THE HYDRO-ELECTRIC COMMISSION

TASMANIA

MERSEY -FORTH POWER DEVELOPMENT

GEOLOGICAL INVESTIGATION REPORT 644-Ceth-I

ON THE

CETHANA DAMSITE

GEOLOGY SECTION FILE

CETHANA

644-Ceth-1

MERSEY - FORTH PR. DEV.

	Date	Author	Report No.
Cethana Damsite.	1965.	G. Hale.	644-Ceth-1.
Detailed Geol. Invest of the Left Abutment of Cethana Damsite.	8/9/65	G Rawlings	—
Detailed Geol. Invest. of the Right Abutment of Cethana Damsite	5/9/65	G Rawlings	—
Seismic Determination of Young's Modulus & Poissons Ratio at Cethana Dam-Site.		P.W. McDowell	644-126-2.
Minutes of Design Conference on Cethana Dam. Dec. 1965.	22/12/65.		—
Cethana Rockfill Quarry.	25/11/66.	G.E. Rawlings.	644-126-4. —
~~Cethana Rockfill Quarry.~~ also Cethana Rockfill: memo	12/12/66 5/12/66	N Boughton. M. Fitzpatrick.	
Cethana Rockfill Quarry.	15/6/67	N. Boughton	
Explanatory notes to Prelim. Outline Geological map of Cethana Quarry Site.	SJP.		FILED Sept. 6th.
Cethana Quarry Investigations.	2/8/67	G.E.R.	—
Cethana Quarry. Stripping Progress Report.		N.H.H.G.	Filed Sept 29th '67
Cethana Quarry. Memo of JR Neall to Planning Eng.	13/10/67	N.H.H.G.	Filed 9th Nov. '67
Cethana Quarry. Stripping progress Report.		N.H.H.G.	Filed. SPARE.

Box 24 5416

E.S.W. CETHANA QUARRY N.H.H. Godfrey.

- Memo of J.R. Neall
To Planning Engineer.

13th October, 1967.

Comments on Memo:-

1. Para 2 sub-paras (a) to (d) are agreed with.

2. The upper bench levels at the North Westerly end of the quarry from the NW (haulage road entrance) quarry limit to about 700' to the South East lie within series 2 and 3 rocks of varying quality.

At 80' from the NW quarry limit, all of bench level 815' is composed of series 2 and 3 rocks. About 3/4 of bench level 780' and 1/2 of the 745' bench level are also composed of series 2 and 3 rocks.

At 340' from the NW quarry limit, all of bench level 815' and upwards should lie in series 2 and 3 rocks with 2/3 of the 780' bench level and 1/3 of 745' bench level in the same sequence.

Surface exposures of series 2 and 3 rocks, where followed down during the course of quarry development have been seen to improve in quality, with depth, though thin seams of soft argillaceous rock occur, apparently haphazardly.

Where seen on originally exposed surfaces nearer the natural surface, the rock is of varying quality and not all unuseable. Drill hole results have generally proved the Series 2 rocks to improve in hardness, with depth. Recent new exposures of series 2 and 3 rocks in the North West quarry area due to the reduction in surface level of haulage roads have uncovered very hard series 2 and 3 rocks.

It is reasonable to assume that about 50% of the series 2 and 3 rocks should be useable as sound rockfill material, but extraction may involve sorting problems.

At around 720' from the North West haulage entrance end of the quarry limits, the quarry, apart from about half of bench level 885', lies within acceptable series 4 quartzites and the bottom conglomerates. Thus, to this point, the limit of acceptable rock transgresses the bench levels obliquely in a South Easterly direction from about 400' from the North West quarry limit.

From 720' the back edge of the quarry extends in an Easterly direction.

At about 950', 2/3 of the 885' bench level lies within series 3 rocks, none of which, here, appears suitable for use.

The 850' and 815' bench levels in this area, also show up on the quarry plan as lying partly within series 3 rock. However, due to the Northerly dip of the beds and the depths of the benches in relation to the boundary of the acceptable rock, only about 1/4 of the 850' bench level and none at all of the 815' bench level should include unacceptable series 3 rocks.

3. The South Westerly assumed limit of good rock on the quarry plan, lies from 30' to 50' to the South West of the limit of good rock as based onsurface mapping.

An area of roughly 75' by 250' of the 675' bench level lies within Cambrian quartzites and also 50' x 280' of the 640' bench level and 25' x 380' of the 605' bench level.

However, this may not all be wasted and the quarry limits seem justified in being taken this far back, as the results of Drill Hole 5521 have proven that:-

(a) The conglomerate can be hard, sound rock right to the contact with the granite.

(b) After an initial 4' to 6' of softer rock at the boundary, the granitized Cambrian quartzites at this depth below the surface (75') are reasonably hard, sound rocks, but again this may involve sorting problems.

(c) The Cambrian quartzite in the Dolcoath granite contact area may not be so highly mineralized as anticipated and the quartzite in DH 5521 remains sound to within 2 feet of the granite.

(d) The granite, in DH 5521, has a 75°N dipping contact with the Cambrian quartzite and so should interfere even less than previously assumed with quarrying operations.

Drill Hole 5523, proving the Moina Sandstone quartzite/Roland conglomerate/Dolcoath granite boundaries, has yet to be completed, but so far has shown sound, hard rock for the majority of the quartzite (all of series 4) and the conglomerate.

Thus, the South Western limit of the quarry seems satisfactory at present and indications from DH 5521 suggest that the quarry limits could be moved even further South West to make use of the Cambrian quartzites at depth in this area.

4. At the South Eastern extremity of the quarry, very hard, sound rocks extend on up the gully in a South Easterly direction and this area would serve well as a possible quarry extension though the hill slopes steepen up here considerably. There is, however, the possibility of faulting up the gully.

5. As mentioned in the memo, the stripping estimates are conservative, especially with regard to the conglomerate and lower beds of the Moina Sandstone quartzites.

N.H.H. GODFREY.

At present most of the quarry is obscured by spoil or talus and detailed surface mapping is not possible. Godfrey's observations are thus largely based on extrapolation of drill hole information.

S.T. Paterson.

Copied From original.

TO:
Geologist-In-Charge

FROM:
N.H.H. Godfrey

MERSEY-FORTH POWER DEVELOPMENT

CETHANA SCHEME

CETHANA QUARRY

STRIPPING PROGRESS REPORT

INTRODUCTION

Cethana quarry site lies on the Western end of Tin Spur about 1/3rd of a mile upstream of the dam site on the right bank. The spur is steep sided and falls away on either side to two creeks.

The geological structure of the spur, is broadly as follows:- At the South Eastern limits of the quarry the rock beds dip from 50 to 60 degrees Northwards, with a general trend of 100 to 125 degrees. As they are followed North West along the spur, the dip becomes less steep (10-20°) in the vicinity of a synclinal axis and dips of 40 to 60 degrees occur on the Northern limb.

At the North West end of the spur the beds are folded to form, in succession, an anticline, a syncline and another anticline, all largely asymmetric, with limbs dipping from 45 to 70 degrees. The axes of these asymmetric folds appear to trend from 110 degrees to 130 degrees at the Western side of the spur and swing round to trend 85 to 110 degrees as they go East. The less competent beds of the broader Southern syncline probably undergo minor buckling within the syncline itself.

Lithologically the spur is composed of five readily discernable rock types. A Devonian granite which intrudes discordantly across the South West corner of Tin Spur; poor quartzites of probable Cambrian age lying between the granite and the conglomerate of the Roland Conglomerate which, then, lies above the Cambrian quartzite. Above these lie rocks of the Moina Sandstone, in which the quarry is mainly placed, and these consist, in the main, of fresh, but generally closely jointed quartzites and soft decomposed and weathered argillaceous rocks which, in some cases may have originally been quartzites and in others a silty sandstone.

Mineralization of mainly quartz, iron, chlorite and lead appears to have found its way into areas of the rock along planes of weakness, and its haphazard distribution could account for the erratic occurence of the badly decomposed and weathered patches.

The Moina Sandstone quartzites show alternate series of fresh and decomposed and weathered beds. Where the asymmetric folds occur at the North Western end of the spur, these decomposed and weathered series are repeated. Also, due to the folding, the jointing is more intense in the fresher quartzite, allowing much more weathering to take place along these joint planes. These two factors combined, produce a largely decomposed and weathered mass of rock in the areas occupied by the folding. A heavy, dashed line on the accompanying map demarks this area.

Method of Working

Details of rocks exposed along dozer trenches, the top working face or batter, the haulage/access road batter and rock outcrops on the spurside, where not covered by spoil and talus, were taken. Hold-ups in the progress of the mapping were encountered, especially when working on the Haulage/Access road batter, due to the large accumulations of spoil which had to be shovelled out of the way each day before the bedrock which was to be inspected was reached. The spoil frequently moved due to the rainy weather.

The Series of Beds Encountered

The fresh series of beds and the decomposed and weathered series are numbered on the map and are described by number, here-under.

2/...

Series 1

A number of soft, silty, completely decomposed and weathered, white, red, grey, green and black siltstones, with intercalating clay bands, forming the top series of the quarry. They are seen on the Northern side of the top (900 ft) working batter, dipping N35°-45°. As the beds are followed Northwards they become less steeply dipping, 'til a synclinal axis is reached and then begin to dip Southwards, at 5° to 15° at first, gradually steepening to dips of from 30 to 50 degrees. Thus, they run in a troughlike formation, back up the spur line on a trend of 110 to 115 degrees. They are about 30 ft to 45 ft thick, individual beds seldom exceeding 18" in thickness. They crush easily to a fine, argillaceous spoil under repeated passes of the D9 'dozer tracks.

Series 2

The majority of this series is exposed in the Haulage/Access road batter. Although this series is shown as fresh quartzite on the map, it is, in fact, quite variable. An outline of the surface variations seen will be given as the Series 2 beds are described, first as seen in the top (900') working batter, and then in the Haulage/Access road batter.

In the top (900') working batter the Series 2 beds occur as a number of massive, well jointed, light creamy grey quartzites and siltstones. The quartzites have a sugary texture and break down under repeated passings of the D9 dozer tracks to white 1" to 6" nuggets in a sandy matrix. The siltstones, which occur in localized patches, break up in the hand to a fine, silty sand. Thin ironstaining occurs along the joints, which are open in many cases, though this ~~batter~~ may be a surface phenomena.

Series 2 beds, when followed along their line of strike in a North Westerly direction, become less rippable by a D9 dozer after 100 ft. The rock becomes harder, buff coloured and more closely jointed with thinly ironstained, discontinuous joints. Within the next 50 ft in the same direction, the dip of the beds decreases, the quartzites become massive in beds of 4 ft to 12 ft thickness, light grey blue in colour, harder and mineralized with purple Haematite and small quartz crystals in occasional ¼" diameter vugs. The rock is still closely jointed with thin, ironstained joints, but these are tight and under the D9 'dozer tracks the rock tends to break across virgin quartzite just as much as along joint planes. When broken up it reaches sizes of from 3 to 18 inches diameter with occasional larger blocks of up to 36" diameter.

This type of rock continues as the beds are followed North Westward 'til the Southern end of the main Haulage/Access road batter is reached. Here, a number of varying rock types occur within the Series 2 beds. These are due to lateral changes of fresh to decomposed and weathered rock within the same horizon.

