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BUREAU OF MINERAL
RESOURCES, GEOLOGY
AND GEOPHYSICS

Record 1972/9

ADA-LA TROBE PUMPED STORAGE HYDRO-ELECTRIC SCHEME, S.E.C., VICTORIA, 1971.

by

B.H. Dolan, P.J. Hill, and E.J. Polak

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SUMMARY

A seismic refraction survey was carried out in January-February 1971 by the Bureau of Mineral Resources, Geology and Geophysics on the site of the proposed pumped storage hydro-electric scheme of the State Electricity Commission of Victoria (S.E.C.) near Powelltown, Victoria. Two 24-channel seismic refraction units were used with geophone spacing of 25 or 50 ft on normal spreads and 10 ft on weathering spreads.

The bedrock in the area consists of Upper Devonian granite. The bedrock is characterized by a very high seismic velocity, but several zones of lower seismic velocity were located and interpreted as shear zones.

The overburden consists of weathered granite in situ, scree material, and alluvium. The weathered rock extends on some locations to depths of 200 feet.

The values of Poisson's ratio and modulus of elasticity for bedrock measured in situ and in the BMR Rock Testing Laboratory on cores are given. The correlation between in situ and laboratory measurements is high.

1. INTRODUCTION

The State Electricity Commission of Victoria proposes to construct a pumped storage hydro-electric scheme on the Ada and La Trobe Rivers near Powelltown. Investigations, consisting of geological mapping, drilling, and seismic refraction surveying, were carried out.

The proposed Ada-La Trobe pumped storage scheme is located in the Warburton area, approximately 70 miles east of Melbourne (see locality map, Plate 1). The scheme consists of an upper storage located on the Ada River and a lower storage located on the La Trobe River. The water storages will be connected through a power station by a tunnel approximately 1½ miles long, the head available for power generation being about 1000 ft. During the low power demand in Melbourne, the turbines will be reversed and the water pumped up from the lower storage area into the upper reservoir. Two alternative sites for the upper dam and tunnel were investigated.

A similar scheme at Wilhelmina has been investigated simultaneously (Dolan et al., 1971). The details of the schemes are discussed by Howard (1970).

A seismic refraction survey was carried out by the BMR Engineering Geophysics Group to assist in the site investigation. The party consisted of E.J. Polak, P.J. Hill, B.H. Dolan (Geophysicists) and M. Dickson (Technical Assistant). The work was carried out between 19 January and 17 February, 1971. The State Electricity Commission provided the topographical survey and six field hands to assist in the geophysical work.

Mr F.J. Taylor assisted with interpretation of results.

The field measurements were made in British units. The laboratory measurements and the plots of modulus of elasticity, which resulted from the laboratory measurements, were made in metric units.

2. GEOLOGY

(Prepared by P. Learmonth, S.E.C., Vic.)

The area covered by the proposed works is located entirely within the Tynong Granite Massif. The granite is a light coloured, medium-grained to porphyritic potash granite of Upper Devonian age (Baker et al., 1938).

Rock outcrops are rare and weathering is extensive, the depth of completely weathered rock extending to at least 150 feet in some instances. Where observed in drilling, the change from completely weathered to hard fresh rock is quite abrupt, there being no distinct zone of moderately weathered rock.

The stream pattern of the area is controlled by a rectangular system of joints and faults. The deep weathering of the granite may also have resulted as a consequence of this joint and fault system.

3. METHODS AND EQUIPMENT

The seismic refraction method was used in the survey (Heiland, 1946). The depths to the different velocity layers at the shotpoints were calculated using the time intercept method (Heiland, 1946, 512) and the depth at each geophone along the traverse was obtained using a modified method of differences (Heiland, 1946, 548). The values of Poisson's ratio and modulus of elasticity for bedrock material at a number of localities were calculated from in situ measurements of longitudinal and transverse wave velocities (Polak, 1963). To determine the ratio of longitudinal to transverse wave velocities, three Hall-Sears 7 Hz 3-component shallow-borehole geophones were used. These were buried at 25 ft spacing along the traverse line and shots were fired at sufficient distance from the geophones to assure bedrock velocities were measured.

In the BMR Rock Testing Laboratory, Poisson's ratio, modulus of elasticity, and logarithmic decrement, were determined on core samples from boreholes in the area. These values were calculated from measurements of ultrasonic velocities in the cores, the resonant frequency of vibrations, and the shape of their frequency response curves near resonance (Polak, 1963).

The equipment used during the survey consisted of two identical 24-channel S.I.E. seismic refraction seismographs and 20 Hz T.I.C. geophones. The spacing of geophones was 25 or 50 ft for normal spreads and 10 ft for weathering spreads. Shots were fired 5 ft and 200-400 ft from each end of the geophone spread and in line with spread, with an additional shot at the centre of the spread.

4. RESULTS

The layout of seismic traverses is shown on plate 2 and the sections obtained from seismic interpretations are shown on plates 3 to 15.

4.1 Seismic velocities

Two broad categories of materials can be resolved on the basis of seismic velocities:

(1) unconsolidated material with a seismic velocity of less than 5,500 ft/sec

(2) weathered and unweathered bedrock with seismic velocities between 3,500 and 20,000 ft/sec.

In the range 3,500 to 5,500 ft/sec, velocities in both groups overlap and therefore the final inclusion of material in any of the groups must be done with the help of geological or drilling evidence.

4.1.1 Unconsolidated material

Unconsolidated material consists of soil, alluvium, hillwash and scree material.

(i) Soil and alluvium - Soil and alluvium form a generally thin layer of up to six ft, but possibly reaching a depth of 25 ft on some locations. Seismic velocity is between 800 to 1,200 ft/sec. In all computations, a velocity of 1,000 ft/sec was accepted for this layer. A velocity of 5,000 ft/sec was obtained in some areas of known alluvium, indicating the layer is completely water saturated and presumably below the water table.

(ii) Hillwash and scree material and very weathered bedrock material - these are found on slopes and on flat areas below the slopes. The material consists of angular or partly rounded boulders imbedded in clay, and the velocities in this layer are between 3,000 and 5,000 ft/sec. It is possible that at the bottom of this layer large boulders increase layer velocity, and scree material may be included into lower layers in the seismic interpretation. Very weathered bedrock material will have the same velocity as scree material, the only difference being that this material is *in situ*.

4.1.2 Weathered to unweathered material

(i) Completely weathered (CW) to highly weathered (HW) rock- This material has the same velocity as scree material; the only difference being that the weathered material is *in situ*, a fact which is not recognizable from seismic velocities.

(ii) Slightly weathered to fresh bedrock - Higher seismic velocities 5,000 ft/sec to approximately 8,000 ft/sec indicate rock less weathered than above with seismic velocities increasing with the decrease in weathering. Above 8,000 ft/sec the rock should be jointed, possibly with some weathering on joints, and the joints may be open for lower velocities in this range; with velocities of above 12,000 ft/sec, the rock is fresh with joints closed.

