DEPARTMENT OF MINES
SOUTH AUSTRALIA

GEOLOGICAL SURVEY
ENGINEERING DIVISION

LITTLE PARA DAM

GEOLOGICAL ASSESSMENT OF THE QUARRY AND WATER TREATMENT WORKS

- E. & W.S. DEPARTMENT -

by

J.C. BEAL
ENGINEERING GEOLOGY SECTION

Rept.Bk.No. 77/93
G.S. No. 5915
Eng.Geol.No. 77/65
D.M. No. 428/77

CONTENTS

		PAGE
ABSTRACT		1
SUMMARY AND CONCLUSIONS		1
INTRODUCTION		2
METHOD OF INVESTIGATIONS		2
STABILITY OF QUARRY BATTERS		3
QUARRY FLOOR FOUNDATION CONDITIONS		4
DISCUSSION OF FURTHER POINTS REQUIRING COMMENT		5
REFERENCES		6
APPENDIX I	Diamond Drill Logs DH26, DH27, DH28. S12980 S12981 S12982 Drawing No.	7
APPENDIX II	Photographs	9

FIGURES

FIGURE No.	TITLE	DRAWING No.
1	Little Para Dam Quarry and Water Treatment Works. Location Plan.	S12760
2	Slope Stability Assessment. Quarry Profile.	77-595
3	Slope Stability Analysis. Fracture Summary - Stereogram.	S12761
4	Slope Stability Analysis.Contours on Poles of Joints and bedding planes. Stereogram.	S12762
5	Joint and Bedding plane poles - prior to Quarry Excavation Stereogram.	S12763
6	Intersection of Joints. Eastern Quarry Batter. Stereogram.	S12764
7	Intersection of Joints and Bedding Plane. Central Quarry Batter. Stereogram.	S12765
8	Intersection of Joints and Bedding Plane. Western Quarry Batter. Stereogram.	S12766

Plates		Negative Number
1	Drill Core DH26. 0.0 m - 10.0 m	13037
2	Drill Core DH27. 0.0 m - 10.0 m	13038
3	Drill Core DH28. 0.0 m - 10.0 m	13039
4	View of Quarry Showing Berm EL 110	13040

TABLES

I Slope Stability Analysis. Factors of Safety(in text).

II Fracture Description (in text).

DEPARTMENT OF MINES

SOUTH AUSTRALIA

Rept.Bk.No. 77/93
G.S. No. 5915
Eng.Geol.No. 77/65
D.M. No. 428/77

LITTLE PARA DAM
GEOLOGICAL ASSESSMENT OF THE QUARRY AND WATER TREATMENT WORKS

ABSTRACT

Fracture data taken from the excavated batters of the quarry was studied stereographically. It is concluded that the vertical batters are stable and will not suffer large scale planar failure.

Quarry floor foundation conditions are acceptable for the water treatment structure on berm EL120. Diamond core drilling along the edge of the EL 110 berm shows that foundation conditions on this berm require further examination and that some remedial treatment of the foundation may be required.

SUMMARY AND CONCLUSIONS

.... The quarry faces at different berm levels present no long term stability problem although continued falls of small blocks (up to 0.5 m maximum dimension) are to be expected. It is recommended that to prevent falling boulders from reaching water treatment structures a cyclone fence should be placed around a ditch 3.0-5.0 m wide and 1.50 m deep.

.... The quarry floor on berm EL 120 is acceptable for the water treatment structure. The quarry floor on berm EL 110 is only acceptable below EL 107 and further investigation of foundation conditions using seismic refraction is advised.

.... Temporary shoring of service trenches in quarry floors should not be required but is advised for trenches excavated close to the edge of the EL 120, and EL 110 berms.

..... A tank underdrainage is required to prevent possible foundation disturbance from future tank leakage.

..... The quarry faces will not suffer significant instability from the effects of weathering and exposure.

..... Slope wash material above the EL 110 level is very thin and does not constitute a stability hazard.

..... Future works extension eastwards is possible providing blasting is strictly controlled.

..... A proposed alternative tank site on the opposite hillside to the existing tank is suitable providing satisfactory batters and berms are achieved.

INTRODUCTION

Following a request from the E. & W.S. Soils and Foundation Laboratory a geological assessment was made of the Water Treatment Works quarry site at Little Para Dam.

The batters were examined to assess their long term stability and the quarry floors investigated for their suitability as foundations for the water treatment structures.

In addition comments were also requested on trench wall stability, seismic activity, future quarry extensions, an alternative water tank site, desirability of tank under-drainage and usability of the quarry disposal area as a vehicle turning circle.

METHOD OF INVESTIGATION

To assess the stability of the quarry faces the strike and dip of fractures were plotted on a stereogram. This allowed the dominant fracture patterns to be identified and factors of safety calculated for loose blocks formed by the intersection of the various fractures.

Values for the friction coefficient had been calculated earlier during the initial quarry investigation prior to excavation.

Air track drilling was used to investigate foundation conditions of the quarry floor on berms EL 110 and EL 120. This is to be followed up by diamond core drilling 10 metres into the quarry floor along the edge of EL 110.

STABILITY OF QUARRY BATTERS

Results of the fracture analysis show that falls of small blocks from the vertical batters of the central and eastern faces of the quarry can be expected. Maximum block sizes of up to 1.0 m x 1.0 m x 0.50 m can be expected to fall intermittently during the life of the quarry. A shallow ditch and cyclone fence should be placed at the foot of batters to prevent falling boulders reaching the treatment works.

The western batter (See Regime III Fig. 1) excavated at 40° will also suffer falls of small blocks and a low safety barrier should be placed at the foot of the batter. Because bedding plane angle of friction is greater than bedding plane dip a planar failure of the batter into the excavation, although geometrically possible, is highly unlikely.

Figures 2 to 8 and Table I summarise the results of the stability and analyses and calculation of Factors of Safety. Table II is a summary of fractures and their description.

Factors of safety are calculated by assuming zero cohesion and zero water pressure across two surfaces. The angle of friction only is used. This is guessed through experience or mechanically

LITTLE PARA DAM QUARRY SITE - SLOPE STABILITY ANALYSIS

FACTORS OF SAFETY

TABLE I

Intersections+ Plane A Plane B	Dip	Dip Direction	Difference Dip Dip Direction	ØA ØB	Tan ØA Tan ØB	A Value B Value	Comments	F.O.S.*
1+ 2	20° 85°	110° 130°	65° 25°	25° 35°	0.47 0.7	> 5 2.0	Plane A, that is the plane designated 1 is the bedding plane. All other planes in the table are near vertical joints, and intersect to form thin elongate wedges. These are unstable except where they sit upon the bedding plane. In this case removal by crow bar is necessary before the batter is safe enough to work or build near. The fracture designated as 3 has a very variable strike (065-100). It is associated with poorly developed shear planes and provides potential toppling failures in the centre of the central batter between EL 120 and EL 130 (See fig.2, Note C).	> 3.75
1 3	20° 75°	110° 175°	55° 65°	25° 35°	0.47 0.7	3.1 0.4		1.74
1 4	20° 90°	110° 090°	70° 20°	25° 25°	0.47 0.47	> 5 2.5		> 3.52
1 5	20° 85°	110° 040°	65° 70°	25° 35°	0.47 0.7	2.7 0.4		1.55
2a 2b	80° 80°	130° 310°	0° 180°	35° 35°	0.7 0.7	> 5 > 5		> 7
2 5	75° 85°	130° 040°	10° 90°	35° 35°	0.7 0.7	<0.3 <0.1		<0.2
3 5	75° 85°	175° 040°	10° 135°	35° 35°	0.7 0.7	0.6 0.5		0.77
5 4	85° 90°	040° 090°	5° 50°	35° 25°	0.7 0.47	0.2 0.2		0.23

Plane A taken as least steep plane. *F.O.S. = A Tan ØA + B Tan ØB. + See Fig.3. for identification and location of planes.

