

1984/60. A preliminary seismic refraction survey of a proposed dam site at Grindelwald, West Tamar.

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Abstract

A proposed 15-20 m high water storage dam and a shallow sewage lagoon in a tributary of Muddy Creek were investigated. The dam site lies in a narrow valley between a basalt plateau and a basalt hill outlier to the west. The site is topographically suitable but the abutment areas appeared to be composed of scree and coarse boulder talus, with only two outcrops of basalt observed. A seismic refraction survey was recommended as a preliminary investigation.

Five seismic refraction spreads were fired, three across the dam centreline, one long spread in the valley floor from the reservoir to the sewage lagoon site, and one across the valley at this site. Three seismic velocity layers were present. The seismic survey indicates that no high velocity rock is close to the surface, that a thick layer of scree overlies the basalt and if the basalt is present in the valley it is deep, probably down-faulted. An alternative interpretation is that the stream has cut through the basalt into a thick layer of Tertiary sediments overlying the high velocity rock presumed to be a lower basalt or dolerite.

Whichever geological interpretation is correct major leakage problems are likely at these sites. This preliminary survey indicates that a site investigation of the dam is going to be difficult and costly, with no certainty of its outcome. Some preliminary trenching will be required to attempt to identify the lithology of the two top seismic velocity layers.

INTRODUCTION

At the request of Campbell-Smith, Phelps and Pedley Ltd, consulting surveyors, a proposed dam site on the Grindelwald property of Rolf Vos Holdings Pty Ltd near Legana, West Tamar, was examined.

After a brief examination of the site on 11 July, a preliminary refraction seismic survey was recommended. Five spreads were fired on 1 August. The dam is to be used for future water supply for Grindelwald and for ornamental purposes. It is proposed to locate a sewage lagoon below the dam site. The seismic spreads covered the two projects.

LOCATION AND TOPOGRAPHY

The proposed dam site is on a NW-trending tributary of Muddy Creek [EQ007218]. The site is located in a narrow, steep, V-shaped valley where the tributary has cut down over 100 m from the plateau on which Grindelwald village is built (fig. 1).

The proposed dam site is topographically attractive, being located in the narrowest section of the valley with outcrops of basalt and basanite near the abutment areas.

The valley broadens and shallows upstream from the site, forming the broad col between the Grindelwald village plateau area and the basalt-capped hill to the south-east, on which the village workshop sheds are located.