The general pattern of the Series 2 beds seen in this exposure is as follows:- Moving down the road in a North Westerly direction the hard, fresh quartzites at the top of the road become decomposed as the beds are followed through. The top 20 ft to 30 ft of the batter is composed of quartzite which is severely weathered on the surface of joint planes and not intrinsically decomposed. The beds can be seen to shallow out and form the bottom of a syncline before steepening up to dips of between 8 and 20 degrees South, about 150 ft from the 848 ft Survey Mark. Here the decomposed beds change to hard, fresh, light blue, massive quartzites. These sweep up at dips of from 40 to 55 degrees to the crest of an anticline just to the South of the corner of the Haulage/Access road. Here the joints become very ironstained and the rock more closely jointed and less massive, though it is still fresh when broken. The last two quartzites are the hardest of all, so far encountered in the beds of Series 2, repeated passes of the D9 dozer tracks crushing them with difficulty to sizes of 6" to 30".

3/...

On the Northern limb of the anticline, the Series 2 beds are well jointed and ironstained and display alternations of 1 ft to 3 ft thick, fresh, hard quartzite interbedded with 6 to 18 inch thick decomposed and weathered bands.

Where seen on the old access road batter, (above the Haulage/Access road batter) the Series 2 beds form massive but partially decomposed quartzites, light grey in colour, argillaceous and crushing easily under hammer blows to a fine, silty white sand.

Series 3

These beds range from a partially decomposed argillaceous quartzite (or partially metamorphosed siltstone) to sandstones. The argillaceous quartzites and siltstones are light grey to light brownish purple in colour, in beds of 12 to 24 inches in thickness. They are evenly jointed, soft and crush easily under hammer blows, to a fine, damp, clayey sand. The sandstones are soft, olive green, white, red, and purple, often blotched and streaked with yellow and brown ironstaining and in 6 to 36 inch thick beds with seams of intercalating white and buff clay up to 1 ft thick.

They are exposed on the South side of the top (900') batter, again at the top of the Haulage/Access road and finally reappear in the form of an anticline on the Haulage/Access road corner. They are some 50 ft to 60 ft thick at their Southern end and reduce in thickness to about 25 ft to 35 ft thick in the North. They are mineralized at their Northern end in thin seams up to ½" thick, of galena, which is often decomposed, and in quartz veins up to 2" thick, which lie in the bedding planes.

Series 4

These beds are of hard and fresh quartzites wherever exposed, with no visible surface decomposition, although D.H's 5503, 5504, 5506, and 5509 indicate the possibility of weathering, down to 40 ft in the case of D.H. 5506 and 25 ft of bedding thickness in the others. As D.H. 5506 traverses an anticlinal fold this may account for the greater depth of weathered rock met with.

Series 4 beds are seen on the Southern edge of the 900' working bench and form the slopes down to the next temporary bench, again in the D.H. 5505 dozer trench and once more as a small exposure in the case of the anticline on the Haulage/Access road corner round about S.L. 755'.

The top most beds of the series consist of a 2 ft to 3 ft thick bed of dark purple and dark grey/green, compact, massive, fresh quartzite, with very thinly ironstained 3" to 6" long, discontinuous, tight joints.

The bulk of the series is composed of a coarse-grained, light purple/brown quartzite with ironstained joints, massive, very hard and fresh, it is only broken down with difficulty by repeated passes of a D.9 'dozer to 9" to 24" sizes.

In the D.H. 5505 dozer trench it grades into a hard, fine grained, semi-translucent, light dirty-white quartzite before meeting with Series 5 beds.

Series 5,6,7 & 8

These series have only been observed in the one exposure and their boundaries extrapolated from here. Series 6 and 8 show fresh quartzite. Series 5 and 7, decomposed and weathered material. The latter two series have not been identified in any of the drill cores. It is assumed, 'til further evidence is forthcoming that these series are a surface weathering phenomena.

Series 5:-

A 17' thick series of soft, yellow and light grey, decomposed siltstones in 2" to 15" bands with 1" to 4" thick bands of sometimes very argillaceous and sometimes hard quartzite as partings. A distinct planar mineralization is present along thin planes, of probable chlorite and haematite. Iron staining also occurs in thin veins and occasional ¼" diam, haematite filled vugs as well.

Series 7 rocks are similar, being a 12'-14' thick series of soft yellow and light grey siltstones.

4/...

Series 6:-

A light brown, hard quartzite grading to a slightly less hard and more sugary textured light grey quarzite. There are few joints and the quartzite occurs in 2' to 4' thick beds with thin ironstained clay seams between the beds. The sugary textured quartzite may be due to weathering caused by the proximity of the natural surface at this point.

Series 8:-

Light buff and light grey/blue, massive, hard quartzites, with fewer joints than seen in Series 4 quartzites. Localized patches of sugary textured rock occur, probably due to the closeness of the natural surface (5-10') at this point and subsequently more severe weathering. The series becomes coarse grained and granular as the boundary with the conglomerate is reached.

CONCLUSION

The Series 2 beds, although possessing much fresh quartzite also contain a lot of decomposed and weathered rock. The Series 3 beds are largely composed of decomposed and weathered or partially decomposed rock.

Series 4 to 8 beds, where seen, apart from Series 5 and 7 whose presence deeper in is doubtful and whose thickness is not great compared to the thickness of the whole span of Series 4 to 8 in anycase, show fresh massive quartzite occurring in the lower levels of the quarry and running South East along the Southern flank of Tin Spur.

N.H.H. Godfrey

c.c. Design Division
Planning Section
through E.C.C.
P.M.M.F.
Geology Section

NHHG/PJB

GER/JIS

Form No.H.E.15

THE HYDRO-ELECTRIC COMMISSION

TO	SUBJECT	FROM
Geologist-in-Charge	CETHANA QUARRY INVESTIGATIONS	G. E. Rawlings

2nd August, 1967.

Due to the probable realignment of the Cethana quarry to the S.side of Tin Spur some of the previous investigation is no longer pertinent. Of the total footage of 2896' drilled for the quarry investigation only 1920' will now lie within the potential quarry and of that some 320' lies in the Series 3 rock which it is intended to dump to waste unless of a higher quality than anticipated. Consequently only 1600' of effective drilling has been completed on the quarry site. Further investigation to prove the required quantity of suitable rock will be needed as follows:-

1. 300' hole to be drilled from the site of D.H. 5515 in a direction 220° at 60° angle to ascertain the quality of the Series 4-8 quartzite and the conglomerate (see attached plan).

2. 100' hole at E412.0317/N890.2882 to investigate the quality of the quartzite close to the granite contact.

3. 400' hole at E412.1277/N890.2590 in a direction 200° at 60° angle to investigate the quality of the Series 4-8 quartzite and the conglomerate in view of the possible E. extension of the quarry.

4. 300' vertical hole at E412.106/N890.2376 to investigate the S.E. part of the possible E extension.

5. A further 100' angled hole sited to investigate the series 3 quartzite to allow for a possible N.E. widening of the quarry.

It is suggested that this drilling should be treated as urgent so that full information may be gained on the realigned quarry as soon as possible.

G. E. Rawlings

G. E. RAWLINGS

c.c's P.M.M.F.
Planning
File

enc. Plan A14659

Herewith unchecked,
for Guy wants it
sent today.

Will go through it with
Nigel on Monday - tidying
up John and Nadia.

Anyway will leave
to give you a
preliminary look.

Love

DEJ

M.F.P.D.

Cethana Scheme.

Explanatory Notes to Preliminary Outline Geological map of Cethana quarry site.

General.

The quarry site is situated about ¼ mi upstream of Cethana damsite on the right bank forming the North West end of Tin Spur.

Broadly the rock beds forming the spur lie in a syncline whose axis trends W-E + W-NW-E-SE. There appears to be an easterly plunge of from 4° to 10° in the syncline. The softer, decomposed + weathered beds also form minor folds within the synclinal basin itself.

At the Northern edge of the syncline a series of tight, steeply dipping, predominantly asymmetric folds occur whose axes generally trend 90 to 120°. The rocks within these folds are much jointed + sheared & comparatively more weathered. The decomposed + weathered quartzite beds are of course repeated within these folds. Thus, due to this latter phenomenon + the increased incidence of jointing + weathering it is not considered acceptable the area in which this folding occurs is not considered to provide suitable quarrying material.

Within the fresh quartzite series of beds localized masses of decomposed + weathered rock occur. These fade out laterally along the same bedding plane into fresh quartzite. Where seen, these areas are marked on the map.

The fresh quartzite + decomposed + weathered quartzite strata have been grouped together in series which are numbered. Each series is described below.

Series 1.

Badly decomposed, soft multicoloured argillaceous, fine grained sandstones. They form the top ~~strata in the series~~ of series of strata & probably ~~&~~ occur undergo a number of small buckles in the core of the syncline.

Series 2.

At the top quarry face now being exposed ~~these~~ massive, light grey quartzites have a sugary texture & are partially decomposed. At lower levels the rock becomes hard, massive & light blue/grey in colour with thin haematite mineralization veins & occasional ¼" diam vugs in parts of the quartzite. They occur in 2 to 12' thick massive beds separated generally by 1" to 2" thick clay seams but several argillaceous sandstone seams of up to 15" thickness ~~&~~ separate some of the beds.

Soft clays & argillaceous sandstones work their way in laterally for up to 25' of so far observable thickness in the ~~new~~ road cliff face. In places surface weathering has produced a soft decomposed much ironstained skin but the rock when cracked open is generally hard.

Near the contact with series 3 beds thin decomposed bands of lead ore mineralization & 1-3" thick quartz bands occur. The series appears to become thicker ~~in~~ as it goes North.

Series 3.

These beds vary from a ~~soft~~ dirty white & light brown ~~read~~ partially decomposed quartzite to dark olive green or white, soft argillaceous sandstones.

The thickness of the series varies from ~~25~~ 45 to ~~35~~ 50' in the Southern extremity to 25 to 35' at the Northern extremity. It is possible that thickening of these beds & minor folding occurs towards the core of the syncline.

Series 4.

Hard coarser grained, purple & brown massive quartzites with few joints & beds of ~~1 to~~ generally 6 to 12' in thickness grade through to hard, finer grained, semi-translucent light blue quartzite towards the bottom of the series.

The series described from now on have only been ~~exposed~~ observed in the one ~~place~~ exposure & their boundaries extrapolated from this information. Until further information is observable their positioning is as yet only approximate.

Series 5.

Soft yellow & light grey argillaceous sandstones, in 2" to 15" thick beds with 1-4" thick clay seam partings & haematite mineralization in thin purple veins along the bedding planes & occasional small ¼" diameter vugs.

Series 6.

A light brown hard quartzite to slightly less hard & more ~~sugary textured~~ or light grey quartzite. Few joints & massive 2 to 4' thick beds with thin iron stained clay ~~partings~~ seams between the beds. The surface is near at this point & the ~~slightly~~ sugary textured bed may become harder with depth.

Series 7.

Soft yellow & light grey, argillaceous fine grained sandstones, similar to those in series 5. Both series 5 & 7 beds may improve laterally with depth to a hard quartzite.

Series 8.

Light buff & light grey/blue, massive, hard, quartzites with few joints. The rock is sugary in texture in localized patches, probably due to the proximity of the original rolling surface of the hillside in the area & subsequent harsh weathering. The series is finer grained at the top & becomes coarser grained & more gritty as the boundary with the conglomerate is neared.

