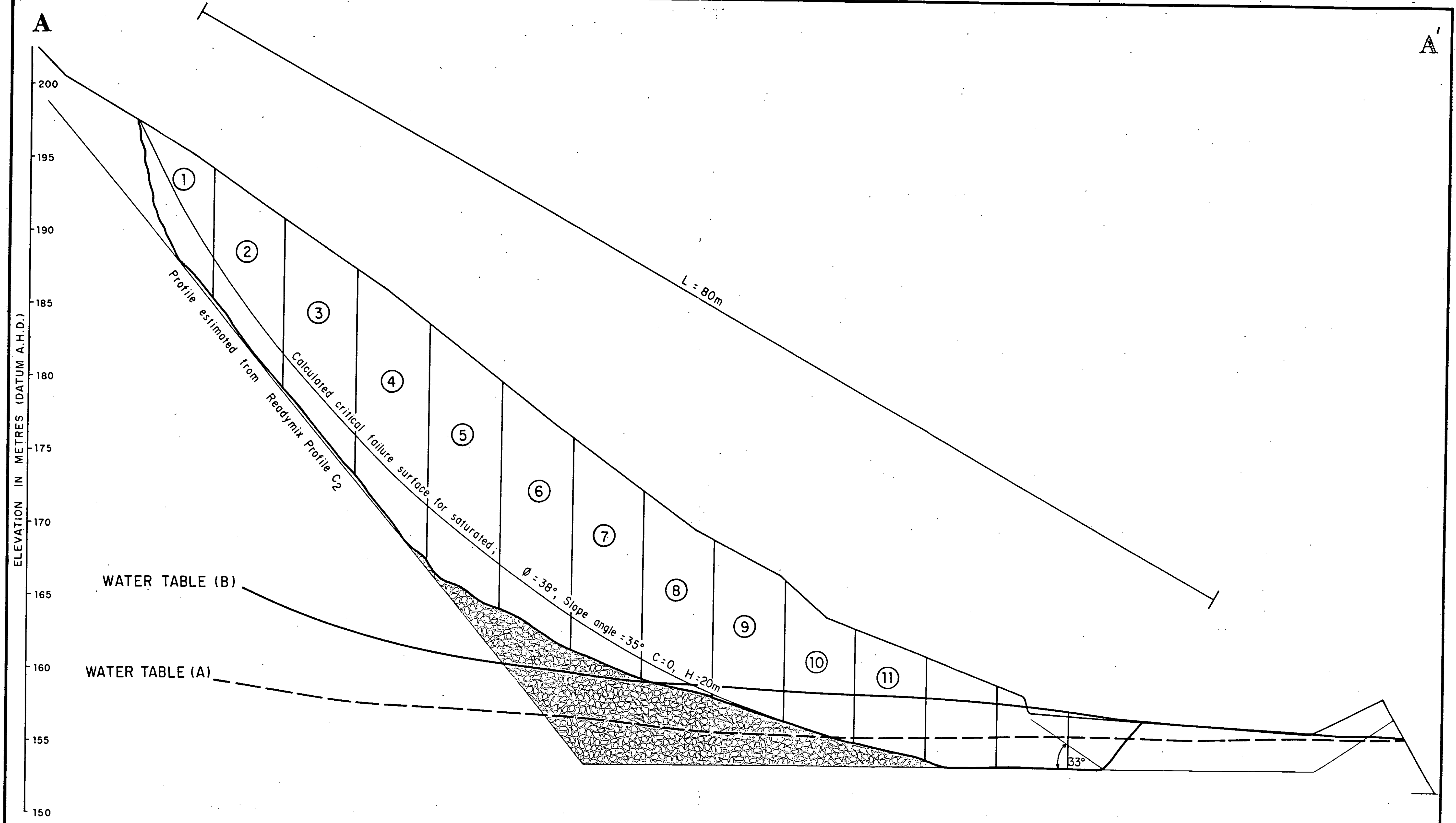


For location, see Plan 85-376

Fig. 3

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED J. B	C.D.O. 18.11.85 DATE
RIVERVIEW QUARRY - REHABILITATED SLOPE STABILITY ANALYSIS	DRAWN M. B.	SCALE 1:1000
SEC. 5394 HD. YATALA	DATE July '85	PLAN NUMBER
PROFILE 1	CHECKED	85-377

