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DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record No. 1968 / 96

Warangoi Dam Site Geophysical Survey

New Britain, TPNG 1966

by

G. Cifali, J. Milsom, and E.J. Polak

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SUMMARY

Seismic refraction and magnetic surveys on the proposed Warangoi dam site, New Britain, T.P.N.G. were done by the Bureau of Mineral Resources, Geology and Geophysics for the Commonwealth Department of Works.

In the river bed along two major faults the bedrock was eroded below present sea level and filled with sand and gravel to a depth of 158 ft.

The abutments of the dam are composed of low velocity rock, very porous and jointed.

A short test indicates that it is possible to delineate the boundary between reef limestone and agglomerate using the magnetic method.

Seismic velocities of longitudinal and transverse waves in rocks on the site are higher than those expected in the core of the dam, therefore differential movement between the dam and abutments during an earthquake is possible.

1. INTRODUCTION

The Administration of the Territory of Papua and New Guinea proposes to construct a power generating station near Rabaul, New Britain. Several kinds of power are being considered (geothermal, hydroelectric, and oil) and several locations for a hydroelectric scheme have been investigated. One of the locations is on the Warangoi River about 32 miles south-south-east of Rabaul (Plate 1).

The investigation of the possible sites is being carried out by the Commonwealth Department of Works assisted by other organisations, including the Bureau of Mineral Resources, Geology and Geophysics. The Geological Branch of the Bureau was responsible for the geological mapping and drilling supervision at the Warangoi dam site while the Geophysical Branch of the Bureau carried out geophysical investigations of the site. The objectives of the geophysical survey were:

1. To provide further information about the properties of the volcanic agglomerate and the known or suspected faults in the abutment and beneath the river channel.

2. To identify any structurally weak zones which have not been located from surface mapping.

3. To determine the depth and extent of unconsolidated material in the river channel.

4. To investigate the feasibility of locating the subsurface boundaries of agglomerate and coral in the left abutment ridge, north of the damsite, by a magnetic survey.

5. To determine some parameters to evaluate resistance of the dam to the damage from earthquakes.

Seismic refraction and magnetic methods were used. The field work extended from 13th July to 6th August and from 31st August to 2nd September 1966. The geophysical party comprised E.J. Polak (party leader) and G. Cifali and J. Milsom (geophysicists). The Commonwealth Department of Works provided field assistants and carried out the topographical survey, of which Mr. D. Jenssen was in charge.

It is desired to acknowledge the help given by the officers of the Commonwealth Department of Works in Rabaul.

2. GEOLOGY

The following summary of the area is taken from reports on a preliminary inspection (Carter and McGregor, 1964) and a preliminary geological investigation (Read, 1965) of the site.

The site is at a narrow constriction of the river where it passes through a major ridge that extends to the south-west of the damsite and forms a divide between the Warangoi River and the Sigule River systems. Upstream from the damsite the river flows for about two miles across a broad valley situated below the confluence of its two major tributaries, the Kavavas and Upper Warangoi Rivers.

At the damsite the ridge is formed of basaltic agglomerate, over and around which is draped Upper Miocene coral limestone. The storage basin, and the southern ridge south-west of the agglomerate, consists entirely of flat-lying to gently east-dipping, soft, moderately compacted sediments of Upper Miocene and Pliocene age.

Two possible leakage areas occur around the reservoir area. The most critical is the southern ridge between the Sigule and Warangoi Rivers, which in places is only 500 feet wide at a height of about 100 feet above river level, and which consists in part of soft, porous sediments. Apart from the coral reef, the stratigraphic sequence is entirely sedimentary and includes beds of claystone, siltstone, sandstone, and conglomerate. The strata are essentially flat-lying to gently dipping east and west.

Three known faults intersect the left abutment (see Plate 1). Two of the faults, F1 and F2, occur on the upstream side of the abutment and the third, F3, is located on the downstream side.

Several diamond-drill holes were put down on the site (Plate 1).

3. METHODS AND EQUIPMENT

Seismic refraction

The seismic method of exploration depends on the contrast in the velocities of elastic waves through different rock formations and on discontinuities between these formations. Details of the method have been given by Wiebenga and Polak (1962).

The seismic recording equipment used in the survey was an S.I.E. 12-channel refraction seismograph with T.I.C. geophones with a natural frequency of 20 c/s.

Theoretically, it is possible to calculate the dynamic properties of rocks from the longitudinal and transverse wave velocities (Leet, 1950). Recording of the transverse waves refracted in the bedrock was not possible owing to the excessive thickness of nonhomogeneous overburden; therefore the measurements of longitudinal and transverse velocities were carried out only on shallow rocks on the right abutment of the proposed dam. For deeper rocks the properties were calculated using empirical formulae based on the work of Wiebenga and Manganwidjoyo (1960), who calculated the relations between different properties of rocks obtained on samples in the laboratory, and by Polak (1963), who correlated the properties of rocks from measurements carried out in the laboratory and in situ.

Magnetic method

The magnetic susceptibility of rocks is related to its magnetite content and therefore the basic rocks are generally indicated by magnetic 'highs'. Through weathering, the magnetite is changed into haematite or limonite, thus lowering the magnetic susceptibility of the rock. The magnetic susceptibility of sedimentary rocks such as sandstone, mudstone, and limestone is lower than that of basic igneous rocks; therefore magnetic measurements may indicate in certain areas such features as faults and boundaries between near-surface formations.

In the survey a torsion magnetometer manufactured by ABEM of Stockholm was used. Measurements were taken at 50-ft intervals along the traverses on the left bank of the river.

Laboratory examination

Eleven pieces of cores obtained during drilling on the site were taken to Canberra and subjected to several tests in the laboratories of the BMR. The cores were cut at right angles to the axis and determinations of the following properties were carried out.

Density. The density of the rock was obtained by weighing the sample and dividing the weight by the volume of the sample calculated from measurement of length and diameter.

