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TITLE: REPORT ON ROCK STABILITY.
MUNDARING WEIR PUMP HOUSE.

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by

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CONTENTS

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INTRODUCTION

In accordance with a request made by the Goldfields Water Supply Department, an examination was made of the rock faces adjacent to the new pump house at Mundaring Weir. Two large joint planes are exposed at the rear of this pump house below a rock overhang and, with considerable water emerging from the joints and a dip towards the station, concern had been expressed as to the long term stability of the rock mass. A recent proposal to site a bus-road down the abandoned zig-zag railway line on the rock face, and thus to introduce vibration from both widening operations and traffic movement was the reason for the present reassessment of rock stability. In view of the capital value of the works directly involved and the potential danger from possible rock movement, it is obvious that concern is proper for any threat to the continued safety of the structure.

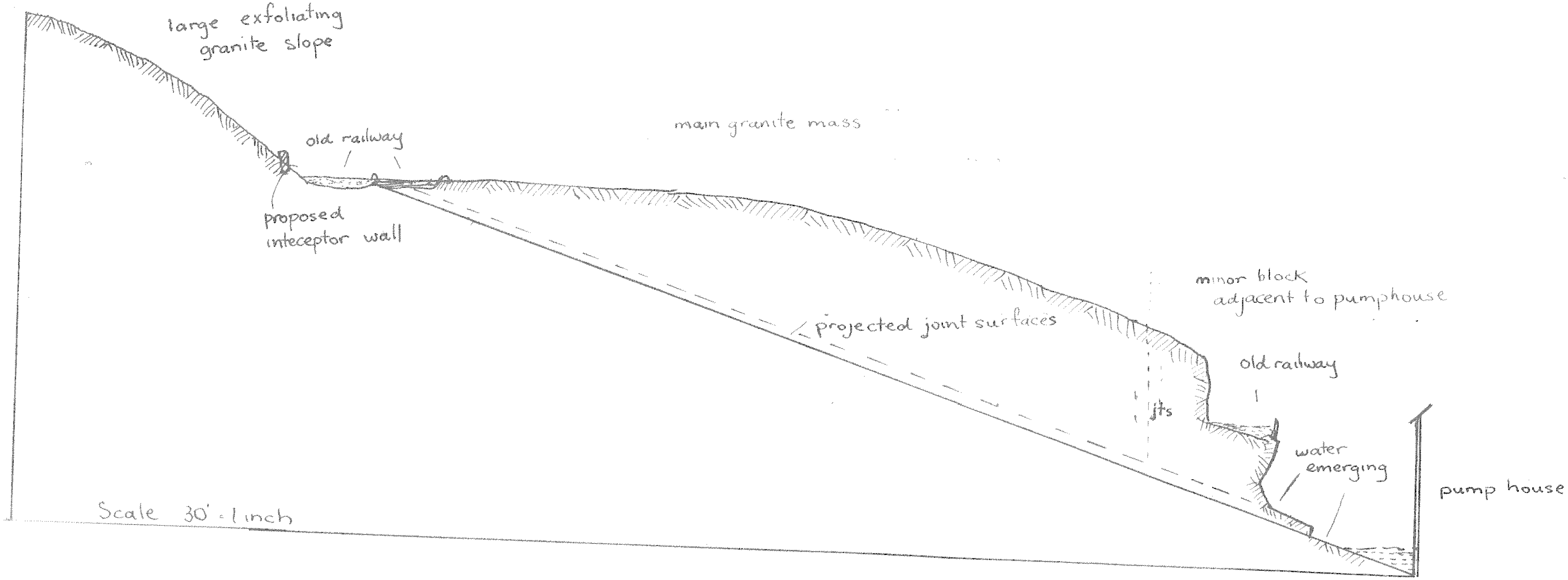
SITE APPRAISAL

After a preliminary examination, it was obvious that two distinct stability problems would have to be considered. Firstly the granite rock mass <u>immediately</u> above the pump house is in a position of potential movement down the two exposed joint faces, and this situation would be aggravated by road construction and operation immediately above. Secondly, the exposed joint surfaces could be projected back to a large exfoliation surface about 220 yards uphill, which dips at the same angle as the joint surfaces. In other words the mass of rock behind the pump house is merely the lower remnant of an exfoliating sheet, which has been eroded from the upper slopes of the valley, and the large lower section may act as a unit in sliding.