TABLE II LITTLE PARA DAM QUARRY AND WATER TREATMENT WORKS, FRACTURE DESCRIPTION

LOCATION	TYPICAL MEASUREMENTS TAKEN	DESCRIPTION	NOTE
Eastern Regime I	090/90^o 160/75^{o}E Bedding 010/20^{o}E	All joints in dolomite are planar curviplanar, uneven iron stained, tight to open upto 2 mm clay coating Average block sizes are in the range: 0.60 m x 0.50 m x 0.20 m to slabs: 1.40 m x 1.00 m x 0.30 m upto large blocks: 2.20 m x 2.10 m x 0.80 m. and rarely 2.70 m x 2.20 m x 1.70 m the last two sizes will require breakdown before use in the embankment.	
E.L.153-168 Quarry Centre Regime IIA	020/80^{o}NW,020/80^{o}NW,022/75^{o}NW	Planar; uneven; clay coated upto 3 mm; discontinuous, against 090/68^{o}N; iron stained.	SEE NOTE A Fig.2.
	080/80^{o}N,080/78^{o}N,080/80^{o}N	Similar orientation to 090/68^{o}N but not planar uneven, semi continuous, fresh clean.	
E.L.137-153 Quarry Centre Regime IIB	040/75^{o}NW,042/80^{o}NW,040/85^{o}NW	Toppling fracture: planar, smooth-uneven continuous; clean, Tight-open (up to 4 mm) occur, 300 mm - 500 mm apart.	SEE NOTE B Fig. 2
	125/80^{o}SW,126/78^{o}SW,125/81^{o}SW	Form wedges when intersect with above group; planar, discontinuous, open upto 10 mm showing clay coating, carbonate or quartz crystals.	
	070/55^{o}N,070/55^{o}N,068/55^{o}N	Planar, even, thinly clay coated, form very unstable wedges when intersect with above two groups	
Along the Quartzite Outcrop Central. Regime IIC.	010/85^{o}W(dominant fracture) 085/85^{o}N	Planar, uneven, ironstained, clay coated: 1-2 mm semi-continuous.	
	(i) 040/50^{o}N) (ii) 115/75^{o}S) fairly common.Shear pair? Form unstable-wedges where inter-sect.	(i) Planar, smooth, semi continuous, iron stained, slight clay development. (ii) Irregular, uneven, ironstained.	
	095/75^{o}N Shear Zones	Mylonite and clay development	SEE NOTE C Fig.2
	Bedding 170^o/22^{o}E	Curviplanar, uneven, discontinuous closed - tight, rarely open 1-2 mm	
E.L.120-137 Central Regime IIC	005/88^{o}N 000/vertical Bedding 000/12^{o}E		
Western Regime III	085/75^{o}N 000/80^{o}W 170/80^{o}E (rare) Bedding 005/3^{o}E		
East of Centre	060/40^{o}N	Common shallow angle joint spaced 0.30 m - 1.20 m apart planar, continuous, rarely coated. Important in reducing size of unit blocks. Common: 0.40 m x 0.25 m 0.10 m to fist size typical large: 0.80 m x 0.50 m x 0.30 m rare large: 1.80 m x 0.80 m x 0.80 m.	
	115/70^{o}SW		
	040/82^{o}N		
	020/90^o		
West of Centre	090/75^{o}N	Planar - irregular; smooth-uneven, iron-stained, no clay coating, tight - open (4 mm); discontinuous.	
	040/vertical; 040/80^{o}SE, 038/85^{o}NW Bedding 025/30^{o}E	Curviplanar, even; continuous, ironstained no clay coating; tight to open (1mm - 3 mm) Unit block sizes. common: 0.60 m x 0.30 m x 0.15 m to fist size. Typical large: 0.90 m 0.70 m x 0.70 m Rare large: 3.0 m x 2.0 m x 1.0 m	

measured in the laboratory on samples of rock taken from the field (Hoek and Bray, 1974). Two coefficients (A and B) have been previously calculated by Hoek for most combinations of plane intersections. These values can be derived using his graphs substituted in a simple equation with the friction angle. The result gives the factor of safety. Factors of safety above 2 indicate a stable condition able to withstand all but the most severe seismic activity.

Low factors of safety shown in Table I indicate only the instability of small thin slabs of rock (0.70 m x 0.30 m x 0.30 m) and do not indicate the presence of an unstable rock mass.

QUARRY FLOOR FOUNDATION CONDITIONS

The quartzite and dolomite are acceptable as a foundation for that part of the treatment works to be located on berm EL 120. Air track drilling on the EL 110 berm has proven sound bedrock lying 2.0 - 3.0 metres deep below fill, colluvium and highly weathered bedrock (Refer E.W.S. Drawing TR 245, April 1977). If the berm level is reduced from EL 110 to EL 107 nearly all the unacceptable material will be removed. It is strongly advised that the water tanks be placed as far back as possible on the EL 110 berm, away from the EL 110 batter. Rock conditions along the edge of the batter may prove unacceptable for bearing structural loads. Fill covering the EL 110 berm outer edge will have to be excavated and the face of the outer edge cleaned up before a final statement as to its stability is possible.

High loading of berm EL 110 from the water tanks requires the bedrock beneath the water tanks to be sound at depth. For this reason three 10.0 m cored holes were drilled from berm EL 110, these cored holes were located by the design engineer and resident geologist.

The logs of these three cored holes are shown in Appendix I. DH26 indicates acceptable rock conditions at 4.10 metres, DH 27 at 4.30 m and DH 28 at either 1.80 m or 5.0 m depending upon rock conditions exposed after excavation.

Excavation approximately 6.0 m deep and ten metres away from the edge of the EL 110 berm, will be carried out for the pipeline works. This excavation will be nearly all in colluvium and alluvium and will not affect the stability or quality of the foundations for the tanks on berm EL 110.

DISCUSSION OF FURTHER POINTS REQUIRING COMMENT

Tank Underdrainage

The three drill cores show varying rock foundation quality making a tank undergrainage a very sensible precaution. Drainage will help eliminate hydraulic opening of fractures and the possible subsequent erosion of all foundation material other than solid bedrock.

Seismic Activity

Seismic activity is not considered a problem for either foundation or structural design.

Quarry Extension

If future extension of the quarry eastwards is required water treatment structures should be placed at a sufficient distance (approximately 7.0 m) away from the eastern limit of the quarry to allow blasting of the eastern face to be carried out without affecting the existing structures or interfering with the operation of the works.

Alternative Water Tank Site

The alternative site for the water tanks on the opposite side of the river is geologically acceptable providing all high eastern facing cuts are suitably designed, with respect to strata dipping eastward at 20°-35°. Trial excavation will be required before a more detailed geological statement is possible.

Quarry Disposal Area

The usability of the quarry disposal area as a vehicle turning circle and its suitability for placing a 750 mm outlet pipe over it is basically a soils problem. The designer should check whether or not any of the disposal fill has been compacted. Because the disposal area is the site of a small hillside creek drainage of storm water around the disposal area is necessary to decrease the risk of soil movement. Should the disposal area be used as a turning circle then all unsafe boulders should be removed from the steep hillside between the quarry and the disposal area.

fp. J.C. BEAL
GEOLOGIST

9th August, 1977
JCB:JK

REFERENCES

1974, HOEK, E., and BRAY, J. Rock Slope Engineering. Inst. Min. and Metall. London.