Seismic wave velocities. The measurements were carried out on the BMR ultrasonic equipment, which produces pulses at a frequency of 105,000 c/s repeated at 0.1-second intervals. The time of transit through the sample is measured with an accuracy of 0.5 micro-seconds. From the time of transit and the length of a sample the seismic velocity in the rock is calculated.

Petrological examination. A thin section was cut from a sample that had the highest seismic velocity. The results of the mineralogical examination are given in Appendix A.

Also a sample was taken of the mud deposited by a major flood during the survey. The sample was investigated by the Petroleum Technology Laboratory of the BMR, who determined the sealing properties of the mud; the results are included in Appendix B together with a short description of the tests carried out.

4. RESULTS

Plate 1 shows the locality plan, the layout of geophysical traverses, and faults.

Plates 2 to 5 show the seismic sections along the traverses and indicate the depths to the bedrock and the velocities of the longitudinal waves in rocks. Vertical magnetic intensity profiles along traverses K and L are shown in Plate 5.

Seismic velocities and depth to the bedrock

The results of the seismic survey were interpreted as a four-layer structure.

Top layer. This thin layer, in which the seismic velocity is about 1000 ft/s, is interpreted as soil.

Second layer. This layer, in which the seismic velocities range from 1600 to 3500 ft/s, is interpreted as agglomerate above the water table.

Third layer. This layer is similar to the second layer but it is below the water table. The fully water-saturated material shows seismic velocities of between 4500 and 5000 ft/s. In the actual gorge of the river this material has been replaced by alluvium with a seismic velocity of 5000 ft/s.

Fourth layer. This is interpreted as bedrock, with seismic velocities of 6300 ft/s up to 14,000 ft/s.

On some locations reef limestone is inbedded in the rocks. Seismic velocity of 5000 ft/s in the limestone was measured on a ledge (Stations H17 to H20). In drill hole WD9 the reef limestone, with a seismic velocity of 4900 ft/s, was found. The limestone bed is thin.

The examination of the drilling logs indicate that the rocks on the site consist of alternate layers of better and poorer quality rocks. The layers may represent the different lava flows, and the lava flows may also have inclusions of blocks brought up in solid state. The laboratory measurements of seismic velocity (Table 1) indicate that a high velocity rock at 124 ft in drill hole WD2 lies over the very low velocity rock at 191 ft. The rock at the 124-ft level shows a velocity of 21,510 ft/s (6.5 km/s). This is the highest velocity ever measured in the BMR laboratory.

The beds of high velocity rocks are thin and therefore are unable to transmit waves, especially if the wave consists of low frequencies, and therefore they are missed in seismic prospecting. The recorded seismic velocity at these places is close to the velocity of the thick bed in which these high velocity rocks are embedded. These conditions were found in other volcanic areas (Wiebenga and Polak, 1962).

The depth to the seismic interfaces was calculated using the velocities in the upper layers obtained from weathering spreads with 10-ft geophone intervals.

The error in depth determination is considered to be less than ± 30 percent of the true depth. This estimate is based on experience of results in other areas where comparable geological conditions exist. Although the error in absolute depth may be large, the error in the relative depth to the bedrock from station to station along the traverse is likely to be much smaller, and the profiles shown for the surface of the bedrock is expected to be reasonably accurate.

The properties of rocks

Porosity. The low seismic velocity recorded in the section above the present water table indicates that the rocks are of poor quality and are extensively jointed. Using an empirical formula (Polak, 1963) it is possible to state that the average porosity of the rocks will exceed 13 percent.

By calculating the value of the ratio of seismic velocity obtained in the field and in the laboratory it is possible to estimate the extent of jointing of the rock in situ. A quantitative estimate was not possible here, because of the variety of rock-type present and the

TABLE 1

Laboratory measurements of seismic velocity in drill hole samples

Sample No.	Hole No.	Depth (ft)	Length (ft)	Density (g/cc)	Seismic velocity (ft/s)
66/114	WD2	124	1.250	2.76	21,510
66/113	WD2	128	0.937	2.77	21,320
66/110	WD2	191	0.625	1.95	4464
66/105	WD3	83	0.377	2.69	15,630
66/116	WD3	166	0.541	2.70	17,180
66/106	WD3	194	0.781	2.66	15,650
66/111	WD8	226	0.729	2.26	5587
66/115	WD9	27	0.354	2.51	11,900
66/110	WD9	191	0.521	1.90	4292
66/109	WD9	199	0.369	2.17	8330
66/108	WD9	237	0.770	2.13	7000
66/107	WD9	268	0.590	2.50	14,200

small number of samples collected. However, the low values of velocities in situ and the very high velocities of the samples make the ratio very low, indicating extensive jointing of the rocks on the dam site. This is supported by the loss of drilling fluid and by the results of water tests. The jointing will allow leakage of water from the reservoir. This leakage will be reduced by the blanketing effect of mud deposited by floods (see Appendix B).

Compressive strength. The approximate value of the compressive strength of the basaltic anglomerate rock in the abutments has been calculated from formula (3b) of Wiebenga and Manganwidjoyo (1960) and amounts to 5000 $lb/in^2 \pm 35\%$.

Poissons ratio. From the times of arrival of the longitudinal and transverse waves near drill hole WD9 the ratio of velocities (transverse to longitudinal) was established as between 0.45 and 0.52. This corresponds to a Poisson's ratio of 0.31 to 0.33 (Knopoff, 1952).

Earthquake resistance. The Warangoi dam site area lies in the high earthquake danger zone (Latter, 1966). To minimise the possible damage to the dam by an earthquake the dam wall should be constructed in such a way that its transverse wave velocity and the natural frequency of vibration are close to those of the abutment rocks (Martin, 1967).

Transverse wave velocities of 1800 to 2200 ft/s were obtained. These velocities are higher than those to be expected in the wall of the dam. Martin (1967) found transverse velocities between 700 and 1400 ft/s on several earth dams. Measurements at Corin dam in the Australian Capital Territory give values between 700 and 900 ft/s (Polak, in preparation). The transverse velocities in a dam depend on the character of the material used in the construction and on the method of the placement of the material, but the variation in velocities has quite a narrow range.