Geologist in Charge

NB/CP

S.E. DAMS II

CETHANA ROCKFILL QUARRY

N. BOUGHTON
15th June, 1967.

1. The Cethana rockfill quarry was inspected with geologist G. Rawlings on 8th and 9th June, 1967. All rock exposures produced by the Construction forces in their current operations were examined with the local geologists, S. Patterson and N. Godfrey, and with the construction engineers G. Kennedy and B. Chalmers.

2. Excavations in the quarry area to date have confirmed the exploratory drilling in showing poorer rock near the top of the knoll and down the crest of the spur parallel to Tin Spur Creek. Elsewhere, dozer trenching has been stopped at a few feet below the ground surface by sound rock. On part of a diagonal trench from about SL 890 on the south side of the quarry, to about SL 790 on the crest of the spur, sound rock had to be blasted for the trench and a D9 bulldozer was producing sound rockfill from the side of the trench.

3. In the light of the quality of the poor material excavated to date, Mr. Kennedy is rightly asking whether the quarry as at present laid out represents the optimum development. As indicated by the exploratory work the nose of the spur parallel to Tin Spur Creek is an anticlinal structure, containing closely jointed and occasionally decomposed rock. Generally sounder rock should be obtained by re-adjusting the quarry boundaries to obtain more rock from the southern section and less from beneath the nose of the spur.

4. Almost all excavation to date has been done using D9 dozers. Near the surface all joints, even in otherwise fresh quartzite, are weathered, so that the dozers can rip or remove with the blade tips, blocks of very competant quartzite. Consequently, in this quarry, rock which can be ripped is not necessarily unsuitable for use in the dam.

5. Because significant quantities of quartzite which is somewhat weathered may be found in the quarry, particularly in the upper levels, it may be well to reconsider the specification requirements to ensure that the wastage of such rock is justified. The basic requirements of the various rockfill zones are listed below:

5.1 Zone 2 Material should be:

(i) capable of being spread and trimmed to a neat surface

(ii) well graded down to fine sand sizes to reduce the rate of leakage from any crack.

(iii) durable under the high water pressure gradients resulting from a crack

(iv) durable during exposure prior to face concreting.

5.2 Zone 3A Material which forms the main supporting rockfill should be:

(i) when placed and compacted, of minimum settlement under water load

(ii) sufficiently pervious to freely drain any face leakage, and to present no moisture control problems in placement

(iii) permanently durable

Note that because of the nature and directions of the self weight and water loads, high shear strength is not, in itself, a requirement for this material.

5.3 Zone 3B Material, forming the downstream face fill should be:

(i) free draining for stability against surface slumping

(ii) durable against exposure to weather

(iii) of suitable grading at the toe for the convenient placement of protective mesh.

6. In relating the above requirements to the material currently being excavated in the quarry, the following points are made:

Zone 2 Material It is considered unlikely that the grading of a fresh quartzite quarried material will meet the requirements of 5.1 (ii). Fresh fine grained quartzites seldom have significant medium and coarse sand sizes in quarry run material.

On the other hand, the slightly weathered material already exposed in the quarry does break down to produce more well graded fines and may prove to be an excellent material for Zone 2. Sufficient quantities of this type of material may occur on the nose of the ridge at all levels in the quarry.

Zone 3A Material As the prime requirement for this material is minimum settlement, laboratory confined compression tests on material of gradings scaled from the results of field trials will give a quantitative indication of suitability. The slightly weathered quartzite will break down more under handling and rolling, and will probably have a better grading, though lower particle strength, than fresh rock. Consequently it may well be that the settlement characteristics of the slightly weathered rockfill are as good as those of the fresh rockfill.

Zone 3B Material Bands of slightly weathered massive quartzite have been exposed at the top of the quarry. This material, when not contaminated by dust from adjacent excavation in unsuitable material, could well meet the requirements listed in paragraph 5.3.

N. BOUGHTON

c.c.
Dams II file
Geologist in Charge
G.E. III

APPENDIX A

DRAFT SPECIFICATION FOR ROCKFILL ZONES

Zone 3A - Slab bedding, zone 10 to 15 ft. thick (measured horizontally) beneath the face slab, consisting of sound rock fragments within the size range of $\frac{3}{4}$" to 12", and well graded over that range. The material would be placed in 24" layers.

Zone 3B - High quality compacted rockfill, forming the main support for the concrete face, and consisting of sound rock fragments, well graded up to the maximum which could be satisfactorily placed in a 3 ft. layer. Not more than 30% shall be smaller than 1", nor more than 3% pass a No. 100 sieve. The material would be placed in 3 ft. layers.

Zone 3C - Supporting rockfill in the remainder of the embankment. This material should be a free-draining rockfill, generally well graded and consisting predominantly of sound rock fragments. Not more than 40% of the rockfill shall be smaller than 1", nor more than 5% pass a No. 100 sieve. The material would be placed in 3 to 6 ft. layers.

Compaction of all zones would be carried out using ten ton vibrating rollers and all rock would be thoroughly wetted before placement. Approximate quantities for each zone are:

Zone 3A	-	70,000 cu. yds.
Zone 3B	-	1,330,000 cu. yds.
Zone 3C	-	400,000 cu. yds.

644-CETH-

Form No.H.E.10

GER/SM

THE HYDRO-ELECTRIC COMMISSION

TO	SUBJECT	FROM
GEOLOGIST-IN-CHARGE.	CETHANA ROCKFILL QUARRY	G.E.RAWLINGS. 25-11-66

Investigation of the Cethana rockfill quarry site has now been concluded and indications are that sufficient quantities of rockfill suitable for the Cethana Dam are available.

The site lies on the western extremity of Tin Spur some ½ mile upstream of Cethana Damsite (see plan No.A14022). The ground falls steeply away to the river to the west and the topographic limit to the investigations was provided by the deeply incised creeks both to the north and south.

Geologically the site lies in quartzites and conglomerates of the Ordovician Roland Conglomerate and Moina Sandstone formations. These rocks are intruded by a granite of Devonian/Carboniferous age which cuts discordantly across the south-west corner of Tin Spur. Poor quartzites of doubtful Cambrian age lie beneath the Roland Conglomerate.

Structurally the quarry site lies on the south limb of a synclinorium whose axis probably lies approximately along Tin Spur Creek. The structure is not entirely clear and folds lower in the structure appear to be thrust out at the higher levels. A major fault (Fault I) runs along the north side of the spur cutting across it at the 700' level. This fault brings poor rock to the north against good rock to the south and has an associated mineralized zone. This may possibly be the extension of Tin Spur mapped by the Mines Department higher on Tin Spur.

Thrust

Investigations consisted of extensive bulldozer trenching and 2,520' of diamond drilling. Quartzite and quartz and quartzite conglomerate are the dominant rock types but thin shales and interbedded shales and quartzite also appear in the sequence. Apart from those holes drilled from the north side of the spur good fresh rock was obtained although many holes showed weathered joints down to 232' (see Sections A-F). The rock itself was not uncommonly found to be strongly weathered or partially decomposed down to 20' often giving the general characteristics of a hard sandstone. Poorer than average rock was encountered in DH5506 down to 205' and DH5504 down to 48' but in both cases the rock may possibly be marginally suitable for rockfill.

The rock is generally closely jointed and it seems unlikely that joint blocks greater than 2' in diameter will be obtained from that part of the quarry above the water table where the joints are weathered. Joint planes rather than bedding planes seem to be the dominant weaknesses and are likely to determine the break-up of the rock utilized.

Detailed investigations were made in the vicinity of Fault I to ascertain its position and the quality of the rock on the down-stream side. Up to the 700' level the fault is well defined and separates unsuitable rock to the north from massive and well-bedded rock to the south. Above this level thick quartzite bands appear

on the north side of the fault and although some suitable rock is present the large proportion of weathered, decomposed and very closely jointed rock makes that part of the quarry unsuitable for development. The degree of jointing makes it impossible to determine the structure in that vicinity. It appears that Fault I dips south at 65-70°.

It is thus considered that the area where suitable rockfill should be obtained is defined by the limit of the conglomerate outcrop to the south and Fault I to the north as shown on the plan. Limited investigations were carried out below the 600' level although it is anticipated that conditions should be similar to the rest of the quarry. Care should be exercised however in the planning of the northern face of the quarry as unfavourable bedding plane attitudes and poor quality closely jointed rock may result in an unstable face. Depth of overburden is variable and although some areas show pockets up to 5' deep which will need to be removed, other areas, as indicated on the plan will need very little stripping.

It is suggested that the behaviour of the various rock types under simulated conditions of emplacement should be ascertained. The influence of the jointing and the shale partings on the break-up of the rock may be determined by compaction and rolling trials.

G. E. Rawlings

G. E. Rawlings.

c.c. - Design Division.
Planning Section
through E.C.C.
P.M.M.F.
Geology Section.

A14022

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT
LOCATION: CETHANA QUARRY TINSOUR AREA.
GEOLOGICAL PLAN: SURVEY PLAN: A 126-912-19.
DATES (c) DRILLED: July '66 (b) WATER TABLE:
METHOD: D.D. DIAMETER: NX, EMLC.
SITE REMARKS: Drilled from Loger bench at 600'SL.

POSITION — CO-ORDINATES: E: 421.0164 N: 891.0725
ON LINE: BEARING: AT CH:
AT STN: BEARING: DIST:

LEVEL — SURFACE: 599.8' COLLAR: WATER TABLE:

INCL. — HOLE DRILLED: ANGLE FROM HORIZONTAL: 45° DIRECTION: Approx. 070°
~~VERT~~/~~HOR~~./INC.

HOLE No. 3502
FILE No.
SHEET 1 OF 1 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY %	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0		2'-0" frag.	NX				Brown			0-7½" Broken weathered grey quartzite.
5							Velocity.			7½"-56'3" Light grey closely to very closely jointed quartzite, joints showing bad limonite staining. Banding occasionally present, rock generally dense.
10						5				
15										
20										
25						4-5				
30										
35										
40										
45										48'7" Shale bands or possibly sheared zones appear as clay seams interbedded with moderately closely jointed quartzite. Joints still iron stained.
50						3-4				
55		1'-6" occasionally fragmented				4-6				56'3"-66'0" Thin bands of brown-grey weakened and/or decomposed quartzite interbedded with grey-brown decomposed shales and zones of angular quartzite fragments set in clay groundmass. Core in very short sticks.
60		4"-frag.								
65		2'-0" occasionally fragmented								Hole discontinued at 66'0" Logged by G.E. Rawlings 15.8.66.
70										
75										
80										
85										
90										
95										
100										

(spare copy No. 4) Geol. - in - Charge Thru E.C.I.

N.C.E./C.C.

S.E. DAMS II CETHANA ROCKFILL QUARRY N. C. BORRETON
12/12/66.

1. QUARRY LOCATION

Of the rock formations in the vicinity of the damsite, the only sources of suitable rock for rockfill were:

(a) Quartzites and quartzite conglomerates of the Roland Conglomerate formation.

(b) Massive quartzite of the Moina Sandstone formation, as distinct from interbedded quartzites and shales with subsidiary sandstone.

(c) Granite

The granite upstream from the dam was variably and deeply weathered on the surface, and for this reason was not considered further.

The only outcrop of rock of the Roland conglomerate formation topographically suitable for a quarry was in the top of the ridge forming the right abutment of the dam. Rock exposed in the dam access road was suitable, but unfavourable bedding and the quarry elevation (about S.L. 1,000) made this site inferior to the one chosen.