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5 cm

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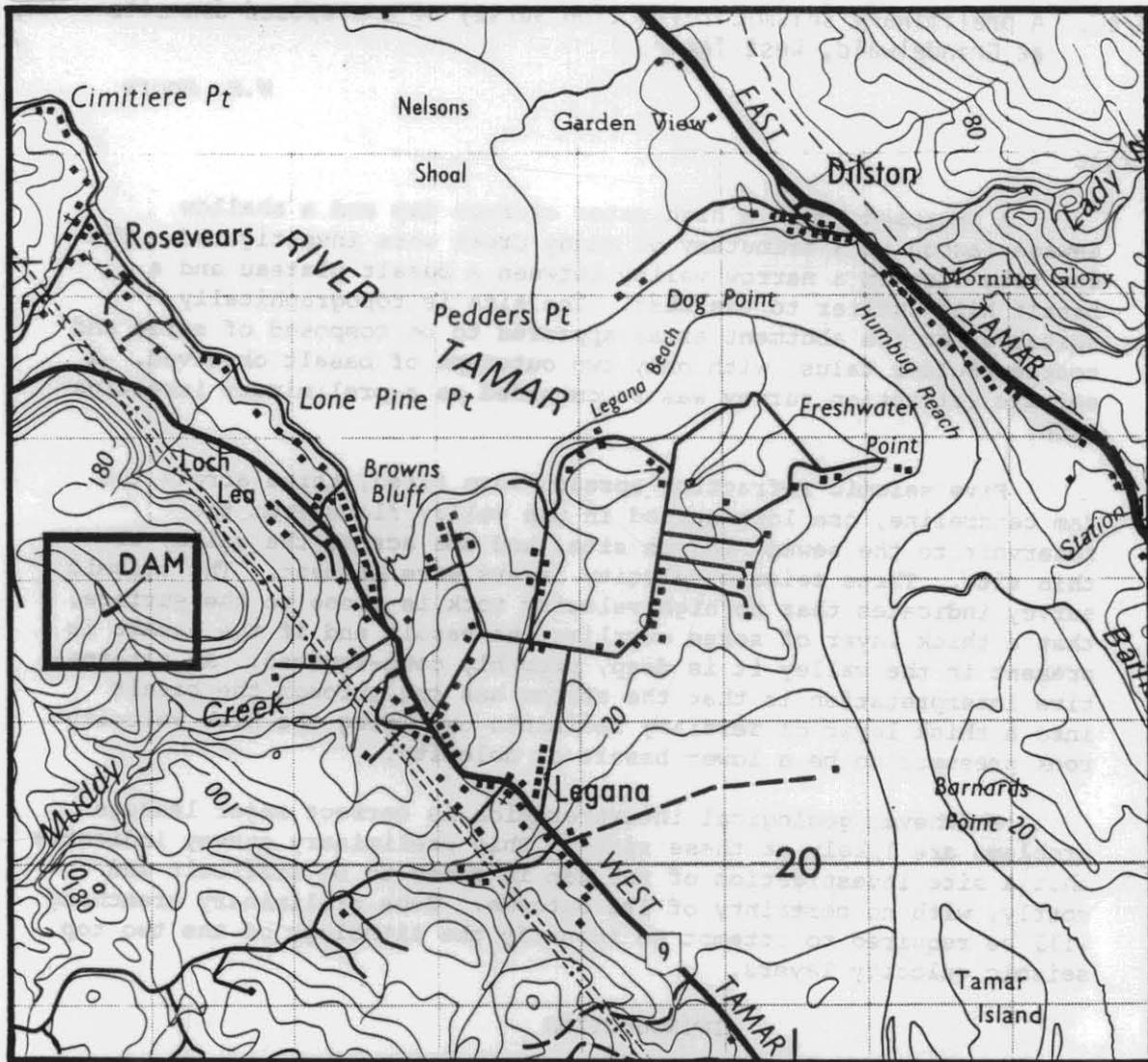


Figure 1. Location of proposed dam site.

The precise height of the proposed dam has not been finalised but the minimum range required is 15 to 20 metres.

GEOLOGY

The surface geology of the basalt plateau and Muddy Creek area (fig. 2) has been regionally mapped by Longman et al. (1964), Gulline et al. (1973) and Sutherland (1971) in his study of the basalts of the Tamar Valley. Matthews (1979) re-examined the area when he was investigating the existing dam which impounds the ornamental lake for Grindelwald village. Both Matthews and Sutherland thought the steep slopes forming the western and eastern abutments of the proposed site were areas where basalt cropped out or was fairly close to the surface.

When the site was examined on 28 July all the vegetation cover and much of the soil had been removed. Both valley slopes had been bulldozed and the soil pushed directly downslope. Both valley slopes appeared to be covered by basalt boulder scree and talus deposits with only two possible outcrops exposed. These are in the zone shown as fine-grained basalt by Matthews near the east abutment area (fig. 2).