The seismic velocities can be related to some physical properties of the rock, and the relationship between seismic velocity and modulus of elasticity will be discussed in parts 4.3 and 4.4. Two important relations should be mentioned here:

(a) the rippability - it is generally possible to remove, without blasting, rock with a seismic velocity of 6,000 ft/sec using a D9 bulldozer (Bartlett, 1969);

(b) the strength of rock - rock with seismic velocity of 7,500 ft/sec will support a medium height earth dam (Wiebenga & Polak, 1956).

4.2 Depth to bedrock

Depths to bedrock obtained during the survey are plotted on plates 3 to 15.

There are some limitations to the seismic method, and these should be remembered when examining the results shown on the plates:

1) Using a spacing of 50 ft between geophones, some of the details of the bedrock surface can be missed and thus narrow zones of deeper weathering may not be recorded at all; the depressions in the buried surface may be shown to be shallower and the uplifts to be depressed.

2) On sections where several low velocity layers are shown to lie directly on high velocity bedrock (e.g. Plate 9), the existence of a thin layer with velocity of 7,000 to 10,000 ft/sec is suspected, but the layer is too thin to be shown on the time distance curves. The depth shown on the section will be slightly underestimated if this layer exists.

3) The depth to bedrock is calculated using a conversion factor obtained at the shot points. Between the shot points, the conversion factor is interpolated assuming a gradual lateral change of properties of upper layers. This may introduce some inaccuracy in depth determination.

4) The boundaries between upper layers are determined at shot points, but interpolated between them. For this reason they are shown as a broken line on the sections.

The error of the absolute depth determinations is estimated to be about 15 percent. This is based on experience from previous surveys where the interpretations of the seismic surveys have been tested by drilling. The relative depth to bedrock and the general shape of the interface will show greater accuracy.

4.3 Structural indications

Structural changes in the bedrock may be indicated by the seismic survey in several ways:

1) by a change in seismic velocity;

2) by a localized change in thickness of overburden or local deflection in the bedrock interface;

3) by a change in character on part of the field record.

It is necessary to stress that the use of only one geophysical method to indicate structural changes will not generally be sufficient for a high level of confidence in the interpretation. Therefore the following indications in this Record should be considered as suggestions for further investigations by geological or other means.

4.3.1 A fault is possible in cutting No. 1 portal (Plate 8) at chainage 799, and in No. 1 dam site (Plate 3) at chainage 2686. Mussa Creek may follow this fault further east, with indications of faulting at chainage 830 (Plate 5 near peg No. A55) and on chainage 350 on cross-line No. 3 (Plate 5).

4.3.2 In tunnel No. 1, an indication of a fault is shown at chainage 4774 followed by a low velocity zone (9,500 ft/sec) extending to chainage 5272 (Plate 9). This indication of a fault is confirmed by thickening of the overburden layer. Continuation of this structure is suggested in tunnel No. 2 at chainage 4566 (Plate 11) by thickening of the weathered layer. However, there is no corresponding drop in bedrock velocity as in tunnel No. 1.

4.3.3 In tunnel No. 1 (Plate 9) at chainage 6760, a boundary between two velocities 17,000 and 11,000 ft/sec may be faulted. This fault may cross the tailrace cut at chainage 600 (Plate 12), although there is no corresponding change in seismic velocities.

4.3.4 Along the whole length of the tailrace cut (Plates 12 and 13), a less weathered layer of velocity 7,000 to 8,500 ft/sec is indicated. The same layer is too thin on the tunnel lines to be recorded. The tunnel lines are located along the slope where the weathered material would be more subject to slumping, resulting in deep penetration of surface water and more rapid removal of weathered material, while the tailrace traverse is level and therefore the weathered material is more stable. It is also possible that the tailrace cut traverse follows a fault, and the deeper weathering is a result of this fault. The thickness of the alluvium (5,000 ft/sec) increases in an easterly direction, indicating deep erosion of La Trobe River.

4.3.5 On the Lower Dam site, the La Trobe River follows a fault which is indicated by a depression in the bedrock and a lower velocity zone (Plate 14) close to peg S.

4.3.6 On the Lower Dam site, a possibility of a fault exists at the southern end at chainage 450 (from peg A) where a low velocity zone is indicated (Plate 14).

4.3.7 Excessive thickness of overburden at chainage 338 (Plate 15), Section U-Y may represent a fault parallel to the La Trobe River, but there is no decrease in bedrock velocity.

4.3.8 Although seismic refraction work indicates that the directions of flow of Mussa Creek and La Trobe River (see 4.3.1 and 4.3.5) are controlled by faults, there is no evidence that the Ada River follows a fault.

4.4 Dynamic properties of rocks in situ

Table 1 gives the dynamic properties of the rock as measured on the sites and the locations where the geophones and the shot were placed for the test.

The computation of the results was carried out according to the usual procedure (Polak, 1963).

In computing the dynamic properties of the rock in situ, it is necessary to know the specific gravity. In order to obtain the specific gravity, use was made of a plot of longitudinal velocity against specific gravity of core samples. Hence from the known values of longitudinal velocity in situ, the specific gravity was chosen. This procedure gives an average value (between shot and geophone), of modulus of elasticity for the rock in situ which is higher than the true value because there is an over-estimation of the density, no account being taken of jointing. This over-estimation may be up to 10 percent for rock of low velocity. For deeper rocks, where the joints are more closed, the overestimation is very small.

The dynamic properties of rocks listed on Table 1 were measured at the interface of the unweathered bedrock (the lowest velocity 13,100 ft/sec). The results are plotted on Plate 16. Extrapolating the best fitting line to the velocity of the rock in the shear zone (9,000 ft/sec = 2,800 m/sec), a value for the modulus of elasticity of 2.3×10^6 lbs/sq in is obtained. This value is lower than the value for average concrete, and therefore if the shear zones extend into the tunnel or underground power station, this fact must be taken into consideration in design of the structures or tunnel lining.

4.5 Laboratory measurements or cores

Table 2 gives the value of some properties of rocks from Ada-La Trobe bores measured in the BMR Rock Testing Laboratory. Plate 16 shows a plot of modulus of elasticity versus the seismic velocity. Table 2 indicates that 3 rock cores described as a "slightly weathered" are characterized by a velocity of more than 17,000 ft/sec and 3 rock cores described as "moderately weathered" give velocity of 10,000-12,000 ft/sec.

The regression coefficients on both laboratory and field measurements are very high, indicating that the quality of rock is uniform over the area investigated.

Values for the logarithmic decrement of the fresh rock cores are low, and even for moderately weathered rock are below 0.1 (E2 = 0.086; E4 = 0.089), indicating uniform weathering throughout each rock core.