Safety of Major Block

The overhanging face at the rear of the pump station is 15 feet high, and the face above the old railway line is a further 20 feet, most of the block being 35 feet thick. (See sketch). There are no apparent buttresses supporting the block between the pump house and the stream and thus the block is unsupported over a width at least equal to the width of the pump house. From head to toe the block is approximately 240 feet in length, and allowing for a $22\frac{1}{2}^{\circ}$ surface, the volume of the rock mass is 20,000 cubic yards, the weight involved being approximately 38,600 tons.

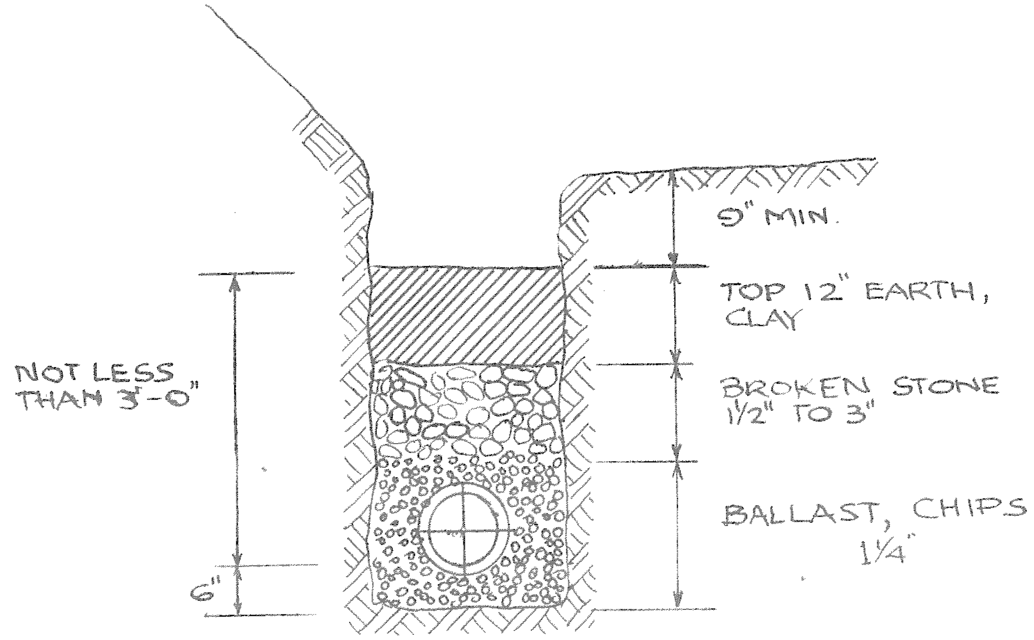
Examination of the two main parallel joint surfaces about 2 feet apart shows that on top of the lower joint plane there is a clay parting with slickensides inclined at 30° to the strike of the joint plane. This indicates former movement in a direction parallel with the small stream valley. Above the thin parting (an attrition product) there are two or three inches of broken granite, and another joint opening. The broken granite is in a condition akin to a lightly cemented sand, some of which is constantly being removed by water seeping along the joint surface. Moss covers the four inches or so of the affected joint surfaces. In places there is no sand or moss parting, but a gap indicates a place where water flow has concentrated. The upper joint does not have a clay layer, and the thickness of crushed and weathered granite is only two inches. Less water emerges from this joint, but again there are two areas where considerable flows emerge after prolonged rain.



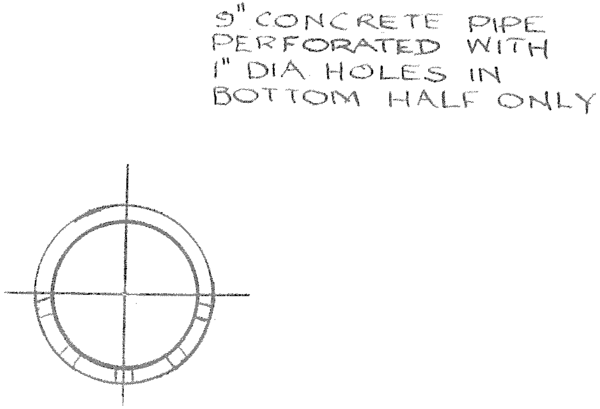
Section showing potential block glides at rear of Mundaring Pumphouse

Water in the joints naturally reduces the factor of safety, and the accelerated weathering of the joint zone materials to sand and clay will lead to further lowering of the safety factor. Examination of the rock mass indicates that the major portion of the water must be derived from the upper exfoliation surface, and enters the joint system at about the westerly point of the old zig-zag railway (see plan). Diversion of this water will be necessary to preserve the long term stability of the rock mass, and the simplest method would be to build an interceptor wall across the foot of the upper rock mass, the water being then led by pipe to discharge downhill in the direction of the stream valley. In addition a properly designed drainage ditch (see sketch) should run along the upper side of the road proposed for the old railway track.

