DEPARTMENT OF
MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD 1975/124

GINNINDERRA SEWER TUNNEL, SEISMIC REFRACTION SURVEY, 1975

by

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SUMMARY

A seismic refraction survey was carried out along the proposed route of the Ginninderra sewer tunnel line. The proposed tunnel is to be used to transport effluent from the Belconnen suburbs, and future suburbs north of Belconnen, to the Lower Molonglo Water Quality Control Centre on the Molonglo River, A.C.T. The proposed tunnel line runs roughly north-south for 6 km on the western side of the Belconnen suburbs.

Bedrock velocities range from 2200 m/sec in sheared granite to 5000 m/sec in fresh dacite, and depth of weathering varies from about 5 m to almost 40 m. Geological boundaries, faults, and shear zones were located from the seismic data. For most of the tunnel length the bedrock boundary is about 30 m above tunnel level, and hence the nearer-surface data deduced from the seismic survey do not necessarily reflect conditions at tunnel level.

1. INTRODUCTION

A seismic refraction survey was carried out along the route of the proposed Ginninderra sewer tunnel which runs for 6 km on the western side of the Belconnen suburbs and connects the Belconnen Water Pollution Control Centre with the Lower Molonglo Water Quality Control Centre on the Molonglo river. The seismic survey was carried out to provide information on the depth of weathering, bedrock velocities, and other geological features likely to affect tunnelling conditions. The location of the seismic traverses is shown in Plate 1.

The seismic work was carried out between November 1974 and May 1975 by a party under the supervision of the author (see Appendix for operational statistics). The term bedrock as used in this report refers to the deepest refractor detected, and the term overburden refers to the soil, alluvium, and weathered rock above that refractor.

The original proposed tunnel line is that shown as traverse A (Plate 1). This proposed line was altered at the northern end in order to avoid a zone of deep weathering north of chainage 500 m; the new tunnel line in this area is that shown as traverses D and E (Plate 1).

The sewerage line will be constructed by open cut along traverse E to a depth of 5 m to 10 m. From the western end of traverse E a vertical shaft will connect this buried pipeline to the tunnel. This tunnel runs for about 5 km to the treatment works on the Molonglo River. The tunnel will surface at chainage 4800 m and two portals will be constructed on the north side and south side of chainage 4800 m. The tunnel level marked on the seismic cross-sections is the bottom of the proposed tunnel and the height of the tunnel is 3 m.

Some sections of the tunnel line were not covered by seismic work. Surface installations prevented work from being carried out along traverse A between 1820 m and 2420 m and along traverse D between 500 m and 800 m. The area around 4200 m on traverse A proved inaccessible, and the interval 1540 m to 1720 m on traverse D was omitted because of the predictability of the depth of weathering in the sandstone and shales.

2. GEOLOGY

The geology of the area is shown on the Canberra 1 250 000 geological map. The detailed geology of the tunnel line is currently being compiled by Lang (1975) of the Engineering Geology Section of the Bureau of Mineral Resources. The rock types along traverse A (Plates 2, 3 and 4) are as follows:

Chainage (metres)		Rock type
000	1105	Dacite
1105	2540	Sandstone and shale
2540	3450	Granite (sill)
3450	3710	Sandstone and shale
3710	5800	Dacite

The dacite on the northern end (0-1105 m) and the granite (2540 m - 3450 m) are deeply weathered. In general there is 20-30 m of completely weathered rock overlying fresh to slightly weathered rock in these areas. The depth of weathering of the sedimentary rocks is in the order of 10 m, and the depth of weathering of the dacite at the southern end (3710 m - 5800 m) varies from a few metres to 10 m. Several faults have been mapped in this dacite between 4200 and 4500 m. A series of drill holes is currently being drilled along the tunnel line. The results of some of these drill holes are shown in the accompanying seismic cross-sections.

3. METHODS AND EQUIPMENT

Statistical data on equipment and field operations is given in the Appendix. The work commenced in November 1974 and was finally completed in May 1975. This work included: 5 km of continuous seismic refraction along the original proposed tunnel line (trav. A), 1.1 km along the new tunnel route on the northern end (trav. D and E), and 900 m.of cross-traversing (trav. B and C). All seismic work was carried out using 24 channel equipment. A geophone spacing of 4 m.was used at all times, and five shots per spread were fired: one in the centre, one at each end, and one long shot off each end.

Data reduction and interpretation were based on the intercept method (Heiland, 1946) and the reciprocal method (Hawkins, 1961). Further notes are included under Section 4.

4. RESULTS AND INTERPRETATION

4.0. General

The results of the seismic refraction survey are shown in Plates 2 to 5 in the form of cross-sections showing seismic velocities and depths. Boundaries between different geological units are shown. Interpreted faults and shear zones are also shown. Vertical lines shown on the sections have been inserted at those points where distinct changes in velocity have been detected. Some of these changes will be significant for tunnelling conditions.

