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PART 1. INTRODUCTION

Dam site 12, located 1.5 km north of the George Town-Bridport road, is one of a number of sites on the Pipers River, to be considered for the supply of water to the East Tamar industrial region. The area surrounding the site is of low relief.

No firm centre line proposal has been made and the site has been generally evaluated with regard to possible points of construction. The principal area examined lies near the point at which the river becomes incised in a shallow asymmetrical gorge.

Information was required on:

- (1) The foundation materials to an abutment height of at least 25 m.
- (2) Leakage problems.
- (3) Construction materials.
- (4) Detailed site assessment.

HISTORY OF THE INVESTIGATIONS

Of the many proposals for a dam along the river (Stevenson, 1968) this site was given a high priority and partly examined geophysically (Leaman, 1973a). At that time a 12-15 m dam was envisaged. Following examination of the favoured site 10 (Leaman, 1973b) drilling commenced on this site. At that time no estimate of the thickness of basalt in the present river valley was possible and the many springs near the centre line on the east bank suggested either multiple basalt flows, permeable scoria zones or sediments. It was hoped that holes 1 and 2, the only bores initially recommended, would clear this substantial doubt and direct any further work. When solid basalt was recovered to 28 m at least a fuller drilling programme was recommended (see Part 2). By the time the sixth hole was drilled several problems had been posed and the whole feasibility of the site came in question. Before the site could be dismissed a study of economics (comparison with a pipeline from the North Esk River) and estimation of hydrogeological problems was needed. A topographic survey was undertaken to assist engineering evaluation as well as three-dimensional geological problems. The geology of the entire region was then examined in great detail and further seismic work undertaken. The latter was necessary as the dam height had been increased and the water level would reach a problem area containing soft sediments.

PART 2. DRILLING RECOMMENDATIONS

Dam sites along basalt and sediment-filled valleys are commonly difficult to assess and any work undertaken should be as a single unit to establish site feasibility. It is never adequate to examine the abutment and storage area or possible leakage paths separately. To this end a multi-staged drilling programme is recommended.

- Stage 1: A line of holes across the valley to detect rock variations and the likely presence of filled channels which were previous courses of the river.

Stage 2: Accessory holes to check out the most likely points for leakage from the storage or around the abutments.

Stage 3: If stages 1 or 2 indicate problem zones these should be drilled in detail in order to assess the likelihood of making a seal. Stages 1 or 2 may indicate that a dam is not feasible from the point of view of rock mechanics or leakage.

Stage 4: Detailed assessment of the abutments.

Stage 5: Some examination of the centre line path.

The drilling programme, bearing in mind the geological conditions prevailing at this site, must be modified as the results become available. Seismic work is of little value due to the presence of basalt outcrops with a high seismic velocity.

Programme for Stage 1

A preliminary line of about 12 holes across the valley is suggested; the line should be at right angles to the course of the river and should bisect the azimuths of the two potential centre lines. There should be six holes on either side of the river. Each hole should be at least 30 m deep, and at least some of the holes should be drilled to the underlying slates. The objective of this initial line of holes is to establish:

- (1) the general foundation conditions near the river,
- (2) the presence of channels, and
- (3) the thickness, form, stability and leakage of the rocks present.

Programme for Stage 2

The preliminary line cannot cover all the doubtful localities about the site and one or two shorter lines will be necessary to test suspected problem areas. Up to 6 holes, about 30 m deep should be adequate.

Programme for Stage 3

If either of the previous programmes detects a problem zone additional closely spaced drilling will be necessary to enable estimates of the scale of the problem and its likely treatment to be made. This may also be the point of termination of the investigation if the problems are insoluble. Three holes should be allowed.

Programme for Stage 4

Abutment assessment will require 4-6 holes to a depth of about 15 m.

Programme for Stage 5

One or two holes on the chosen centre line to establish foundation conditions between abutments.

All holes should be vertical, cored and water-pressure tested.

If a rock fill dam is required up to 6 holes 30 m deep will be necessary to prove the quantity and quality of the rock fill.

PART 3. ENGINEERING GEOLOGY FEASIBILITY STUDY

GEOLOGY

A region about 2 km by 1.5 km, covering the incised valley of the Pipers River, has been studied in detail to determine the structural conditions and the geology (fig. 55). The locations of bore holes and the local seismic spreads with interpretation are also indicated.

The basic material on which all others are overlaid is a closely-jointed dark grey slaty mudstone. This has limited exposure within the area of detailed assessment but is the predominant material in the storage area and, with the exception of the dam site itself forms the margin to the storage. Deep weathering, with production of clay and silt products, is common and outcrops are rare. Hence the areas indicated as slate in Figure 55 are places where there are many fragments of weathered material suggesting near outcrop. The principal occurrences are in the west of the area.

