

1982/33. Preliminary site investigation of a proposed reservoir at Heybridge, north-west Tasmania

R.C. Donaldson  
W.R. Moore

#### Abstract

The proposed site of a 35 m diameter tank reservoir for the town of Heybridge was investigated. The site is 58 m above sea level on an 18° slope above the Bass Highway. There are no rock outcrops at the site. Access problems made subsurface investigation such as trenching with a backhoe difficult. A seismic refraction survey was undertaken on the site, combined with a slope stability analysis of a 20 m high cutting in the sediments of the Burnie Formation at the base of the spur on which the reservoir is to be sited. The seismic survey indicates that these type of sediments underlie the proposed site, with the possible presence of an unknown thickness of talus. A 12 - 13 m high rock face with a 55° slope is recommended if the geological conditions are similar to the Bass Highway cutting.

#### INTRODUCTION

The North West Regional Water Authority requested the Department of Mines to advise on the geological suitability of a proposed reservoir site at Heybridge, north-west Tasmania [DQ157517]. Initially, the Authority indicated two sites that were under consideration, but required that only one of these be investigated.

The proposed reservoir is to be sited on the slopes above the Bass Highway approximately one kilometre east of Heybridge (fig. 1). It is to be a concrete structure of 35 m diameter, 6 m high, having a capacity of 5 Ml and a formation level of 58 m above sea level. Ground pressures when full would be in the order of 6 kPa.

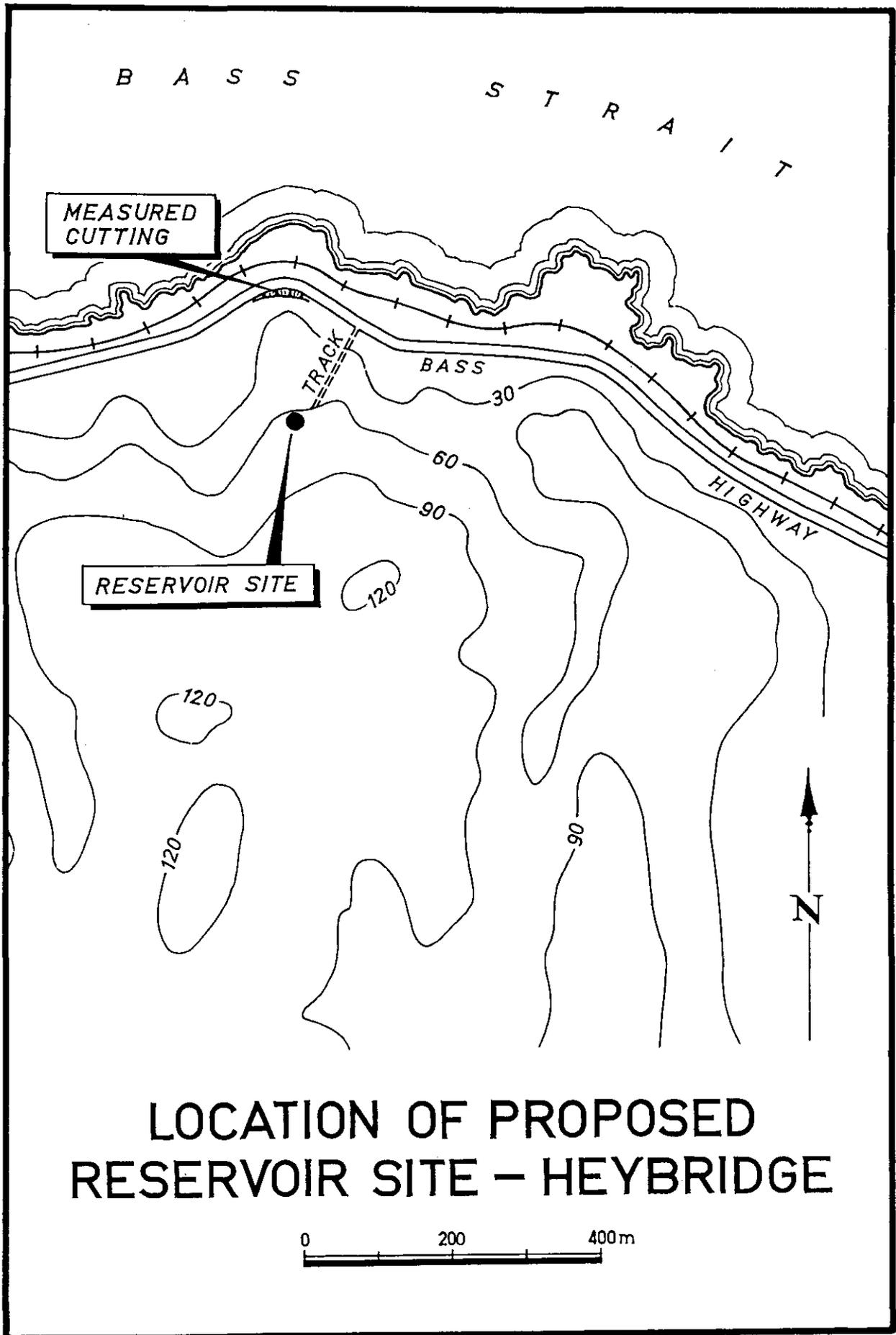
Unfavourable terrain and site conditions prevented the ready access of machinery to the site for trenching, and it was decided to employ geophysical methods as the preliminary investigation tool.