APPENDIX I

Diamond Drill Logs DH26, DH27, DH28

DEPARTMENT OF MINES SOUTH AUSTRALIA

LOG OF DIAMOND DRILL HOLE

PROJECT LITTLE PARA DAM	SECTION HUNDRED	HOLE NO. DH 26
FEATURE. FOUNDATION DRILLING	CO-ORDINATES 6151417 ; 290850	SERIAL No
LOCATION QUARRY E.L. 110 BERM	ANGLE FROM HORIZ 90°. DIRECTION	E.L. Surface ~~109.0~~ m
		E.L. Collar 108·98 m
		Datum

DESCRIPTION OF CORE	② GROUP SYMBOL	① STRENGTH TERM (VS S MS W VW SO)	CORE SIZE DEPTH E.L. m	LOG	③ FRACTURE LOG (2 10 50 200)	STRUCTURES JOINTS, VEINS, SEAMS. SHEARED ZONES, CRUSHED ZONES	LIFT CORE LOSS% (10, 5 50)	WATER LEVEL DATE	CASING	DRILL WATER LOSS % (0 100)	WATER PRESSURE TESTS LUGEONS ④ (0.5 1 5 10 50 100)
REGOLITH — COLLUVIUM	ML / CL / GP		0–1			0·92m–1·55m Quartzite (boulder?).					
QUARTZITE BOULDER Cemented colluvium?	GP		1.5–3			2·40m–2·65m. Quartzite brecciated. (Also at 3·10–3·12m).					
	ML / GP		3								
TORRENSIAN SERIES : BURRA GROUP — AUBURN DOLOMITE — SHALY DOLOMITE Highly weathered – completely weathered	ML		3.5–4			3·76m–4·00m. Quartz vein.					
SHALY DOLOMITE Moderately weathered medium strength. Pale grey-brown with wispy shale lenses 1mm–4mm thick.	GP		4–5								
	ML		5.5			5·54m–5·57+m (3mm thick) Silty seam. Bedding plane 5°–10° to core axis at 2mm–3mm apart. Planar, smooth–uneven, micaceous.					
SHALY SILTSTONE/SANDSTONE Moderataly weathered			9.4–10			Sandstone lenses. 9·60m to 9·70m. 9·72 m. to 9·76m. 9·79 m. to 9·84m. 9·95m. to 10·0m.					

50 10 2 0.5 length of core in cm

① ROCK SUBSTANCE

STRENGTH TERM
- VS-Very Strong
- S-Strong
- MS-Medium Strong
- W-Weak
- VW-Very Weak
- SO-Soil properties

CONDITION TERM
- Fresh
- Weathered
- Altered
- Not Applicable

③ FRACTURE LOG

2 10 50 200 Natural fractures per metre of core

50 10 2 0.5 Equivalent length of core in cm

④ (350) Maximum effective pressure (kilopascals) reached during test.

Min: Minimum value.

② Substances with soil properties remoulded and classified by Unified System.

ENGINEERING GEOLOGY SECTION	
DRILL No.	LOGGED J.C. Beal
TYPE E 1000	
DRILLER J. JENSEN.	DATE 11-7-77.
START.	TRACED
FINISH	CHECKED
SHEET 1 OF 1	DRG. No. S12980

6628 III

DEPARTMENT OF MINES SOUTH AUSTRALIA

LOG OF DIAMOND DRILL HOLE

HOLE NO.	DH 27
SERIAL No	

PROJECT. LITTLE PARA DAM

FEATURE. FOUNDATION DRILLING

LOCATION QUARRY E.L. 110 BERM

SECTION — HUNDRED

CO-ORDINATES 6151428, 290912

ANGLE FROM HORIZ. 90°. DIRECTION

E.L. Surface ~~110.8~~ m

E.L. Collar 110.19 m

Datum

DESCRIPTION OF CORE	② GROUP SYMBOL	① STRENGTH TERM (VS S MS W VW SO)	CORE SIZE / DEPTH E.L. m	LOG	③ FRACTURE LOG (2 10 50 200)	STRUCTURES JOINTS, VEINS, SEAMS, SHEARED ZONES, CRUSHED ZONES	LIFT CORE LOSS% (10 / 5 50)	WATER LEVEL DATE	CASING	DRILL WATER LOSS % (0 100)	④ WATER PRESSURE TESTS LUGEONS (0.5 5 10 50 100)
REGOLITH — COLLUVIUM Clay, silt, gravel, quartzite boulders.	ML/CL		0–1								
			1–2			1.32 - 1.58 m. Quartzite (boulder).					
	ML/CL		2			2.45m - 2.62m. Quartzite (boulder).					
	ML/CL		3			3.45m. - 3.80m. Quartzite (boulder).					
	ML/CL/GP		4								
TORRENSIAN SERIES : BURRA GROUP. AUBURN DOLOMITE — SHALY DOLOMITE Highly weathered to completely weathered.	ML/GP		5–6								
SHALY DOLOMITE (PHYLLITIC DOLOMITE) Moderately weathered Medium strength Pale grey-brown - green wispy lenses 1m.m. - 3m.m. thick.			6–7			6.36m - 6.44m. Vuggy quartz vein.					
	GP/ML		7			6.83m. - 6.85m. Shear zone?					
						6.89m. - 6.93m. Quartz vein					
			8			7.90m. - 7.98m. Vuggy quartz vein. Shear zone.?					
						8.43 - 8.47 / 8.53 - 8.55 } Quartz vein.					
	GP		9–10			9.50m - 9.66m - quartz vein. Shear zone					

50 10 2 0.5 length of core in cm

① ROCK SUBSTANCE

STRENGTH TERM
- VS-Very Strong
- S-Strong
- MS-Medium Strong
- W-Weak
- VW-Very Weak.
- SO-Soil properties

CONDITION TERM
- Fresh
- Weathered
- Altered
- Not Applicable

② Substances with soil properties remoulded and classified by Unified System

③ FRACTURE LOG

2 10 50 200 Natural fractures per metre of core

50 10 2 0.5 Equivalent length of core in cm

④ (350) Maximum effective pressure (kilopascals) reached during test.

Min. = Minimum value.

ENGINEERING GEOLOGY SECTION

DRILL No.	LOGGED J.C. Beal
TYPE. E.1000.	DATE 11-7-77
DRILLER J. Jensen	TRACED J.W.
START.	CHECKED
FINISH	
SHEET 1 OF 1.	DRG. No. S12981

6628-III

DEPARTMENT OF MINES SOUTH AUSTRALIA

LOG OF DIAMOND DRILL HOLE

PROJECT. LITTLE PARA DAM.
FEATURE. FOUNDATION. DRILLING.
LOCATION QUARRY E.L. 110. BERM

SECTION
HUNDRED
CO-ORDINATES 616417, 290 850
ANGLE FROM HORIZ. 90°
DIRECTION

HOLE NO. DH28
SERIAL No
E.L. Surface ~~113.7~~ m
E.L. Collar. 113.09 m
Datum

DESCRIPTION OF CORE	② GROUP SYMBOL	① STRENGTH TERM (VS S MS W VW SO)	CORE SIZE DEPTH E.L. m	LOG	③ FRACTURE LOG (2 10 50 200)	STRUCTURES JOINTS, VEINS, SEAMS, SHEARED ZONES, CRUSHED ZONES	LIFT CORE LOSS% (10 5 50)	WATER LEVEL DATE	CASING	DRILL WATER LOSS % (0 100)	WATER PRESSURE TESTS LUGEONS (0.5 1 5 10 50 100) ④
REGOLITH: 'A' HORIZON.											
'B/C' HORIZON.			1								
TORRENSIAN SERIES : BURRA GROUP — DOLOMITE: SHALY DOLOMITE. Highly weathered to moderately weathered weak; pale yellow brown			2								
		CORE		LOSS							
	G.P		3			Fissile bedding planes 3mm (2mm-5mm.) apart; planar, smooth, 5°-10° off rt. ∠'s to core axis.					
		CORE	4	LOSS							
	G.P										
		CORE		LOSS							
	ML/CL		5								
	GP										
	GP/ML		6								
	GP/ML		7								
SHALY DOLOMITE W; MS. Pale grey.			8								
			9								
SILICOUS SILTSTONE QUARTZITE	GP		10								

① ROCK SUBSTANCE
STRENGTH TERM
VS-Very Strong
S-Strong
MS-Medium Strong
W-Weak
VW-Very Weak
SO-Soil properties

CONDITION TERM
Fresh
Weathered
Altered
Not Applicable

② Substances with soil properties remoulded and classified by Unified System

③ FRACTURE LOG
50 10 2 0.5 length of core in cm
2 10 50 200 Natural fractures per metre of core
50 10 2 0.5 Equivalent length of core in cm

④ (350) Maximum effective pressure (kilopascals) reached during test.
Min. = Minimum value.