Massive quartzites of the Moina Sandstone formation in a suitable location for quarrying occurred only upstream from the dam. On the left bank they formed a prominent spur which was cut by the Wilmot Power Station access road. However extensive sheets of rock on the dip-slope in between the quarry site and the dam would have made the construction and maintenance of haulroads both hazardous and expensive. Consequently attention was confined to the ridge to the south of Tin Spur Creek on the right bank. Here initial dozer trenching exposed sound rock and further trenching and drilling have confirmed that sufficient quantities of suitable rock are available. While there are difficulties in quarry development, the site is probably the most convenient of any that could be found in this area, particularly as the adjacent right abutment of the dam is the most convenient location for the establishment of haul roads.

2. ROCK QUALITY

Specification requirements for the rockfill have not yet been finalised. A draft specification based on current practice elsewhere (and preliminary results of our own rockfill settlement tests) is attached as an appendix to this report, and sets out possible requirements for three zones; 3A, 3B and 3C.

The quality of the rock in the quarry site is described in the geological report. With reference to this report, it is considered that once the stripping is removed, the weathered rock within 20 ft. of the surface could be incorporated in zone 3C. The quality of the rock in the upper parts of drill holes 5506 and 5504 is such that it may break down too much to be suitable for inclusion in zone 3C, except in small quantities, and this local pocket may have to be avoided or wasted. Elsewhere to the south of the fault the rock appears to be of suitable quality for all zones and there should be little wastage. The close jointing of the drill cores suggests that little secondary blasting may be required to obtain the zone 3B grading.

3. ROCK QUANTITIES

Considering the potential quarry as bounded on the north by the fault and on the east at the saddle in the ridge, the following gives the approximate quantities of rock which are available:

above S.L. 800	700,000 cu. yds.	solid measure.
S.L. 700 to S.L. 800	1,200,000 cu. yds.	
S.L. 600 to S.L. 700	1,200,000 cu. yds.	
S.L. 500 to S.L. 600	900,000 cu. yds.	
Total	4,000,000 cu. yds.	

Despite indications that there would be little wastage, it is prudent at this stage to plan the quarry to give about 50% more rock than required in the dam. Allowing a bulking factor of 25%, the quarry would then be laid out to produce about 2,200,000 cu. yds. solid. Consequently it is apparent that ample rock is available at the site and that there is scope for adjusting the quarry boundaries to suit construction convenience.

4. FURTHER INVESTIGATIONS

Exploration to date appears to have been adequate to prove the quality and quantity of the rock material. Trial quarrying may be required to develop a suitable and economic blasting pattern. This work could well be done in conjunction with any rolling trials that may be required prior to construction.

N. HOUGHTON

s/c
4 spares

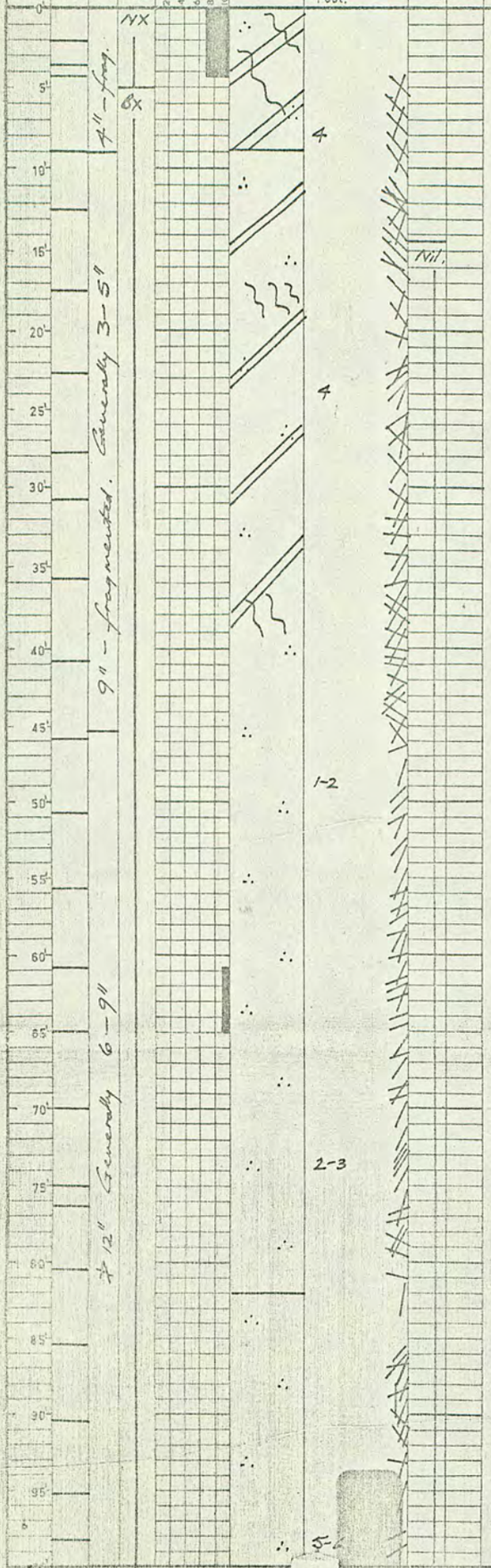
DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E: 421.0313	N: 891.0362
LOCATION: CETHANA QUARRY – TINSPUR AREA		ON LINE:	BEARING:	AT CH:
GEOLOGICAL PLAN: SURVEY PLAN: A.126-912-19		STN:	BEARING:	DIST:
DATES (a) DRILLED: July–Aug. '66 (b) WATER TABLE: 124' below surface	LEVEL.	SURFACE	COLLAR	WATER TABLE
METHOD: D.D. DIAMETER: NMLC, BMLC.		708.6		
SITE REMARKS: Drilled from 'dozer bench at 700' S.L.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
		VERT./~~HOR./INC.~~	90°	

HOLE No. 5503

FILE No.

SHEET 1 OF 2 SHEETS



REMARKS

0–8'9" Strongly weathered and indurated quartzite much broken up down to 5'0". Joints all open and strongly limonite coated.

8'9"–82'0" Weathered dark to light grey dense, often speckled, quartzite showing prominent banding parallel to bedding. Joints closely spaced, generally open and iron stained. Speckling probably due to mineralisation.

15'0" Bedding 65°–70°.

The dense grey unbanded quartzites show little mineralisation, many joints and much weathering.

55'0" Bedding 55°.

Joints become fresher below 65' although many still iron stained.

72'0" Bedding 45°.

82'0"–117'0" Light grey-green/grey dense quartzite, banding no longer present. Joints closely–moderately closely spaced generally showing thick coatings of limonite. Rock fresh or locally weathered, joints all weathered. Pyrite present as veins or disseminations, often in thin brecciated zones.

DRILLING RECORD

AREA: MERCEY NORTH POWER DEVELOPMENT

LOCATION: CETHANA QUARRY – TINSPUR AREA

GEOLOGICAL PLAN: SURVEY PLAN: A126-912-19

DATES (a) DRILLED: July – Aug '66 (b) WATER TABLE: 124'

METHOD: D.D DIAMETER: NMLC, BMLC.

SITE REMARKS: Drilled from 'dozer bench at 700' S.L.

POSITION

CO-ORDINATES:	E: 421. 0313	N: 891. 8362
ON LINE:	BEARING:	AT CH:
AT STN:	BEARING:	DIST:

LEVEL

SURFACE	COLLAR	WATER TABLE
708·6		

INCL.

HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
VERT./~~HOR./INC.~~	90°	

HOLE No. 5303

FILE No.

SHEET 2 OF 2 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
700			BX				Nil			
5'										
10'						5-6	Slight			
15'										117'6" – 199'8" light grey – green/grey quartzite locally speckled or dense showing laminations of grey-green shale. Rock closely to very closely jointed, joints being wider spaced below 175'. Most joints above 124' show prominent iron staining. Rock often shows much pyrite mineralisation & white-grey clay is seen along a joint at 130'5", 125'8" and 130'11". Bands of glassy quartzite are common up to 18" thick, they are often much fragmented
20'										
25'										
30'		7'8" Generally 3-6"				4				
35'										
40'										118'5" Bedding 65°-70°
45'										
50'		7'6" Generally 1-4"				5				146'6" Vertical bedding.
55'										155'6" Bedding 55°
60'		5'2"					Nil			Mostly glassy quartzite.
65'		4'-fragmented								165'5"–166'2" Angular quartzite fragments set in grey clay — weathered breccia?
70'						7				
75'										
80'		2'7" Generally				1-2				180'6" Bedding 60°
85'										
90'										Hole completed 199'8" logged by G.E. Rawlings 17.8.66
95'										
800		1'9"				1				199'6" Bedding vertical.

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E: 921.0432	N: 891.0162
LOCATION: CETHANA QUARRY - TINSTER AREA		ON LINE:	BEARING:	AT CH:
GEOLOGICAL PLAN: SURVEY PLAN: A126-912-19		A. STN:	BEARING:	DIST:
DATES (a) DRILLED: July-Aug '66 (b) WATER TABLE: 185'	LEVEL.	SURFACE	COLLAR	WATER TABLE
METHOD: D.D. DIAMETER: NMLC, BMLC		799.6		
SITE REMARKS: Drilled from 'dozer bench at 800' S.L.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
		VERT./~~HOR./INC.~~	90°	

HOLE No. 5504 | FILE No. | SHEET 1 OF 3 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0			BX				Yellow			0-6'10" Badly weathered and broken grey to light brown quartzite often showing prominent weathered joints.
5'										
10'						7-12				6'10"-14'11" Light to dark grey closely to very closely jointed quartzite. Rock slightly weathered overall, joints generally open, often discoloured by limonite.
15'										
20'						4-6	Dark Grey			14'11"-23'0" Badly indurated quartzite (possibly sandstone) in which intergranular cement has broken down. Rock badly iron stained often broken in drilling. Closely jointed.
25'						3-6				23'0"-38'0" Black to dark grey quartzite with occasional black shale partings, showing tubicolar markings. Rock mineralized in places and occasionally indurated. Closely jointed.
30'										
35'							Yellow			
40'										38'0"-48'0" Closely jointed strongly weathered light grey to light brown quartzite which breaks up readily during drilling. Joints iron stained and may show clay fillings.
45'						3-4				
50'							White			48'0"-111'10" Dark grey, light grey-green or purple laminated quartzites showing thin shale or silty laminations up to ¼" thick separating quartzite layers ½"-18". Rock has overall banded appearance but seems quite tough. Joints moderately closely spaced often showing thick coatings of limonite. Rock occasionally weakened especially where mineralized. Shale partings become less frequent and more discontinuous below 92'6".
55'										
60'						2-3				
65'										
70'						4				
75'										75'0": Dip 15°
80'						3-4				
85'										
90'										
95'										
100'						3				97'4"-97'6" Clay along joints
105'										

1-12" generally 5'-6"

±9" generally much less or fragmented.

DRILLING RECORD

AREA: HEAVY EARTH POWER DEVELOPMENT

LOCATION: COTHAM QUARRY – TINSIDE AREA

GEOLOGICAL PLAN: SURVEY PLAN: A. 126 – 912 – 19

DATES: (a) DRILLED: July – Aug '66. (b) WATER TABLE: 185'

METHOD: S.S. DIAMETER: NMLC, BMLC.

SITE REMARKS: Drilled from 'dozer bench at 800' S.L.