The investigation involved a reconnaissance seismic refraction survey in conjunction with an assessment of the rock conditions and stability of existing cuttings in the nearby area.

#### REGIONAL GEOLOGY

The Burnie Sheet of the One Mile Geological Atlas Series (Gee et al., 1968) shows that the reservoir site is underlain by the quartzite and slate of the Burnie Formation. These rocks are of Precambrian age and have been complexly and closely folded into a sequence of alternating slaty mudstone with siltstone and sandstone.

Exposures in nearby road cuttings on both the Bass Highway and Cuprona Road confirm the presence of these rocks in the area. The site itself was covered by a sandy silt (ML) containing rock fragments composed mainly of quartzite and siltstone.



# LOCATION OF PROPOSED RESERVOIR SITE - HEYBRIDGE

Figure 1

SEISMIC REFRACTION SURVEY

*Survey details*

Control for the survey was provided by a survey peg marking the centre of the site; flagging was used to indicate the approximate outline of the proposed reservoir.

Four seismic spreads were fired using a twelve-channel Nimbus seismograph. The spreads were fired from both ends using gelignite and seismic boosters with electric detonators. Geophone spacing was nominally set at 2.5 m but reduced to a combination of 1.0 m and 2.0 m intervals for the weathering spread. The location of the spreads is shown on Figure 2.

*Survey constraints and limitations*

Survey conditions were far from ideal. The site lies on a narrow ridge with slopes down to the Bass Highway of between 14° and 18°; the flanks of the ridge, in particular the eastern flank segment, fall away rapidly at angles of up to 20°. This placed limitations on the effective lateral and vertical coverage that each spread could achieve due to constraints of geophone spacing and shot point positions.

It is stressed that the survey, because of its limited coverage, is only reconnaissance in nature and aims only to provide seismic velocities as a general guide for the interpretation of the nature and types of the subsurface materials.

Similarly, depth determinations are to be regarded only as approximate; the method used to calculate the depth to the various velocity layers was that of critical distances.

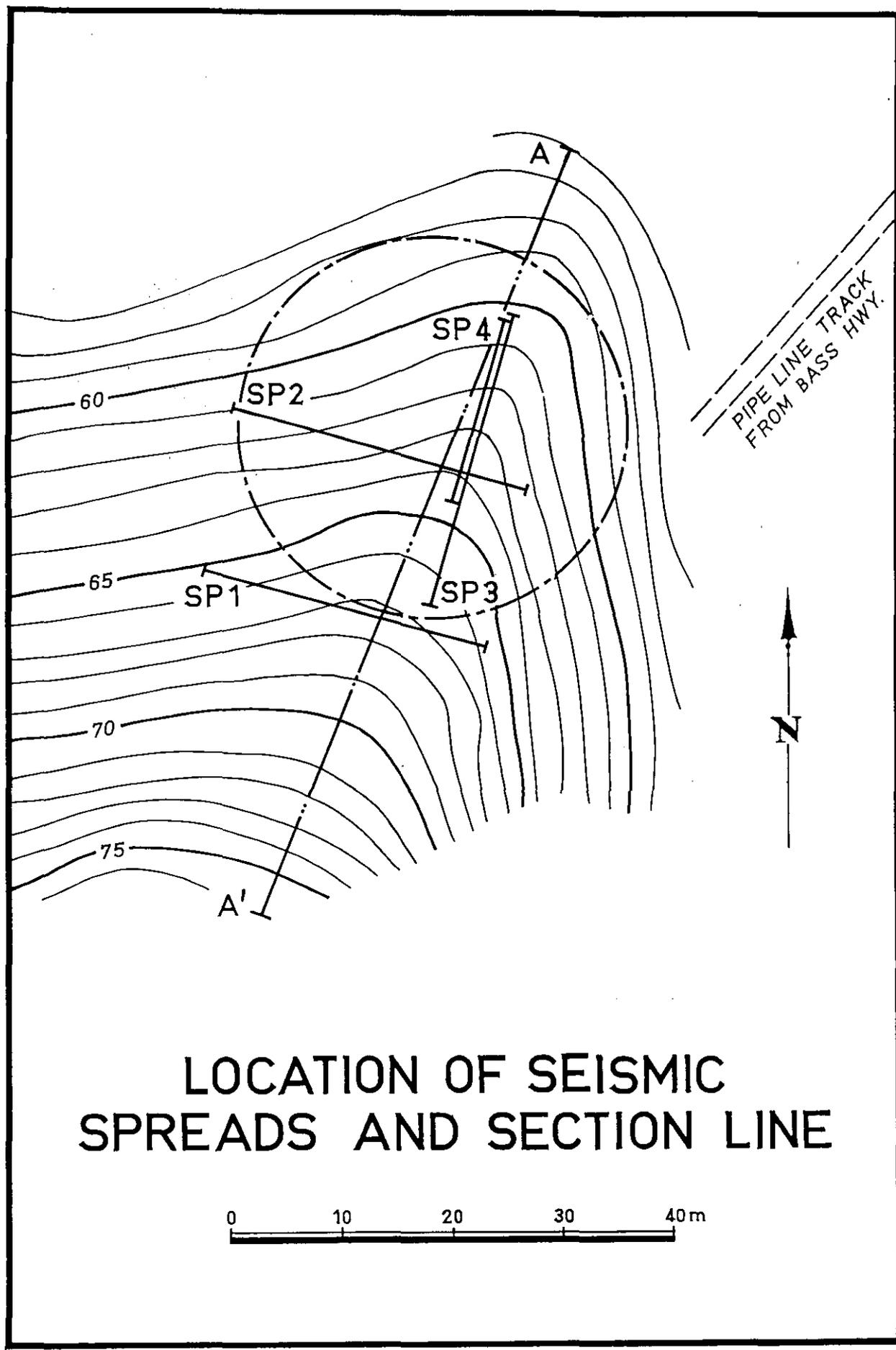
Thus the results should not be used for tendering purposes involving costings for the amount of material to be removed from the proposed excavation by scraping, ripping, or blasting; the survey's coverage is too limited for this type of detail.