ENGINEERING GEOLOGY SECTION

DRILL No.
TYPE. E 1000
DRILLER J. Jensen
START.
FINISH

LOGGED J.C. Beal
DATE 11-7-77
TRACED
CHECKED

SHEET 1 OF 1. DRG. No. S12982

6628-III

APPENDIX II

Photographs

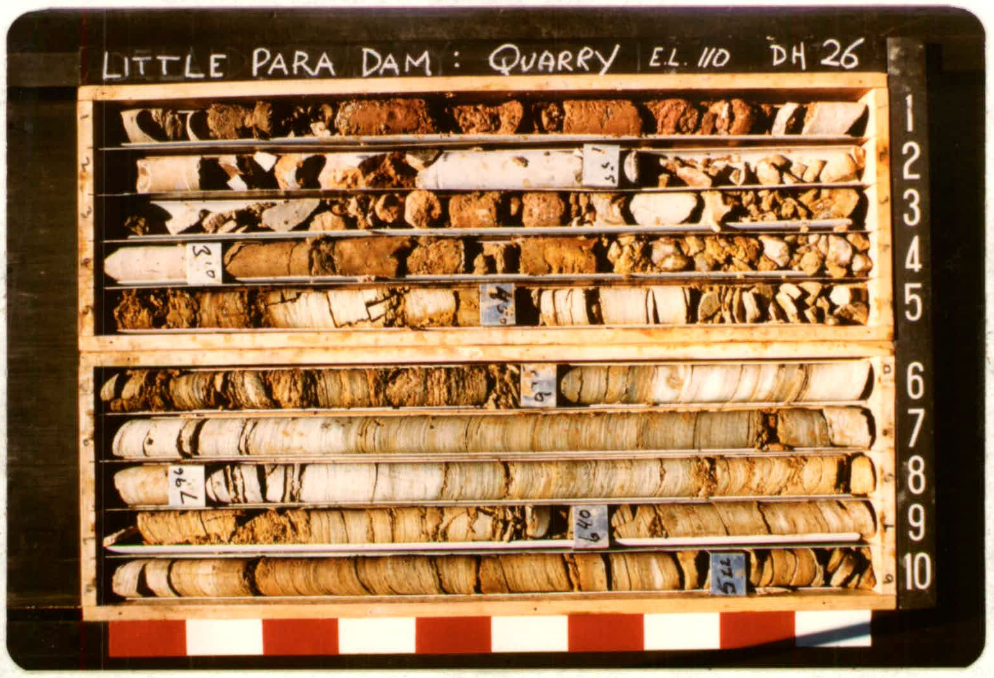


PLATE 1 **Drill Core DH26 0.0 m - 10.0 m**

Wrong Way Round.

PLATE 2 **Drill Core DH27 0.0 m - 10.0 m**

PLATE 3 Drill Core DH28 0.0 m - 10.0 m

PLATE 4 View of Quarry Showing Berm EL 110

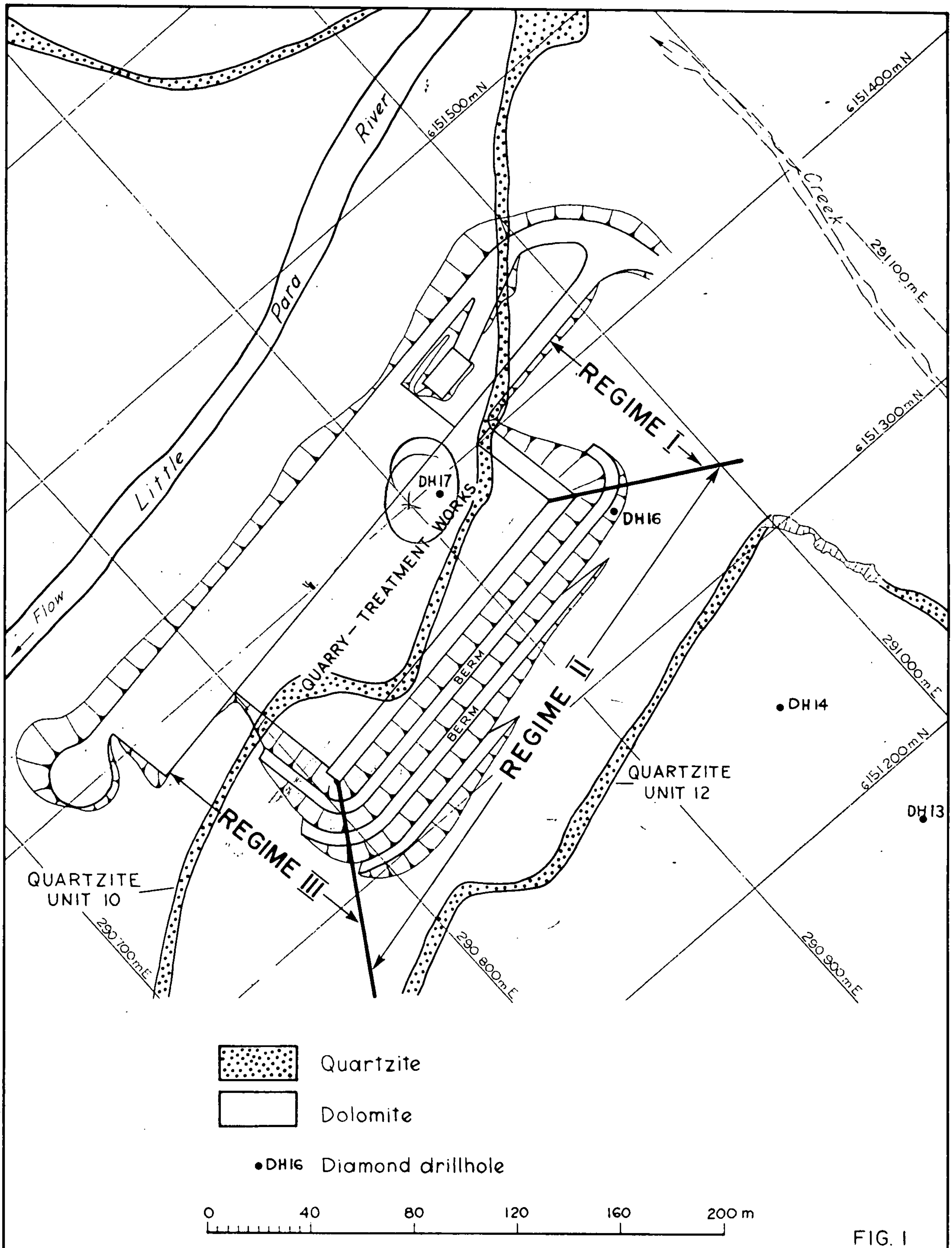


FIG. 1

ENGINEERING SERVICES	DEPARTMENT OF MINES – SOUTH AUSTRALIA	SCALE 1:2000
COMPILED: J C Bea	LITTLE PARA DAM – WATER TREATMENT WORKS	DATE 28·6·77
DRN: A F / CKD.	SLOPE STABILITY ANALYSIS	PLAN NUMBER
	REGIME LOCATIONS	S 12760