POSITION	CO-ORDINATES:	E: 421.0432	N: 891.0162	HOLE No. 550A
	ON LINE:	BEARING:	AT CH:	
	AT STN:	BEARING:	DIST:	FILE No.
LEVEL.	SURFACE	COLLAR	WATER TABLE	
	794.6			
INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	SHEET 2 OF 3 SHEETS
	VERT./~~HOR./INC.~~	90°		

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS: No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0						3	White			
5		1'–9"								Dip 33°?
10										111'10" – 123'9" Dense grey quartzite, probably recrystallized with close strongly weathered joints. Breccia at 116'6" suggests this may be a fault zone although it could be a fold core also. All surfaces strongly limonite coated.
15										
20		2'–7"								
25						1-2				123'9" – 131'6". Hard grey qtzite with partings of shale often discontinuous.
30										126' Dip 60°
35										131'6" – 212'0" light grey closely jointed quartzite separated by bands of interbedded quartzite/shale as at 123'9". Joints generally weathered showing thick coatings of limonite. Quartzite often glassy. Rock fresh below 190'6"
40										142' Bedding 65–70°
45										145'–152' Interbedded quartzite and shale
50						2-3				
55							Grey			
60										
65										
70										
75						7				
80										
85										Joints show as discolouration below 185'
90										190' Bedding 60°
95										190'6" – 193'2" Altered and mineralized quartzites appear as fractured rocks.
100		1'–10" occasionally fragmented, generally 5"–8"								
105										
110										
115										
120										
125										
130										
135										
140										
145										
150										
155										
160										
165										
170										
175										
180										
185										
190										
195										
200		3'–15"				3				

DRILLING RECORD

AREA: Mineral Rights Development

LOCATION: Cethana Quarry - Tinsur Area

GEOLOGICAL PLAN: SURVEY PLAN:

DATES (c) DRILLED: July-Aug. '66 (b) WATER TABLE: 185'

METHOD: D.D. DIAMETER: NMLC, BMLC

SITE REMARKS: drilled from 'dozer bench at 800' S.L.

POSITION

CO-ORDINATES:	E. 421 0432	N. 891 8162
ON LINE:	BEARING:	AT CH:
STN:	BEARING:	DIST:

LEVEL

SURFACE	COLLAR	WATER TABLE
794·6		

INCL.

HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
VERT./~~HOR./INC.~~	90°	

HOLE No. 5504

FILE No.

SHEET 3 OF 3 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
200'					∴	1/1				201'0". Pyrite and chlorite.
5'										
10'										Hole completed 202'0"
15'										logged by G.C. Rawlings
20'										15.8.66.
25'										
30'										
35'										
40'										
45'										
50'										
55'										
60'										
65'										
70'										
75'										
80'										
85'										
90'										
95'										

DRILLING RECORD

AREA: Kemano 4th Power Development

LOCATION: Cathana Quarry — Tinsaw Area

GEOLOGICAL PLAN: — SURVEY PLAN: A126-912-19

DATES (c) DRILLED: Aug. '66 (b) WATER TABLE: 232'

METHOD: DD. DIAMETER: NMLC, BMLC

SITE REMARKS: Drilled from 'dozer trench at approx. 800' El.

POSITION	CO-ORDINATES:	E: 421.0845	N: 892.2675	HOLE No. 5505
	ON LINE:	BEARING:	AT CH:	
	AT STN:	BEARING:	DIST:	FILE No.
LEVEL.	SURFACE	COLLAR	WATER TABLE	
				SHEET 1 OF 4 SHEETS
INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
	VERT./~~HOR./INC.~~	90°		

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY %	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0			BX.							0-10'2" Clay with angular fragments of weathered and decomposed quartzite - may partially represent road spoil.
5'		4'0"- fragmented								
10'						6				10'2" - 16'0" Grey to light brown closely jointed quartzite in which most of the joints are open and stained with limonite and/or showing clay fillings. Rock itself generally not decomposed.
15'										
20'		2 - 11"								16'0" - 77'0" Light to dark grey to light brown fresh hard quartzite becoming gritty at some horizons and showing possible traces of tubicolar casts. Joints moderately closely to widely spaced generally, showing iron staining. Occasional specks of opaque mineral — cassiterite?
25'						2				
30'										
35'						2-3				23'7" - 23'10" Sheared quartzite.
40'							Colour change - grey - pale brown.			
45'						3				
50'		Logs to 2'6"								
55'						2				
60'										
65'						2				65'0". 1" Sheared quartzite.
70'										
75'						3				77'0" - 134'0" Light to dark grey to light brown dense quartzite showing zones of closely fractured rock. Major joints as before but minor joints tight but stained. Uniform lithology.
80'										
85'		1 - 12" generally 2-8"				2				
90'										
95'						3				96'3" Sheared layer 6" with showing clay and mica.
100'										

Stable oil.

DRILLING RECORD

AREA: Mahanadi Basin Investigations

LOCATION: Cuttack Quarry - Tinspur Area

GEOLOGICAL PLAN: SURVEY PLAN: A126 - 9/2 - 19

DATES (c) DRILLED: Aug '66 (b) WATER TABLE: 232'

METHOD: DD DIAMETER: NMLC, BMLC

SITE REMARKS: Drilled from 'dozer bench at approx. 800' S.L.

POSITION	CO-ORDINATES:	E: 421.0545	N: 812.2675	HOLE No. 565
	ON LINE:	BEARING:	AT CH:	
	AT STN:	BEARING:	DIST:	FILE No.
LEVEL.	SURFACE	COLLAR	WATER TABLE	
				SHEET 2 OF 4 SHEETS
INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
	VERT./~~HOR./INC.~~	90°		

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY %	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0							Soluble Oil.			
5										
10						4				108'6" - 109'6" Shearing / mineralisation.
15										
20						3				
25										
30						2-3				
35										134'0" - 197'6" Light grey dense uniform quartzite, moderately closely & very closely jointed. Joints badly iron stained, occasionally showing limonite up to ½" thick.
40						5				
45										
50		7/16" generally 2 - 7"				1				
55										
60						4				159'6" - 159'7" Quartz / clay shear.
65										Jointing becomes close & very close below 165'.
70						4				
75										
80						9-10				
85										
90		Generally 1 - 6"				10				197'6" quartz clay seam.
95										
100										
105										
					0					

FORM No. H.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E: 421.0545	N: 892.2675
LOCATION: CETHANA QUARRY – TAILRACE AREA		ON LINE:	BEARING:	AT CH:
GEOLOGICAL PLAN: SURVEY PLAN: 126-912-19		AT STN:	BEARING:	DIST:
DATES (a) DRILLED: Aug '66. (b) WATER TABLE: 232'	LEVEL.	SURFACE	COLLAR	WATER TABLE
METHOD: dd. DIAMETER: NMLC, BMLC				
SITE REMARKS: Drilled from 'dozer trench at approx 800' E.L.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
		VERT./~~HOR./INC.~~	90°	

HOLE No. 5505 | FILE No. | SHEET 3 OF 4 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
200'							Soluble Oil			191'6"–231'8" Light grey recrystallized quartz and quartzite conglomerate. Pebbles rounded to sub-angular often very difficult to see. Rock fresh, hard, moderately closely to closely jointed, joints generally iron stained. Occasional pockets of clay or quartz clay seams as at 200'. Rock becomes very broken below 222'6" with close jointing, quartz/clay seams and bad iron staining.
5'						8				
10'						6				
15'		1–8"								
20'						8				
25'										
30'						7				231'8"–276' Dark grey, fresh, quartz and quartzite conglomerate with occasional cemented brecciated zones as at 237'3". Joints moderately closely to closely spaced, very seldom iron stained. Occasional mineralisation along joints. Pebbles rounded–sub-rounded ±3" diameter generally of quartz, quartzite and green-grey friable quartzite (Cambrian ?).
35'										
40'		1–8"				3				
45'										
50'						5				
55'										
60'						2				
65'		2–20"								
70'						2				
75'										276'–285' Light grey–red quartz and quartzite conglomerate. Lithology generally as above but joints closer spaced and colour changes.
80'						4				
85'		1–6" occ. fragments								283'6"–285' Brecciated conglomerate.
90'		Generally 3'6"				2–3	Soluble Oil.			285'–397'6" Conglomerate as at 231'8". Joints widely spaced, fresh, with occasional thin clay partings, occasionally moderately closely jointed.
95'		±25"				1				294'4" Quartz cassiterite vein.
300'										

FORM MA/H.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E: 421.0545	N: 892.2675
LOCATION: CETHANA QUARRY – TIARNA CREEK.	POSITION	ON LINE:	BEARING:	AT CH:
GEOLOGICAL PLAN: SURVEY PLAN: 126-912-19.	POSITION	AT STN:	BEARING:	DIST:
DATES (a) DRILLED: Aug. '66 (b) WATER TABLE: 232'	LEVEL.	SURFACE	COLLAR	WATER TABLE
METHOD: D.D. DIAMETER: NMLC, BMLC.	LEVEL.			
SITE REMARKS: Drilled from dozer trench at approx. 800' S.L.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
	INCL.	VERT. ~~HOR./INC.~~	90°	

HOLE No. 5505

FILE No.

SHEET 1 OF 1 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0'00"							Soluble oil			
5'										
10'										
15'										
20'						2				
25'										
30'						2				
35'										
40'		3'-12" generally				3				
45'										
50'						3-4				
55'										
60'						2-3				
65'										
70'						1				
75'										
80'						1				
85'										
90'						1				
95'										
9'00"										

+ 2¾"

Hole completed 397'6"
Logged by G.E. Rawlings
9.9.66.

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E: 421 0458	N: 891 0167
LOCATION: CETHANA QUARRY – TINSPUR AREA		ON LINE:	BEARING:	AT CH:
GEOLOGICAL PLAN: SURVEY PLAN: A126-912-19		AT STN:	BEARING:	DIST:
DATES (a) DRILLED: Aug '66 (b) WATER TABLE:	LEVEL.	SURFACE	COLLAR	WATER TABLE
METHOD: D.D. DIAMETER: NX, NMLC.		795.4		
SITE REMARKS: Drilled from 'dozer bench at 800' S.L. level. Same site as DH 5504	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
		~~VERT./HOR./~~INC.	30°	060° approx.

HOLE No. 5506

FILE No.

SHEET 1 OF 3 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0			NX				Brown			0-7'0" light grey to light brown weathered fragmented quartzite.
5		frag.								
10		1-12"				2				7'0"-16'0" Light to dark grey slightly banded quartzite often very closely jointed. Joints generally weathered, rock slightly weathered overall.
15										
20		frag.				9	Brown & Grey			16'0"-46'0" Strongly weathered or decomposed quartzite generally light brown, occasionally grey. Rock often desilicified, closely to very closely jointed, all joints weathered, occasionally clay filled. 19'0 Bedding 65°
25										
30						5				
35										
40						7				
45		1-8" occ. fragmented								46'0"-59'6" Dark grey – black, occasionally green-grey, banded quartzite with thin shale partings showing occasional desilicified bands as at 50-52'. Rock moderately closely to closely jointed, joints generally weathered, occasionally showing limonite ± ½" thick. 49'0" Bedding 50°
50						3				
55										
60						7-8				59'6"-63'0" Rock as above but badly decomposed and broken up. Rock weathered overall, occasional pyrite filled joints and patches of grit.
65										
70						2				63'0"-72'0" Decomposed or strongly weathered dark grey-green interbedded quartzite and shale. Rock closely jointed, often fragmented, joints very weathered. Rock weathered overall.
75										72'0-108'0" Weathered closely jointed grey quartzite showing strongly weathered joints. Rock occasionally fragmented and irregularly banded, weathered overall. Joints may show clay, limonite or pyrite fillings.
80		2-12"				2-3				
85										
90						1-2	Grey			
95		frag. - 7"								96'0" Bedding 45°
100						8				

FORM No. M.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E: 721.0438	N: 891.0167
LOCATION: CETHANA QUARRY – TINEAN AREA		ON LINE:	BEARING:	AT CH:
GEOLOGICAL PLAN: SURVEY PLAN: A126-912-19		AT STN:	BEARING:	DIST:
DATES (a) DRILLED: Aug '66 (b) WATER TABLE:	LEVEL.	SURFACE	COLLAR	WATER TABLE
METHOD: D.D. DIAMETER: NX, NMLC		795.4		
SITE REMARKS: Drilled from dozer bench at 800' S.L. Same site as DH. 5504	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
		~~VERT./HOR.~~/INC.	30°	060° approx.