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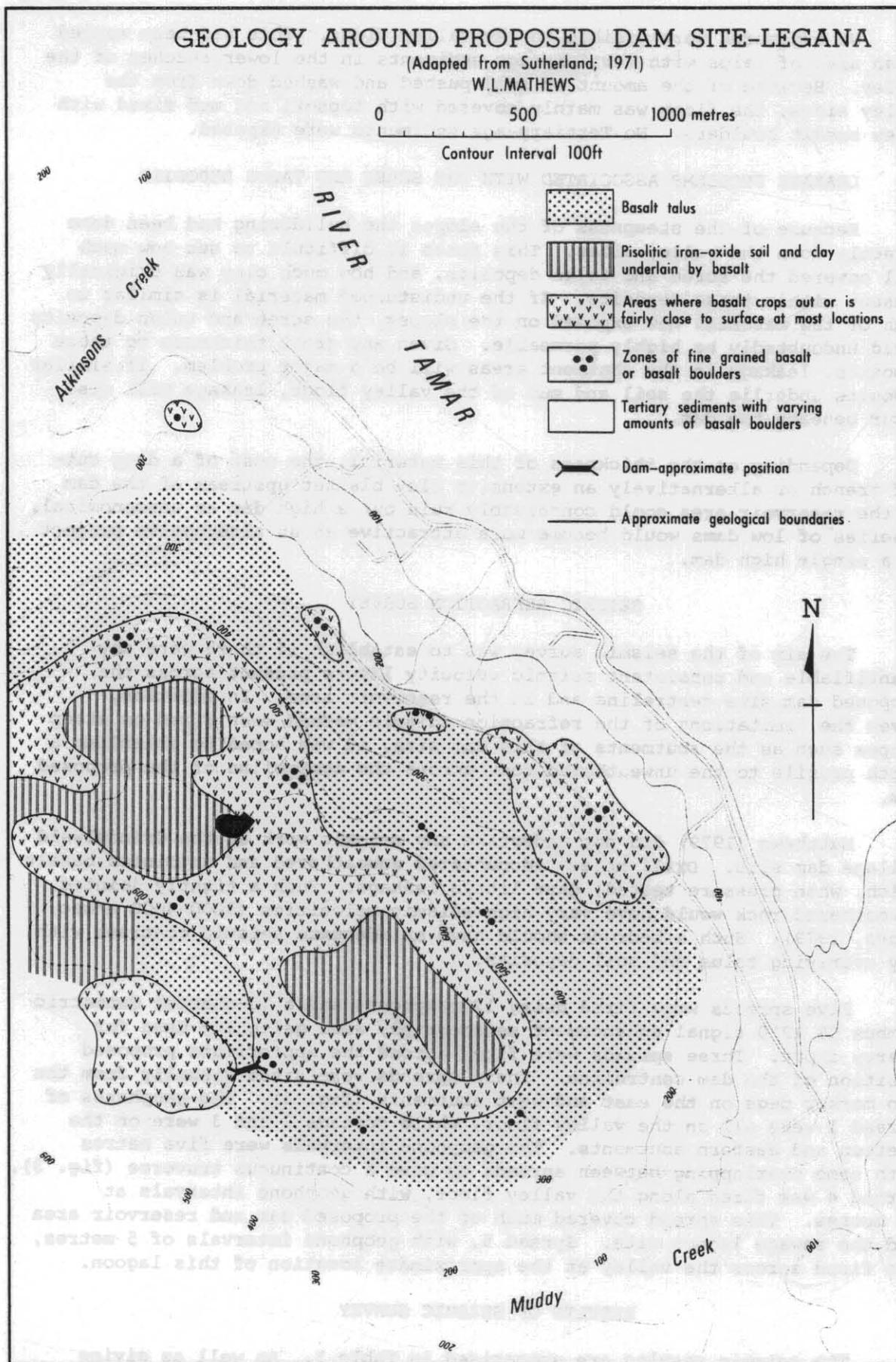
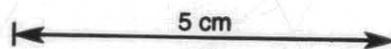


Figure 2.



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No exposures were visible in the valley floor. This had been mapped as an area of talus with Tertiary-age sediments in the lower reaches of the valley. Because of the amount of soil pushed and washed down from the valley sides, the floor was mainly covered with topsoil and mud mixed with a few basalt boulders. No Tertiary-age sediments were exposed.

LEAKAGE PROBLEMS ASSOCIATED WITH THE SCREE AND TALUS DEPOSITS

Because of the steepness of the slopes the bulldozing had been done directly down the valley sides. This makes it difficult to see how much soil covered the scree and talus deposits, and how much clay was originally present within these deposits. If the undisturbed material is similar to much of the material now exposed on the slopes, the scree and talus deposits would undoubtedly be highly permeable. Given any great thickness to these deposits, leakage in the abutment areas will be a major problem. If similar deposits underlie the soil and mud of the valley floor, leakage will also occur beneath the dam.

Depending on the thickness of this material, the cost of a deep cut-off trench or alternatively an extensive clay blanket upstream of the dam in the reservoir area could conceivably rule out a high dam as uneconomical. A series of low dams would become more attractive as an alternative project to a single high dam.

SEISMIC REFRACTION SURVEY

The aim of the seismic survey was to establish if there were any identifiable and consistent seismic velocity layers present across the proposed dam site centreline and in the reservoir area. In addition, given the limitations of the refraction seismic method when fired on steep slopes such as the abutments of this dam site, it was hoped to establish a depth profile to the unweathered rock across the centreline of the proposed dam.

Matthews (1979) did not undertake any seismic work at the Grindelwald village dam site. Drill holes encountered unweathered and unjointed basalt which, when pressure tested, gave little leakage. Such a tightly jointed, unweathered rock would have very high seismic velocities (3000-4000 m/sec; Moore, 1979). Such a bedrock should have an adequate seismic contrast with any overlying talus and soil deposits.