The measurements of the natural frequency of response of the ground requires complicated and heavy equipment and therefore the tests were not carried out.

Magnetic susceptibility. Magnetic measurements made along Traverses K and L (Plate 5) indicate several abrupt changes in magnetic anomaly level. These changes occur while crossing from agglomerate (high magnetic intensity) to reef limestone (low magnetic intensity). These conclusions were tested on an outcrop of reef limestone close to drill hole WD2; a station on the agglomerate gave a reading 180 gammas higher than a reading at a station on the outcropping limestone. The results suggests that the magnetic method can locate thin beds of reef limestone if they are close to the surface, but the spacing of stations must be very close. Continuation of magnetic work was not warranted.

5. CONCLUSIONS

Both abutments of the dam consist of low seismic velocity rocks, which are very porous, because they are heavily jointed. In the river valley the lowest velocity material has been eroded along two faults by the 'old' river, and newly deposited sand and gravel is more than 150 ft thick.

A short magnetic test indicates that the method is useful for location of shallow deposits of reef limestone.

Seismic velocities of longitudinal and transverse waves in rocks on the site are higher than than those expected in the core of the dam.

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APPENDIX A

MINERALOGICAL COMPOSITION OF ROCK SAMPLE WITH THE HIGHEST SEISMIC VELOCITY

The mineralogical composition of sample No. 66/113 from drill hole WD2, depth 124 ft, on Warangoi dam site was determined by H. L. Davies of the Geological Branch of the Bureau of Mineral Resources:

> "Predominantly labradorite phenocrysts, minor augite phenocrysts (possibly some olivine) in very fine-grained matrix predominantly plagioclase (probably labradorite) laths. Augite mostly altered to chlorite minerals. A lava or lave fragments in agglomerate."

APPENDIX B

FILTRATE-PERMEABILITY TESTS ON UNCONSOLIDATED SILT FROM THE RABAUL AREA, TERRITORY OF PAPUA AND NEW GUINEA

P. Duff

A sample of compacted silt containing some clay was brought to the Petroleum Technology Laboratory by E.J. Polak of the Geophysical Engineering Section with a request for an examination of this sample as it was considered that the material might be used to form a natural seal in a dam to be constructed near Rabaul. The silt and clay would normally be brought down with water running into the dam.

The sample had been "cored" using an open-ended can from a deposit of material, which had been laid down by flood water.

It was found during testing that the top portion of the core contained a clay fraction which proved to be of importance in filtration characteristics.

Testing consisted, initially, of mixing the silt from the three sections of the core (top, middle, bottom) in varying concentrations with water and then filtering through the standard filter-press used in testing drilling muds. This filter press uses water as the pressuring medium.

No changes in the 100 p.s.i. pressure, normally used in the filter press, was thought necessary as the height of water in the proposed dam will be approximately 220 feet and will exert a pressure of 95 p.s.i. on the dam bottom.

Results

Table 2 shows that in all samples the filtrate expressed per given time was inversely proportional to the cake thickness.

In samples containing little or no clay the filtrate rate reached a steady, higher value in a much shorter time even when the cap was removed from the press and more silt slurry added before repressurising.

The clay content of the material was observed when the filter cakes, obtained during testing, were allowed to dry. It was found then that cakes from the top and middle of the core consisted of a solid silt plug capped by a thin clay layer; the thin clay layer was absent from dried plugs formed during filtration of slurries produced from the bottom of the core.

The material from the top portion of the core was reclaimed and used to produce a thick slurry with which the filter press was charged. Pressure was applied, using water, and when the filtrate had reached a steady rate, pressure was released, water was decanted from above the compacted cake formed in the press and replaced with more of the thick silty slurry. This procedure was repeated many times until the filter press was filled with a 3-inch cake, the capacity of the press (see Table 3).

The minimum filtrate obtained in this manner was 8 cc. per 5 minutes per 7 square inches of filtration area. This could be converted to give a loss of 453,000 gallons of water per acre per day. However, a cake of 8 inches, which was the thickness of the core plug handed into the laboratory, would, no doubt, reduce this loss considerably.

It is probable that a small quantity of bentonite added to the dam water would serve to form an impervious cake on the silt layer and if required, tests could be carried out on these lines, in the Petroleum Technology Laboratory.

TABLE 2

Readings at 5-minute intervals	FILTRATE (cc)					
	Top sample with clay contents - Cake 0.36 ins.	Top sample with clay content - Cake 0.62 ins.	Middle sample with clay content - Cake 1.1 ins.	Bottom sample no clay content	Same sample more slurry added	Further slurry added Cake 2.5 ins.
1	80	76	55	118	60	32
2	60	57	29	75	34	23
3	42	45	20	72	34	23
4	38	37	17	71	34	23
5	32	29	16	70	-	-
6	28	24	13	70	-	-
7	25	23	12	69	-	-
8	23	22	12	68	-	-
9	22	18	11	68	-	-
10	20	16	10	68	-	-
11	19	16	10	-	-	-
12	18	15	9	-	-	-
13	18	15	9	-	-	-
14	17	14	8	-	-	-
15	17	14	8	-	-	-
16	17	14	8	-	-	-