HOLE No. 5506 | FILE No. | SHEET 2 OF 3 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
100'							Grey			108'0" – 141'8" Thick, uniform, banded or speckled quartzites with thin interbedded shales. Quartzites moderately closely to closely jointed, shales and decomposed quartzite very broken up. Many joints open and filled by debris, others decomposed. Rock weathered overall, decomposed where mineralised.
5'		9" occ. frag.								
10'						6				
15'										
20'		± 9" often fragmented				5				
25'										
30'		± 9"				6				
35'		5" frag. occ.								135'0" Bedding 45°
40'										141'8" – 179' Thick light grey quartzites with decomposed thin shale partings or possibly weathered mineralised zones. Rock moderately closely to closely jointed, joints generally very weathered or decomposed. Rock weathered overall.
45'										
50'		1 – 12"				2				
55'										
60'						4				
65'										
70'		7" – frag.				7				179'0" Bedding 70°
75'										
80'										179' – 198' light grey closely to very closely jointed quartzite. Many joints only slightly weathered some show thin fillings. Rock much fresher than previously but still shows slight overall weathering.
85'						7				
90'		Gen. 1-6" occ. 2'0"				3				
95'							Grey & Brown			198 – 206'4" Rock very weathered and decomposed, joints very stained – probably fault zone.
200'										

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT

LOCATION: CETHANA QUARRY – TINSTEAD AREA.

GEOLOGICAL PLAN: SURVEY PLAN: A 126-912-19

DATES (a) DRILLED: Aug '66 (b) WATER TABLE:

METHOD: J.J. DIAMETER: NX, NHLC

SITE REMARKS: Drilled from 'dozer trench at 800' S.L. Same site as DH. 5504

POSITION

CO-ORDINATES:	E: 421, 0438	N: 891, 0167
ON LINE:	BEARING:	AT CH:
AT STN:	BEARING:	DIST:

LEVEL.

SURFACE	COLLAR	WATER TABLE

INCL.

HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
~~VERT./HOR.~~/INC.	30°	060° approx.

HOLE No. 5506

FILE No.

SHEET 3 OF 3 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE
0		2½ feet							
5									
10						3			
15									
20						1			
25									
30						3			
35									
40		2 – 12"				4			
45									
50						2			
55		5½ feet							
60						4			
65									
70									
75						1			
80									
85									
90		± 16" occ. fragments				2			
95									
300									

REMARKS

205'4" – 252'2" Grey, moderately closely jointed quartzite often banded or showing mineralisation. Small veins of pyrite often permeate rock. Joints usually weathered, occasionally decomposed. Rock harder than above.

252'2" – 257'. Broken and decomposed dark grey-green & brown grey quartzite showing strong mineralisation – possibly fault.

257' – 303' Quartzite as at 205' but joints more weathered although rock harder. Fresh quartzite.

Joints become very iron stained below 294'4"

Hole completed 303'.

Logged by G. E. Rawlings 3.10.66

FORM No. H.E. 443

DRILLING RECORD

AREA:	Mersey Forth Power Development
LOCATION:	Cethana Quarry – Tin Spur Area
GEOLOGICAL PLAN:	SURVEY PLAN A126-9.2-19
DATES (a) DRILLED:	Aug. '66 (b) WATER TABLE: 117'
METHOD:	D.D. DIAMETER: NX, NMLC, BMLC
SITE REMARKS:	Drilled from 'dozer bench

POSITION				
CO-ORDINATES:	E: 421.0769	N: 892.2502	HOLE No.	5507
ON LINE:	BEARING:	AT CH.		
AT STN:	BEARING:	DIST:	FILE No.	
LEVEL				
SURFACE	COLLAR	WATER TABLE		
INCL.				
HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	SHEET 1 OF 3 SHEETS	
VERT./~~HOR.~~/~~INC.~~	90°			

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY %	GRAPHIC LOG	JOINTS No. Per Foot	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE
0'–~33'		± 16" generally 8" – fragmented	8X			3-4 (at ~10'); 3 (at ~20'); 4-5 (at ~30')	Yellow; Soluble oil (at ~29')		
~33'–~51'		4 – 7"				2 (at ~40'); 5 (at ~50')			
~51'–~90'		± 11" generally 1 – 9"				5 (at ~60'); 3 (at ~70'); 7 (at ~80'); 10+ (at ~90')			
~90'–~95'		1 – 6"							
~95'–100'		2" – frag. occ. 5"							

REMARKS

0–3'0" Overburden

3'0"–36'0" Light grey to light brown closely jointed quartzite. Joints mostly weathered showing strong iron staining. Rock overall sound although possibly closely fractured locally. Occasional zones of pebbly quartzite. Rock occasionally completely iron stained and fragmented as at 30'6"–31'6".

35'0" Bedding 50°.

36'0"–56'3" Light grey – light brown quartzite with thin bands of quartz and quartzite conglomerate. Rock generally as above showing closely to moderately closely spaced iron stained joints with occasional pockets of mineralisation.

40'3" Breccia along joint.

56'3"–124'11" Light grey to light brown quartz and quartzite conglomerate, partially recrystallized making quartzite pebbles particularly difficult to see. Pebbles up to 1" diameter generally rounded to sub-rounded, occasionally sub-angular. Joints closely spaced occasionally very close generally showing strong iron staining. Rock often glassy.

56'3"–56'9" mineralised conglomerate.

90'–104' Rock becomes very closely jointed, joints weathered with many showing brown-white clay. Believed to represent weathered mineralised zone.

DRILLING RECORD

AREA: MERSEY FORTH ANAK DEVELOPMENT	POSITION	CO-ORDINATES:	E: 421, 0769	N: 892, 2502	HOLE No. 5507
LOCATION: CETHANA QUARRY – TIN SPUR AREA		ON LINE:	BEARING:	AT CH:	
GEOLOGICAL PLAN: SURVEY PLAN: A126 – 912 – 19		AT STN:	BEARING:	DIST:	FILE No.
DATES (a) DRILLED: Aug '66 (b) WATER TABLE: 117'	LEVEL.	SURFACE	COLLAR	WATER TABLE	
METHOD: D.D. DIAMETER: NX, NMLC, BMLC					SHEET 2 OF 3 SHEETS
SITE REMARKS: Drilled from 'dozer bench.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
		VERT./~~HOR./INC.~~	90°		

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
100			BX				Soluble Oil			
5'										
10'										
15'										Little weathering effect seen below 117'
20'		3 – 8"				2	Fairly			
25'										124'11" – 125'1" 2" of chlorite and white clay.
30'										125'1" – 144'5" Dark grey to black mineralised sheared quartzite or conglomerate showing occasional pebbles of quartzite in the upper and lower parts. Pockets, veins and segregations of possibly cassiterite. Shearing ∝ (bedding .') irregular 35° – 50°.
35'						4				
40'										
45'										
50'		7 – 6"				3				144'5" – 199'4" light & dark grey quartz and quartzite conglomerate. Pebbles rounded & sub-rounded ≠5" diameter. Pebbles of quartz fewer than above and grain size much larger. Rock closely & very closely jointed, joints generally tight or slightly open. Pyrite often present as veins or joint coatings. Slight discolouration on joints but no major weathering. Occasional small pockets of quartz, chlorite, clay and ~~flourite~~? as at 161'6", clay also present as joint fillings. Quartz/galena veins occasionally present.
55'						4				
60'										
65'		1 – 4"				5				
70'										
75'						7				
80'										
85'		2 – 10"				3				
90'										
95'		3 – 12"				3				199'4" – 212'0" Conglomerate as above but more recrystallized – many pebbles vague
200'										

FORM No. M.E. 443

DRILLING RECORD

AREA: MERSEY ESTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E: 421.0769	N: 892.2502
LOCATION: CETHANA QUARRY - TINEHUR AREA		ON LINE:	BEARING:	AT CH:
GEOLOGICAL PLAN: SURVEY PLAN: A126-9/2-19		AT STN:	BEARING:	DIST:
DATES (a) DRILLED: Aug. '66 (b) WATER TABLE: 117'	LEVEL.	SURFACE	COLLAR	WATER TABLE
METHOD: D.D. DIAMETER: NX, NMLC, BMLC				
SITE REMARKS: Drilled from 'dozer trench	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
		VERT./~~HOR./INC.~~	90°	

HOLE No. 5507

FILE No.

SHEET 3 OF 3 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0'							Grey			
5'										
10'						2				212'-291'9" light grey-green grey conglomerate as at 194'6". Rock closely to very closely jointed, joints generally tight or slightly open, fresh or filled by pyrite. Small pockets of joint fillings of white clay.
15'										
20'		1-6"				4				
25'							Slight oil.			
30'						6				
35'										
40'						6				
45'										
50'						3				
55'										
60'		3-12"				4				
65'										
70'						5				
75'										
80'						6				
85'		1-6"								
90'						3				291'9" - 296'0" Olive green sheared quartz chlorite rock.
95'						3 3				296'0" - 297'3" Closely jointed quartzite with chlorite filled joints. Hole completed 297'3". Logged by G.E. Rawlings 8.9.66.
300'										

DRILLING RECORD

AREA: HERSEY FORTH POWER DEVELOPMENT

LOCATION: CETHANA QUARRY – TINSPUR AREA

GEOLOGICAL PLAN: SURVEY PLAN: A126-912-19

DATES (a) DRILLED: Sept. '66 (b) WATER TABLE:

METHOD: D.D. DIAMETER: No. 4, NMLC, BMLC

SITE REMARKS: Drilled from quartzite talus slope.

POSITION	CO-ORDINATES:	E: 421.0723	N: 892.2893.	HOLE No. 5508
	ON LINE:	BEARING:	AT CH:	
	AT STN:	BEARING:	DIST:	FILE No.
LEVEL.	SURFACE	COLLAR	WATER TABLE	
				SHEET 1 OF 3 SHEETS
INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
	~~VERT./HOR.~~/INC.	45°	205°	

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0			NQ				No return			0–26'0" Strongly weathered and/or decomposed light brown & dark grey quartzite. Joints and rock overall show strong iron staining.
5'										
10'			NX							
15'										
20'		2–8" occ. fragmented				2				
25'										26'0"–46'0" Grey & light brown, moderately closely jointed, occasionally banded quartzite showing very badly stained and decomposed joints. Rock occasionally badly stained and decomposed.
30'		3" pcs	ox			2				
35'										
40'		8"–fragmented, occ. 12"				3				40'9" Bedding 10° (angle to L to core axis)
45'										
50'						7				45'6"–98'0" Hard grey quartzite occasionally brown and weathered, moderately closely & closely jointed. Joints occasionally iron stained but also fresh and mineralised.
55'										
60'						3				
65'		3–10"								
70'						6				
75'										
80'						5				81'–84' Rock weathered.
85'		1–8"								
90'						7				98'0"–113'6" Dark grey & black banded quartzite often weathered or fragmented and showing weathered joints.
95'										
100						6				

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT		CO-ORDINATES: E: 421.0723	N: 892.2893
LOCATION: CETHANA QUARRY – TINSPUR AREA		ON LINE: BEARING:	AT CH:
GEOLOGICAL PLAN:	SURVEY PLAN: A126-912-19	AT STN: BEARING:	DIST:
DATES (a) DRILLED: Sept. '66	(b) WATER TABLE:	LEVEL: SURFACE	COLLAR / WATER TABLE
METHOD: J.J.	DIAMETER: No. 4, NMLC, BMLC		
SITE REMARKS: Drilled from quartzite talus slope.		INCL.: HOLE DRILLED ~~VERT./HOR.~~/INC.	ANGLE FROM HORIZONTAL: 45° / DIRECTION: 205°

HOLE No. 5508

FILE No.