Five spreads were fired using 12 geophones and a 12-channel Geometric Nimbus ES 1210 signal enhancement seismograph, with gelignite used for energy input. Three spreads were fired across the approximate proposed position of the dam centreline. These spreads were sited visually from the two marker pegs on the east and west abutments (fig. 3). The geophones of Spread 1 were all on the valley floor, while Spreads 2 and 3 were on the western and eastern abutments. The geophone intervals were five metres with some overlapping between spreads to give a continuous traverse (fig. 3). Spread 4 was fired along the valley floor, with geophone intervals at 15 metres. This spread covered much of the proposed dam and reservoir area and the sewage lagoon site. Spread 5, with geophone intervals of 5 metres, was fired across the valley at the approximate location of this lagoon.

RESULTS OF SEISMIC SURVEY

The seismic results are summarised in Table 1. As well as giving details of the individual spreads the table shows the velocity layers present (V_0 , V_1 and V_2) and the calculated thicknesses (Z_0 & Z_1) for these

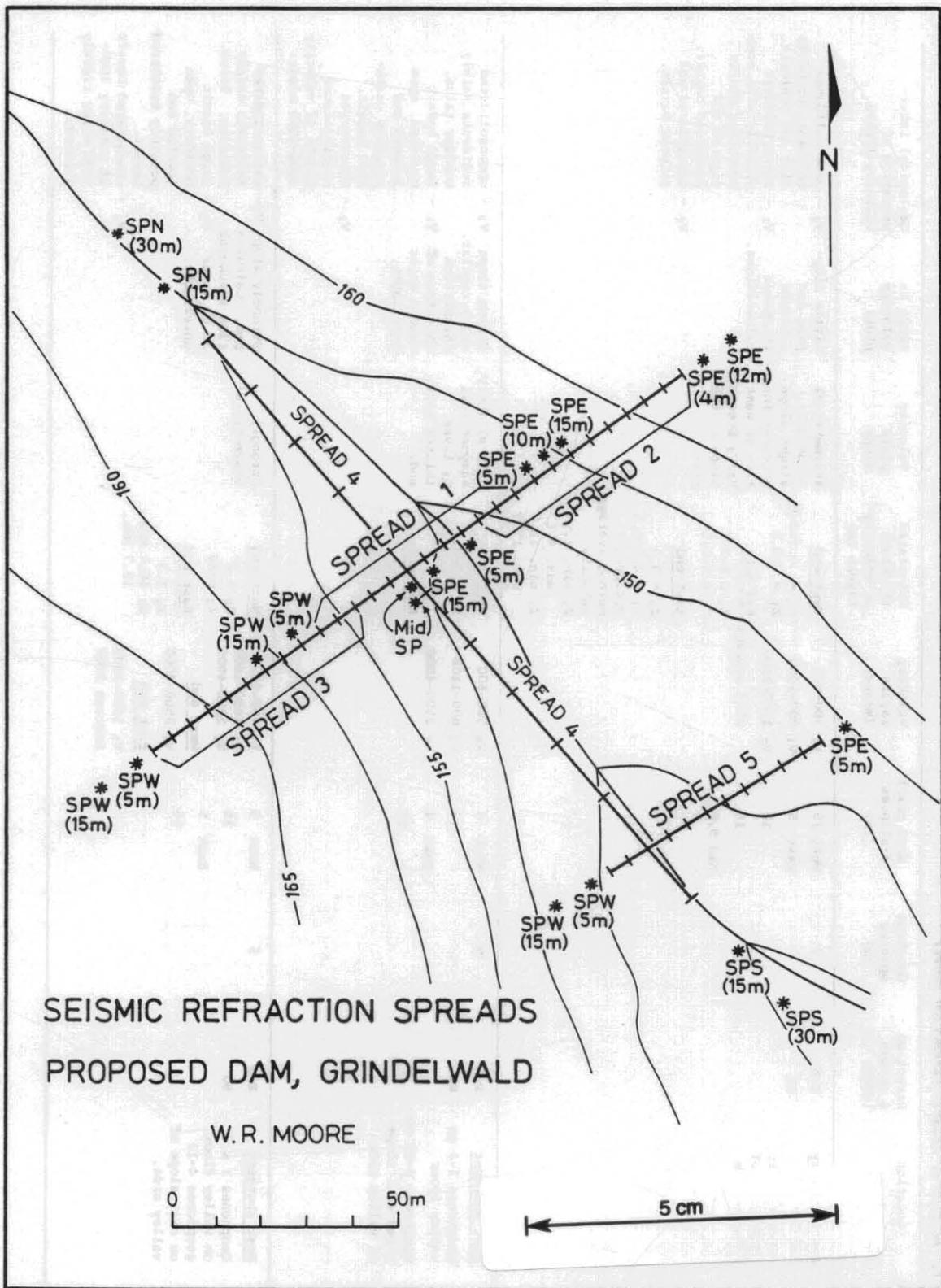


Figure 3.

Table 1. RESULTS OF SEISMIC REFRACTION SURVEY

Spread no.	Location	Direction & spread length (m)	Geophone spacing (m)	Shot point distances (m)	Velocity layers (m/sec)	Calculated thickness of velocity layers (m)	Velocity plots slope	Steps in velocity plots	Geological interpretation of velocity layers