*Interpretation of seismic velocities*

With the exception of the weathering spread, four velocity layers were distinguished in all spreads. The time-distance (velocity) plots are basically symmetrical, but are typically stepped and inverted in the higher velocity layers, making interpretation more difficult. A summary of the results of the seismic refraction survey are given in Table 1.

Table 1. SEISMIC VELOCITIES AND GEOLOGICAL INTERPRETATION

<i>Seismic velocity (m/s)</i>	<i>Layer thickness (m)</i>	<i>Interpreted material</i>
350 - 450 (V <sub>0</sub> )	1.0 - 2.5	Unconsolidated surface layer - topsoil with associated clay and weathered rock fragments
500 - 1000 (V <sub>1</sub> )	5.5 - 7.0	(1) Talus deposits (2) Extremely weathered to highly weathered rock - dominantly quartzite and slate (bedrock)
1400 - 2100 (V <sub>2</sub> )	9.0 - 12.0	Highly weathered to slightly weathered bedrock
5000 (V <sub>3</sub> )	-	Fresh hard bedrock



# LOCATION OF SEISMIC SPREADS AND SECTION LINE

0 10 20 30 40 m

5 cm

Figure 2

One major uncertainty in the interpretation is the nature of the materials in the  $V_1$  (500 - 1000 m/s) velocity layer. Talus deposits overlying quartzite and slate in the Round Hill quarries at Burnie have velocities in the range of 600 - 900 m/s (Moore, 1976a; 1977). These deposits are up to several metres thick and are known to extend up the slope to beyond the 60 m contour. Alternatively, these velocities could equally well represent extremely to highly weathered, weak, *in situ* rock with open jointing. This apparent anomaly will have little effect on the final conclusions on the suitability of the site and can be best resolved during the cutting of access tracks prior to commencement of site works.

The stepping effect and reversals of the velocity profiles suggest an irregular surface between the  $V_1/V_2$  and  $V_2/V_3$  seismic interfaces. A layered situation is indicated by the  $V_2$  layer of the plots - one may expect an alternating sequence of differentially weathered quartzite and slate.

The results indicate that the water table lies below the  $V_1$  velocity layer; the depth to the water table is not known.

*Rippability and excavation conditions*

It is estimated that between 7000 m<sup>3</sup> and 9000 m<sup>3</sup> of material will be excavated in preparation for the proposed reservoir, depending on the final angle of the cut face.

Material in the top or surface ( $V_0$ ) layer can be readily removed by light machinery such as backhoe or scrapers with little difficulty.

The second ( $V_1$ ) velocity layer, whether it be a talus deposit or extremely to highly weathered bedrock, could be removed by bulldozing with little or no ripping.

In the third layer ( $V_2$ ) the rock condition is likely to vary considerably between a highly weathered state as indicated by the lower end of the velocity range to a slightly weathered condition as reflected by the top end of the range. Most of this layer should be rippable using heavy machinery, but blasting may be required for the less weathered higher velocity material.

Moore (1976a) reported that the weathered quartzite and slate in the Round Hill quarries with velocities of 1300 - 1700 m/s would be rippable. Further work by Moore (1977) showed that the benches in Holloway's Quarry at Round Hill, with velocities averaging 2100 m/s, had been cut by bulldozer, and that explosives had not been used.

Ultimately, the frequency and attitude of discontinuities, and the degree of interbedding of the less competent slate/mudstone beds with the quartzite will determine the amount of rippable material.

SLOPE STABILITY ANALYSIS

A series of outcrops occur down Cuprona Road from the reservoir site to the Bass Highway. Although these outcrops are too small and too weathered to be used in slope analysis, they do show that the type of folding and type of sediment that occur in the Bass Highway cuttings in the Burnie Formation are likely to occur at the proposed reservoir site. Therefore any structural slope analysis applied to the cutting on the same spur as the reservoir site is likely to apply to the rock face cut at the proposed reservoir site.

From previous investigations in the Burnie Formation rocks at Round Hill (Moore, 1976a; 1977), Cam River (Moore, 1976b), and other quarries it appears that joint relaxation in these sediments makes it possible to rip with heavy machinery to a considerable depth in well bedded and well jointed quartzite, argillite, and slate. In the weathered and unweathered competent rocks, joint relaxation makes for slope stability problems, which in the weathered zone are mainly fretting failures. Wedge failures become common in the less weathered and unweathered rocks, and with certain face orientations planar and toppling failures also occur.

