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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1964/83

PIEMAN RIVER SEISMIC RECONNAISSANCE SURVEY, TASMANIA 1962

by

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SUMMARY

Details and results are given of a reconnaissance seismic refraction survey that was made to determine the depth to bedrock along the centre line of the tidal section of the Pieman River, Tasmania, between the Hells Gates and Donaldson dam sites.

The closest distance to bedrock (in which the velocity is 14,000 ft/sec) is 102 ft below river level on seismic spread No. 10.

Partly weathered or jointed rock (in which the velocity is 9600 ft/sec), which may be suitable as foundation, is 35 ft below river level about 1800 ft downstream from the Hells Gates dam site. This rock should be tested by drilling. A more-detailed seismic survey and drilling should be done to investigate the 'high' feature in this area.

1. INTRODUCTION

The Hydro-Electric Commission of Tasmania (HEC) has selected two possible alternative dam sites on the tidal section of the Pieman River as part of the Pieman Development Scheme. This Record gives the results of a seismic survey by the Bureau of Mineral Resources, Geology and Geophysics, along the centre line of the Pieman River between the Hells Gates and Donaldson dam sites.

The depth to bedrock below mean sea level at the Donaldson dam site (Polak 1963) is over 100 ft greater than at the Hells Gates dam site (Polak and Moss 1959). The construction of a dam either at Hells Gates, where the tidal water has a maximum depth of 120 ft and is frequently rough, or at the Donaldson dam site, where the water is 60 ft deep and the bedrock about 200 ft deep, would be difficult and costly. The HEC considered it important to know whether the bedrock is shallower at any place in the river along the one-and-a-half miles between the two dam sites. The Bureau was requested to make a reconnaissance survey to determine the nature of river detritus and the depth to bedrock. The only access to the area was by boat from Corinna, about eleven miles upstream.

The survey was made between 25th June and 14th July 1962 by a geophysical party consisting of P.E. Mann (geophysicist and party leader) and four field assistants supplied by the HEC. Field work was hampered by rain and wind. About one week's work was lost when the seismic equipment had to be repaired and overhauled after some flood damage.

The HEC provided a 25-ft cabin launch and two small fishing boats. The cabin launch served as the recording boat; it housed the seismic equipment and photographic darkroom. The fishing boats were used as shooter's boats for placing and detonating the gelignite charges in the water. The HEC surveyed pairs of markers on the right and left banks of the river to aid in locating the hydrophone spreads.

Thirty-six water spreads were surveyed along the centre of the river.

2. GEOLOGY

Spry (1958) carried out geological mapping in the Mount Donaldson area and a reconnaissance along the Pieman River. Mather (personal communication) carried out geological mapping at Hells Gates and Donaldson dam sites. In the survey area (Plate 2) the bedrock consists of two formations of Precambrian age, viz. Interview Slate and Quartzite and the Donaldson Group. Field mapping indicates that the Donaldson Group, predominantly quartzite, conformably overlies the Interview Slate and Quartzite, and the boundary between the formations occurs on the Pieman River about half-a-mile above the confluence with the Donaldson River. A major fault, the Donaldson Fault, crosses the Pieman River near the confluence with the Donaldson River. South of the Pieman River (south of area shown in Plate 2) this fault forms the boundary between the Interview Slate and Quartzite and the Donaldson Group, but it is difficult to trace north of the river because the Interview Slate and Quartzite lie on both sides of it. The regional strike of the formations is roughly north-east and the regional dip is south-east.

River detritus of Quaternary age partly fills the drowned river valley forming steep banks covered with thick vegetation.

To account for the difference in the depth to bedrock at the two dam sites Mather (personal communication) suggests it is possible that a sudden increase in the depth to bedrock in the river occurs in the vicinity of the Donaldson Fault, or at the boundary of the Donaldson Group of rocks about half-a-mile upstream. However, he considers it is more likely that the bedrock depth increases uniformly between the two dam sites.

Three holes have been drilled in the river bed. The drill-hole locations and logs are shown in Plate 3.