1	Across valley floor Approximately centreline of proposed dam	E-W 85	5	West 15 East 5 10 15 Mid S.P.	V ₀ 300-500 V ₁ 900-1500 V ₂ 1700-2500 2100 average	West end Z ₀ = 4.2-4.6 Z ₁ = 15.2 Mid S.P. Z ₀ 2.0-2.5 Z ₁ 4.5-6.5 East end Z ₀ = 3.3 Z ₁ = 4.5-6.5 Reciprocal method average velocity Z ₀ min. 1.9 max. 4.6 Z ₁ min. 11.8 max. 17.3	Assymetrical velocities, slight slope on V ₀ /V ₁ interface to west. V ₂ /V ₃ Steeper slope to the west.	Little stepping and reliable thickness calculations.	V ₀ - unconsolidated sediments probably clay and boulders. V ₁ - talus boulders possibly with some cementing and/or jointed and weathered basalt. V ₂ - unweathered and jointed basalt.
2	East abutment Geophones 1-3 on valley floor Geophones 8-12 on steep east slope on valley side	E-W 82	5	West 5 15 East 4 12	V ₀ 500-600 V ₁ 800-1100 V ₂ 2500-4000	West end Z ₀ 2.3-3.1 Z ₁ 6.0-7.1 East end Z ₀ 1.00 Z ₁ 2.7-8.7	Only slightly assymetrical Z ₀ layer thicker west end.	Strong steps and irregular. Calculation thickness of second layer unreliable.	V ₀ - unconsolidated sediments mainly boulder talus. V ₁ - large basalt boulders, open jointed and possibly weathered basalt. V ₂ - unweathered tight-jointed basalt if velocity 3000-4000 m/sec.
3	West abutment Geophones 1 & 2 on valley floor, geophones 4-12 on east slope of valley side.	E-W 90	5	West 5 15 East 5 15	V ₀ 400-500 V ₁ 1000-1600 V ₂ 2200-4000 West end V ₂ 3500-4000 East end V ₂ 1600-3000 Average 2400	West end Z ₀ 3.0 Z ₁ 6-10 East end Z ₀ 1.3 Z ₁ 10.1 min. 19.7 max.	Strongly assymetrical	Strongly stepped. Calculation thickness of Z ₀ layer unreliable.	V ₀ - unconsolidated sediments mainly boulders. Talus. V ₁ - large basalt boulders, open jointed and possibly weathered basalt. V ₂ - unweathered basalt If velocity 3000-4000 m/sec tightly jointed.

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Table 1. (continued)