Any great thickness of talus deposits present on the reservoir site may, because of their cementing properties, have a high angle of friction and often form steeper stable slopes than the underlying weathered and open jointed underlying rock.

*Slope analysis - Bass Highway cutting*

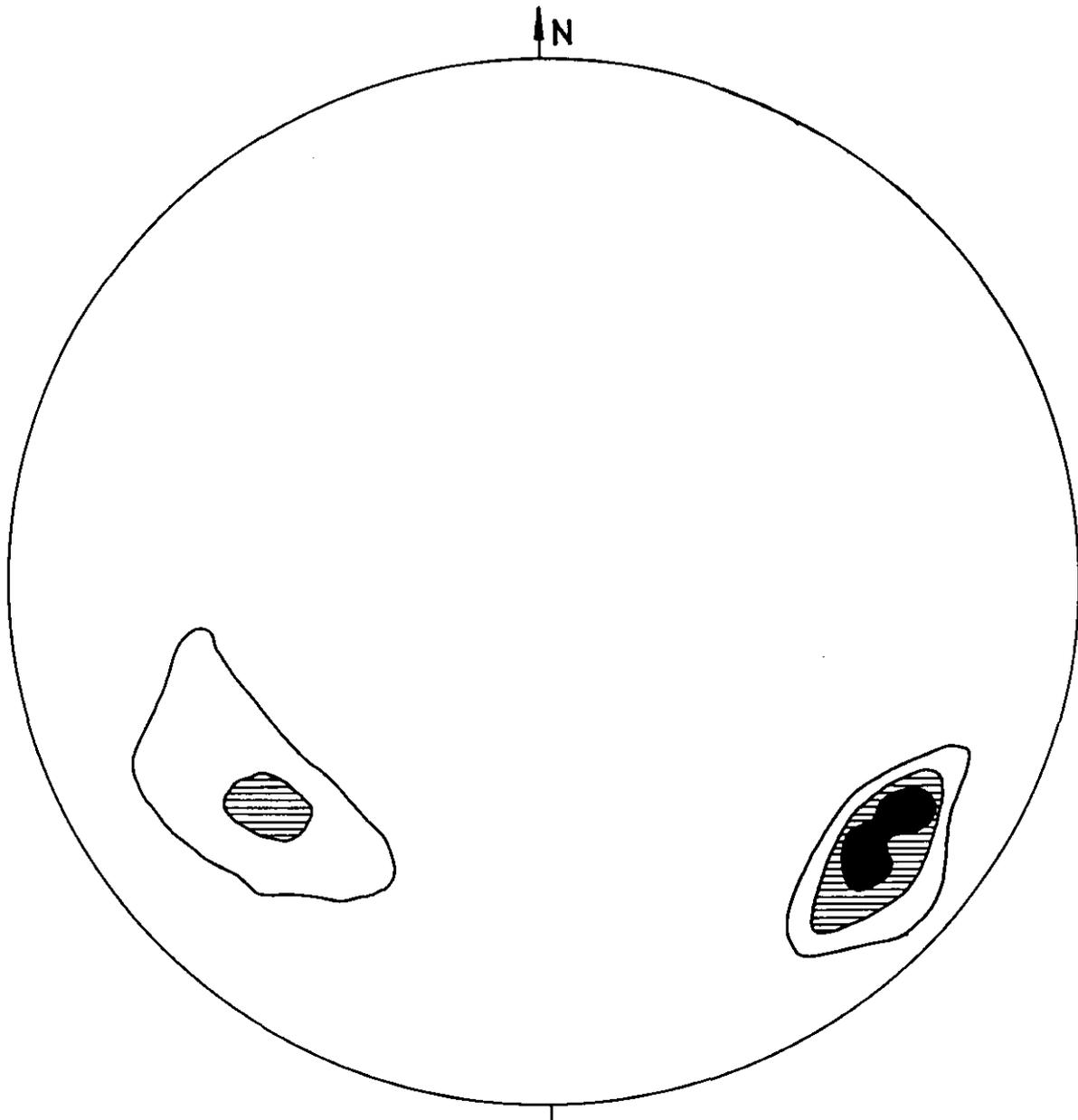
The statistical and back analysis techniques of Hoek and Bray (1977) were used on the eastern end of a cutting on the Bass Highway located on the spur below the reservoir site (fig. 1). This cutting is 20 - 25 m high with a face angle of 51° at the eastern end, and with the face striking at 285° (M) at the location where the 15 m section was measured at road level. The cutting is curved and swings in strike southwards towards the WSW and has its maximum face slope of 67° towards the western end. Ninety discontinuities were measured along the section with the length of the discontinuities being estimated and the type of discontinuity noted. Only one wedge failure was measured on this section, but three others occur close to the measured section which allow for back analysis between the predicted failures (fig. 4) and those on the face of the cutting (fig. 5).

A strong concentration of bedding plane (+ 15%) poles are present on the polar equal area stereonet plot (fig. 3). Bedding planes dip steeply in a NW to NNW direction with bedding dip direction ranging between 323° and 293° (M) with a strong concentration of bedding dip direction between 300° and 315° (M). The dips of the bedding planes range from 65° to 78° with a marked concentration between 65° and 75°.