3869



Quarry waste not affected by failure surfaces

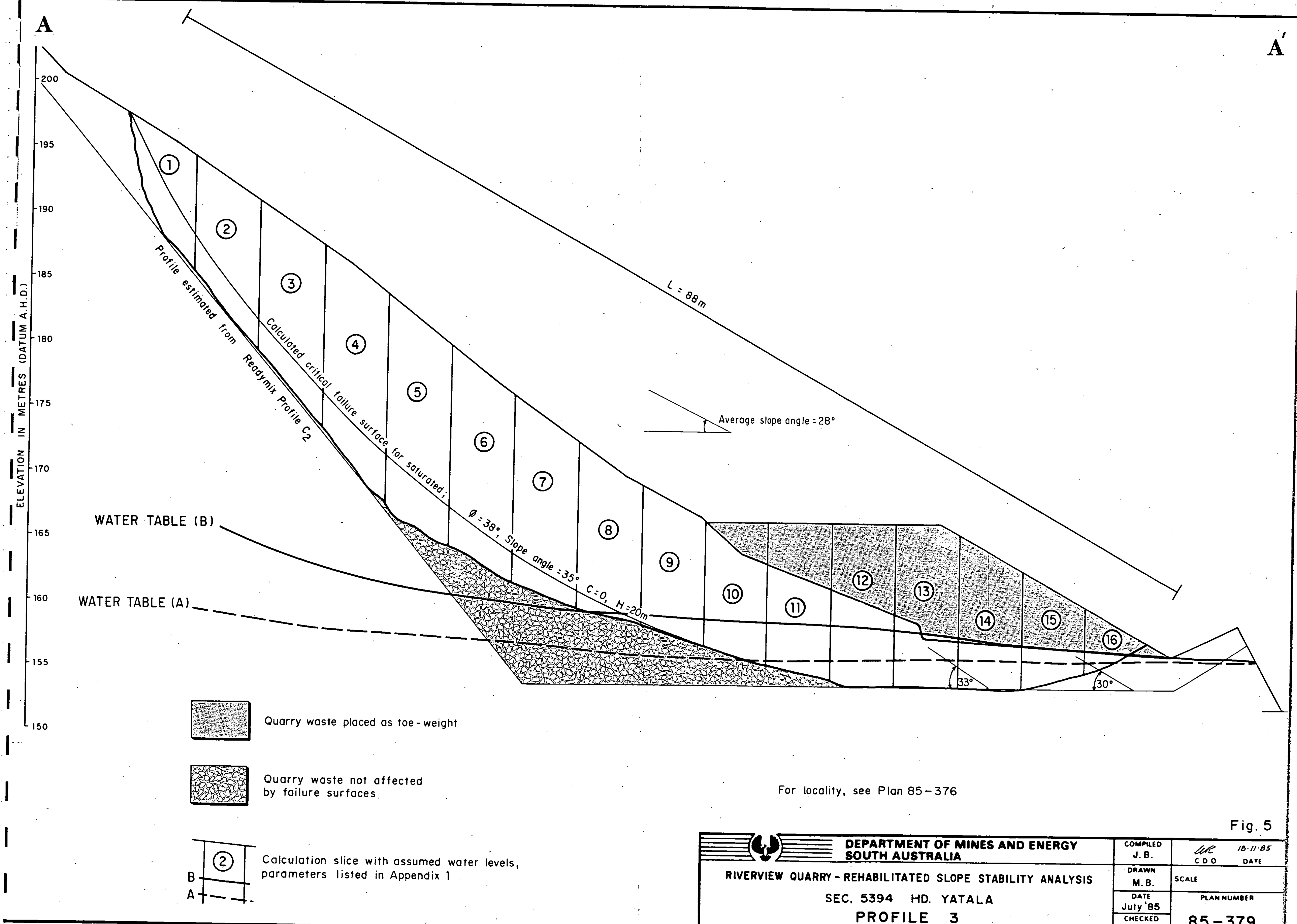
2 — Calculation slice with assumed water levels, parameters listed in Appendix 1
B
A

For locality, see Plan 85 - 376

Fig. 4

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED J. B.	18·11·85 C D O DATE
RIVERVIEW QUARRY - REHABILITATED SLOPE STABILITY ANALYSIS	DRAWN M. B.	SCALE
SEC. 5394 HD. YATALA	DATE July '85	PLAN NUMBER
PROFILE 2	CHECKED	85-378

3869


A
A′
ELEVATION IN METRES (DATUM A.H.D.)
200
195
190
185
180
175
170
165
160
155
150
L = 88m
Profile estimated from Readymix Profile C_2
Calculated critical failure surface for saturated; Ø = 38°, Slope angle = 35° C = 0, H = 20m
Average slope angle = 28°
WATER TABLE (B)
WATER TABLE (A)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
33°
30°
Quarry waste placed as toe-weight
Quarry waste not affected by failure surfaces
Calculation slice with assumed water levels, parameters listed in Appendix 1
B
A
For locality, see Plan 85-376
Fig. 5
DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA
RIVERVIEW QUARRY - REHABILITATED SLOPE STABILITY ANALYSIS
SEC. 5394 HD. YATALA
PROFILE 3
COMPILED J. B.
DRAWN M. B.
DATE July '85
CHECKED
C D O
DATE 18·11·85
SCALE
PLAN NUMBER
85-379
3869

Surface boundaries : 1-7
Subsurface boundaries : 8-12
Assumed water table : ▼
Soil types : MATERIAL 1-3

Note : Value of parameters shown on this plan show the general condition and may vary from values of calculations recorded in Appendix 2.