5. CONCLUSIONS

The following conclusions can be reached from the results of the seismic refraction survey:

5.1 Weathering

The extent of weathering is considerable in all parts of the surveyed area and weathering depths of 180 to 200 ft are quite common.

On many locations in the area, the highly weathered material is so thick that the thin slightly weathered layer beneath it has probably been missed. The deeper weathering along the tunnel lines may indicate slumping of the weathered material down the slope.

5.2 The bedrock

High seismic velocities indicate good quality rock. Several wide zones of lower velocity were found and may indicate shear zones connected with faulting.

5.3 Dynamic properties of rocks

Moduli of elasticity of the bedrock, as measured in the field and in the laboratory, are high. Values of both measurements correlate very closely. It is expected that the bedrock, if jointed, has the joints closed. Where there are low velocity zones (less than 11,000 ft/sec), the modulus of elasticity of the rock is lower than that of concrete. Some of these zones extend below tunnel level.

6. REFERENCES

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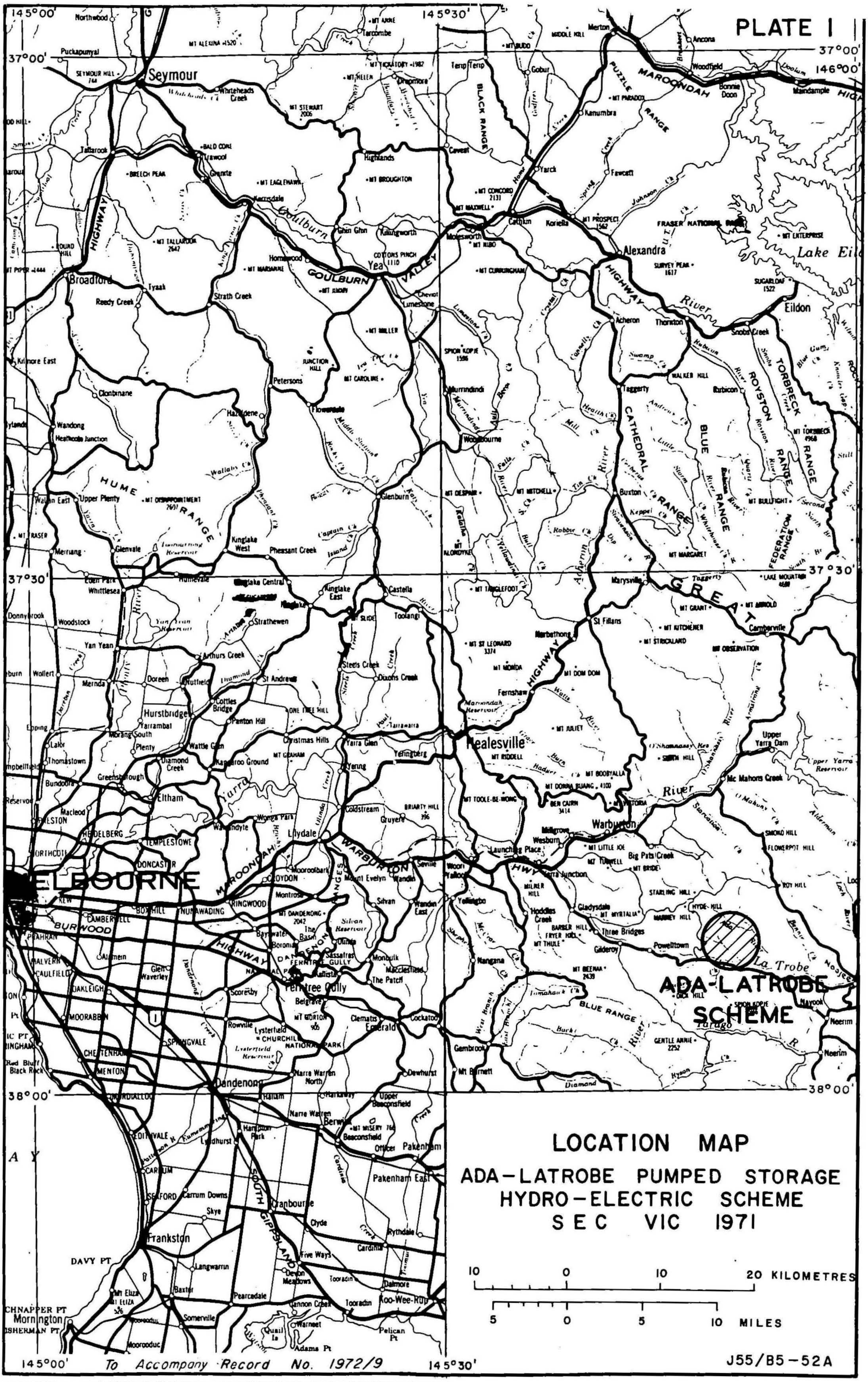
TABLE 1. DYNAMIC PROPERTIES OF ROCKS - IN SITU MEASUREMENTS

Location: Geophone Position (chainage)	Location: Shot Position	Longitudinal Velocity m/sec	Longitudinal Velocity ft/sec	Poisson's Ratio	Modulus of Elasticity $kg/cm^2 \times 10^5$	Modulus of Elasticity $lbs/sq\ in \times 10^6$	S.G. as measured from the plot of S.G. against velocity for core samples
NO. 1 DAM SITE							
2050	3,205	4,600	15,000	0.21	4.93	7.01	2.57
2150	800	4,600	15,000	0.28	4.34	6.17	2.57
2550	2,820	4,600	15,000	0.28	4.34	6.17	2.57
DAM NO. 2							
400 ft South of Peg A61	00 (Peg A55)	4,900	16,000	0.245	5.32	7.56	2.58
1125 Between Pegs A43, A50)	1,600 (A50)	4,600	15,000	0.28	4.34	6.17	2.57
SUBSIDIARY DAM SITE							
Peg A28	250 ft East of Peg A23	4,000	13,100	0.25	3.44	4.89	2.53
CONNECTION TIE (SUBSIDIARY, NO. 2 DAM SITES)							
300 (Between Pegs A17, A19)	Peg A23	5,100	16,700	0.29	5.27	7.49	2.60
LOWER DAM SITE							
500	1125	4,600	15,000	0.27	4.44	6.31	2.57
TUNNEL NO. 1							
750	295	4,900	16,000	0.285	4.88	6.95	2.58
5700	4900	4,600	15,000	0.3	4.12	5.86	2.57
2350	1200	4,600	15,000	0.295	4.18	5.94	2.57
2250	3200	4,300	14,100	0.26	3.93	5.59	2.55
5650	4125	4,300	14,100	0.3	3.57	5.08	2.55