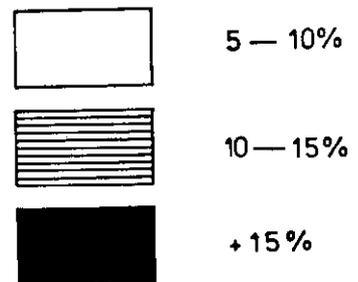
Joint planes measured also show a strong concentration with high dips and dip directions in the NE and ENE directions. Compared with the bedding planes, the joint planes cover a wide range of both dip and dip direction, with dips ranging between 55° and 70° and dip directions between 028° and 080° (M). A concentration of joint poles of 10 - 15% is present with a joint dip direction range of 045° to 055° (M) and a dip range of 55° to 60°.

These two widely spaced concentrations of the discontinuities, the major joints and the bedding, make for potential wedge failures. The dip direction and dip concentration planes of both the bedding and joints are plotted as great circles on an equatorial equal area stereonet (fig. 4) and the intersection of these two sets of great circles indicates the range of potential wedge failures. The direction of the intersecting line and the plunge of these two planes are measured and listed (fig. 4).

It is along the line of intersection of the two planes or its direction of movement that the potential wedge will slide, given that the plunge of this line of intersection is less than that of the face angle of the cutting or any proposed rock face. With the intersection

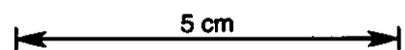


POLAR PROJECTION (EQUAL AREA)  
90 PLOTS



### PLOT OF DISCONTINUITIES, BASS HIGHWAY CUTTING

FIGURE 3.



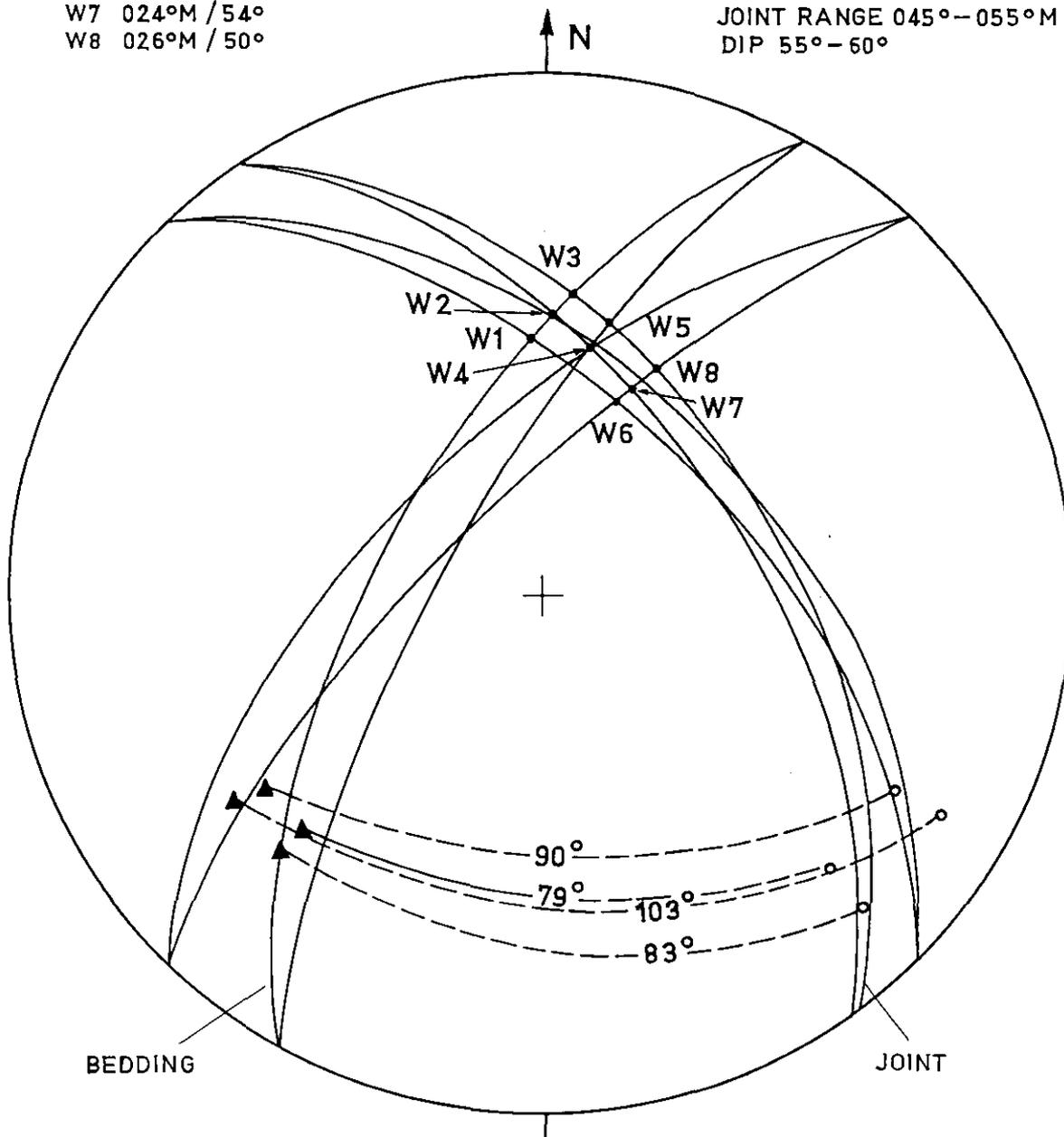
POTENTIAL WEDGE BEARING/PLUNGE

- W1 358°M / 50°
- W2 002°M / 46°
- W3 006°M / 42°
- W4 010°M / 52°
- W5 012°M / 46°
- W6 022°M / 58°
- W7 024°M / 54°
- W8 026°M / 50°