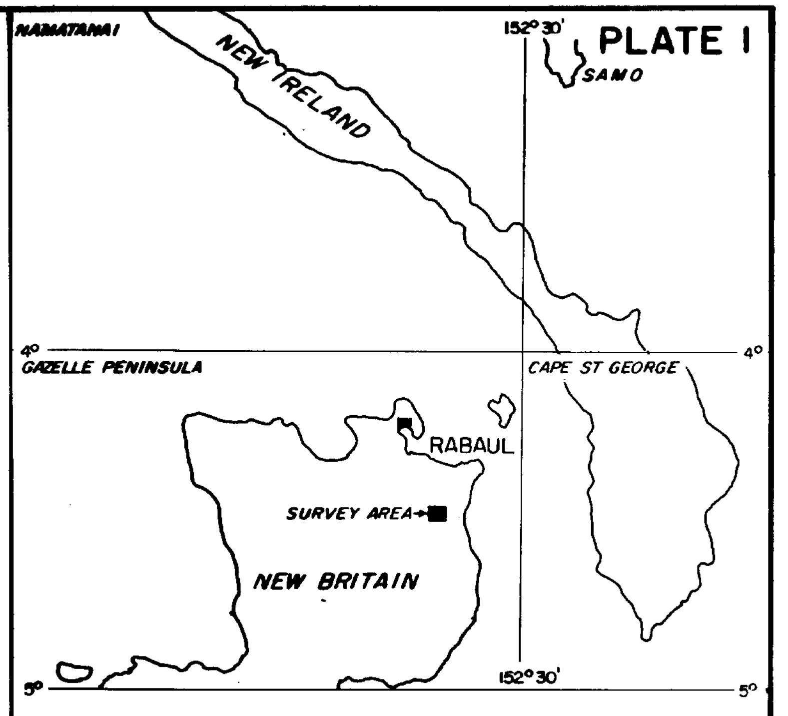
TABLE 3

Reading at 5-minute intervals	Sample from Middle and Top of Core. Clay present. Filtrate in cc					
	Thick slurry used	Top of cake in filter press-smoothed and further thick slurry added	Top of cake again smoothed and further thick slurry added	Smoothed and thick slurry added	As before	As before Final cake 3 ins.
1	136	52	30	21	21	14
2	92	45	18	14	10	9
3	88	44	18	13	10	8
4	84	41	18	13	10	8
5	84	41	-	13	-	8
6	84	41	-	-	-	-

WARANGOI DAM SITE, NEW BRITAIN, 1966

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

PLATE I



REFERENCE TO 1:250,000 STANDARD MAP SERIES

LOCALITY MAP

LEGEND

- Ridge
- Road
- Track
- Seismic traverse
- Drill hole
- Fault

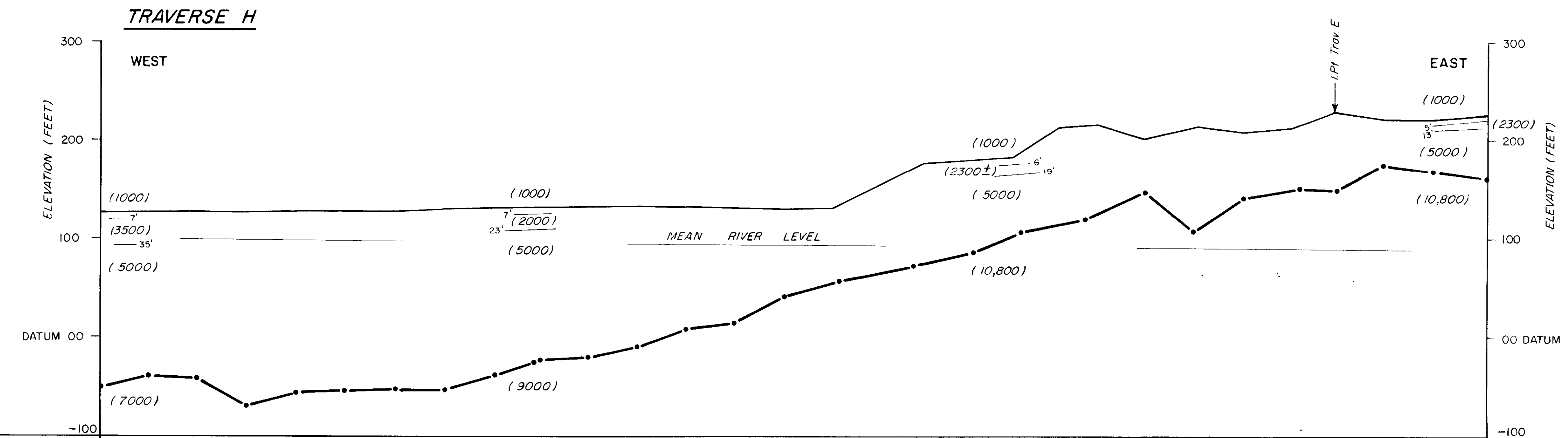
Based on Dept of Works, Papua and New Guinea, Plan RS872/1

WARANGOI DAM SITE
NEW BRITAIN, 1966

LOCALITY MAP AND LAYOUT OF TRAVERSES

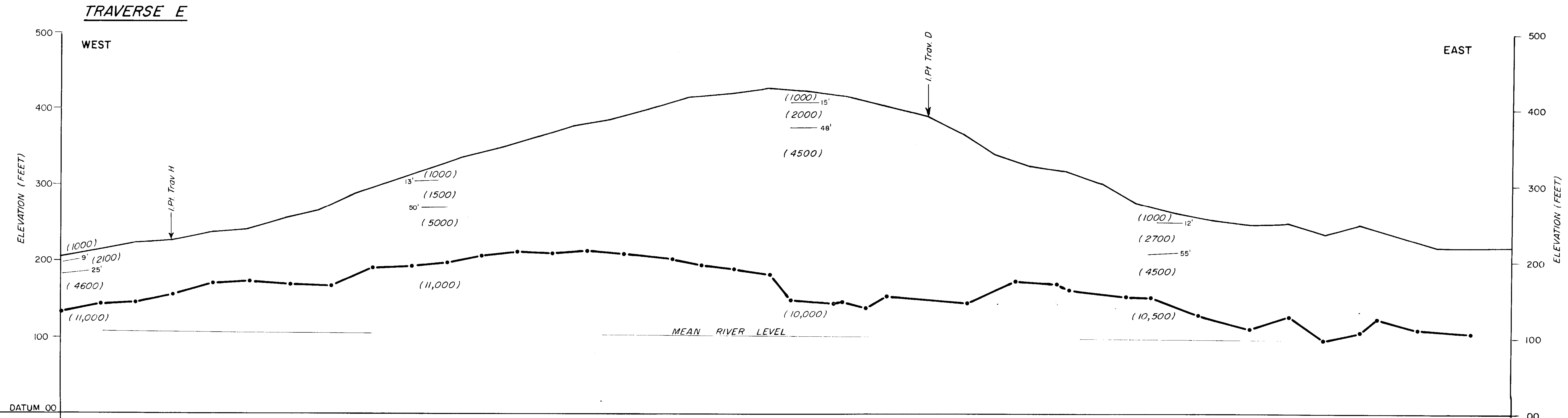
TO ACCOMPANY RECORD No 1968/96 B56/B5-5

TRAVERSE H



STATION NUMBER	1				5					10					15					20					25					30
STATION ELEVATION (FEET)	127	127	126	126	127	127	128	130	131	132	132	133	134	132	132	133	154	179	182	187	216	219	206	219	211	217	232	224	223	230
DEPTH TO BEDROCK (FEET)	180	168	170	199	185	180	180	182	171	158	151	141	125	115	90	78	90	102	95	80	100	90	55	109	59	68	80	50	54	55