TABLE 2. LABORATORY MEASUREMENTS

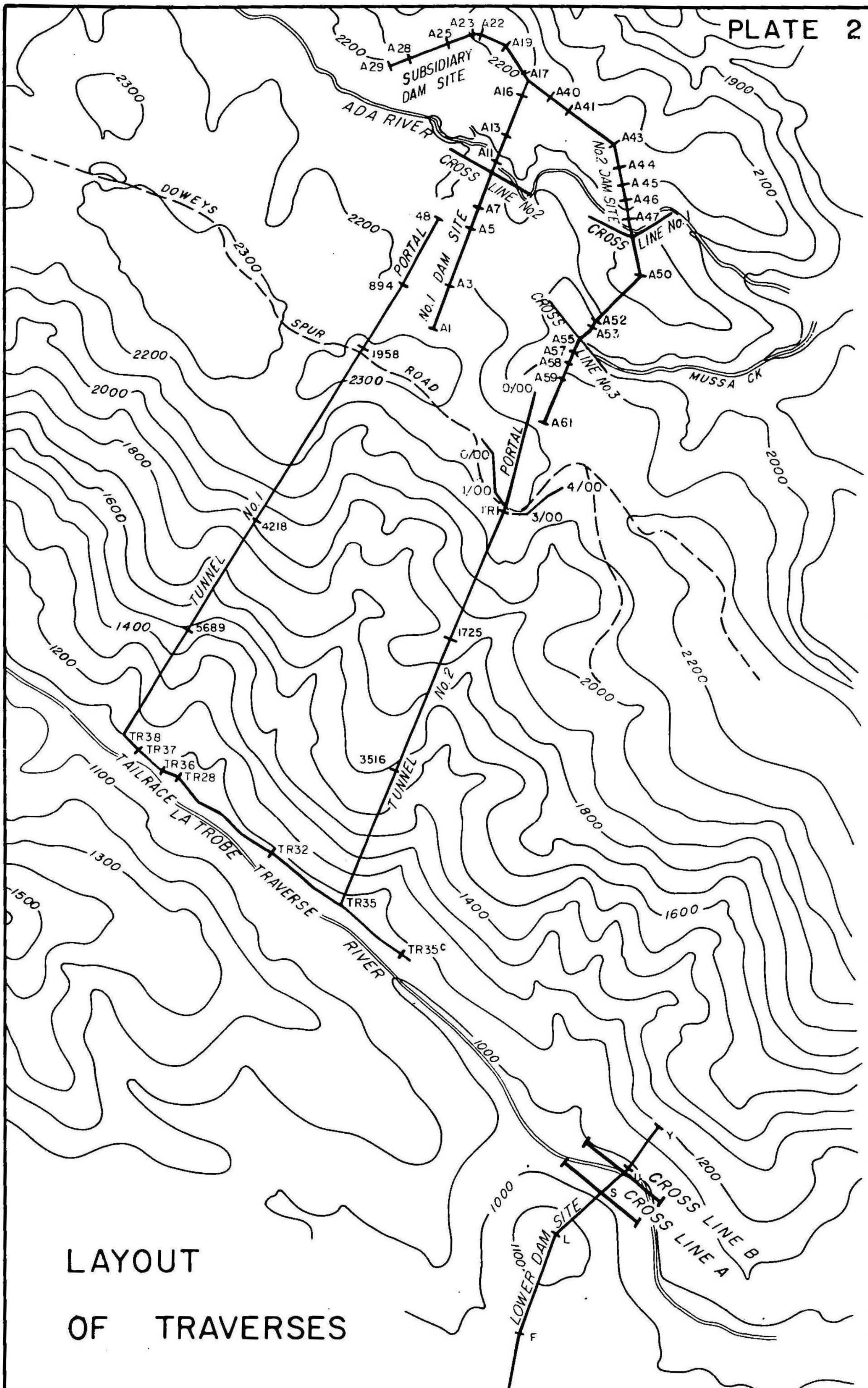
Borehole	Depth Feet	Rock Type	Specific Gravity	Longitudinal Velocity m/sec	Longitudinal Velocity ft/sec	Modulus of Elasticity kg/cm^2 x10^5	Modulus of Elasticity lbs/in^2 x10^6	Poisson's Ratio	Logarithmic Decrement
E1	99'6" - 100'	Granite Slightly Weathered	2.58	5,279	17,300	5.73	8.15	0.28	0.056
E2	134'6" - 135'	Moderately Weathered	2.49	3,194	10,500	2.21	3.14	0.24	0.096
E2	168'6" - 169'	Slightly Weathered	2.56	5,223	17,100	5.97	8.49	0.25	0.032
E4	155' - 155'6"	Moderately Weathered	2.53	3,723	12,200	2.80	3.98	0.28	0.089
E5	136'	Highly Weathered	2.08						
E7	121' - 121'6"	Fresh	2.65	5,733	18,800	7.04	10.01	0.28	0.021
E7	90'6" - 91'	Moderately Weathered	2.45	2,600	8,500				
E7	94' - 94'6"	Slightly Weathered	2.61	5,275	17,300	5.36	7.62	0.31	0.050
E8	24'6" - 25'	Slightly Weathered	2.60	4,841	15,900	5.00	7.11	0.27	0.056
E12	36'5" - 36'	Fresh	2.63	4,975	16,300	5.14	7.31	0.29	0.041