The overburden velocities vary from 300 m/s to 3100 m/s depending on the geology, while bedrock velocities vary from 2000 m/s to 6000 m/s depending on the occurrence of joints, faults, and shear zones. In general the results along the tunnel line vary widely depending on the rock type. For this reason the results will be discussed in groups according to the geological setting. The geological boundaries shown on the sections - for example, the change from shales and sandstone to granite at 2540 m on traverse A - have been determined from overburden velocities and depths and not from bedrock velocities. In general the bedrock velocity is not a guide to rock types along the tunnel line.

All faults, shear zones and contacts shown in the seismic sections in this report are interpreted from the seismic refraction data. Some of the anomalies are obvious on the time-distance plots from the comparatively large changes in the weathering time, bedrock velocities, and overburden velocities; for example the contact at 2540 m between sedimentary rock and granite involves a change in weathering time from 12 mS to 27 mS, a change in overburden velocity from 1600 m/s to 900 m/s, and a localized anomaly in bedrock velocity. However the majority of these interpreted anomalies are not always obvious on the seismic sections and interpretation is based on the appearance of the time-distance plots which may alter considerably or may show only subtle change at an anomaly. Examples of the criteria used for selecting these anomalies are described below.

One criterion used to determine anomalies in bedrock is the linearity in the plot of average bedrock velocity. If all points of this plot lie close to a straight line then there is little probability of anomalies in bedrock. Of the 15 seismic spreads between 4000 m and 5500 m, 11 show undisturbed bedrock velocity plots. Another three show major disturbances in this plot and coincide with anomalies indicated at 4030 m, 4360 m, and 4950 m, while the final one shows only minor disturbances and coincides with the anomaly indicated at 5200 m.

A second criterion used to detect anomalies is to analyse the near-surface weathering velocities over a considerable distance. If these velocities tend to be uniform over large distance and then show abrupt changes, then an anomaly can be expected near such changes. For example, the contact shown at 3710 m between sediments and volcanics was not detected on first analysis. Later, geological mapping indicated that such a contact must exist between 3600 m and 3800 m and, hence a search was made for any subtle change in the time-distance data. The change finally detected occurred at the junction of two seismic spreads and showed up only as an abrupt increase in the thickness of highly weathered rock (900 m/s) with no disturbance in the bedrock velocity plot.

A third criterion used to detect anomalies, particularly narrow shear zones, is to look for small 'humps' of the order of 1 mS to 2 mS in the time-distance plots. Such 'humps' are generally common to all time-distance plots of the same spread and can be expected at shears and faults because of the greater degree of weathering which can occur in broken ground. This is the basis for the shear shown at 1400 m on traverse D.

Evidence for suspected faults as at 1200 m and 15200 m on traverse D is not as definite, and may be a rapid change in weathered layer velocity or travel time, or a combination of such factors.

4.1. Traverse E(0-500 m), traverse D(500-1135 m)(Plate 5): dacite

Apart from a thin layer of surface soil, the overburden in this area has a velocity ranging from 700 m/s to 1500 m/s. Along traverse E, where the sewerage pipe will be buried in open-cut trenches, the seismic velocities indicate that much of the excavation will be accomplished without blasting. However, blasting will be necessary near the bottom of the trench in the areas of 440 m to 480 m and 290 m to 330 m.

Along traverse D the bedrock-overburden boundary is well above the tunnel level between chainage 900 m and 1135 m. However, north of chainage 900 m this boundary approaches within 1 m of the top of the tunnel. The region north of chainage 800 m was not covered by seismic work because of surface installations, and hence it is not known whether or not this boundary will intercept the roof of the tunnel in this area.

Bedrock velocities in the interval 800 m to 1140 m are generally high and indicate good tunnelling conditions. However, factors which may affect tunnelling conditions are the deep weathering between 800 m and 900 m, the fault shown at 1020 m with the associated low bedrock velocity, and the low velocity zone at 1100 m.

4.2. Traverse D(1135-1710 m)(Plate 5);traverse A(1710-2540 m)(Plates 2 and 3); shale and sandstone

The overburden consists of a thin layer of soil overlying weathered rock of velocity varying from 800 m/s to 2000 m/s. The bedrock velocity varies from 4200 m/s to 5400 m/s and in general is fairly uniform. The bedrock-overburden boundary is 20-40 m above tunnel level. Factors likely to affect tunnelling conditions are the suspected faults at 1200 m and 1530 m and the indicated 15-m-wide shear zone at 1400 m.