- ▲ POLES OF JOINT PLANES
- POLES OF BEDDING PLANES

BEDDING DIRECTION RANGE  
300°-315°M DIP 65°-75°

JOINT RANGE 045°-055°M  
DIP 55°-60°



EQUATORIAL EQUAL AREA PROJECTION

# ANALYSED POTENTIAL WEDGE FAILURE BASS HIGHWAY CUTTING

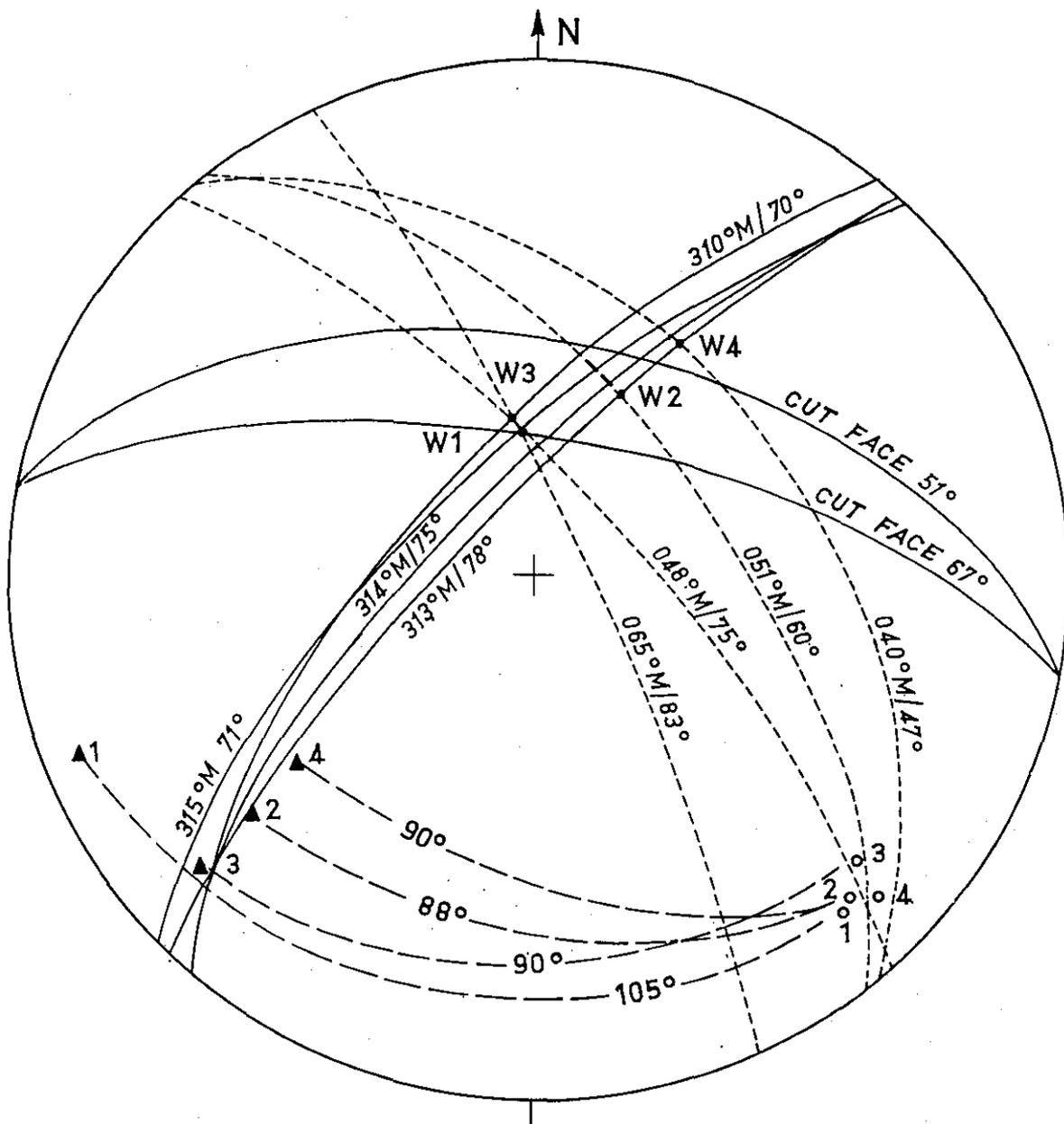
FIG.4

5 cm

WEDGE PLUNGE AND DIRECTION

- W1 356°M 68°
- W2 023°M 56°
- W3 352°M 64°
- W4 030°M 46°

- ▲ POLES OF JOINT PLANES
- JOINT PLANES
- POLES OF BEDDING PLANES
- BEDDING PLANES



MEASURED WEDGE FAILURES  
BASS HIGHWAY CUTTING

FIG. 5

5 cm

plunge angle being less than the face angle, the wedge will daylight and fail given that this plunge angle is greater than the friction angle of the rock in question (Hoek and Bray, 1977). The friction angle for the Burnie Formation quartzite and argillite is between 32° and 35°. With a designed face angle less than the plunges of these lines of intersections the potential for wedge failure is eliminated.