PLATE I



LOCATION MAP
ADA-LATROBE PUMPED STORAGE
HYDRO-ELECTRIC SCHEME
S E C VIC 1971

PLATE 2

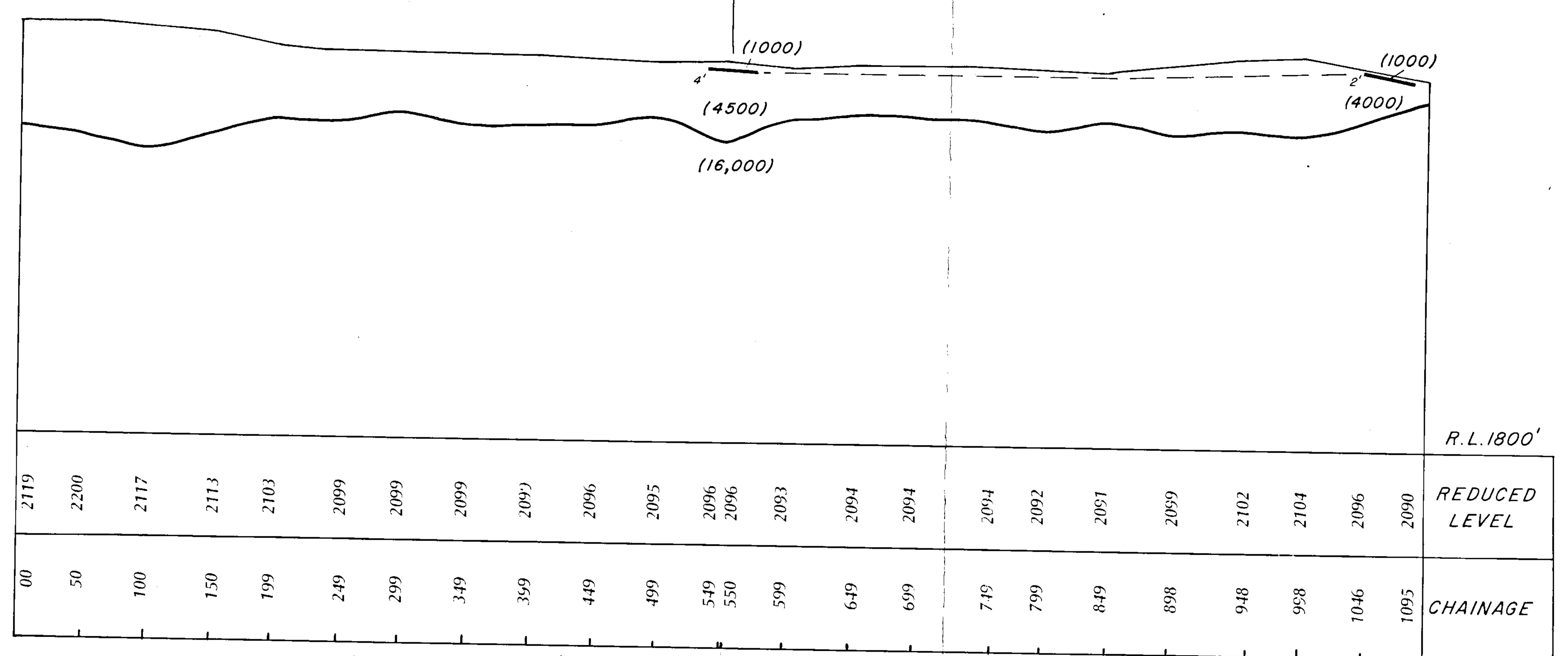


LAYOUT OF TRAVERSES

To Accompany Record No. 1972/9

J55/B5-43A

UPPER DAM SITE No. 1



CROSS LINE No. 2

UPPER DAM SITE No I

SEISMIC CROSS-SECTIONS

100 0 100 200 Feet
40 0 40 80 Metres
(Horizontal and Vertical)

To Accompany Record No. 1972/9

J55/B5-53

PART UPPER DAM SITE No. 2

CROSS LINE No. 1

UPPER DAM SITE No 2

SEISMIC CROSS-SECTIONS

(Horizontal and Vertical)

To Accompany Record No. 1972/9

J55/B5-54

PART UPPER DAM SITE No. 2

CROSS LINE No. 3

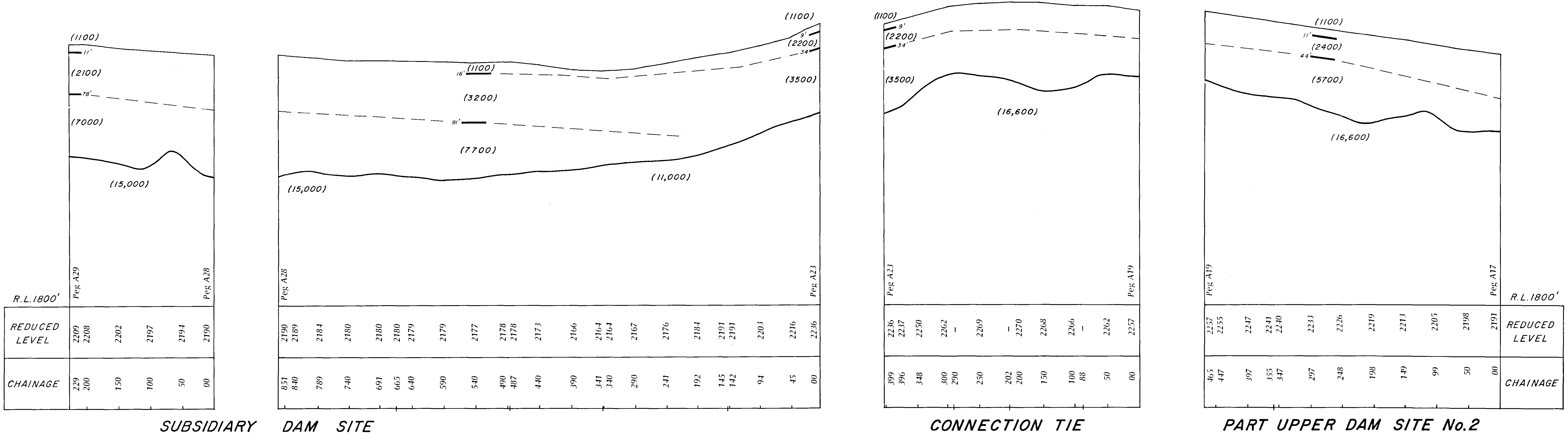
SUBSIDIARY DAM SITE

SEISMIC CROSS-SECTIONS

100 0 100 200 Feet
40 0 40 80 Metres
(Horizontal and Vertical)

To Accompany Record No 1972/9

J55/B5-55



SEISMIC CROSS-SECTIONS

100 0 100 200 Feet
40 0 40 80 Metres
(Horizontal and Vertical)

To Accompany Record No. 1972/9

J55/B5-56

DOWEYS SPUR ROAD TRAVERSE

DOWEYS SPUR ROAD TRAVERSE

SEISMIC CROSS-SECTIONS

100 0 100 200 Feet

40 0 40 80 Metres

(Horizontal and Vertical)

To Accompany Record No. 1972/9

J55/B5-57

REDUCED LEVEL	2184	2199	2213	2227	2238	2248	2256	2264	2270	2273	2272	2270	2267	2265	2265	2267	2271	2275	2279	2284	2290	2297	2304	2304	2307
CHAINAGE	3572	3524	3476	3428	3379	3330	3281	3231	3181	3132	3082	3032	2982	2932	2882	2832	2782	2732	2682	2632	2583	2533	2483	2433	2383

REDUCED LEVEL	2310	2313	2317	2318	2318	2319	2319	2321	-	2322	2323	2325	2324	2321	2318	2312	2306	2301	2295	2289	2284	2279	2273	2268	2259
CHAINAGE	2333	2283	2233	2183	2133	2083	2033	1983	1958	1933	1883	1833	1783	1733	1683	1633	1584	1534	1484	1435	1385	1335	1286	1236	1187

REDUCED LEVEL	2250	2241	2230	2220	2203	2191	2175	2163	2153	2149	2143	2139	2137	2133	2132	2130	2130	2135	2131	2135	2133	2128	2125	2125
CHAINAGE	1137	1088	1039	991	943	894	847	799	749	699	650	600	550	499	450	400	350	300	249	200	150	100	50	00