TRAVERSE E



STATION NUMBER	1				5					10					15					20					25					30					35					40
STATION ELEVATION (FEET)	209	215	226	229	239	242	257	267	288	304	319	337	347	363	377	385	397	415	421	427	425	418	404	393	369	344	325	318	304	278	265	256	251	252	238	248	232	218	218	217
DEPTH TO BEDROCK (FEET)	72	70	79	73	70	70	90	100	108	112	123	139	140	155	168	178	195	220	233	249	280	273	260'	242	221	180	155	155	149	125	123	130	140	125	140	141	118	111	115	100

LEGEND

(11,000) Seismic velocity (ft/s) in formation

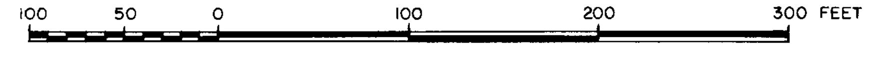
—— 50' Depth to formation with different seismic velocity

I Pt Traverse intersection point

•——• Unweathered bedrock boundary

Based on Dept of Works, Papua and New Guinea, Plans RS66/30 sheets 5 and 2

HORIZONTAL AND VERTICAL SCALE

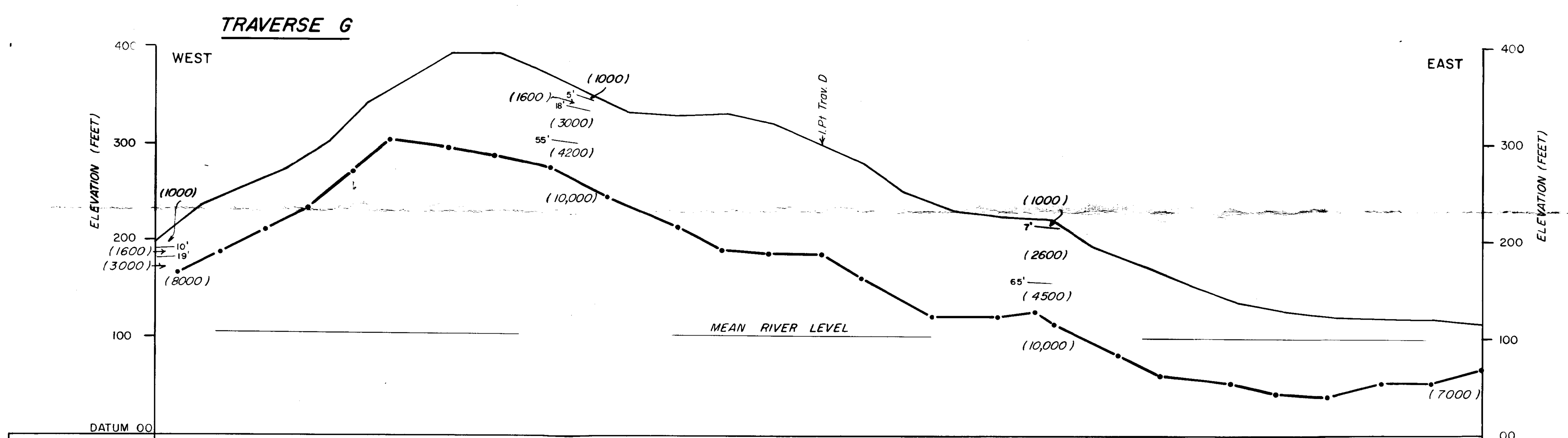


TRAVERSES H AND E

SEISMIC CROSS-SECTIONS

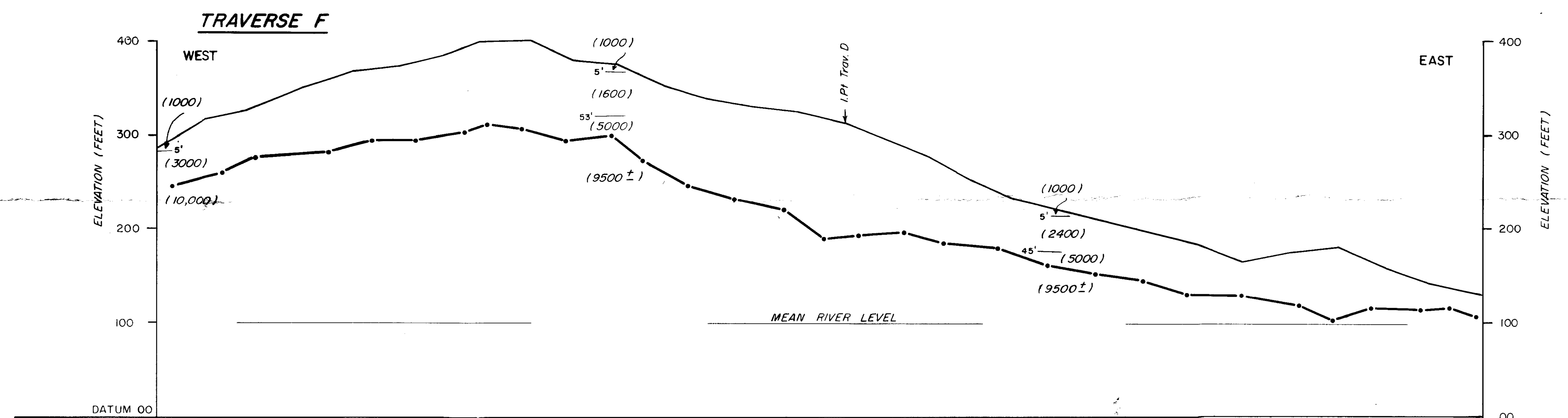
WARANGOI DAM SITE 1966

TRAVERSE G



STATION NUMBER	STATION ELEVATION (FEET)	DEPTH TO BEDROCK (FEET)
1	195	45
	233	59
	251	55
	272	51
5	301	55
	338	59
	368	68
	394	100
	394	108
10	371	100
	352	98
	333	98
	330	120
	329	140
15	320	132
	298	112
	277	120
	249	115
	232	110
20	224	101
	221	105
	194	100
	173	109
	153	99
25	135	85
	125	88
	122	80
	119	68
	119	68
30	113	48

TRAVERSE F



STATION NUMBER	STATION ELEVATION (FEET)	DEPTH TO BEDROCK (FEET)
1	287	48
	316	62
	326	55
	352	70
5	369	80
	373	80
	385	89
	400	90
	401	98
10	382	85
	377	80
	355	92
	340	100
	331	105
15	326	115
	317	122
	298	100
	279	90
	256	70
20	234	60
	224	62
	208	60
	198	55
	183	52
25	167	38
	175	56
	179	75
	157	43
	142	29
30	129	29

TRAVERSE D

STATION NUMBER	STATION ELEVATION (FEET)	DEPTH TO BEDROCK (FEET)
1	411	199
	409	202
	403	210
	397	222
5	393	220
	376	212
	389	225
	394	234
	382	218
10	377	205
	366	206
	354	175
	343	155
	341	135
15	314	105
	295	92
	292	95
	279	79
	290	92
20	290	109
	292	109
	294	105
	278	99
	296	110
25	308	125
	291	103
	294	112
	312	129
	311	120
30	312	125
	297	100
	279	80
	298	104
	306	119
35	317	135
	302	132
	295	109
	274	58
	262	69
40	272	68
	281	86
	281	120
	294	130
	280	85
45	295	120
	298	139
	297	120
	297	124
	300	109
50	278	95
	306	112
	306	100
	303	89
	288	78
55	302	90
	295	84
	290	94
	287	80
	283	78
60	256	

LEGEND

(5000) Seismic velocity (ft/s) in formation

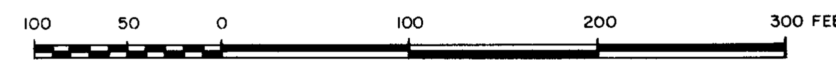
5' —— Depth to formation with different seismic velocity