A series of sand, sand with gravel and clay deposits overlie the slate; the two former are the most commonly exposed at the surface. The rock is variable but has a high silt and clay content generally. Every exposure of such sediments is in a region where the basalt cover has been removed.

Basalt covers most of the remainder of the area. Where outcrops are present these are indicated, as is basalt debris and soil. Such soils may conceal more solid rock or sands and clays as there is a possibility of some soil creep.

Some alluvium is present in the valley north of the site and also in the plain which will form the storage area.

The geological complexity of the dam site is related to the geological history of the river. The original Pipers River flowed north-south in a valley cut in slates east of borehole 2. Subsequently the whole area was covered with sands and clays and gravels and the river began to cut a new valley, one which did not always coincide with its previous course. After some time the whole was buried beneath extensive flows of basalt. The thickest basalt occupied the valley cut in the sediments. This valley must have contained cliffs as evidenced by the steep basalt margins. The thickest basalt was more susceptible to weathering in the more frequent joints and the river cut back into it where it is now incised.

SUMMARY OF BORE LOGS

	Depth (m)	Recovery (%)	Log
BORE 1	0- 2.8	75	soil and weathered basalt.
	2.8-13.0	100	massive, unweathered basalt, occasionally jointed with sealed amygdaloes.
	13.0-28.0	100	massive basalt.
BORE 2	0- 0.8	0	soil.
	0.8- 4.9	100	massive, very slightly weathered basalt.
	4.9-13.7	100	massive, amygdaloidal basalt jointing minor and closed.
	13.7-27.3	100	massive basalt.
BORE 3	0- 2.1	0	soil.
	2.1- 5.5	100	amygdaloidal basalt, quite fresh with

	Depth (m)	Recovery (%)	Log
	5.5-25.0	100	amygdales intact. Slight chloritic weathering with some calcite on joints. Some iron oxide coating.
	25.0-27.6	100	Joints at 0-45° to core, about one per metre.
BORE 4	0- 2.4	0	soil.
	2.4- 4.9	63	fragmented basalt, weathered, 2 joints per metre.
	4.9- 5.5	100	1 joint per metre, fractured basalt.
	5.5- 8.4	68	weathered basalt, iron coated joints (1-2 per metre).
	8.4- 9.4	70	very weathered basalt (6 joints per metre).
	9.4-14.6	75	soft, pyroclastic cemented pebbly sand. Partly silicified.
	14.6-15.4	100	fresh basalt, calcite in joints (3 joints per metre).
	15.4-17.7	100	fresh basalt.
	17.7-21.6	100	basalt showing slight chloritic weathering. Joints at 0-30° to core (1 joint per metre). Major joints at 18.6 m.
	21.6-27.0	90	basalt fragments to 27.2 m. Silicified sandstone to 27.5 m then clay, sand with wood fragments.
BORE 5	0-19.1	12	sand, clay, quartz pebbles. Some sizeable slate fragments also present.
	19.1-22.2	2	sand, clay quartz pebbles.
	22.2-26.5	100	weathered slaty mudstone.
BORE 6	0-22.1	5	sandy clay, quartz pebbles.
	22.1-26.7	100	weathered, grey, slaty mudstone.
BORE 7	0-21.6	5	sand, clay, quartz pebbles.
	21.6-23.2	100	weathered, grey, slaty mudstone. Dip of bedding less than 10°.
BORE 8	0-11.9	2	basalt, soil and fragments.
	11.9-14.2	30	basalt fragments.
	14.2-14.7	90	weathered basalt, grey and soft.
	14.7-16.7	100	massive basalt showing slight whole rock weathering with thick coating of iron oxides. Amygdales weathered.
	16.7-22.0	100	iron oxide weathering obvious only in shatter zones in basalt at 17.5, 20.1 and 21.4 m.
	22.0-26.4	100	generally fresh and massive basalt with thin grey oxidation coatings at 23.3 and 26.1 m.
	26.4-31.1	100	coarse, amygdaloidal basalt with 3 fine fractures per metre. Shatter zone at 27.4 m.
	31.1-39.0	100	solid, massive basalt. About one joint per metre, sealed.
	39.0-40.3	75	clay, quartzite boulders.
	40.3-43.0	25	slate fragments.