PART TUNNEL No. 1 AND TUNNEL PORTAL

PORTAL and TUNNEL No 1

SEISMIC CROSS-SECTIONS

100 0 100 200 Feet

40 0 40 80 Metres

(Horizontal and Vertical)

To Accompany Record No 1972/9

J55/B5-58

TUNNEL No I CONTINUATION

SEISMIC CROSS-SECTIONS

REDUCED LEVEL	CHAINAGE
1068	7159
1072	7127
1073	7109
1077	7059
1081	7010
1080	6959
1086	6910
1087	6860
1088	6810
1090	6760
1099	6710
1104	6661
1106	6611
1116	6562
1122	6512
1141	6465
1161	6420
1181	6374
1203	6329
1223	6283
1242	6236
1262	6190
1282	6144
1301	6098

REDUCED LEVEL	CHAINAGE
1301	6098
1323	6053
1347	6009
1369	5964
1391	5918
1412	5872
1434	5828
1455	5782
1475	5736
1495	5689
1514	5643
1537	5598
1554	5551
1574	5505
1594	5459
1613	5412
1633	5366
1650	5319
1667	5272
1679	5223
1684	5173
1685	5123
1682	5073
1681	5023
1680	4973
1682	4923
1681	4873
1675	4823
1683	4774
1705	4729
1729	4685
1749	4639
1768	4592
1783	4544
1800	4497
1817	4450
1832	4402
1846	4354
1863	4307
1884	4262
1907	4218
1933	4175
1957	4129
1978	4083
1998	4037
2017	3991
2038	3945
2059	3900
2080	3854
2100	3808
2119	3762
2138	3715
2154	3668
2170	3620
2184	3572

PART TUNNEL No.1

PART OF TUNNEL No 2

SEISMIC CROSS-SECTIONS

REDUCED LEVEL	CHAINAGE
1028	5053
1034	5029
1051	4982
1070	4935
1088	4889
1108	4842
1126	4796
1145	4749
1164	4703
1180	4666
1180	4657
1202	4612
1221	4566
1241	4520
1264	4476
1289	4433
1298	4411
1311	4387
1330	4341
1352	4296
1373	4251
1387	4219
1394	4204
1414	4158
1436	4112
1453	4065
1458	4053
1472	4016
1490	3971
1506	3925
1513	3906
1522	3877
1534	3828
1538	3808
1543	3779
1551	3729
1559	3680
1567	3630
1575	3581
1586	3532
1587	3516
1592	3483
1599	3433
1605	3383
1610	3334
1616	3284
1622	3234
1628	3184
1630	3157
1632	3134
1635	3084
1637	3034
1642	2985
1648	2935
1657	2886
1667	2837
1675	2796
1677	2788
1687	2739
1691	2724
1698	2690
1704	2640
1704	2633
1706	2590
1705	2540
1704	2490
1707	2440
1712	2390
1720	2349
1722	2341
1734	2292
1748	2244
1762	2196
1772	2156
1774	2147
1787	2099
1793	2065
1796	2050
1803	2001
1810	1951
1819	1902
1828	1853
1836	1803

R.L.800'

To accompany Record No. 1972/9

PART TUNNEL No.2

J55/B5-61

CONTINUATION OF TUNNEL No 2 AND TUNNEL PORTAL SEISMIC CROSS-SECTIONS

REDUCED LEVEL	1837	1843	1844	1844	1845	1846	1850	1859	1867	1876	1887	1898
CHAINAGE	1797	1754	1725	1704	1654	1604	1554	1504	1455	1406	1357	1309

REDUCED LEVEL	1912	1916	1925	1939	1953	1968	1980	1993	2007	2022	2037	2051
CHAINAGE	1261	1247	1213	1164	1115	1067	1019	971	923	875	827	779

REDUCED LEVEL	2064	2073	2075	2087	2099	2110	2118	2122	2127	2130	2139	2151
CHAINAGE	731	690	682	633	585	536	486	437	398	387	338	289

REDUCED LEVEL	2164	2178	2191	2205	2218	2229	2230	2240	2249	2257	2262	2266
CHAINAGE	241	193	141	97	49	00	1425	1376	1327	1277	1227	1178

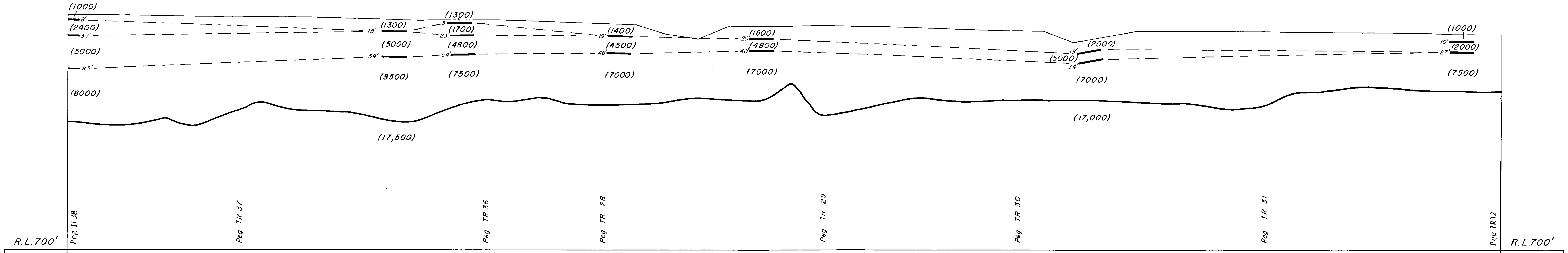
REDUCED LEVEL	2266	2266	2268	2268	2269	2268	2265	2262	2258	2255	2252	2251
CHAINAGE	1128	1078	1028	978	928	878	828	778	728	678	628	578

REDUCED LEVEL	2245	2241	2237	2231	2225	2215	2200	2182	2161	2140	2119	2109
CHAINAGE	528	478	428	379	329	280	233	186	141	94	49	00

PART TUNNEL No.2 — *TUNNEL PORTAL*

To Accompany Record No 1972/9

J55/85-60



CHAINAGE	REDUCED LEVEL
00	1072
50	1072
100	1071
150	1070
200	1070
250	1069
269	1069
300	1069
350	1069
400	1067
450	1065
500	1064
550	1063
600	1063
650	1063
660	1063
700	1062
750	1060
800	1059
848	1057
850	1057
900	1054
948	1040
998	1033
1045	1052
1095	1053
1145	1053
1194	1054
1198	1054
1244	1051
1294	1051
1344	1050
1394	1049
1444	1048
1494	1047
1508	1046
1544	1045
1591	1028
1640	1038
1690	1045
1740	1045
1790	1044
1840	1044
1890	1044
1894	1044
1940	1043
1990	1043
2040	1042
2090	1042
2140	1041
2190	1040
2240	1040
2269	1040