I.P.I. Traverse intersection point

—•—•— Unweathered bedrock boundary

Based on Dept of Works, Papua and New Guinea, Plans RS66/30 Sheets 1, 3 and 4

HORIZONTAL AND VERTICAL SCALE

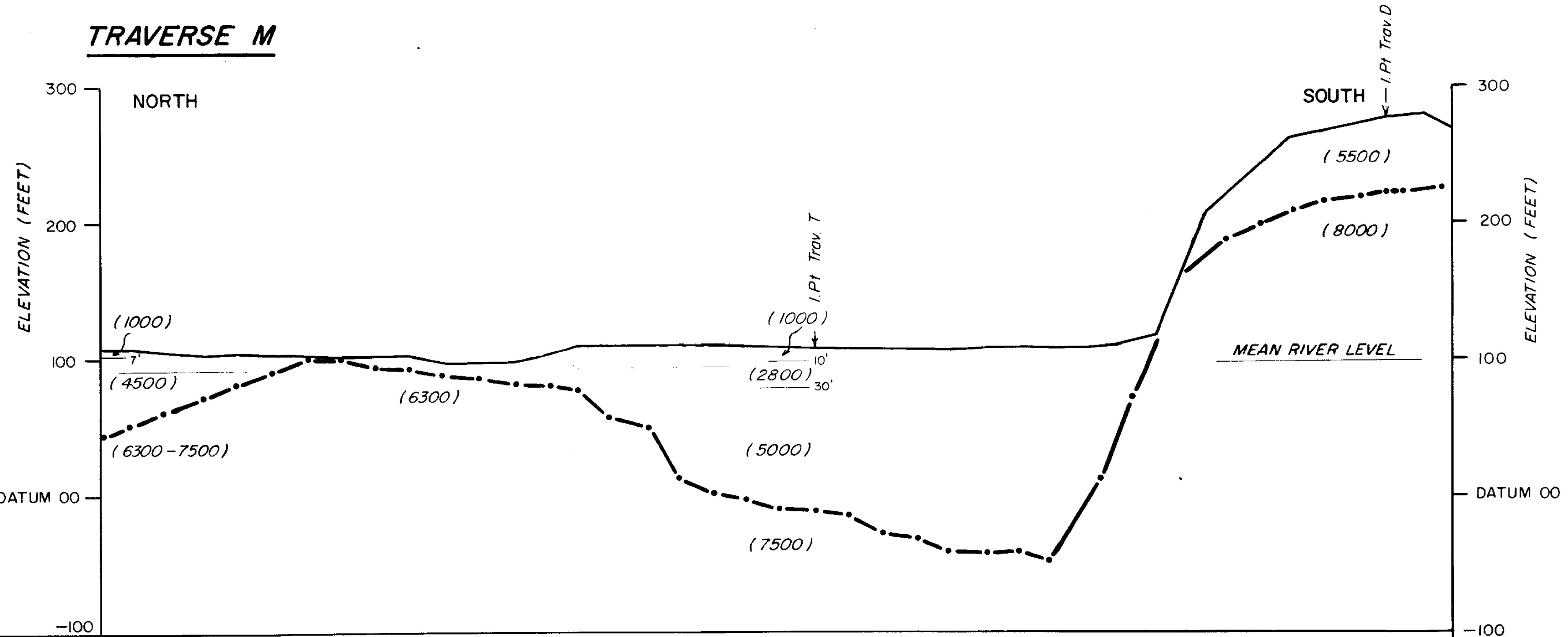


TRAVERSES D, F, and G

SEISMIC CROSS-SECTIONS

WARANGOI DAMSITE, 1966

TRAVERSE M

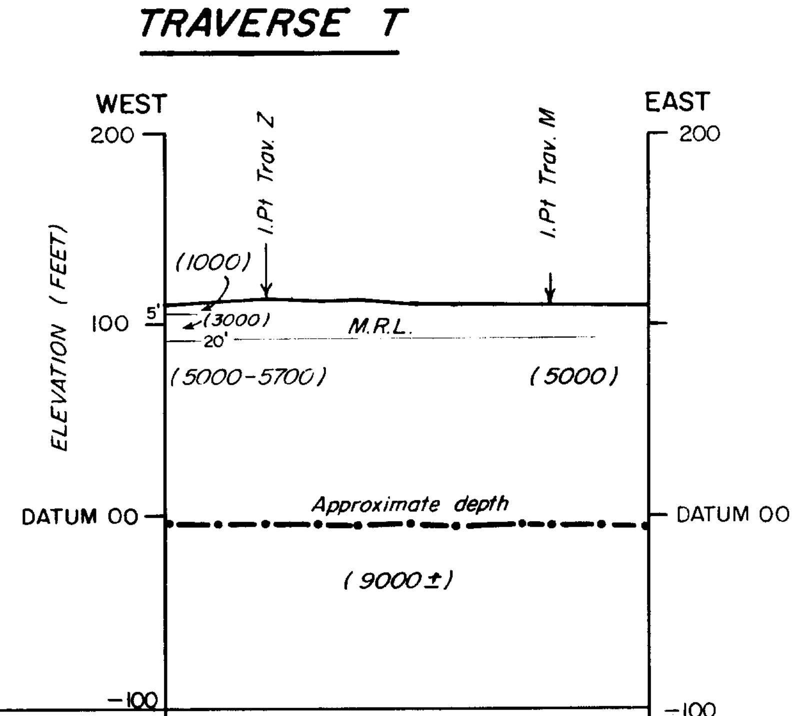


STATION NUMBER	1								5					
STATION ELEVATION (FEET)	112	111	110	107	108	107	107	104	106	106	103	101	103	108
DEPTH TO BEDROCK (FEET)	68	55	41	30	21	11		0	10	13	10	10	18	20

STATION NUMBER					10									
STATION ELEVATION (FEET)	112	111	112	111	113	112	112	110	112	111	113	112	112	113