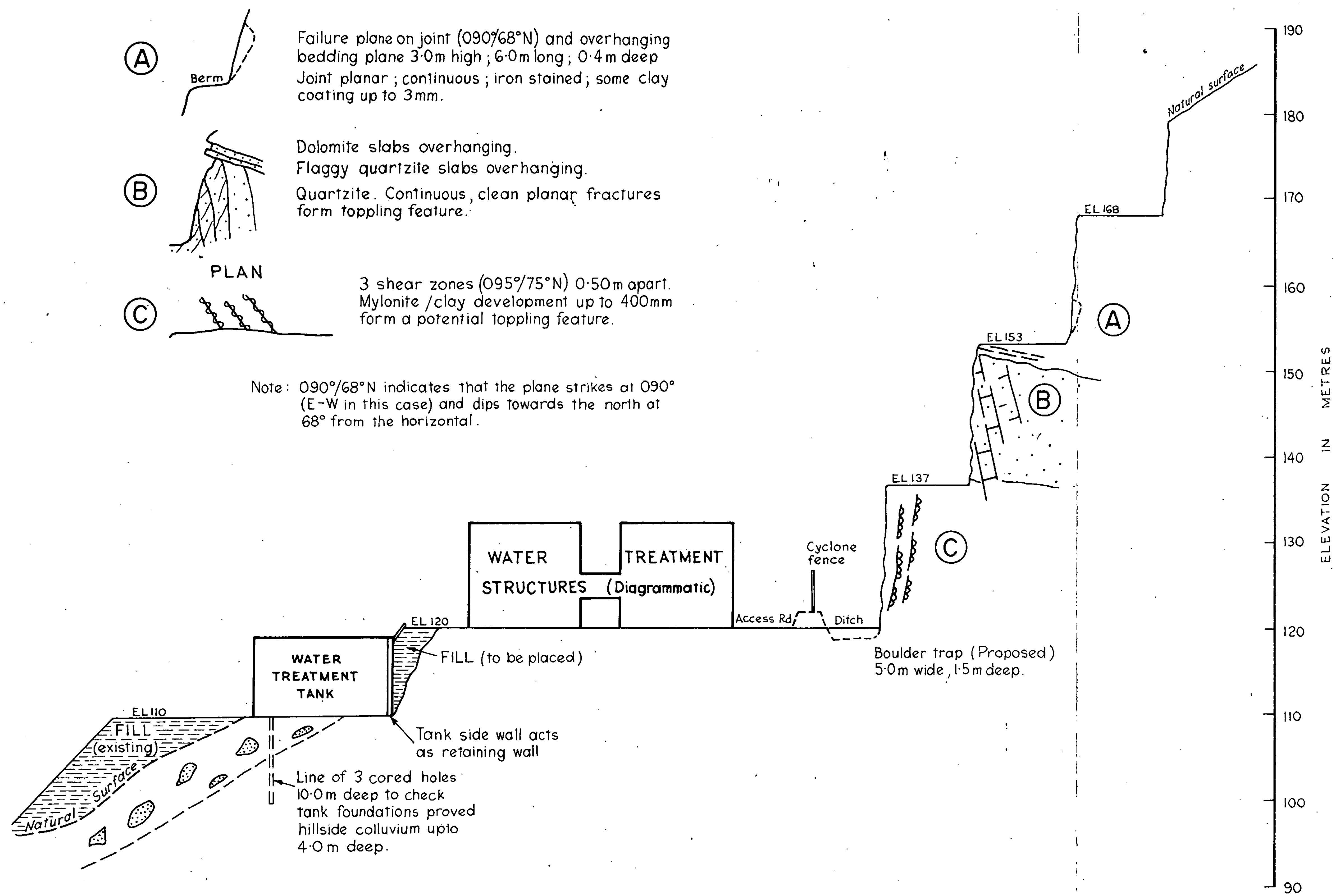
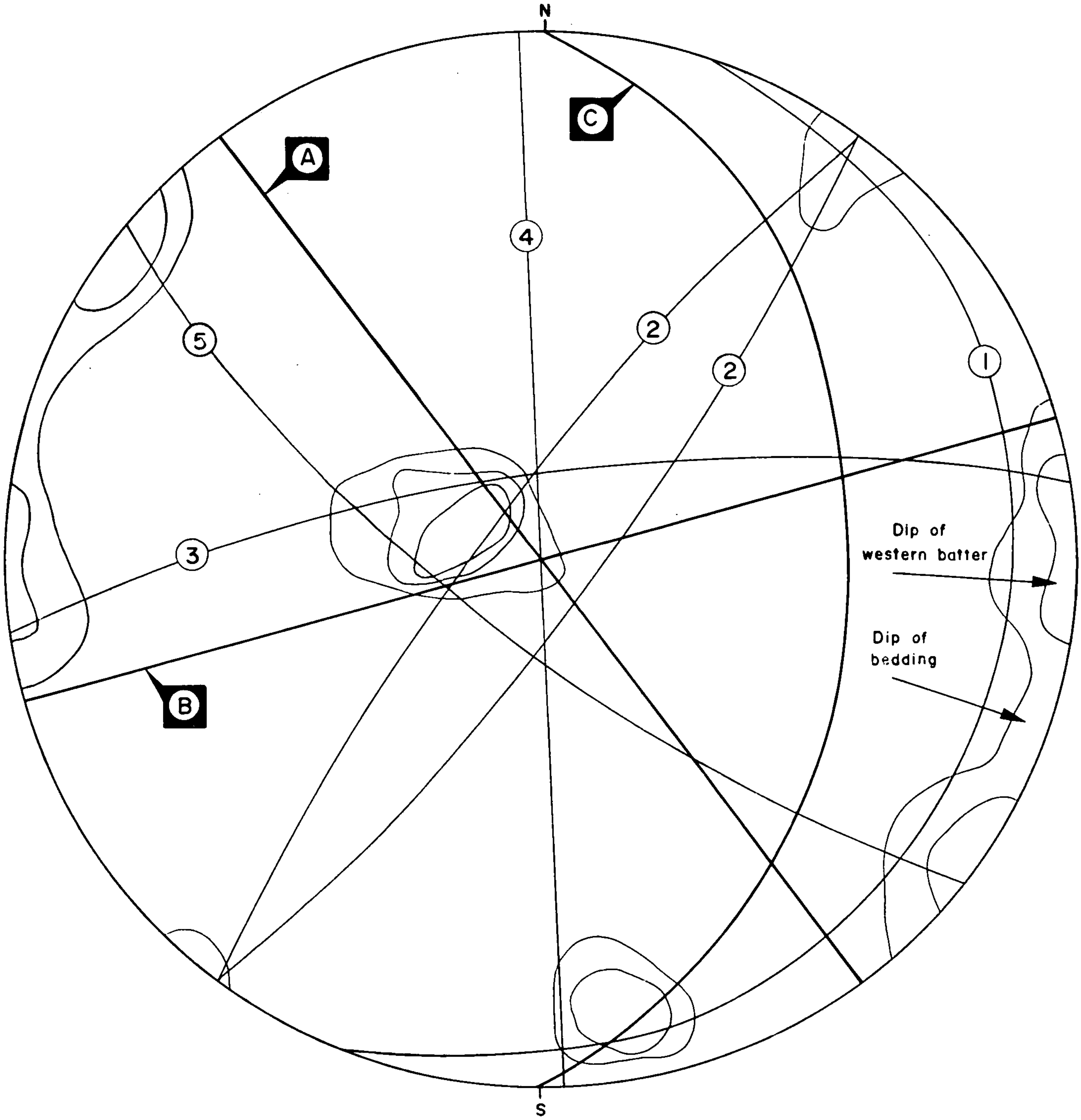


FIG. 2

ENGINEERING SERVICES	DEPARTMENT OF MINES – SOUTH AUSTRALIA	SCALE 1:500
COMPILED. J.C. Beal	LITTLE PARA DAM MAIN QUARRY AND WATER TREATMENT WORKS	DATE 30·6·77
DRN. A.F. CKD	SLOPE STABILITY ASSESMENT – QUARRY PROFILE	PLAN NUMBER 77-595



(1) Bedding plane.

(2) Near vertical joints in quartzite and dolomite.

(3) Steep joints mainly found in quartzite and associated with shear zone.

(4) Vertical joints mainly found in dolomite.