PART TAILRACE TRAVERSE

TAILRACE CUT

SEISMIC CROSS-SECTIONS

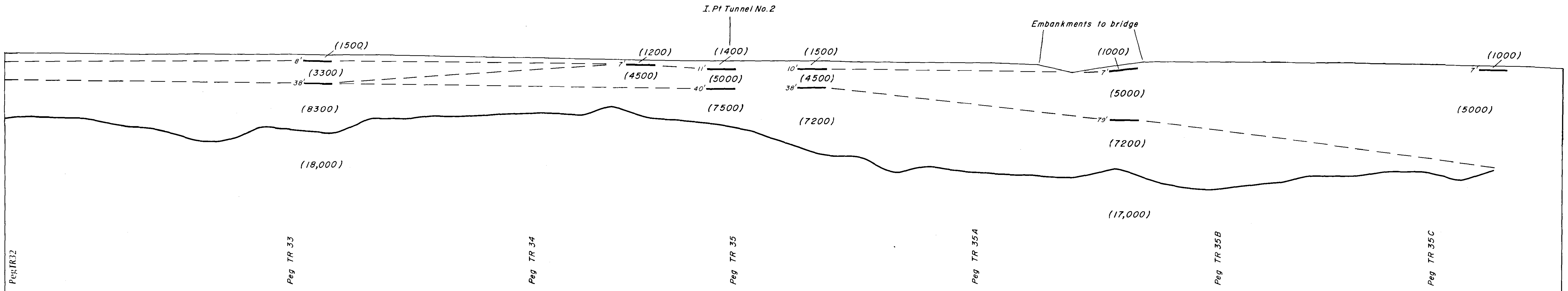
100 0 100 200 Feet

40 0 40 80 Metres

(Horizontal and Vertical)

To Accompany Record No 1972/9

J55/B5-62

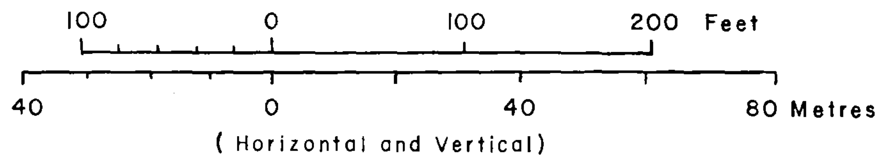


CHAINAGE	REDUCED LEVEL
2269	1040
2290	1040
2340	1040
2390	1039
2440	1038
2490	1037
2540	1037
2590	1037
2640	1036
2674	1036
2689	1036
2739	1035
2789	1034
2839	1034
2889	1033
2939	1032
2989	1031
3019	1031
3039	1031
3089	1030
3139	1030
3189	1029
3239	1028
3289	1028
3302	1027
3339	1027
3389	1027
3439	1027
3489	1026
3539	1026
3589	1025
3639	1025
3649	1025
3689	1024
3739	1022
3787	1011
3837	1020
3887	1027
3937	1028
3987	1028
3994	1028
4037	1028
4087	1028
4137	1027
4187	1027
4237	1026
4287	1025
4305	1025
4337	1024
4387	1023
4437	1023
4487	1021

PART TAILRACE TRAVERSE

TAILRACE CUT CONTINUATION

SEISMIC CROSS-SECTIONS



To Accompany Record No. 1972/9

J55/B5-63

R.L. 700'

Peg	REDUCED LEVEL	CHAINAGE
Peg A	1190	00
	1184	50
	1176	99
	1168	148
	1160 1161	196 197
	1154	247
	1147	296
	1140	346
	1134	396
	1130	423
	1128	446
	1122	496
	1116	545
	1111	595
	1106	646
	1100 1100	694 695
	1096	745
	1092	795
	1088	845
	1083	894
	1079	944
	1075	994
	1071 1070	1042 1044
	1066	1094
	1061	1143
	1057	1193
	1053	1243
	1049	1292
	1046	1342
	1043	1392
	1041	1442
Peg F	1039 1040	1493 1505

Peg	REDUCED LEVEL	CHAINAGE
Peg F	1040	00
	1040	50
	1042	100
	1045	149
	1049	200
	1052	250
	1056 1051	296 299
	1062	349
	1066	399
	1071	450
	1069	477
	1073	500
	1078	549
	1083	599
	1088	649
	1094	698
	1101 1103	736 748
	1112	797
	1124	846
	1131	869
	1136	895
	1144	944
	1152	993
	1159 1161	1043 1059
	1165	1093
	1172	1142
	1179	1192
Peg L	1182 1182	1242 1258

Peg	REDUCED LEVEL	CHAINAGE
Peg L	1182	00
	1181 1179	50 66
	1173	99
	1162 1161	148 152
	1147	196
	1132 1131	244 247
	1115	291
	1101 1096	327 338
	1076	383
	1058	431
	1041 1039	473 477
	1024	524
	1014 1011	572 577
	1000	620
Peg S	989 981	667 696

R.L. 700'

PART LOWER DAM SITE

LOWER DAM SITE

SEISMIC CROSS-SECTIONS

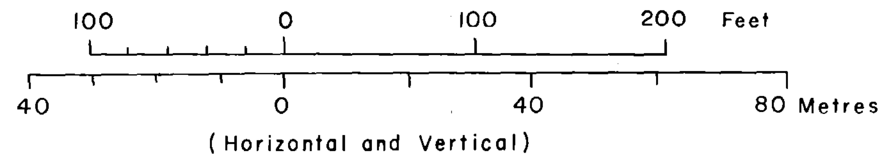
100 0 100 200 Feet
40 0 40 80 Metres
(Horizontal and Vertical)