3. METHODS

Seismic

The seismic refraction method was selected as the one most suitable for estimating the depth to bedrock in the river. A general description of the method is given by Polak and Moss (1959).

In the drowned portion of the river with steep banks it is reasonable to assume that the bedrock cross-section is roughly V-shaped. A hydrophone spread close to the water surface would record refracted first-arrivals of energy from that part of the bedrock surface which, by the geometry of a V-shaped cross-section, is closest to the spread. The refracted arrivals could originate from either 'wall' of the V-shaped cross-section; thus the information obtained will not indicate the depth to bedrock, but will define a minimum distance to the refractor from the recording hydrophone. For convenience, these distances are plotted as ordinates below the arbitrary datum in the form of a cross-section in Plate 3.

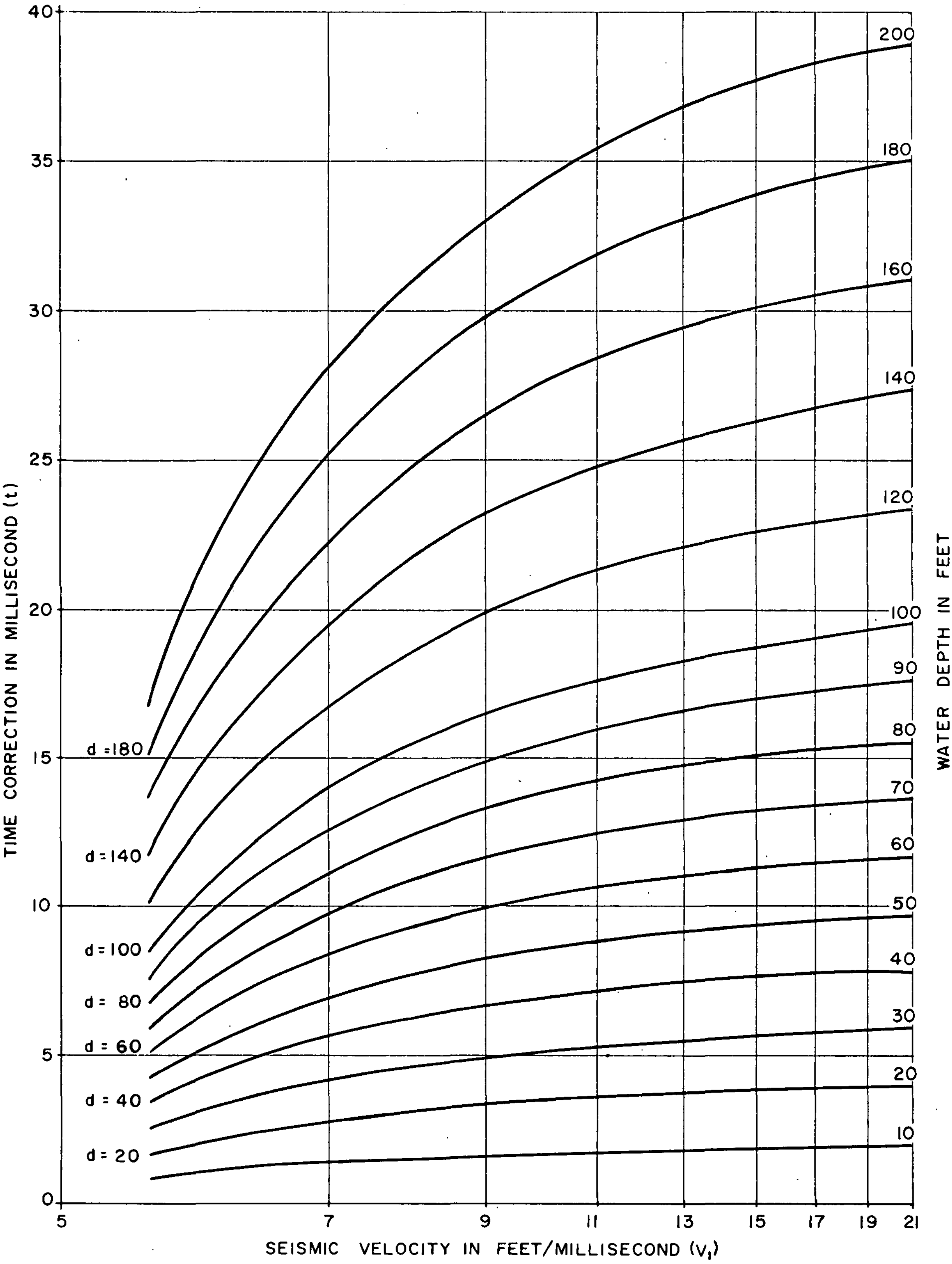
It was not considered advisable to lay out a spread on the river bed because the cable and hydrophones might snag permanently on tree trunks in the river bed. No cross traverses were surveyed because of poor weather and the unreliable performance of the seismic equipment after being flooded.