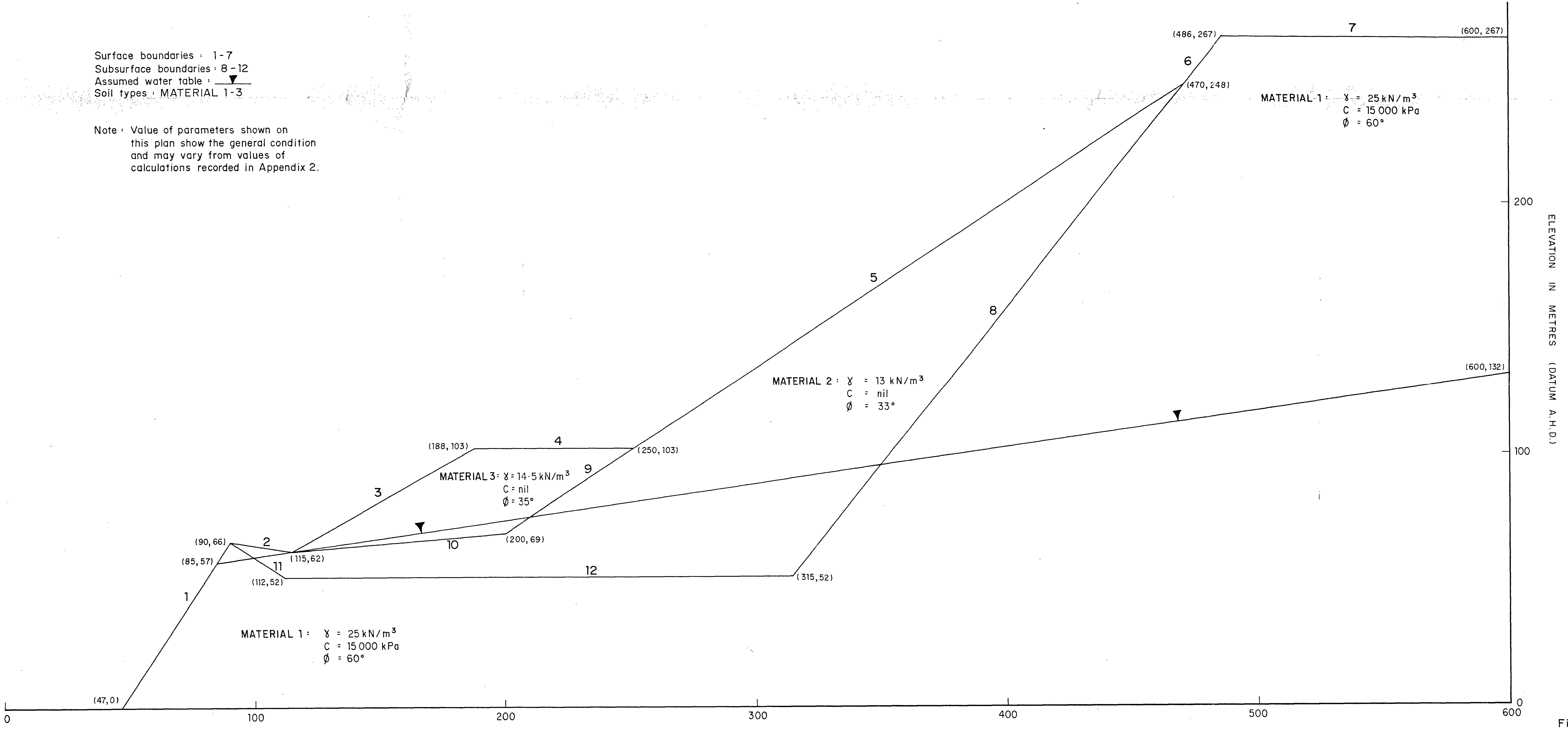


Fig. 6

SCALE

0 20 40 60 80 100 METRES

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED J. B.	18·11·85 C D O DATE	
RIVERVIEW QUARRY - REHABILITATED SLOPE STABILITY ANALYSIS	DRAWN M. B.	SCALE 1 : 1000	
SEC. 5394 HD. YATALA	DATE July '85	PLAN NUMBER 85-380	
PROFILE 4 - 'STABL' ANALYSIS	CHECKED		

3869