4	<u>Down the valley floor</u> From reservoir area to sewage lagoon area	N-S	15	North 15	<u>North</u>	<u>North end</u>	Assymetrical V ₀ /V ₁ interface shallows to the north. Z ₁ thickness difficult because only south and mid S.P. show 3 velocities.	Wide step of 3-4 geophones in the mid S.P. area	<u>Southern end</u>
		210		30	V ₀ = 1000 V ₁ 2100-3000	Z ₀ 3.2-5.0 <u>Mid S.P.</u>			V ₀ Clay and talus boulders V ₁ Large basalt boulders etc. and/or Tertiary sediments V ₂ Basalt or dolerite
				Mid S.P.	<u>Mid S.P. and South</u>	<u>South end</u>			<u>Northern end</u>
				South 15	V ₀ 500-600 V ₁ 1300-1700 V ₂ 2200-3000	Z ₀ 2.0-6.0 Z ₁ 14.2 Z ₀ 4.0-5.0 Z ₁ 20 min. 36 max.			V ₀ Clay and weathered basalt and/or boulders. V ₁ Basalt.
5	<u>Across valley floor</u> At proposed sewage lagoon site	E-W	5	West 15	V ₀ 400 east end, 800-900 on west slope. V ₁ 1200-1500. V ₂ 2200-2400, only seen eastern end	Z ₀ 0.5-1.8 on valley sides, 5-10 on valley floor. Z ₁ 9-12. Minimum not reliable as based on two geophones	Symmetrical	Stepping at west end. S.P. fired at west end giving higher velocities in V ₀ layer.	V ₀ Unconsolidated sediments, clay and boulders V ₁ Large basalt boulders etc. and/or consolidated Tertiary sediments plus weathered basalt. V ₂ Basalt or dolerite.
		75		5					
				East 5					

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layers. Three methods of calculation were used to obtain layer thicknesses; critical distance, intercept time and reciprocal (Leaman, 1979). The symmetry of the velocity plots and the amount of stepping present is also given in the tables to indicate the reliability of the velocities and calculated thickness values. A geological interpretation of each of the velocity layers is attempted.

Centreline spreads (fig. 4a).

Three velocity layers are present on all spreads fired on the centreline. Of these three spreads the calculated thicknesses of the layers of Spread 1 are the most reliable. Even though the velocities are asymmetrical, there is no stepping present such as occurs on the two abutment spreads, especially at the ends where the shots are fired on the abutment slopes.

The low surface layer velocity (V_0) of 300-600 m/sec and intermediate layer velocity (V_1) of 900-1600 m/sec shows that no hard rock is present close to the surface in the valley or either of the abutments. The slow surface layer is 2-7 m deep and the depth to the V_1/V_2 or hard rock interface, with velocities above 2000 m/sec, has been calculated at about 15-20 metres.

The end of the spread on the eastern abutment was located on what appeared to be a large outcrop of fine-grained basalt, but the seismic velocity indicates that this is a large tilted block which appears not to be *in situ*. Even allowing for the stepping indicating an irregular hard rock profile and the unreliability that these steps create in depth calculations, the depth to hard bedrock is considerable in both abutments, as well as in the valley.

The surface velocity layer comprises unconsolidated sediments, soil and boulders in the floor of the valley, and loose boulders with little soil in the abutments. The intermediate velocity layer is probably compacted boulder scree and talus which may have some cementing, underlain by open jointed, fissured basalt, probably partially weathered. Previous experience with refraction seismic surveys in basalt (Moore, 1979) has shown that the geological and velocity boundaries do not generally coincide precisely in this difficult intermediate velocity range.

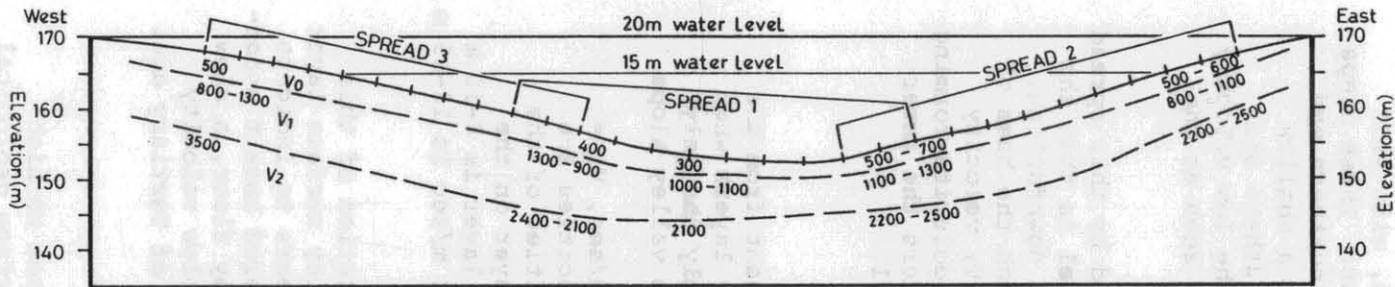
The third layer velocities are low, averaging between 2000-3000 m/sec, and the higher velocities between 3000-4000 m/sec are only occasionally present in the short steps on the abutment spreads. As an overall third velocity layer the anticipated velocities of 3000-4000+ m/sec for unweathered and unjointed basalt are not present.