It has been established that the vertical angle of repose for rock masses resting on joint surfaces with saturated clay partings is 15°, and 25° for sand and other materials. It is thus apparent that as the joint surface here is at about 22½° with the parting mainly sand, conditions are close to the equilibrium point. In addition to this small frictional restraint we have, however, a certain support from the materials at the foot of the rock slope, for only where the joint surfaces are exposed is there lack of material at the toe. The most effective method of increasing the factor of safety is the removal of water from the joint planes, but we could consider positive restraint by the use of bolts or anchors. In view of the size of the block involved it is obvious that an enormous number of rock bolts would



SOIL DRAIN



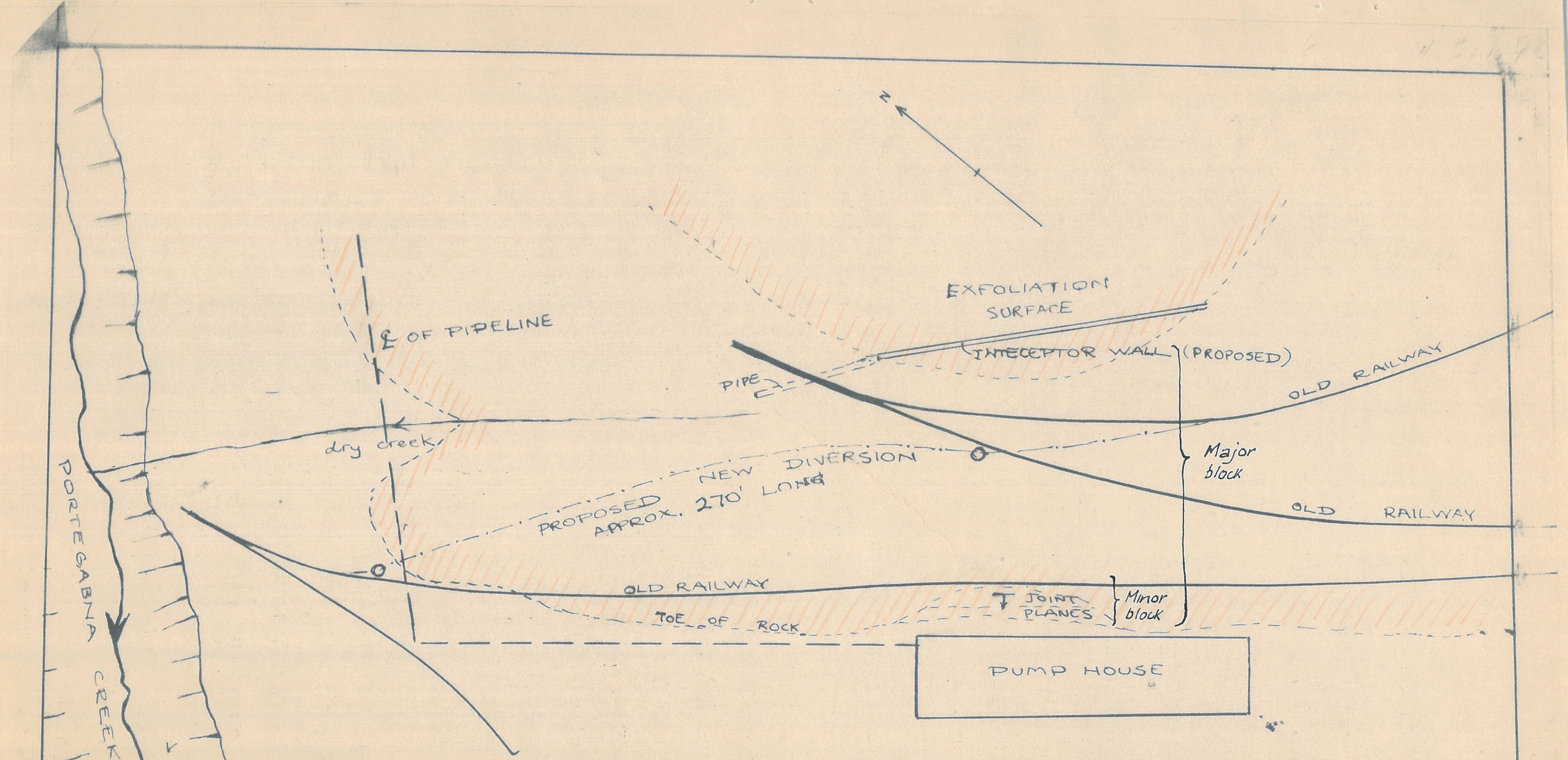
SECTION THROUGH PIPE

be needed to provide effective restraint if movement were initiated by some outside agency, (e.g. earthquake). However, a small additional restraint may prevent initial movement, but once a block of rock has started moving, restraint is most difficult. The longest effective bolts in use at present are 30 footers, which is less than the average thickness of the block, so rock dowelling would appear to be the only practical method, i.e. holes are drilled into the rock normal to the joint planes, and heavy steel dowels are grouted in the holes.

The final consideration is to determine the effect of placing and using a new road across the toe of the potential block glide. The factors will be (1) vibrations from blasting to widen the railway cutting, (2) vibrations from traffic, (3) removal of part of the toe of the block. These features will all tend to reduce the factor of safety, but none will be as detrimental as the removal of water is beneficial. In other words the major block will not be greatly affected by the proposed alterations if effective measures are taken for the prevention of entry of water.

Rock adjacent to Pump House

The safety of the mass of rock immediately behind the pump house is determined to a large extent by the positional relation of the major joints. On the diagram the main joints are shown, and geometrical considerations indicate that fracture or breakage down the 105° set is likely, and thus a block of 60 feet wide x 20 feet high x 20 feet deep is involved, i.e. 42,000 cubic feet or 3,100 tons. In its present position it shows no sign of movement but the cutting of a road, with



SKETCH PLAN of PROPOSED
ROAD DEVIATION

blasting and vibrations would probably be critical, and movement of a rock slide or block glide type would possibly be initiated. As the block is not large, and several surfaces are exposed parallel to the joint surface, it would appear that the rock bolting would offer effective restraint.