Computation

In this survey most of the computations are based on a two-layer seismic refraction problem, viz. river detritus overlying unweathered bedrock. This is similar to the interpretation adopted for the dam site surveys (Polak & Moss, 1959; Polak, 1963). Spreads No. 7 and 8 are interpreted as a three-layer problem. The computation method used is the 'method of differences' (Heiland, 1946, p.548). On a water-borne survey of this type the use of a hydrophone to measure the reciprocal time is impracticable. Consequently the reciprocal time was found by the extrapolation of the time/distance curves of the long-distance shots. This method led to discrepancies in the values of reciprocal times although theory indicates that with uniform refractors the reciprocal times should be equal. The differences between the reciprocal times found by extrapolating the time/distance curves probably arose from two main sources:

(Facing page 3)

FIG 1



NOMOGRAM FOR FORMULA $t = \frac{d}{5V_1}\sqrt{V_1^2 - 25}$

d = Mean depth of water beneath hydrophone spread (ft)

V_1 = Longitudinal velocity of seismic waves in refractor beneath river detritus (ft/msec)

Longitudinal velocity of seismic waves in water = 5 ft / sec

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(a) Departures from uniform conditions between the two shot-points. A measure of the non-uniformity is given by the uncertainty of the gradient of the time/distance curve,

(b) Uncertainty of the distance of the shot-point from the spread. The shot distances were calculated from the direct water-wave i.e. the pressure wave travelling through the water and which was identified on the seismogram by high frequency and large amplitude. Because of errors in timing the arrival of the water-wave, the inaccuracy in location of the long-distance shot is probably about ± 20 ft. Generally an error of 20 ft in the shot-point distance yields a difference of about 2 msec in the reciprocal time.

Generally the difference in reciprocal time owing to the uncertainty of the gradient of the time/distance curve is greater than the difference owing to the uncertainty in the shot-distance and is about 10 to 20 msec.

The error in time-depth to a refractor will be at least equal to the possible error in the reciprocal time. Generally the mean error in the minimum distance to a refractor is not less than ± 20 percent.

In a survey of this type it is necessary to know the seismic velocity in the river detritus. Refractions from the river detritus were recorded when small charges were detonated close to the hydrophones at the ends of the spreads. The seismic velocity in the detritus ranged from 5500 to 6000 ft/sec on about 75 percent of the spreads. For the remainder of the spreads, velocities in this range could not be identified on the seismograms because the direct water-wave masked the pulse. Polak and Moss (1959) and Polak (1963) recorded seismic velocities of 5800 and 5600 ft/sec respectively in the river detritus. For this survey an average velocity of 5750 ft/sec was adopted. An error of 250 ft/sec in this velocity will lead to a six-percent error in the thickness of the river detritus.

The velocity of the water-wave was determined on a special spread by detonating a small charge about 3 ft below the water surface and in line with the spread. The velocity of 5000 ft/sec in the water corresponds to the velocity found for the pulse interpreted as the water-wave on the normal seismograms.