(5) Near vertical joint mainly found in quartzite.

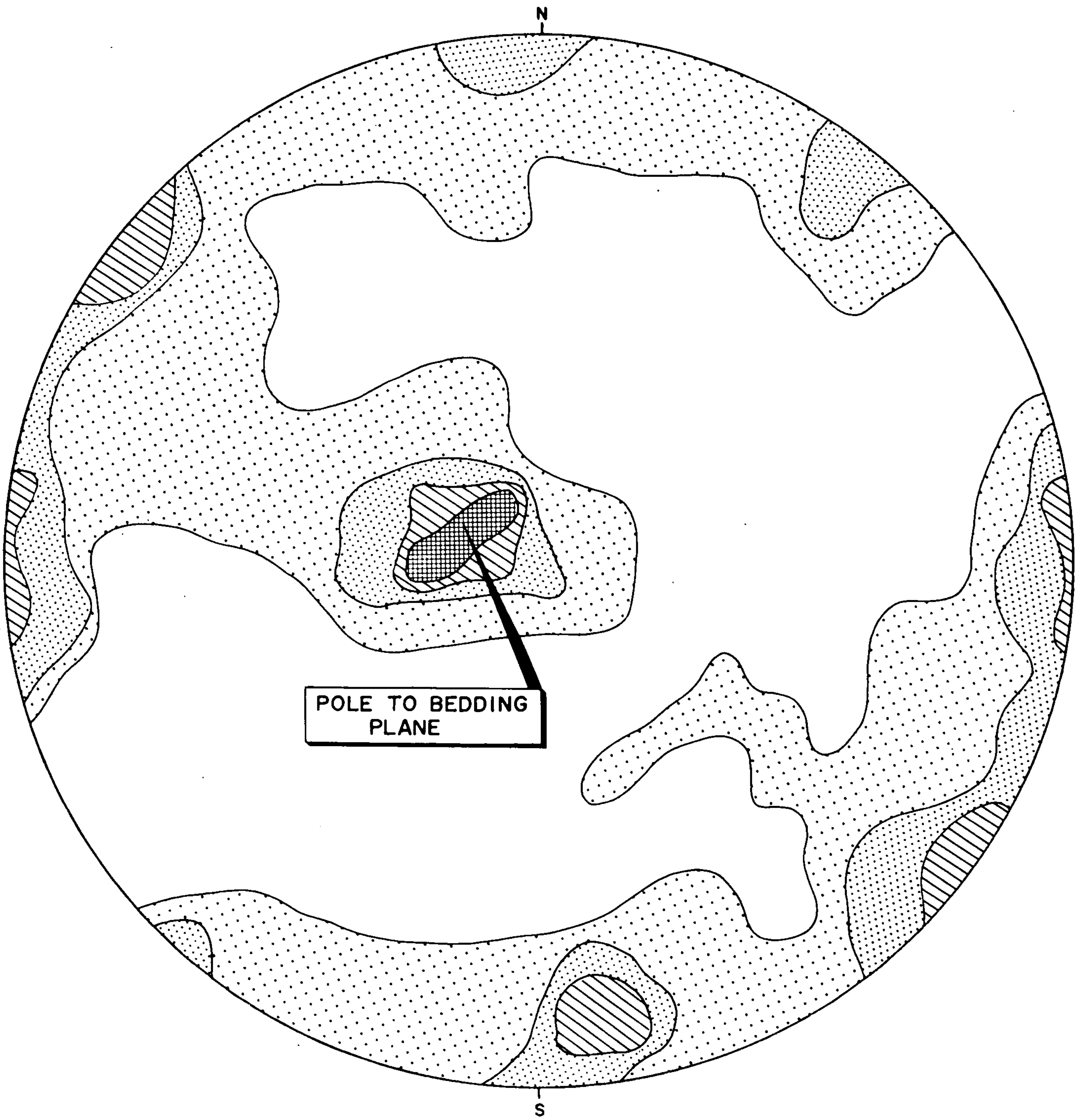
(A) EASTERN BATTERS VERTICAL

(B) CENTRAL BATTERS VERTICAL

(C) WESTERN BATTERS 40°–45°

FIG. 3

ENGINEERING SERVICES	DEPARTMENT OF MINES – SOUTH AUSTRALIA	SCALE —
COMPILED J.C. Beal	LITTLE PARA DAM – WATER TREATMENT WORKS SLOPE STABILITY ANALYSIS	DATE 30-6-77
DRN N.S. | CKD	STEREOGRAPHIC REPRESENTATION OF RELATIONSHIP BETWEEN FRACTURE POLES, FRACTURE PLANES AND QUARRY BATTER PLANES	PLAN NUMBER S 12761

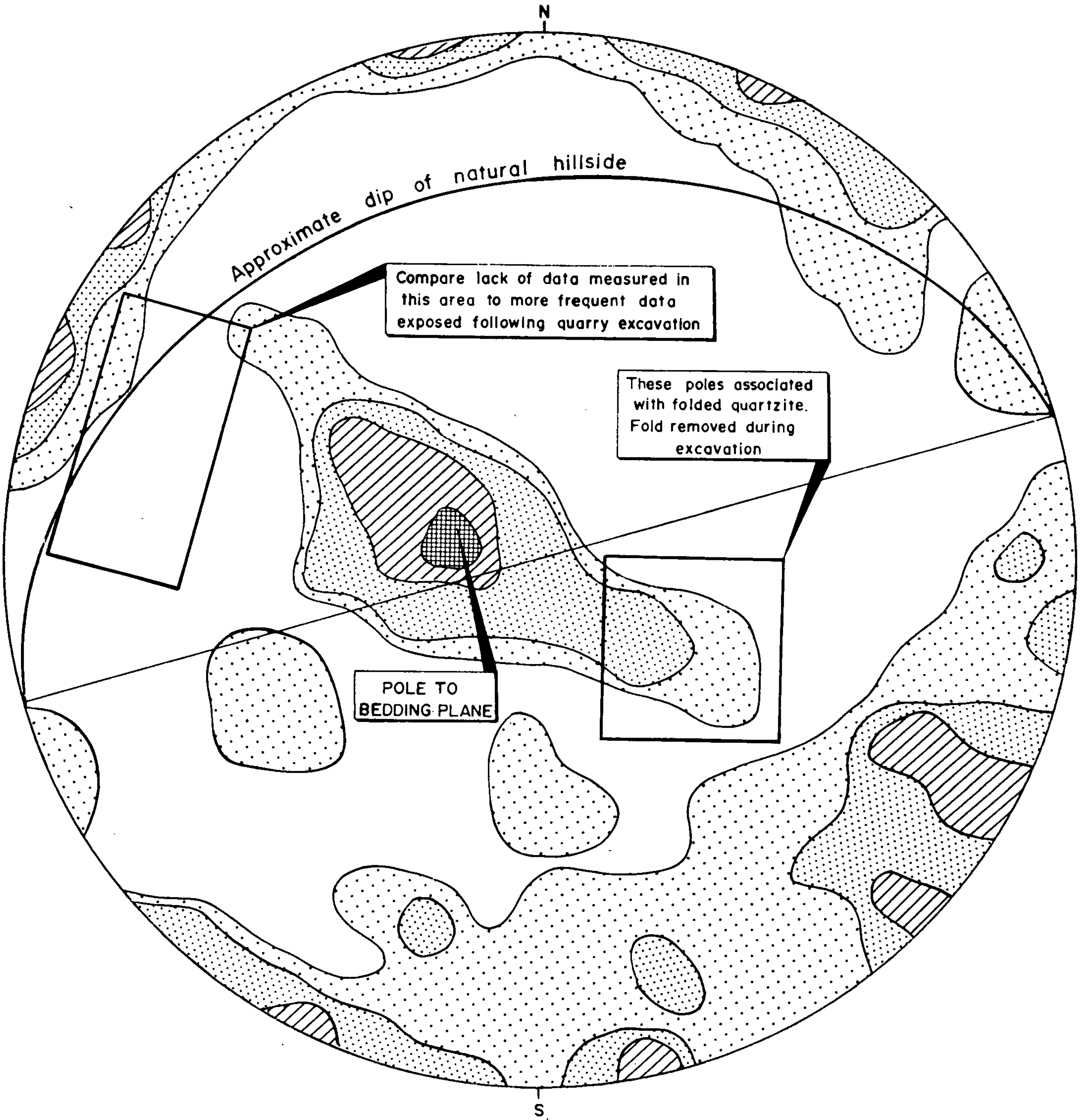


TOTAL POLES 140

1–4	(3%)	
5–9	(6·5%)	
10–14	(10%)	
>14	(>10%)	