DEPTH TO BEDROCK (FEET)	34	55	60	100	109	110	120	120	123	138	140	150	154	150

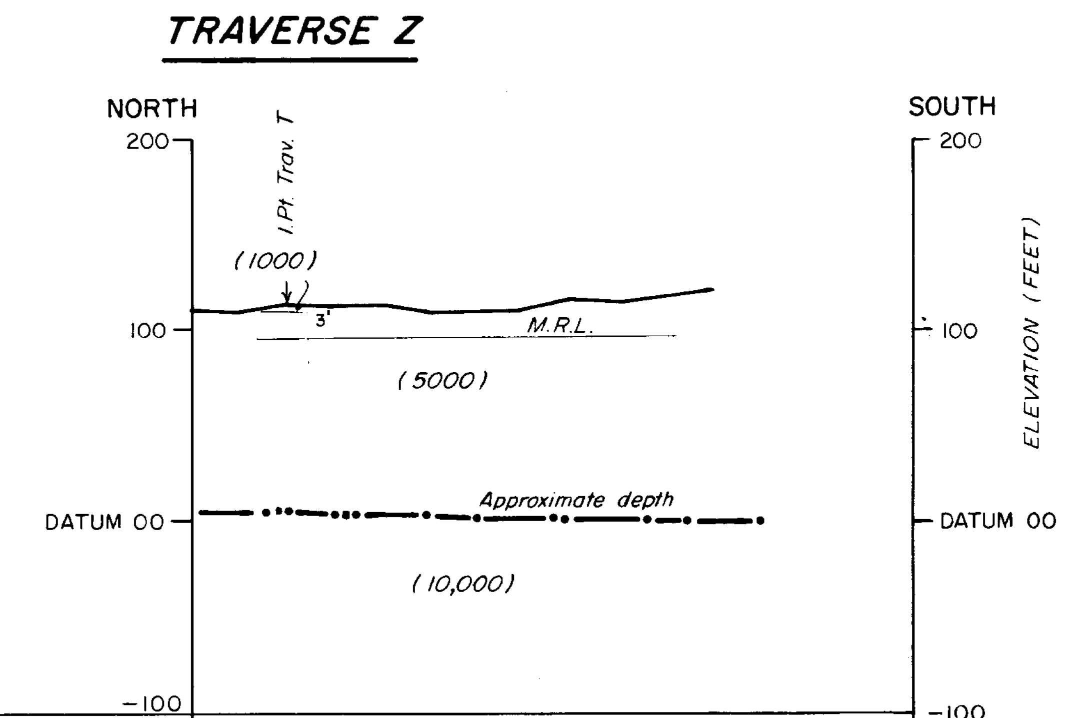
STATION NUMBER	15										20		21
STATION ELEVATION (FEET)	113	113	116	126	213	229	248	265	268	276	283	279	269
DEPTH TO BEDROCK (FEET)	158	120	65	0	29	35	48	55	52	52	55	55	42

TRAVERSE T



STATION NUMBER	1				5					10	11
STATION ELEVATION (FEET)	111	112	113	112	112	112	110	111	112	111	109
DEPTH TO BEDROCK (FEET)	115	119	118	120	120	115	117	116	114	114	114

TRAVERSE Z



STATION NUMBER	1				5					10	11
STATION ELEVATION (FEET)	112	112	113	113	114	112	111	112	116	116	122
DEPTH TO BEDROCK (FEET)	109	107	109	110	111	108	109	112	117	114	122