SHEET 2 OF 3 SHEETS

DEPTH | CORE DRAWN | CORE LENGTH | CASING | RECOVERY % (20 40 60 80 100) | GRAPHIC LOG | JOINTS No. Per Foot | FLUID RETURN | GROUND WATER | WATER PRESSURE TESTS LEAKAGE | REMARKS

Depth	Core length	Casing	Joints No. per foot	Fluid return
100	6" – 6' Gen. 4" – frag.	SX		No return
5				
10			5	White & Black
15	6" – 12" occ. frag.			
20			4	
25				
30	5" – frag.		7	
35				
40	1" – 12"		4	
45				Grey
50			3	No Return.
55				
60	+8" Generally 4" – fragmented			
65				
70				
75				
80			6	
85				
90	1" – 11"		5	
95			6	
200				

REMARKS

113'6" – 139'8" Hard grey quartzite, occasionally banded & speckled, showing slightly weathered joints or occasional seams of white clay as at 119'6" – 121'10" and 131' – 131'10". Joints closely spaced.

139'8" – 184'6" Light grey to light brown, closely jointed quartzite occasionally banded, speckled & ~~mineralised. Rock generally fresh~~ but occasionally weathered. Joints very weathered showing thick coatings of limonite.

184'6" – 286'7" Grey to light brown quartzite, occasionally banded. Rock fresh and hard but joints strongly iron stained and widely & closely spaced.

DRILLING RECORD

AREA: Horsay Forth River Development

LOCATION: Cothana Quarry - Tinspur Area.

GEOLOGICAL PLAN: SURVEY PLAN: 1:26-912-19

DATES (a) DRILLED: Sept '66 (b) WATER TABLE:

METHOD: D.D. DIAMETER: N.4, NMLC, BMLC

SITE REMARKS: Drilled from quartzite talus slope.

POSITION	CO-ORDINATES:	E:	N:	HOLE No.
	ON LINE:	BEARING:	AT CH:	5508
	AT STN:	BEARING:	DIST:	FILE No.
LEVEL.	SURFACE	COLLAR	WATER TABLE	
				SHEET 3 OF 3 SHEETS
INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
	VERT./HOR./INC.			

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0							No return			
5		1–11'								
10						3				
15										
20		1–10'				2				
25										
30		#17' Gneissy				3				
35										
40						1				
45										
50						2				
55		1–8'								
60						7				
65										
70						5				
75										
80		#12' Gneissy mush clayey								Hole completed 286'7". Logged by G.E. Rawlings 5.10.66.
85										
90										
95										
00										

DRILLING RECORD

AREA: Norway Path River Development

LOCATION: Cothanna Quarry - Tinstar Area.

GEOLOGICAL PLAN: SURVEY PLAN: A.26 - 9.2 - 19

DATES (a) DRILLED: Sept '66 (b) WATER TABLE:

METHOD: D.D. DIAMETER: N.4, NMLC, BMLC

SITE REMARKS: Drilled from quartzite talus slope.

POSITION

CO-ORDINATES:	E:	N:
ON LINE:	BEARING:	AT CH:
AT STN:	BEARING:	DIST:

LEVEL

SURFACE	COLLAR	WATER TABLE

INCL.

HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
VERT./HOR./INC.		

HOLE No. 5308

FILE No.

SHEET 3 OF 3 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
200							No Return			
5'		1–11"								
10'						3				
15'										
20'		1–10"				2				
25'										
30'		≯17' Generally				3				
35'										
40'						1				
45'										
50'						2				
55'		1–8"								
60'						7				
65'										
70'						5				
75'										
80'		≯12' Generally smash chapter,								Hole completed 286'7". Logged by G.E. Rawlings 5.10.66.
85'										
90'										
95'										

FORM No. H.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT

LOCATION: COTTANA QUARRY – TINSIDE AREA.

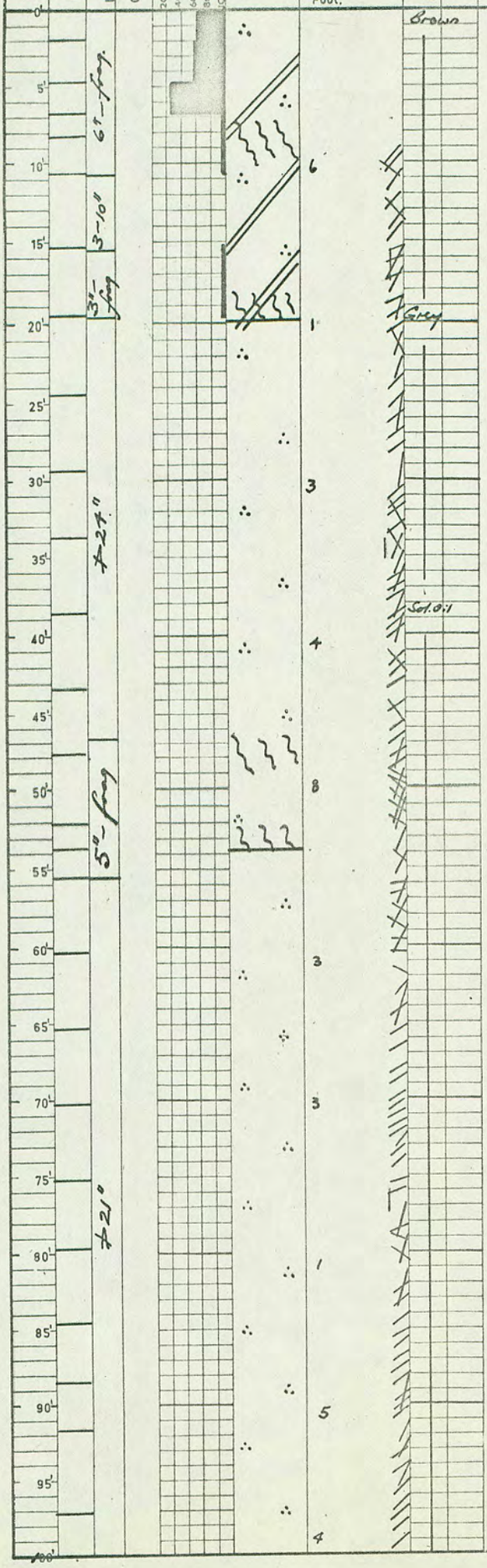
GEOLOGICAL PLAN: A14022 SURVEY PLAN: S.A.11 : 896 A126-912-19

DATES (a) DRILLED: Aug. – Sept. '66 (b) WATER TABLE:

METHOD: D.D. DIAMETER: NX, NMLC, BMLC

SITE REMARKS: Drilled from 'dozer bench towards fault

POSITION	CO-ORDINATES:	E: 421.0678	N: 892.2562	HOLE No. 5509
	ON LINE:	BEARING:	AT CH:	
	AT STN:	BEARING:	DIST:	FILE No.
LEVEL.	SURFACE	COLLAR	WATER TABLE	
	839			SHEET 1 OF 2 SHEETS
INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
	~~VERT.~~/~~HOR.~~/INC.	30°	025° approx.	



REMARKS

0-19'9" light grey – light brown weathered and/or decomposed quartzite. Joints closely to very closely spaced, weathered and occasionally showing fillings.

19'9"-53'9" light grey to brown slightly weathered to hard, banded, sparkled or dense, moderately closely to very closely jointed quartzite. Joints weathered.

53'9"-139'6" Fresh, hard, light grey to dark grey to light brown, sparkled, banded and dense quartzite. Joints widely to moderately closely spaced, weathered.

DRILLING RECORD

AREA: NEEDY NORTH ADIT DEVELOPMENT

LOCATION: CATHANA BULLA — TINSUR AREA.

GEOLOGICAL PLAN: SURVEY PLAN: A126-912-19

DATES (a) DRILLED: Sept '66 (b) WATER TABLE:

METHOD: S.S. DIAMETER: NX, NMLC, BHLC

SITE REMARKS: Drilled from dozer track towards fault.

POSITION			
	CO-ORDINATES:	E: 721.0678	N: 872.2562
	ON LINE:	BEARING:	AT CH:
	AT STN:	BEARING:	DIST:

LEVEL.			
	SURFACE	COLLAR	WATER TABLE

INCL.			
	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
	~~VERT./HOR.~~/INC.	30°	025° approx.

HOLE No. 5509

FILE No.

SHEET 2 OF 2 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (70 90 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0'-0"							Sat. Oil			
5'						3				
10'										
15'										
20'		7-2'1				2				
25'										
30'						1				
35'										
										Basilla fault at 139'.
40'						3				139'-201'4" light to dark grey or brown banded a dense quartzite occasionally badly weathered & fragmented. Joints close to moderately closely spaced, weathered. Lithology as above but rock is more weathered and has closer jointing. Rock occasionally slightly weathered overall.
45'										
50'						3				
55'										
60'						7				
65'		2'-10"								
70'						7				
75'										
80'						1				
85'										
90'						10+				
95'		8'-frag.								Hole completed 201'4" Logged by G.E. Rawlings 5.10.66.
100'										

DRILLING RECORD

AREA: Mersey Forth Power Development.

LOCATION: Cethana Quarry.

GEOLOGICAL PLAN: As for → SURVEY PLAN: A 126-912-19

DATES (a) DRILLED: 4.10.66 (b) WATER TABLE:

METHOD: DD DIAMETER: NX, NMLC, BMLC.