The potential wedge failures predicted from the statistical analysis of the measured section (figs. 3, 4) fit very closely to the great circle plots of the observed wedge failures on the cutting face. All the plunges of the lines of intersections are less than the face angles of the Bass Highway cutting, hence the failures (fig. 5). For simplicity only one strike direction of the face was plotted, that of the eastern end, as it approximates closely the likely direction of the face at the proposed reservoir site. The higher face angle of the road cutting is achieved without any noticeable increase in the number of wedge failures at the west end of the cutting because of the swing in the face towards the west-south-west. This swing in face direction would eliminate the low angle plunging wedges numbered W<sub>2</sub> and W<sub>4</sub> of Figure 5. These two wedges would not daylight on the face at this direction.

At the proposed reservoir site the direction of the face cut will have to be in an east-west direction similar to that of the eastern section of the Bass Highway cutting. The direction and narrowness of the ridge, and the steepness of its eastern flank allow little flexibility for changing the face direction.

Given that the face direction approximates the east-west direction of the road cutting, potential wedge failures are possible on faces cut as low as 42°. Wedge failures present on the existing road cutting indicate from the plunge of their lines of intersections that the face would have to be cut at an angle of 45° for these failures to be eliminated.

*Lack of wedge failures on the Bass Highway cutting*

From the statistical analysis, wedge failures should be far more numerous than actually occur on the face of the road cutting. This is thought to be because the horizontal statistical analysis measurement does not show a set of major, low angle, irregularly spaced joints with dips of 2° to 10° with dip directions ranging from 125° to 133° (M). Although not as numerous as the steeply dipping bedding of the high angle joints these low dipping discontinuities offset the major discontinuities and break the length of these units down to 3 - 7 metres. Even the thick quartzite beds seldom continue uninterrupted for the entire height of the cutting.

These low dipping beds break up the blocks, allowing fretting to be the dominant type of failure on this cutting and others along the Bass Highway. Although fallen boulders are cleared regularly, irregular square slope blocks of 0.5 - 1.0 m size were found at the base of the cutting.

*Proposed face angle*

Irrespective of whether the face is cut into dominantly talus material or extremely weathered rock, some material will in time fall off the cut face. A bounce pit, probably combined with a protecting rock fall fence, would be advised at this site.

Given that the material is dominantly rock, fretting failure will occur with blocks up to one metre in size falling off the face irrespective of what angle the face is cut between 45 and 65 degrees. The slope analysis has demonstrated that with increasing face slope angles, the greater the potential danger from wedge type of rock failures. Observations of the Bass Highway wedge failures show that rock falls in the order of 2 to 10 t are possible. The height of the cut at the proposed reservoir site is likely to be only half that of Bass Highway (fig. 6). Wedge failures of the above order have been observed in the Burnie Formation at Round Hill on rock benches of a lower height than this proposed face height (Moore, 1976a). To totally eliminate any possibility of wedge failures occurring, the face angle would have to be cut at less than 45° (from observed failures on the Bass Highway) or 41° (from statistical analysis).

From the cross-section line A' - A' drawn from the contour map (fig. 2), the amount of material required to be excavated to lower the face from a 65° to a 45° angle will be increased by approximately 20%. Therefore the cost advantage by increasing the slope angle is considerable, but this must be counter-balanced by the increase in the potential risk.

With a rock face cut at a slope of 50° only one wedge failure would have occurred on the Bass Highway cutting. The number of potential failures would also have been reduced by 50%. If the face angle is increased to 55° no increase in the observed failures would have occurred but the potential failures would be reduced by only 12%.

With a face height of 12.5 m and a 55° cut slope, and with the proposed face only half the height of the Bass Highway cutting, this high potential risk appears acceptable for a planned face slope angle. This planned face angle may have to be modified when the cut is open. The 12 - 13 m height of the face does not appear to warrant any benching.

#### CONCLUSIONS

- (1) Well jointed steeply dipping bedded quartzite, argillite, and slate of the Burnie Formation are likely to occur on the reservoir site. Talus deposits of an unknown thickness are likely to be present at the site.
- (2) Four velocity layers were distinguished in the refraction seismic survey. The interpreted materials for these velocity layers range from a surface layer of unconsolidated material to fresh, hard bedrock.
- (3) The second velocity layer material, with velocities ranging between 500 - 1000 m/s, is the most difficult to interpret geologically. This layer may be composed entirely of the cemented talus deposits or the highly weathered open jointed bedrock or a combination of both with an irregular profile between the talus and the weathered rock. The correct interpretation of this layer may be possible when the track to the reservoir is bulldozed.
- (4) Calculations from the seismic survey indicate that the majority of the material for the site can be removed by bulldozing and ripping. The use of explosives is anticipated to be minimal.
- (5) The cut face slope angle will depend ultimately on the amount of talus and depth of the weathered rock exposed at the site.