In this survey, because charges were detonated on the river bed and the hydrophones floated about 3 ft below the water surface, it was necessary to refer all travel times used in the calculations to a reference datum. For convenience the river bed was selected as reference datum and all travel times were reduced by a correction (in msec)

$$(d/5V_1)\ \sqrt{V_1^{\,2} - 25}$$

where d (ft) is the mean depth of water beneath the hydrophone spread; V_1 (ft/msec) is the longitudinal velocity of seismic waves in the refractor beneath the river detritus.

The correction in the form of a nomogram is shown in Figure 1.

The tidal variation of the river was recorded by a recording gauge on the left bank of the river at the Donaldson dam site. No correction was applied to the calculated bedrock depth to allow for tidal and flow variations of the river level. The correction was negligible in comparison with other errors inherent in the seismic method. The arbitrary datum shown in Plate 3 is about 2 ft above mean sea level.

Topographical surveying

To locate the position of the hydrophone spreads, numbered markers were placed in pairs about every 200 ft along both banks of the river between Hells Gates and Donaldson dam sites. When the launch and the hydrophone spread were anchored to the banks, the distance and bearing of all survey points visible from the launch were read by an optical range-finder and magnetic compass. The hydrophone spread was anchored securely at a fixed distance from the launch and its bearing checked several times whilst a series of charges were detonated for a particular hydrophone spread. The lateral error in the location of a spread shown in Plate 2 is probably not more than 15 ft and is less than 10 ft for spreads No. 1, 2, and 3 in the narrow part of the river at Hells Gates.

The water depth found by plumbing from the shooter's boat and the main launch at the close shot-points for each hydrophone spread is shown in Plate 3.

Equipment

The seismic equipment used was an SIE portable 12-channel P-19 refraction seismograph. An SIE 24-channel PRO-11-6 oscillograph was used with an Electro-Tech 'Seismod' display unit to give conventional and variable-density displays. The equipment was mounted in and operated from the launch. Twelve Electro-Tech EVP-5 pressure-type hydrophones, attached to a cable floated by plastic buoys, were suspended about 3 ft below the water surface. Two Traeger transceivers type 51MA were tried for the transmission of the shot instant and for communications between the shooting boat and the recording boat. However, they proved unreliable and had to be replaced by a telephone system.

Operations

When the cabin launch was roughly in the centre of the river, it was tied to both river banks. The cable and attached hydrophones were paid out until the nearest hydrophone was 15 ft from the stern of the launch. Tie lines from the downstream end of the cable were fixed to the banks when the hydrophone spread reached a steady position under the influence of the river current. This procedure yielded a stable spread roughly positioned in the centre of the river. Plate 2 shows that the spreads were not distributed continuously along the approximate centre-line of the river. This was due to the river current dragging the launch from a selected position. Moreover, spread locations could not be plotted until the survey plans were available which was several weeks after the field work terminated; therefore, gaps in the traverse could not be filled.

At each shot-point the water depth was plumbed before placing the charge. At the downstream end of the spread, charges at different shot-points were placed and detonated from a shooting boat. At the upstream end of the spread, the end shot was placed and fired from the main launch; charges at other shot-points were placed and detonated from a shooting boat. Charges were placed and fired on the river bed in line with, and up to 800 ft from, the spread.

4. RESULTS

Table 1 shows the velocities of longitudinal seismic waves which are characteristic for the different media.

Table 1

Rock type	Seismic velocity (ft/sec)
Water	5000
River detritus	5500 to 6000, average 5750
Bedrock in fault zone or partly weathered bedrock	9000 to 13,000
Slightly weathered to unweathered bedrock	14,000 to 20,000

Plate 3 shows the minimum distance from the hydrophone spread of a seismic refractor for different spreads plotted as a cross-section roughly along the centre line of the river between the two dam sites. Each spread, except for spreads No. 5, 23, and 25, shows the velocity, average slope of the refractor, and minimum distance from the centre of the spread to the refracting boundary. On spread No. 5, no shot was detonated far enough away from the spread to record refractions from the high-velocity layer. On spread No. 23, the indicated refractor boundary has a pronounced shape that is not shown by any other spread. The seismograms of spread No. 25 were interpreted by refraction and reflection methods. Each method gave results inconsistent with the data from adjacent spreads, and no results are plotted. Possibly the first events on the seismogram are a mixture of refractions originating from the right and left 'walls' of the bedrock cross-section.