SEISMIC SURVEYS

The initial seismic surveys were undertaken in the valley around the region of the centre line (fig. 55). Basalt at shallow depth was inferred in all spreads and was verified by subsequent drilling (bore holes 1, 2, 3). Seismic velocities of 3,500-6,000 m/s are related to massive, generally un-weathered basalt with closed joints.

Following drilling on the spur top and the availability of a contoured base map further seismic work was undertaken (fig.55). Depth to the main refractor is indicated in the figure (slate unless otherwise indicated).

Spread 1:

Layer 1: $v = 1,525$ m/s, thickness 21-27 m

Layer 2: $v = 2,600$ m/s

Inferred material: sand and clay overlying slightly weathered slate.

Spread 2:

Layer 1: $v = 1,400$ m/s, thickness 14-23 m

Layer 2: $v = 2,130$ m/s

Inferred material sand and clay overlying weathered slate.

Spread 3:

Layer 1: $v = 1,370$ m/s, thickness 8-18 m

Layer 2: $v = 1,980$ m/s

Inferred material: sand and clay overlying weathered slate. As shown in section CD the thickness of the sand-clay cover decreases toward the suspected near outcrop of the slate.

Spread 4:

Layer 1: $v = 1,070$ m/s, thickness 20-23 m

Layer 2: $v = 2,900$ m/s

Inferred material: sand and clay overlying weathered-unweathered slate. Limited information obtained due to interference due to solid basalt near part of the spread.

Spread 5:

Layer 1: $v = 915$ m/s, thickness 11-15 m

Layer 2: $v = 2,450$ m/s

Inferred material: sand and clay overlying slightly weathered slate.

Spread 6:

Layer 1: $v = 1,220$ m/s, thickness 12-15 m

Layer 2: $v = 3,650$ m/s

Inferred material: sand and clay overlying weathered slate.

Quarry site spreads

Spread 7:

v = 3,050 m/s

Spread 8:

v = 1,525-1,770; 6,000 m/s

Spread 9:

v = 1,525-2,010; 3,350 m/s

Depth of weathering up to 12-17 m.

Alternative abutment spreads

Spread 10:

Layer 1: v = 1,830 m/s, thickness about 9 m

Layer 2: v = 21-2,200 m/s

Inferred material: basalt boulders(?) overlying slate(?) or more solid but fractured basalt.

Spread 11:

Layer 1: v = 1,830 m/s, thickness about 6 m

Layer 2: v = 21-2,200 m/s

Inferred material: as for Spread 10.

Spread 12:

Layer 1: v = 2,290-2,590 m/s

Layer 2(?): v = 4,270 m/s

Inferred material: fractured basalt overlying massive basalt.

In the case of Spreads 1 to 6, sand and clay with pebbles is exposed at the surface. There is a little doubt as to whether the profile is entirely as indicated. Normally sand and clay deposits of this type have seismic velocities of the order to 1,525 m/s. Only in Spread 1 is this velocity achieved. Unweathered basalt normally has seismic velocities of more than 4,570 m/s whilst fractured basalt has velocities of 2,100-3,350 m/s. Basalt talus and boulders may have seismic velocities as low as 460 m/s (see Leaman, 1973a, b, site 10). Unweathered slate may have seismic velocities of more than 3,050 m/s and weathered slate normally ranges between 1,220 m/s and 3,050 m/s.

It is thus seen that there is some overlap in the seismic velocities which leads to uncertainty in the interpretation. The very low values shown in Spreads 10 and 11 are considered to be basalt remnants by analogy with similar values, and subsequent drilling at site 10. In addition the edge of the basalt flow must occur on this spur. It thus appears that solid basalt is generally at depth and is only exposed near river level (see Spread 12).

Drilling has taken place near Spreads 1 and 2 and a seismic velocity as low as 1,370 m/s must be admitted for the sand and clay material. This

suggests that they have either more sand or gravel than usual or are less compacted. At the time of survey they would also have been dry. Similar velocities could be obtained from weathered slate. Velocities in Spreads 4, 5, 6 are low and cannot at this time be completely explained. It is possible that there has been interference due to nearby basalt materials and that the seismic velocities are not true ones.

Seismic velocities obtained in quarry spreads suggest intensely fractured and blocky basalt to considerable depth.

WATER PRESSURE TESTS

Water losses are quoted in litres for a 10 minute test at 345 kPa.

Bore 1. From 3.9-7m the water loss was 9 litres. No losses were recorded in the remainder of the hole, thus confirming massive basalt with tight joints.

Bore 2. From 1.5-4.9 m the water loss was 60 litres. No losses were recorded in tests in massive basalt.

Bore 3. From 2.1-27.6 m no losses were recorded.