# SECTIONS THROUGH PROPOSED RESERVOIR SITE AND HIGHWAY CUTTING, HEYBRIDGE

33-12

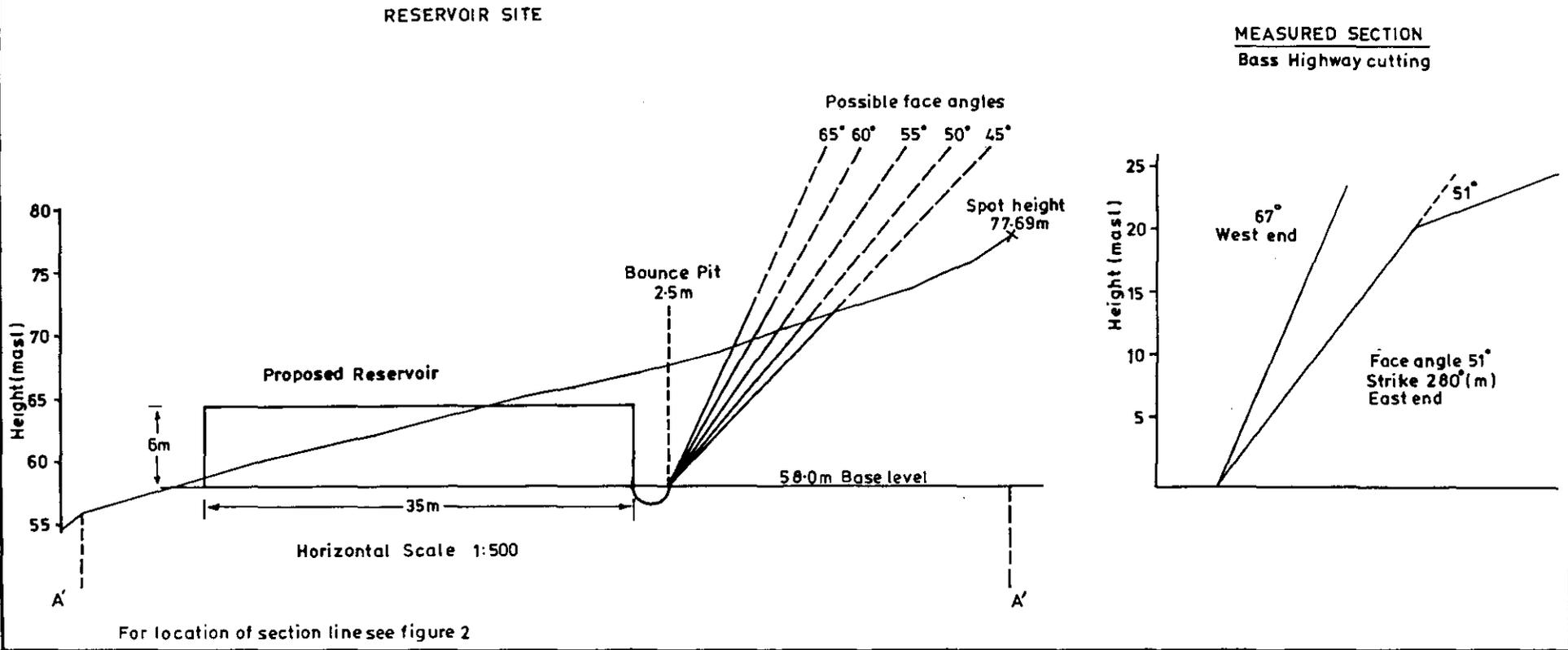


Figure 6

5 cm

12/13

(6) If the material has the same degree of weathering and has the same structural pattern as the cutting on the Bass Highway immediately below the reservoir site, the same type of rock failures will occur at the site.

(7) Fretting failures will be dominant and will cause blocks up to one metre and larger to fall from faces cut as low as 45°. Protection from these blocks is advised by the use of a bounce pit combined with a rock fall fence.

(8) Statistical slope analysis of the discontinuities combined with back analysis of actual failures show that wedge failures of 2 - 10 t are possible and their potential danger increases with steeper faces cut in an east-west direction.

(9) The cost of totally eliminating the risk of wedge failure by lowering the face angle to 45° (based on observed failures) or to 41° (based on statistical analysis of potential failures) appears too great. Therefore a planned 55° face slope is recommended but this may have to be modified when the cut is open. A 55° face will form a rock face of 12.5 - 13.0 m high depending on the width of the proposed bounce pit.

(10) No stability advantage is apparent in benching this face.

RECOMMENDATIONS

(1) The access track to the reservoir site be examined geologically when it is bulldozed down the slope to see if talus deposits or weathered bed-rock are present and their thickness.

(2) When the reservoir ledge is being cut that the material be re-examined geologically in order to check the above conclusions.

REFERENCES

HOEK, E.; BRAY, J.W. 1977. *Rock slope engineering*. Institution of Mining and Metallurgy : London. Second Edition.

GEE, R.D.; GULLINE, A.B.; BRAVO, A.P. 1968. Geological atlas one mile series. Zone 7 Sheet 28 (8015N). Burnie. *Department of Mines, Tasmania*.

MOORE, W.R. 1976a. Engineering geology and slope stability analyses of Round Hill quarries, Burnie. *Unpubl.Rep.Dep.Mines Tasm.* 1976/31.

MOORE, W.R. 1976b. Engineering geology investigation of a proposed cutting on the Murchison Highway at Somerset. *Unpubl.Rep.Dep.Mines Tasm.* 1976/71.

MOORE, W.R. 1977. Seismic survey to establish the rippability of rock at Holloway's quarry at Round Hill, Burnie. *Unpubl.Rep.Dep.Mines Tasm.* 1977/50.

[8 September 1982]