This would involve the use of bolts from 5 feet to 30 feet long (depending on the position above the joint surfaces) placed at 3 foot centres. With a tension of 10,000 lbs. each, the number of bolts N would have to be:

$$N \times 10{,}000 + \frac{N \times 10{,}000}{2} = 3{,}100 \times 2{,}240$$

i.e. 443 bolts, once movement had been initiated. However, we are only interested in raising the factor of safety, and 50 bolts would offer over 300 tons of restraint.

One inch nominal diameter, hollow, mild steel bolts loaded to 10,000 lbs. are suggested, with a Williams impact setting anchor, and the bolts should be grouted on taking up. Bolts of this type have been widely tested and used in the Snowy Mountains tunnels, and are supplied by G.K.N. - Lysaght Pty.Ltd., Alexandria, N.S.W. (An illustrated article on their use is in the Chemical Engineering and Mining Review of April 16, 1960, page 49).

The layout of the holes for the bolts will depend on the thickness of rock above the joint plane and the inclination of the rock surface. Bolts are most effective at right angles to the surface of potential movement, but in this case a few inclined bolts will be effective in pinning the whole rock mass together. There are a few refinements of technique now available such as the use of heavy grease between the bolt head and bearing plate, but these may be considered at a later date.

Rock bolting will permit the building of the proposed road down the old railway line; however, scientific shooting and drilling during the formation widening will cut down the vibrations, and thus the risk of sliding. The use of milli-second delay firing will be the most effective item to ensure that vibrations do not reinforce during blasting, and control by an experienced quarryman would be essential to prevent excessive flying rock and to determine the most effective hole loadings.

REMEDIAL MEASURES

Some measures for the constraint of movement have already been discussed, however the whole problem could be avoided if the road were relocated clear of the pump house region. This is possible by locating the road down the inside slope of the hill from the point of the zig-zag to the end of the sealed road from the pump house (see photographs). The distance is 275 feet and the fall is 56 feet i.e. 1 in 5 or 20% (11°). A turning area could be provided in the bottom area but this will be also necessary with the zig-zag proposal. It is suggested that strong consideration be given to this proposal which would involve little excavation, the only additional item being a crossing of the main pipe line.