The centreline seismic profile indicates that a major leakage problem is possible both in the abutments and valley of the proposed site. The depth to impermeable tight-jointed hard basalt or rock with velocities in the order of 3000 m/sec is considerable probably in the order of 6 to 20 metres.

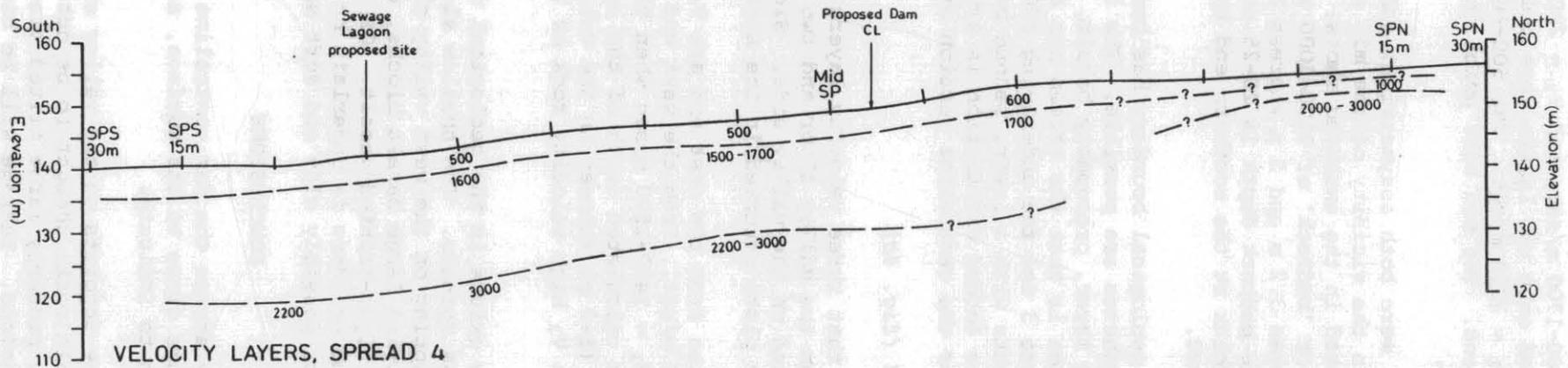
Trenching alone will not be adequate at this site but will need to be followed by a diamond drilling programme with pressure testing as well as sluicing and trenching, both on the valley floor and abutments.

N-S valley floor seismic spread 4 (fig. 4b)

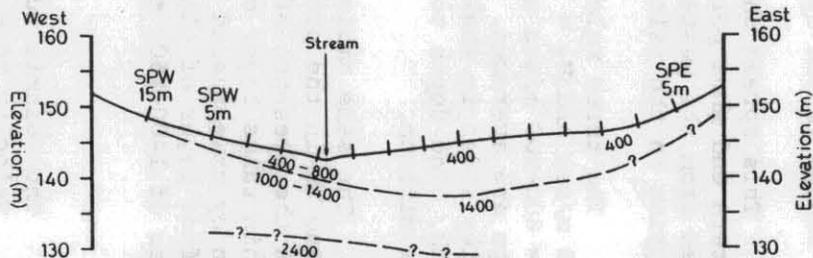
This was a 210 m long spread fired along the valley floor. Three velocity layers were present at the south end, with velocities of



VELOCITY LAYERS ACROSS PROPOSED CENTRELINE



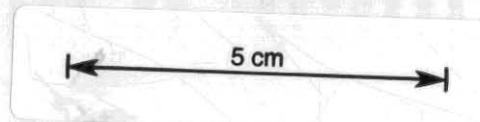
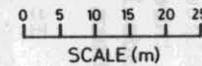
VELOCITY LAYERS, SPREAD 4



VELOCITY LAYERS, SPREAD 5

SEISMIC SECTIONS
 PROPOSED DAM, GRINDELWALD

W. R. MOORE



60-9

Figure 4.

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$V_0 = 500$ m/sec, $V_2 = 1600-1700$ m/sec, and $V_3 = 2200-2500$ m/sec. At the northern end of the spread only two layers were present, with velocities of $V_0 = 1000$ m/sec and $V_1 = 3000$ m/sec. The 500-600 m/sec surface layer was not present at this end. The mid shot point showed the three velocities present at the south end.