FIG. 4

ENGINEERING SERVICES	DEPARTMENT OF MINES – SOUTH AUSTRALIA	SCALE —
COMPILED J.C. Beal	LITTLE PARA DAM – WATER TREATMENT WORKS SLOPE STABILITY ANALYSIS STEREOGRAPHIC PROJECTION OF CONTOURS ON POLES OF JOINTS AND BEDDING PLANES	DATE 30-6-77
DRN N.S. CKD		PLAN NUMBER S 12762



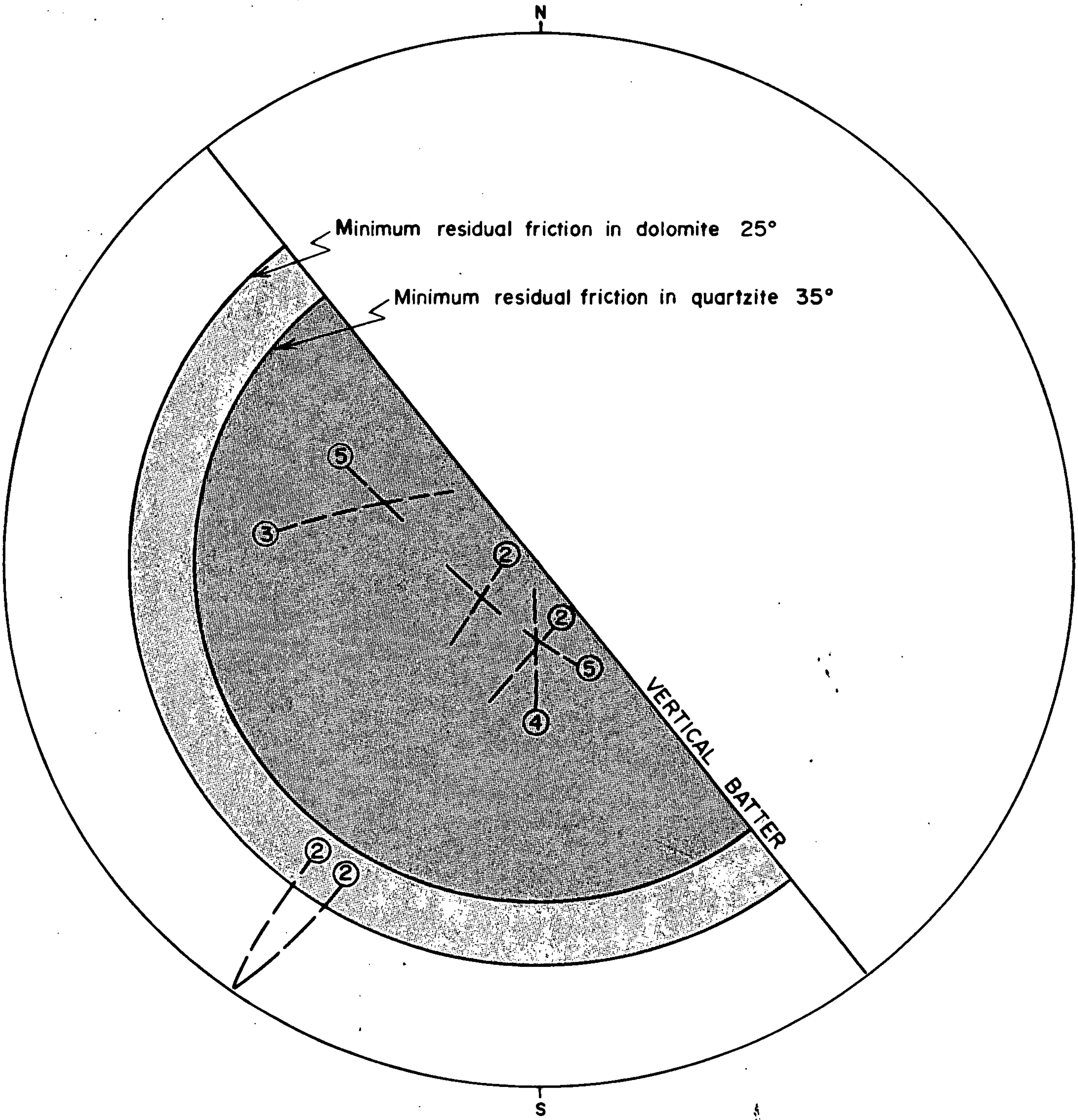
TOTAL POLES 80

4–8	(5–10%)	
8–16	(10–20%)	
16–20	(20–25%)	
>20	(>25%)	

FIG. 5

TAKEN FROM NATURAL OUTCROP PRIOR TO QUARRY EXCAVATION 1975

ENGINEERING SERVICES	DEPARTMENT OF MINES – SOUTH AUSTRALIA	SCALE —
COMPILED J.C. Beal	LITTLE PARA DAM – WATER TREATMENT WORKS SLOPE STABILITY ANALYSIS STEREOGRAPHIC PROJECTION OF CONTOURS ON POLES OF JOINTS AND BEDDING PLANES	DATE 30-6-77
DRN N.S. CKD		PLAN NUMBER S 12763