As explained in the previous section, the first-arrivals of energy may have been refracted from either 'wall' of the V-shaped cross-section of the bedrock depending on the relative position of the hydrophone spread and the refractor boundary.

The refractor boundary for each spread has been classified as being a portion of the right or left 'wall' of the V-shaped bedrock cross-section. This classification is reasonable because some spreads are closer to one steep bank than they are to the other bank. Spreads No. 7 and 33 are closer to the right bank and the refractor boundary is interpreted as part of the right 'wall' of the bedrock cross-section. The refractor boundary of spread No. 35 if interpreted as part of the 'left' wall of the bedrock cross-section. The minimum distance from the hydrophones is roughly equal to the distance to steeply dipping bedrock shown by Polak (1963) on Traverse A. The refractor boundaries of spreads No. 1, 2, and 3 at Hells Gates, where the river is narrowest, cannot be identified with either bank. The classification of the remaining refracting boundaries as part of the right or left 'wall' of the bedrock cross-section is based on the above three spreads, and is designed to give coherent seismic cross-section. However, the unique classification of each refracting boundary was not the aim of the survey.

The inset in Plate 3 shows the interpretation on Cross-section AB near the Donaldson River of the minimum distance to a refractor boundary along an inclined path between hydrophones and refractor boundary.

It is not possible to compare directly the depths to bedrock found by drilling with those found by seismic methods. The depths in these drill holes were measured vertically, whereas the minimum distances calculated by the seismic method are the inclined distances between hydrophone and refracting boundary. Moreover, rock cored from a drill hole may not be equivalent to the highest-velocity refractor. Probably quartzite and slate recovered from DH 6203 and interpreted as bedrock correspond to the refractor interpreted as partly weathered bedrock with seismic velocity 11,000 ft/sec recorded on spread No. 6.

Generally, the seismic velocities on spreads No. 17, 18, 19, 21, and 22 are lower than on other spreads. This may be associated with the Donaldson Fault found by geological evidence.

Partly weathered bedrock, in which the velocity is 9600 ft/sec, is about 35 ft below water level on spreads No. 7 and 8 about 600 ft downstream from DH 6203. However, the extent of this refractor across the river is unknown.

There is a suggestion that downstream from the boundary of the Donaldson Group and the Interview Slate and Quartzite the refracting boundaries below the river bed deepen.

No significant variation was found in the seismic velocity in the river detritus although Polak (1963) considers detrital material is coarser at Hells Gates dam site than at Donaldson dam site.

5. CONCLUSIONS

The closest distance to bedrock in which the velocity is 14,000 ft/sec or greater is 102 ft below river level at spread No. 10. Elsewhere the depths to bedrock are generally much greater than this.

Rock in which the seismic velocity is 9600 ft/sec was measured at 35-ft depth about 600 ft downstream from DH6203 (spreads No. 7 and 8). This rock, probably partly weathered or jointed bedrock, may be suitable for the foundation of a dam; however, it should be tested by drilling. More-detailed seismic work and drilling should be done to investigate the structure thoroughly in this area.

It should be noted that this 'high' feature coincides with the inferred boundary between the Donaldson Group and the Interview Slate and Quartzite and may be associated with this boundary.