The velocity plots were both assymetrical and stepped, with wide steps of 3-4 geophones in the vicinity of the mid shot point. These steps are valid as they persisted in the extended shots. At the northern end the high velocity layer or 'bedrock' of 2000-3000 m/sec has a shallow calculated depth of between 3.2 m and 5 m whereas at the southern end with three velocities the bedrock depth is 20-25 metres. The low velocity surface layer is 5-6 m thick at the southern end but is not seen at the northern end of the spread.

It appears that a geological boundary has been crossed by this spread and two alternative hypotheses are possible. The first model is that the 2000-3000 m/sec velocity layer, presumably basalt, has been downfaulted. An alternative explanation is that the stream has cut through the base of the basalt beyond geophone 3 and the underlying 1700 m/sec V_1 velocity layer is Tertiary sediments with a lower, second basalt or dolerite forming the third layer. If this second explanation is true it alters the interpretation given above for the centreline section of Spread 1.

E-W sewage lagoon spread (fig. 4c)

This spread shows that three velocity layers are present from the eastern end shot point on the valley floor and two velocity layers when fired from the western end on the valley side. Significantly the only stepping in the velocity plots occurred in the shots on the valley slope.

The three velocities from the east end are $V_0 = 400$ m/sec, $V_1 = 1400$ m/sec and $V_2 = 2500$ m/sec. From the west end the velocities are $V_0 = 800-900$ m/sec and $V_1 = 1400-1500$ m/sec when the velocities of the steps are averaged. The calculated depth of the surface layer on the valley sides is shallow (1-2 m) whereas in the valley this layer is 8-10 m thick. The depth to the V_3 high velocity rock of 2400-2500 m/sec is 12-15 m as a minimum.

The same ambiguity exists in the geological interpretation of this spread as in the previous spreads. The shallow slow velocity surface layer with the presence of stepping on the west valley slope appears to indicate a thin talus layer overlying large basalt blocks, or weathered basalt underlain by unweathered and tight-jointed basalt. On the valley floor, a slow surface layer of clay and boulders is underlain by a deep slow velocity layer of 1400-1500 m/sec, possibly clay and soft sandstone of Tertiary age.

CONCLUSIONS

- (1) The seismic survey across the dam centreline shows that no high velocity rock occurs close to the surface, as the surface geological mapping would seem to indicate.
- (2) The talus and scree deposits on the valley slopes appear to be thick, and the large basalt rocks thought to be outcrops appear not to be *in situ*. They are probably large tilted blocks which have moved some distance downslope. Leakage will be high through the boulder scree and talus deposits if their clay content is low.

- (3) The only high velocity rock close to the surface occurs in the valley floor some 60-70 m upstream from the proposed dam centreline.
- (4) The rock profile and depth of weathering on the valley sides in the abutment areas appears highly irregular and any depth interpretation from the seismic survey cannot be considered reliable. It is a guide, at best, in these areas.
- (5) The depth to hard rock in the valley floor at the centreline and in the sewage lagoon areas is deep. The seismic calculations of depth are reliable in this area and any cut-off trench to hard bedrock would be very costly because of the depth. Major leakage problems could occur in both these areas if clay does not occur in the upper surface layer.
- (6) The geological interpretation of the seismic layers is ambiguous and as the feasibility of the dam depends on the composition of the surface and intermediate velocity layers further investigation will be required.

RECOMMENDATIONS

The seismic survey has shown that this dam is not just a large farm dam, but one which will need to be treated as a major construction project. The dam will be equally difficult to construct whether it is 15 or 20 m high. To evaluate the feasibility of the site will require a considerable investigation programme which would include trenching, drilling (both percussion and diamond), pressure testing and possibly sluicing, with more geophysics.

The principals of Vos Holdings Pty Ltd should evaluate how much finance they are prepared to outlay before such an investigation is commenced. Some limited trenching using a heavy traxcavator should first be attempted on the abutment and valley area but problems with groundwater and boulders falling in are likely to occur, and more expensive methods would then be needed. A seismic spread could be fired at the existing Grindelwald ornamental lake dam to check the basalt velocity at this site and compare it with proposed site third velocity layer. If it proves higher than that found for the V_3 velocity at the proposed dam, the site becomes an even more difficult project.

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