4.3. Traverse A(2540-3450 m) (Plate 3); granite

Along this part of traverse A the overburden consists of a layer 2-6 m thick of velocity 600-800 m/s overlying moderately weathered granite of velocity 1100-1700 m/sec. The chainage 2540-2670 m is an exception; here the overburden consists almost entirely of 25 m of completely weathered granite. Drill hole GST No. 1 drilled at chainage 2593 m penetrated 25 m of completely to highly weathered granite before reaching bedrock.

Bedrock velocities vary from 2000 m/s to 5200 m/s and the rapid variation of these measured velocities indicates that bedrock is not uniform, and that tunnelling conditions will vary considerably along this section of the tunnel. However caution should be exercised in extrapolating bedrock velocities to tunnel level, since the granite is known to be a sill and the geophysics gives no data on the depth to the base of the sill or conditions below the base. The distance between the bedrock-overburden boundary and the tunnel level is large enough to be disregarded as a factor likely to affect tunnelling conditions. Particular factors which are likely to affect tunnelling conditions are the low velocity zones and discontinuities indicated at 2570 m, 2940 m, 3070 m, 3140 m, and 3180 m.

4.4. Traverse A(3450-3710 m)(Plate 3); shale and sandstone

This section of the tunnel line is similar to the section of shale and sandstone on the tunnel line farther north. There are no shear zones, faults, or low velocity zones indicated along this chainage.

4.5. Traverse A(3710-5500 m)(Plates 3 and 4); dacite

The dacite over this final section of the tunnel line differs from that encountered at the northern end: overburden velocities are higher and the depth of weathering shallower than those at the northern end. This indicates that this dacite is more resistant to weathering.

The depth of weathering lies between 10 and 20 m for the majority of the tunnel line along this chainage, and the bedrock-overburden boundary is well above the tunnel level. The excavations for the two portals near chainage 4800 m will be in moderately weathered to fresh rock, very little of which will be removed without blasting.

In general bedrock velocities are below 4000 m/s, which is unusually low for dacite. The low velocities (3000 m/s-3700 m/s) between 4380 and 4680 m are known to coincide with a wide fault zone. The low velocities (3500 m/s-3900 m/s) between 5000 and 5400 m may reflect extensive fractures in bedrock. Other factors which may affect tunnelling conditions are the two faults indicated at 4030 and 4350 m, and the shear zones indicated at 4950 and 5200 m.

Between 5100 and 5500 m, the bedrock-overburden boundary is between 35 and 45 m above the tunnel level. For this reason the values of bedrock velocity are not expected to reflect tunnelling conditions. The value of seismic work in such areas of obvious shallow weathering is questionable, particularly when the depth to the tunnel level is quite large.

4.6. Traverse C(Plate 5): granite and sandstone

This short traverse was shot at right-angles to traverse A at chainage 2593 m in order to determine the boundary between the sedimentary rocks and granite. The locations of this boundary on traverse A (Plate 3) and traverse C (Plate 5) make it possible to determine the strike of the interface in the vicinity of the tunnel.

4.7. Traverse B(Plate 5): dacite

A short traverse was shot at right-angles to traverse A at chainage 4260 m to locate a possible faulted contact between two different geological units just to the west of the tunnel line. The contact between the two units is shown (Plate 5) as a slight change in the degree of weathering in the overburden, but no faulting could be detected. A fault has been detected on the eastern side of the tunnel line; it may link with the one shown on traverse A at chainage 4350 m.

5. CONCLUSIONS

The seismic refraction survey was successful in locating boundaries between different rock units along the tunnel line. Several faults and shear zones were also located. The wide zones of low bedrock velocity on the southern end of the tunnel line are due to fractures in bedrock. Tunnelling conditions in these zones will depend on the distribution of the fractures and whether the voids are filled with clay; they will also depend on whether the velocities shown are representative of rock properties at depth.

Correlation of the seismic results with current drill-hole data shows the seismic results to be quite reliable.

6. REFERENCES

HEILAND, C.A., 1946 - GEOPHYSICAL EXPLORATION. New York, Prentice Hall Inc.

HAWKINS, L.V., 1961 - Reciprocal method routine seismic refraction investigations. Geophysics, 26 (6), 806-19.

LANG, P., in prep. - Geological investigation of the proposed Ginninderra Sewer Tunnel. Bur. Miner. Resour. Aust. Rec. (unpubl.).

APPENDIX: OPERATIONAL STATISTICS

PERSONNEL

Supervisor	- F.J. TAYLOR
Observer	- D. FRANCIS
Shooters	- R. CHERRY
	L. RICKARDSSON
	E. CHUDYK
	and two field hands.