LEGEND

(7500) Seismic velocity (ft/s) in formation

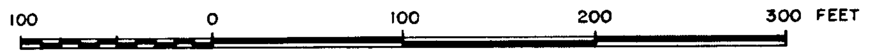
10'——— Depthto formation with different seismic velocity

I.Pt Traverse intersection point

•——• Unweathered bedrock boundary

Based on Dept of Works, Papua and New Guinea, plans RS66/30, Sheets 8 and 9

HORIZONTAL AND VERTICAL SCALE



TRAVERSES M, T, and Z

SEISMIC CROSS-SECTIONS

WARANGOI DAMSITE, 1966

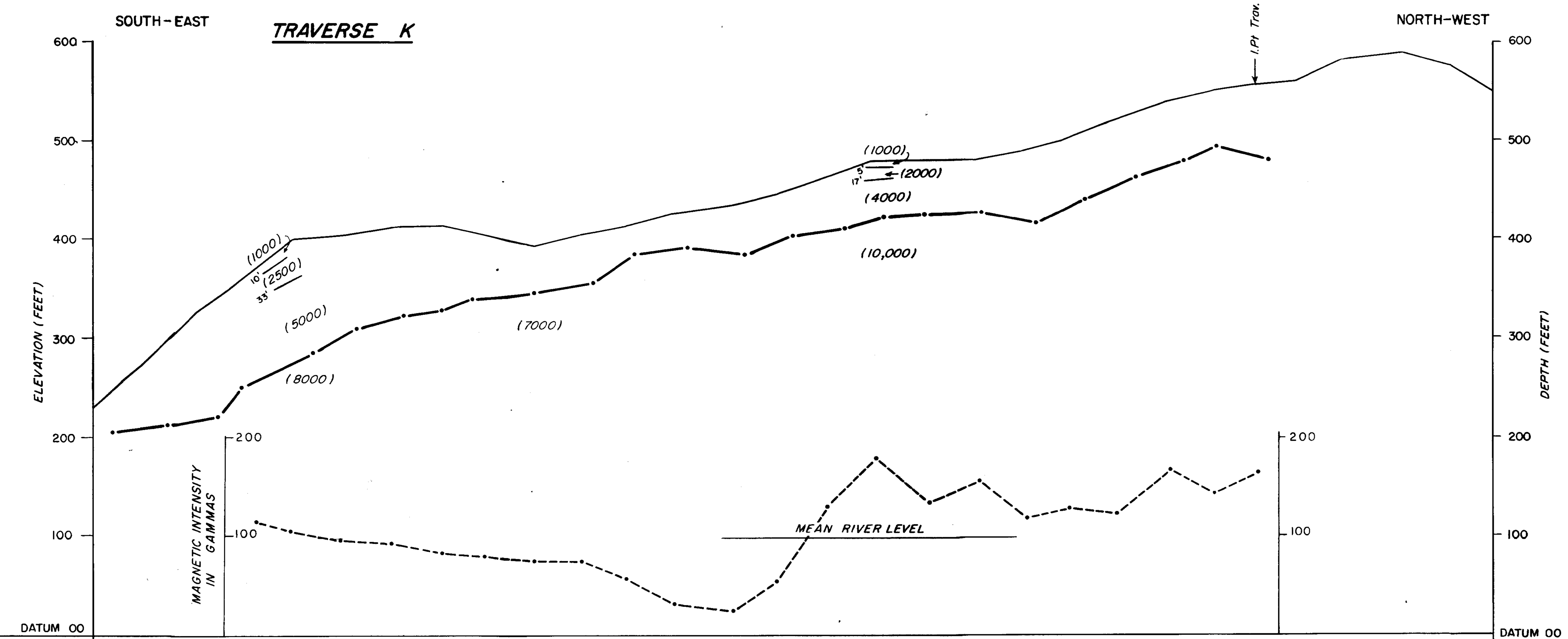
TO ACCOMPANY RECORD No 1968/96 Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics B56/B5-4

PLATE 5

STATION NUMBER	1				5					10					15					20
STATION ELEVATION (FEET)	538	561	583	601	600	591	577	564	551	541	531	523	524	519	516	512	510	509	508	506
DEPTH TO BEDROCK (FEET)		88	100	98	80	76	86	80	61	63	65	73	65	60	59	44	35	41	62	70

STATION NUMBER					25					30					35					40
STATION ELEVATION (FEET)	505	504	505	506	508	510	512	511	509	505	502	499	496	492	486	486	485	486	484	483
DEPTH TO BEDROCK (FEET)	88	79	73	70	100	89	80	74	60	78	98	100	94	91						

STATION NUMBER					45					50					55					60	61
STATION ELEVATION (FEET)	483	480	478	473	470	470	467	466	465	464	463	464	464	464	463	452	435	409	391	389	388
DEPTH TO BEDROCK (FEET)																					



STATION NUMBER	1				WD 2A	5					10					15
STATION ELEVATION (FEET)	233	271	306	344	361	379	407	409	416	418	409	402	409	418	434	441
DEPTH TO BEDROCK (FEET)		55	83	115	114	112	125	100	90	85	61	50	51	35	39	50

STATION NUMBER					20					25						31
STATION ELEVATION (FEET)	453	466	483	483	485	494	505	525	544	554	561	567	585	589	582	562
DEPTH TO BEDROCK (FEET)	50	56	60	55	58	70	71	68	69	60	75					

(6000) Seismic velocity (ft/s) in formation

20' — Depth to formation with different seismic velocity

I.Pt Traverse intersection point

•———• Unweathered bedrock boundary

•- - - -• Magnetic profile

HORIZONTAL AND VERTICAL SCALE

100 50 0 100 200 300 FEET

TRAVERSES K AND L

SEISMIC CROSS-SECTIONS

Based on Dept of Works, Papua and New Guinea, Plans RS66/30 Sheets 6 and 7   Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics   TO ACCOMPANY RECORD No 1968/96 B56/B5-1