Bore 4. The only losses were recorded in the depth range 12.3-22.5 m. From 12.3-19.2 m the loss was 25 litres and from 19.2-22.5 m, 51 litres.

Bore 5. No testing was possible in the sand and clay to 22.2 m. From 22.2-26.5 m the slate absorbed 18 litres.

Bore 6. No tests were carried out in this hole.

Bore 7. No tests were carried out in this hole.

Massive basalt sustained no losses while fractured basalt passed up to 59 litres and slate 18 litres. No pressure tests were possible in the sand and clay sediments but in view of the importance of the hydrological properties of these sediments to the feasibility of the site surface testing methods were devised using the available bore holes. Bores 7 and 6 were used for this purpose. Effective water pressures were compatible with those to be exerted by a 23 m high dam at the site.

Permeability tests based on the rate of level change suggest an average figure of about 0.45 m/day whilst calculations based on static maintained levels of discharge gives a figure of about 0.3 m/day. This implies a possible leakage rate of up to 490 litres/day/m² of discharge area.

Field conductivity tests imply an absorption of 290 litres/day/m² in short term tests (2 hours). Long term tests, over a period of two days during which soil saturation was maximised following stabilisation of test flow and heavy rainfall, showed an absorption average of 390-440 litres/day/m². Also of interest is the fact that 75 mm of rainfall in one day (23 hours) caused a 4 m rise of the water table in an observation hole, indicating very high permeability (3.4 m in 5 hours). Voids 2% (from moist to saturated).

ENGINEERING GEOLOGY SUMMARY

The geology of the site is presented in Figure 55. Three sections across the region where the dam is to be placed are shown in Figure 55 which

also incorporates relevant sections of the seismic interpretation. Figure 55 has been made as simple and factual as possible and reflects, at this stage, the great lack of information about the east abutment. The deficiencies in the west abutment are discussed below. The following discussion assumes that the dam wall is about 25 m high, that T.W.L. is at about 44-45 m and that the centre line approximates Bores 1 to 5.

The known data suggest that the eastern three quarters of the dam will be founded on massive, tight basalt. Little is known about the eastern abutment proper, but at this stage, however, the evaluation of western abutment appears crucial. It is set on sediments on the gentle top of a low spur with water impounded around it to the north-west for over 365 m. Sediments are exposed over this entire length and may have from 12-21 m of the applied head of water upon it. The average intake surface is thus about 6,130 m² behind the dam and about 1,670 m² in front of it. The total sectional intake area is 7,800 m².

As the sediments underlie the basalt which forms the plateau on which 'Leura' is situated, the leakage path is either directly to the north where the sediments crop out north of the homestead or to the north-east. The shortest path is from the abutment spur by the slate constriction. The near outcrop of slate north of the west abutment (north of Bores 5-7) is probably a hill remnant left by a previous course of Pipers River; its position and the seismic results support this. The shortest inlet-outlet path is about 245-305 m and the average path around this slate block is only 335 m. Potential outlet points are difficult to determine due to the cover of basalt debris (as near seismic spreads 10, 11, 12). The section of the discharge area is likely to be at least 3,900 m² and the average transmission section about 4,460 m².

The sediments in their present state would thus transfer about 2 megalitres per day, or more if piping is initiated.

The only other notable source of leakage is the steep margin of the basalt (see leakages Bore 4), sections AB, CE. This zone of leakage extends across the entire site but is probably less than 12 m wide; it may be very variable in width as seen in the cuttings south of the site on the Bridport road.

The only suitable material, found within 15 km of the dam site, which could be used for dam wall fill is basalt, provided it is uniform and relatively fresh. A potential quarry site south of the drilled area (Spreads 7, 8, 9) showed fractured and slightly weathered basalt. Its suitability would have to be verified by further drilling. There are few other possible quarry sites.

CONCLUSIONS

The following comments apply only to the west side of the river since the nature of eastern abutment remains in doubt. However, the feasibility of the site rests on an ability to prevent:

- (1) leakage in the basalt/sand-clay margin, and
- (2) leakage through the sand-clay sediments; any leakage might lead to piping and storage failure.

The first source of leakage is relatively minor and probably preventable in large measure by grouting. The latter may need special cut-off treatment, sheet piling wall or surface covering. Chemical sealing might be

effective but insufficient is yet known about the sediments to recommend such treatment.

Should the site remain a feasible proposition the drilling programme recommended in Part 2 of this report should be completed. All holes should be thoroughly water tested, with surface procedures or pressure tests where possible to confirm the figures suggested in this report. Drilling should also confirm the slate block acting as a constriction to flow across the site.

REFERENCES

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