NO LARGE SCALE INSTABILITY

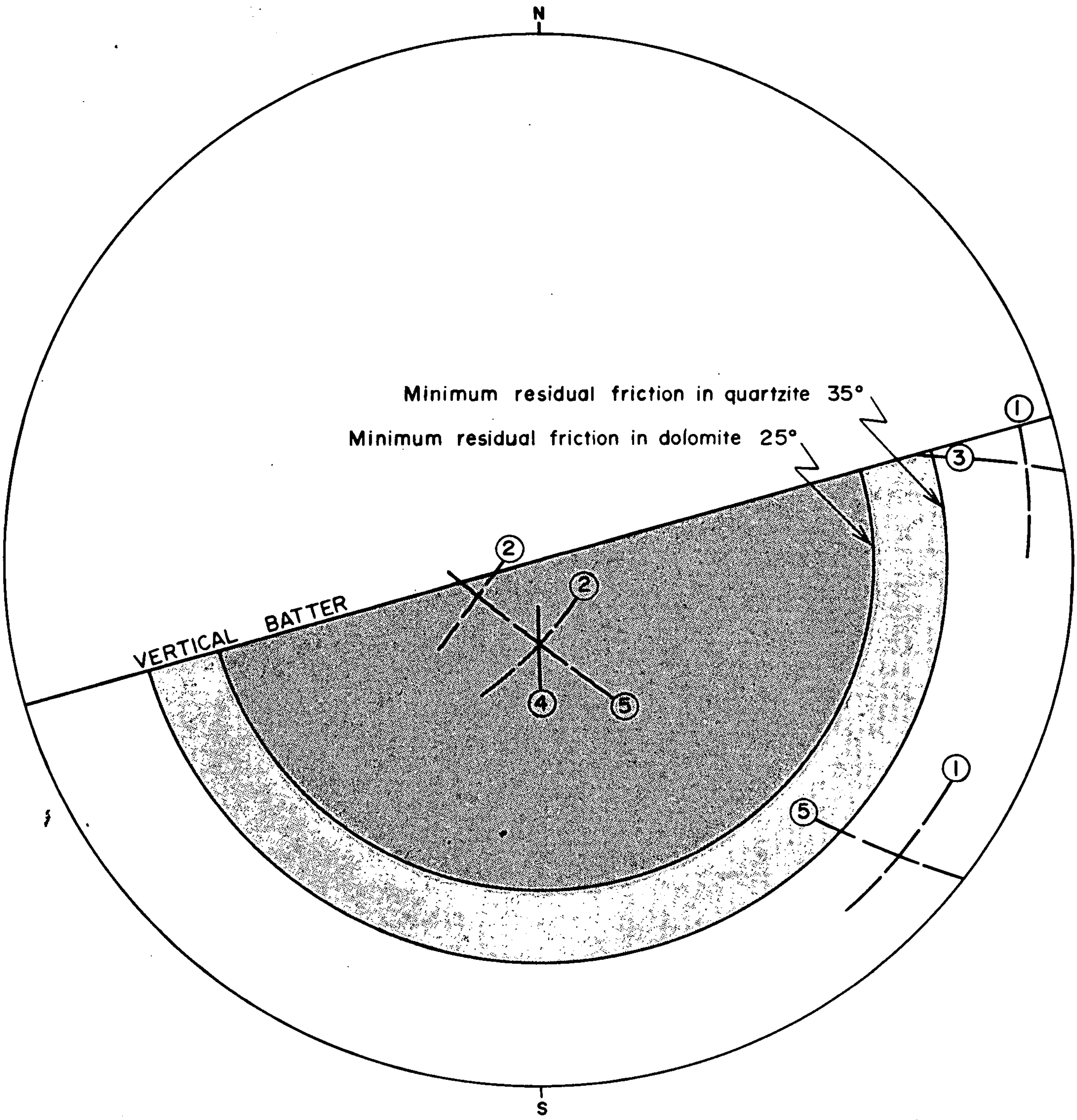
FAILURE MODE	FRACTURE INTERSECTIONS
Small wedge-blocks	5 and 3 ; 2 and 5 ; 5 and 4

Intersections falling within shaded areas form potentially unstable wedges.

(from HOEK AND BRAY 1974)

FIG. 6

ENGINEERING SERVICES	DEPARTMENT OF MINES – SOUTH AUSTRALIA		SCALE —
COMPILED: J.C. Beal		LITTLE PARA DAM – WATER TREATMENT WORKS SLOPE STABILITY ANALYSIS STEREOGRAPHIC PROJECTION SHOWING INTERSECTION OF JOINTS – EASTERN QUARRY BATTER	DATE 30-6-77
DRN. N.S.	CKD		PLAN NUMBER S 12764



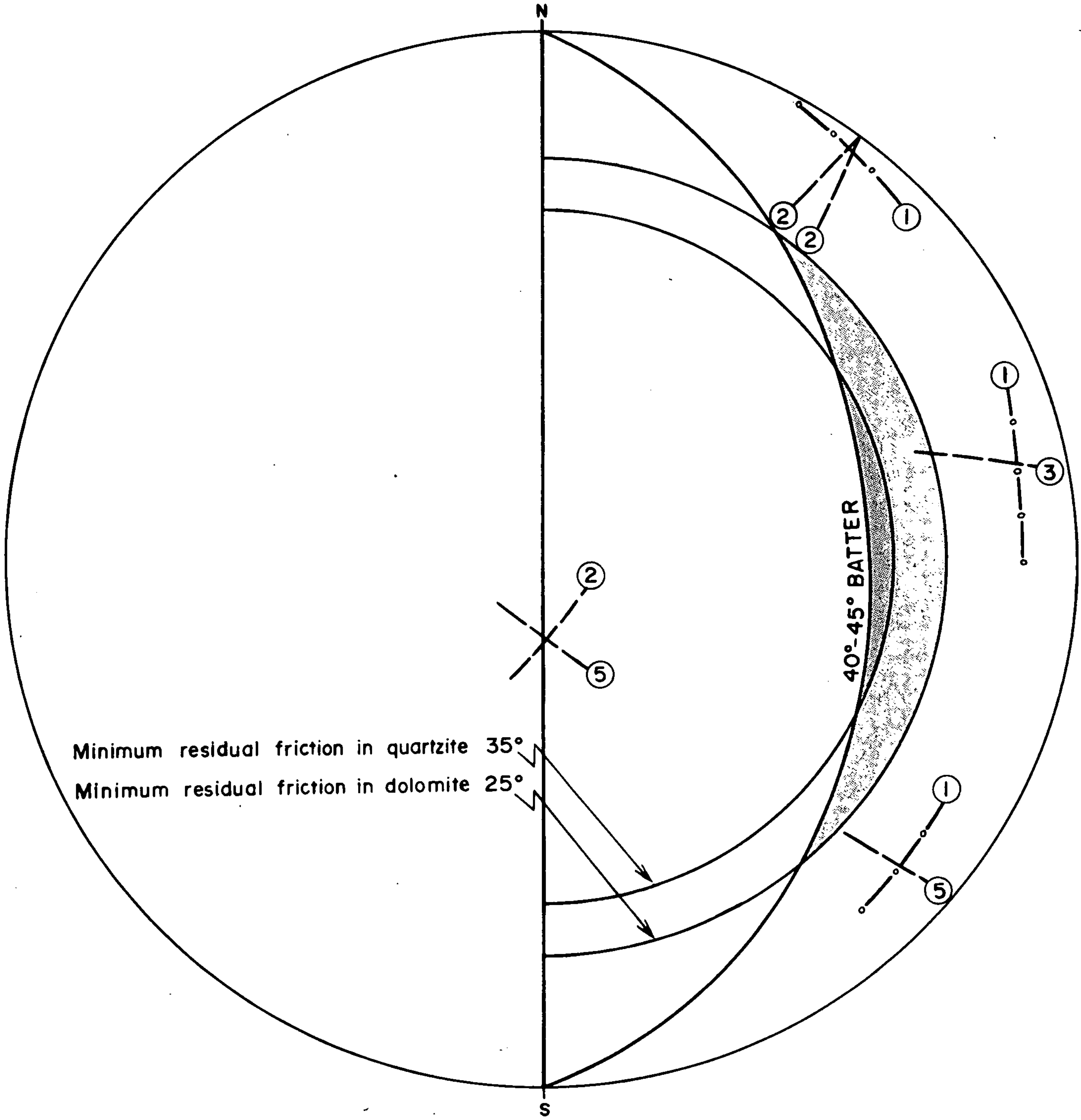
FAILURE MODE	FRACTURE INTERSECTIONS
Wedge failure of small blocks	2 and 5 ; 4 and 5

Intersections falling within shaded areas forms potentially unstable wedges.

(from HOEK AND BRAY 1974)

FIG. 7

ENGINEERING SERVICES	DEPARTMENT OF MINES – SOUTH AUSTRALIA	SCALE —
COMPILED: J.C. Beal	LITTLE PARA DAM – WATER TREATMENT WORKS SLOPE STABILITY ANALYSIS STEREOGRAPHIC PROJECTION OF THE INTERSECTION OF JOINTS AND BEDDING PLANE – CENTRAL QUARRY BATTER	DATE 30-6-77
DRN: N.S. CKD.		PLAN NUMBER S 12765



All intersections form stable blocks.

Intersections falling within shaded areas form potentially unstable wedges.

(from HOEK AND BRAY 1974)

FIG. 8

ENGINEERING SERVICES	DEPARTMENT OF MINES – SOUTH AUSTRALIA	SCALE —
COMPILED: J.C. Beal	LITTLE PARA DAM – WATER TREATMENT WORKS SLOPE STABILITY ANALYSIS STEREOGRAPHIC PROJECTION OF THE INTERSECTION OF JOINTS AND BEDDING PLANE – WESTERN QUARRY BATTER	DATE 30-6-77
DRN N.S.	CKD.		PLAN NUMBER S 12766