To Accompany Record No. 1972/9

J55/B5-64

LOWER DAM SITE CONTINUATION

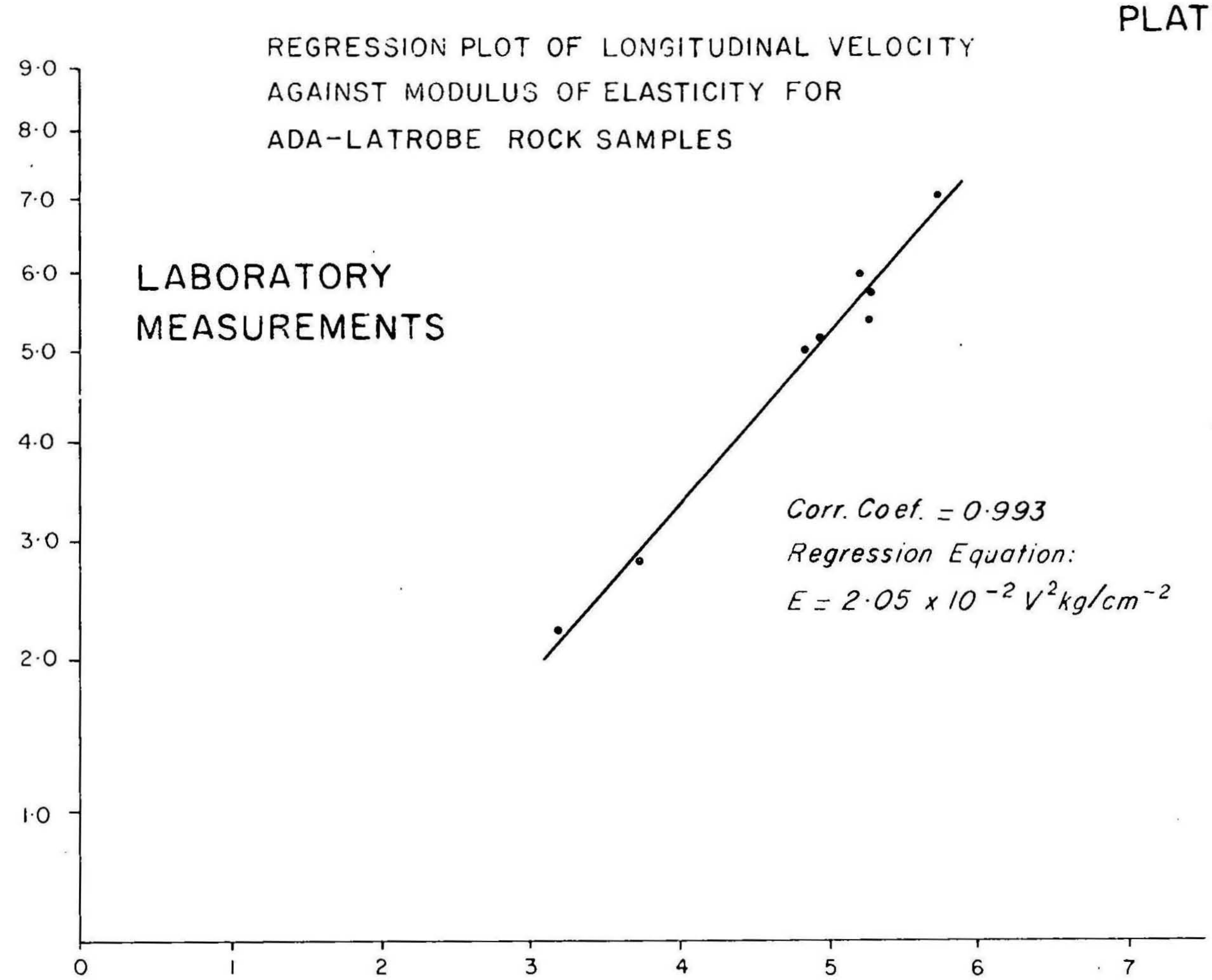
SEISMIC CROSS-SECTIONS



To Accompany Record No. 1972/9

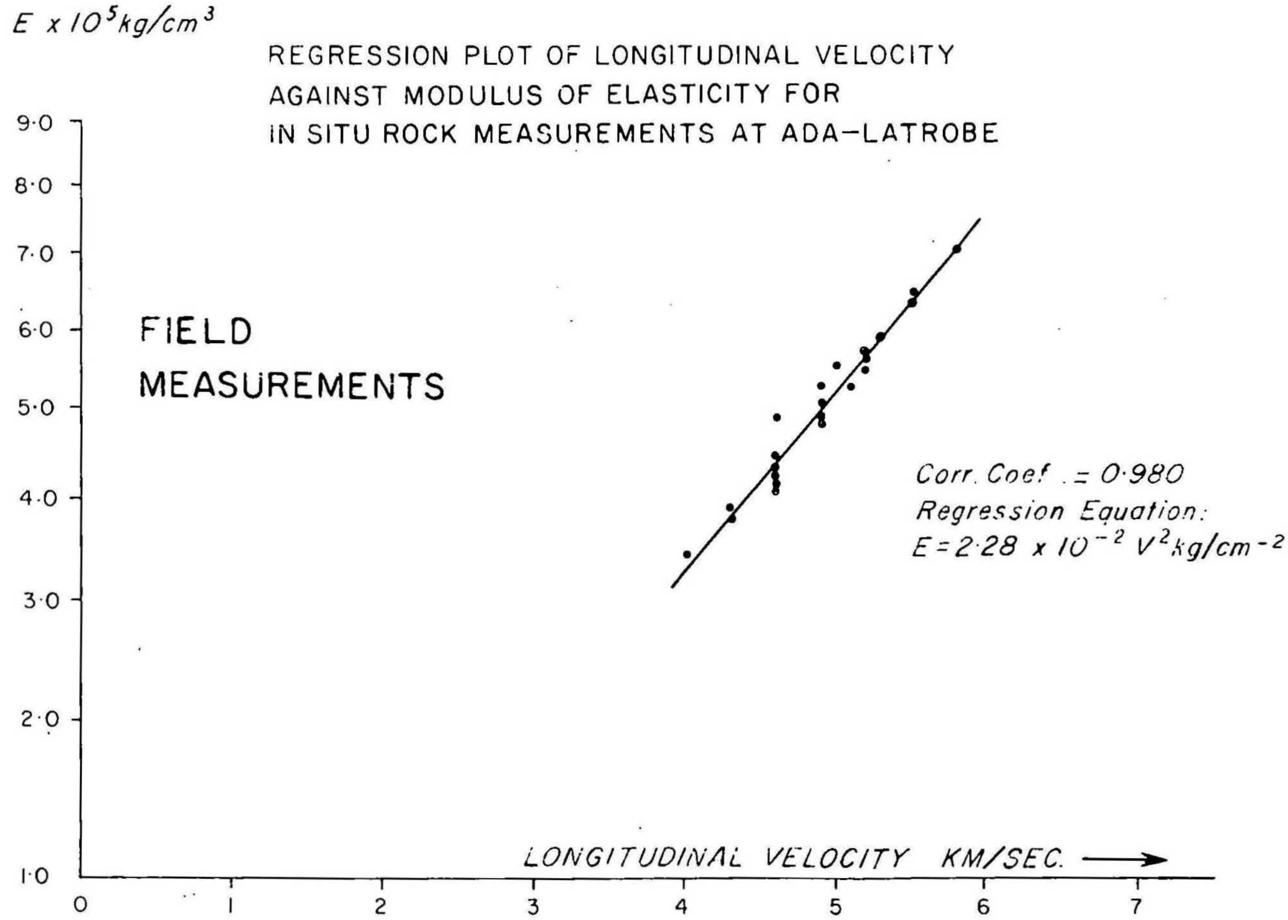
J55/B5-65

PLATE 16



DYNAMIC PROPERTIES OF ROCKS

$E \times 10^5 kg/cm^3$



To Accompany Record No. 1972/9

J55/B5—66A