6. REFERENCES

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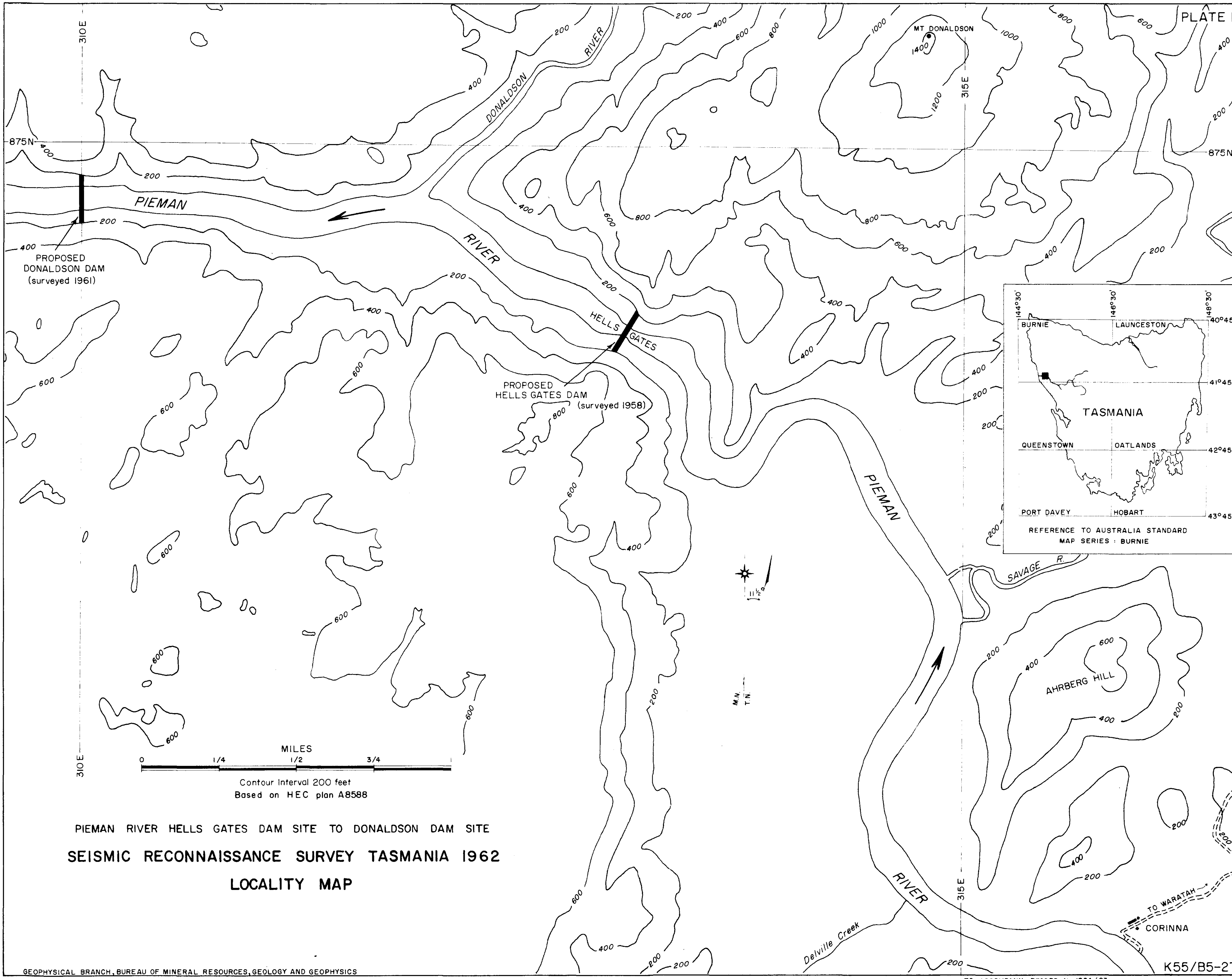

Contour Interval 200 feet
Based on HEC plan A8588

PIEMAN RIVER HELLS GATES DAM SITE TO DONALDSON DAM SITE

SEISMIC RECONNAISSANCE SURVEY TASMANIA 1962

LOCALITY MAP

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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PIEMAN RIVER

TRAVERSE AND GEOLOGY

(Based on HEC plans, S 309 1/3 874, 310 1/3 874, 311 1/3 874, 312 1/3 874, 312 2/3 873 1/3, and GS 31)

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CROSS-SECTION SHOWING MINIMUM DISTANCE OF SEISMIC REFRACTORS FROM HYDROPHONE SPREAD