STATISTICS

No. of days of fieldwork	30
Explosives (gelignite)	230 kg
Detonators (electric)	450
Geophone spacing	4 m
Distance covered	7 km

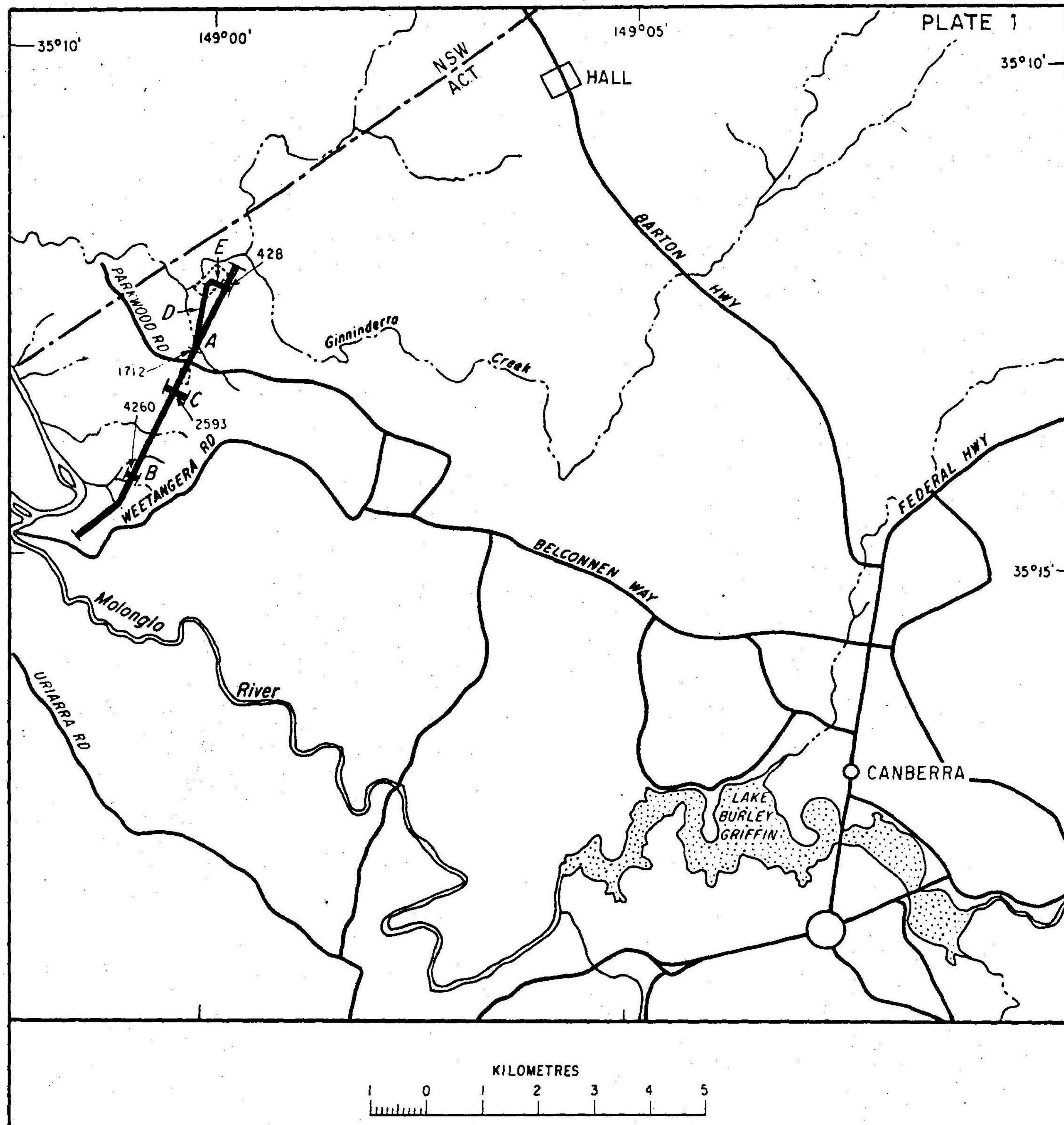
EQUIPMENT

Amplifier	24 channel S.I.E. PSU-19
Camera	VRO-6D
Geophones	GSG-20D
Blastor	BC8-A

VEHICLES

Recorder	International 1300
Shooting truck	L.W.B. Landrover utility

PLATE 1



GINNINDERRA SEWER TUNNEL, A.C.T., 1975

LOCATION OF TRAVERSES

TRAVERSE "A"
0-2000
SIESMIC CROSS-SECTION

PLATE 3

TRAVERSE A
2000-4000
SIESMIC CROSS-SECTION

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TRAVERSE "A"
4000-5800
SIESMIC CROSS-SECTION

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TRAVERSE B,C,D,&E
SIESMIC CROSS-SECTIONS
GINNINDERA SEWER TUNNEL

I55/B5-269

Record No 1975/124