In view of the desirability to ensure long-term stability of the rock mass it is considered necessary to initiate preventive measures apart from consideration of the access road. Thus the channelling of water off the upper rock surface and the bolting of the lower blocks are both regarded as essential for future conservation.

CONCLUSIONS.

(1) No concern is felt for the immediate stability of the rock at the rear of the pump station. Considering the engineering life of the structure, however, it is considered that water diversion and rock pinning and bolting will be essential.

(2) As far as the proposed access road is concerned, a new location is suggested. However, if this is not acceptable, water diversion, rock bolting and expertly conducted excavation during widening, (naturally with the pump house protected) should allow the use of the old zig-zag without increasing the present risk to the structure.

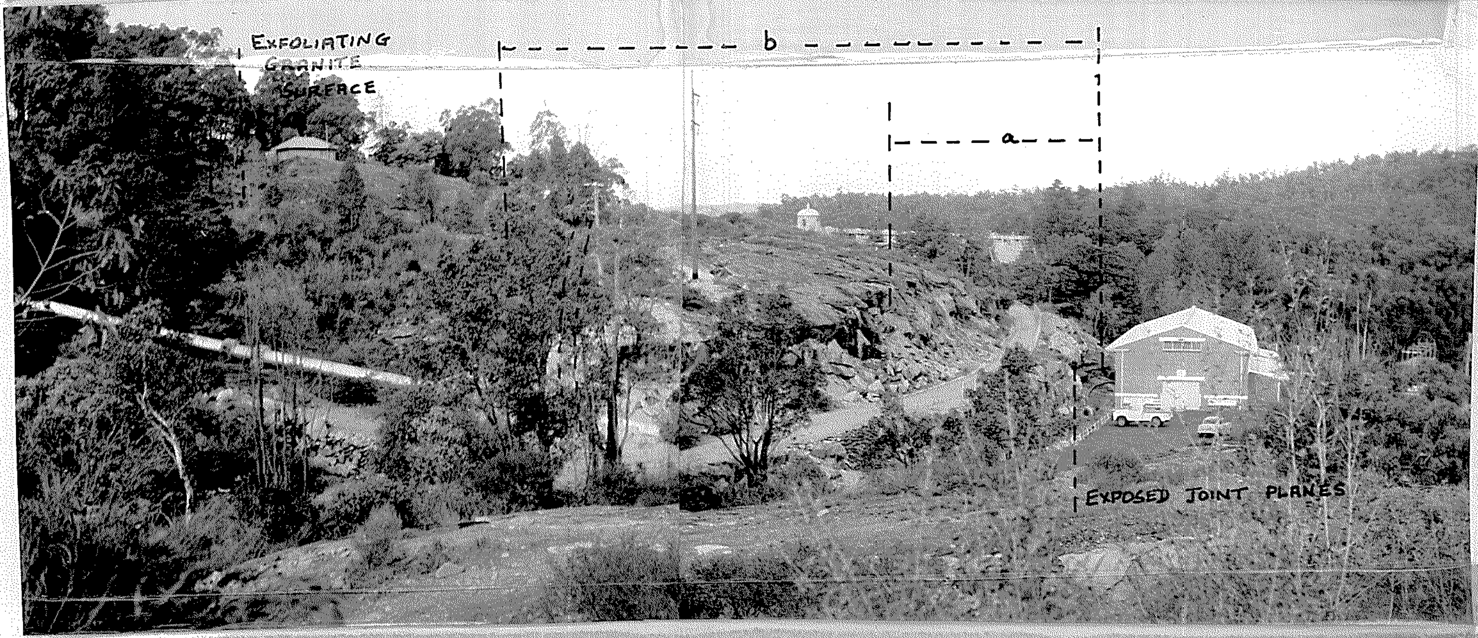


Photo 1: Panoramic view from Kalamunda road showing the relationship of the exposed joint forces behind the pump house to the minor block 'a' and the major block 'b'.

The proposed deviation follows down the centre of the photograph.

Photo 2: Taken at the rear of the pump house. The joint planes sloping at $22\frac{1}{2}^{\circ}$ are covered with water from the joint. The 75° overhang and a small block in a position of potential block glide are notable.