SITE REMARKS: On bench just to South of crest line of spur

POSITION				HOLE No.
	CO-ORDINATES:	E 412.0590.	N 890.2942.	5510
	ON LINE:	BEARING:	AT CH:	
	AT STN:	BEARING:	DIST:	FILE No.
LEVEL.	SURFACE	COLLAR	WATER TABLE	
	873'-00"			
INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	SHEET 1 OF 4 SHEETS
	~~VERT./HOR.~~/INC.	45°	045°	

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0										
5'			NX							
10'		8" plus fragments.								
15'										
20'										
25'		4" to 12"								
30'						3				9' to 67'. Yellow white to bluish white, closely jointed, often brown stained, quartzite, getting harder, more compact and less closely jointed after 30'. Joints predominantly oblique and iron oxide stained. Open joints filled with limonite or limonite clay up to ¼" in thickness. Core occasionally broken into fragments along close joint planes for 3" or 4" of its length — as at 38'.
35'		3" to 5"								
40'		9"								
45'			BX							
50'										
55'										Open joint from 57' to 63" down length of core filled to ¼" with limonite.
60'						5/6				
65'		3" to 12"								
70'										
75'		4" to 9"								
80'										
85'										
90'		11" Mostly								
95'		2"-3" much broken				10				

BROWN TO WHITE CLAY

NO RETURN

DRILLING RECORD

AREA: M.F.P.D.	POSITION	CO-ORDINATES:	E: 412.0590.	N: 890.2942.
LOCATION: CETHANA QUARRY.		ON LINE:	BEARING:	AT CH:
GEOLOGICAL PLAN: As for → SURVEY PLAN: A 126-912-19.		AT STN:	BEARING:	DIST:
DATES (a) DRILLED: OCT '66 (b) WATER TABLE:	LEVEL.	SURFACE	COLLAR	WATER TABLE
METHOD: DD DIAMETER: BMLC.		873'.00"		
SITE REMARKS: In bench just to South of crest line of spur	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
		~~VERT./HOR.~~/INC.	45°	045°

HOLE No. 5510 | FILE No. | SHEET 2 OF 4 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY %	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
100'										Yellow tinged, white, slightly clayey, fine sandstone and core loss near 104'.
105'										
110'		Fragmented.								67' to 153', Light grey to yellow white quartzite, mostly massive, hard and compact, often showing very close, brown stained jointing as at 73', mineralization with iron pyrites and haematite as at 92', 94' & 139', decomposition and fragmentation as at 100' to 109'. In places whorls and blebs of grey, red and yellow colourization due to mineralization. Most joints tight. Open joints clay or mainly limonite filled.
115'										
120'										
125'		≠14'. Some 2'. Mostly from 3'6".								
130'										
135'						2				
140'		3" to 8".								
145'										½" wide, 9" long, oblique, clay & white mica filled joint at 148'.
150'										
155'		8" to 12".								153' to 187' light grey to dark greenish gray, hard, compact quartzite showing much iron pyrites mineralization in vugs and along joint planes. Crumbling in places to fragments, as at 169 & 179'. Joints fewer & tending to be more transverse.
160'						5				
165'										
170'										
175'										
180'		≠11". Mostly 3" to 8".								187' to 213'. Dark green, softer, shaly quartzite, decomposing to brown and yellow clay along joints. Much iron pyrites mineralization & sections of ½' of consecutive core broken down into ½" clayey fragments coloured yellow & olive green, as at 201'. Tubicolor markings present in several zones.
185'										
190'						3				
195'		≠5'. Mostly 12".								
200'										

NO RETURN

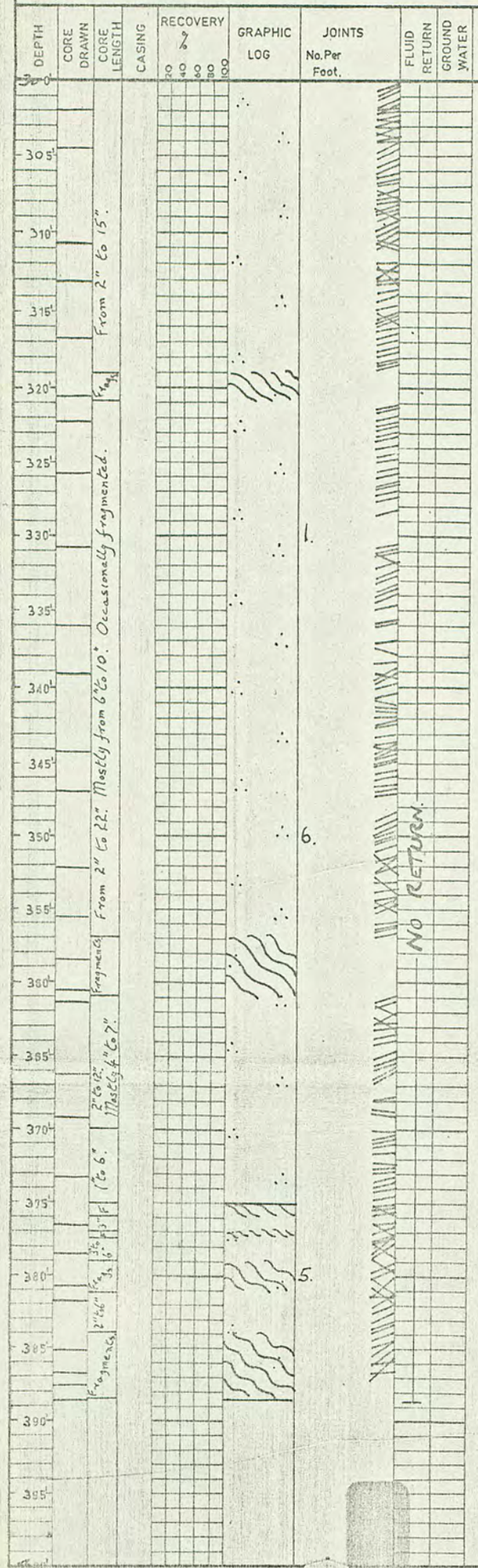
DRILLING RECORD

AREA: MFPD		POSITION	CO-ORDINATES:	E 412·0590	N 890·2942	HOLE No. 5510
LOCATION: CETHANA QUARRY			ON LINE:	BEARING:	AT CH:	
GEOLOGICAL PLAN: AS FOR →	SURVEY PLAN: A 126–912–19		AT STN:	BEARING:	DIST:	FILE No.
DATES (a) DRILLED: OCT. '66	(b) WATER TABLE:	LEVEL	SURFACE	COLLAR	WATER TABLE	
METHOD: DD.	DIAMETER: BMLC.		873'·00"			SHEET 3 OF 4 SHEETS
SITE REMARKS: In bench just to South of crest line of spur.		INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
			~~VERT~~/~~HOR~~/INC.	45°	045°	

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
200'–205'		F; 2" to 3"; Frag ments								
205'–216'		> 8", generally 2" to 6". Much of it fragmental.								
216'–230'		> 14". From 4" to 9".				1				213' to 230'. Dark green to medium grey, compact, hard quartzite, showing fewer joints, occasional pockets of mineralization, and limonite filling to two major, long, oblique joints.
230'–233'		2" to 3"; Frag								
233'–235'		> 2" + frags								
235'–248'		From 6" to 14".					NO RETURN.			230' to 259'·5". Grey, red-brown + yellow speckled, hard, massive quartzite, fragmented in places, with pyrites mineralization in joints. Of note is a quartz mineralization band > 4" wide showing wavy bands + splitting + breakage along the planes of the bands. Joints are tight, wide + oblique. Those open have small amounts of clay +/or limonite.
248'–250'		Frags.								
250'–259'		1 × 12". A few of 2". Most 6" to 8".								
259'–263'		Fragments								
263'–277'		1 + 2" discs + fragments. Some 6" lengths.				6				
277'–280'		Fr; 1" to 6"; Fr								259'·5" to 290'. Joints closer and quartzite of grey and blue much broken to fragments along the joints, which have thin clay fillings. Qtz + pyrites mineralization zones exist in places, as at 275'. The quartzite is largely hard + massive.
280'–291'		From 2" to 8".								
291'–300'		Most about 6". Occasional fragments				2				

DRILLING RECORD

AREA: M.E.B.D.	POSITION	CO-ORDINATES:	E 412·0590	N 890·2942	HOLE No. 5510
LOCATION: CETHANA QUARRY		ON LINE:	BEARING:	AT CH:	
GEOLOGICAL PLAN: AS FOR → SURVEY PLAN: A 126-912-19.		AT TTN:	BEARING:	DIST:	FILE No.
DATES (a) DRILLED: OCT '66 (b) WATER TABLE:	LEVEL.	SURFACE	COLLAR	WATER TABLE	
METHOD: DD DIAMETER: BMLC.		873'·0"			SHEET 4 OF 4 SHEETS
SITE REMARKS: In bench just to South of crest line of spur.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
		~~VERT./HOR.~~/INC.	45°	045°.	



REMARKS

290' to 384'·00". Hard massive, grey, white and blue quartzite with occasionally fragmented lengths of core. Joints widely spaced, those existing — mostly open with slight limonite + /or clay filling. Pyrites mineralization in several places in the joint planes ∓ ¼" thick. Tubicolor markings also present in several zones

372' to 374'·8" — much pyrites mineralization in blebs through the rock.

At 372'+ 374'·8" 2" thick Bands of a sienna Brown or Black coloured, conchoidally fracturing, lightweight, Brittle rock; it often fills open joints in this region, is glassy, translucent at the edges + gives a brown streak.

375' to 388'·8". Grey/Brown/White, hard quartzite fragmented along the joint planes in places + the rock described above at 372' etc., occuring in fragments for up to 3" of core length also.

Bedding overall lies at 90° to axis of hole

Hole completed:— 11 Nov '66 at 388'·8"

Logged by:— W. Godfrey.

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPEMENT.
LOCATION: CETHANA QUARRY.
GEOLOGICAL PLAN: AS FOR → SURVEY PLAN: A 126-912-19.
DATES (a) DRILLED: OCT-NOV (b) WATER TABLE:
METHOD: DD DIAMETER: NMLC.
SITE REMARKS: In 700' Bench to North of spur crest line.

POSITION: CO-ORDINATES: E: N: | ON LINE: BEARING: AT CH: | AT STN: BEARING: DIST:
LEVEL: SURFACE COLLAR WATER TABLE
INCL.: HOLE DRILLED ANGLE FROM HORIZONTAL DIRECTION | ~~VERT/HOR.~~/INC. 30° 040° approx.

HOLE No. 5512.
FILE No.
SHEET 1 OF 2 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0'			N X				I GREY			0' to 43'. Hard, white quartzite, except for the last 2' which is grey and massive. The rock is much fragmented to pebbles + cobbles along innumerable joint planes with the joint faces weathered to a red-Brown limonite clay. A few lengths of core exist in places with widely spaced, open joints.
5'										
10'										
15'										
20'										44' to 52'-10" Buff, grey + light yellow, clayey, decomposed and fragmented quartzites. Some core lengths but these much weathered along numerous tight, close, joint planes to a relatively soft, iron-stained rock.
25'										
30'										
35'										
40'		Pebbles + cobbles mostly; several lengths of core + 12".								
45'		Decomposed + weathered fragments.								
50'										52'-10" to 65'. Dark grey, compact, fine-grained quartzite with lighter grey markings – possibly Cubicolour, and 2 Bands of hard, quartzitic shale. Many tight, close, iron oxide stained joints. Open joints have ± 1/4" thick, clay seams or black/brown limonite clay fillings.
55'						4				
60'		1 Core discs, initially, then mostly 6" lengths.								
65'		Fragm 2x3								65' to 69'. Dark, grey/green, silty shale with thin fgrites seams along predominantly transverse joints – or occasionally white clay fillings ± 1/4" thick. 1m 2' of core fragmented + 2' complete.
70'		2"x3".								
75'		Fragments								69' to 71'. Pebbles + cobbles of fragmented, white quartzite with red/brown limonite clay-spread fracture/joint faces.
80'										
85'		Some 1"x3". Largely 6".				6				
90'										71' to 100'. Dark grey/green quartzite with predominantly oblique and widely spaced joints which, when open, are full of Brown + Black limonite clay ± 1/2" thick. Zones from 81' to 90' and 98' to 100' much weathered and stained, brown, pinky yellow by iron oxides, but though softer, core is still complete.
95'										
100'										

DRILLING RECORD

AREA: M.F.P.D.

LOCATION: CETHANA QUARRY.

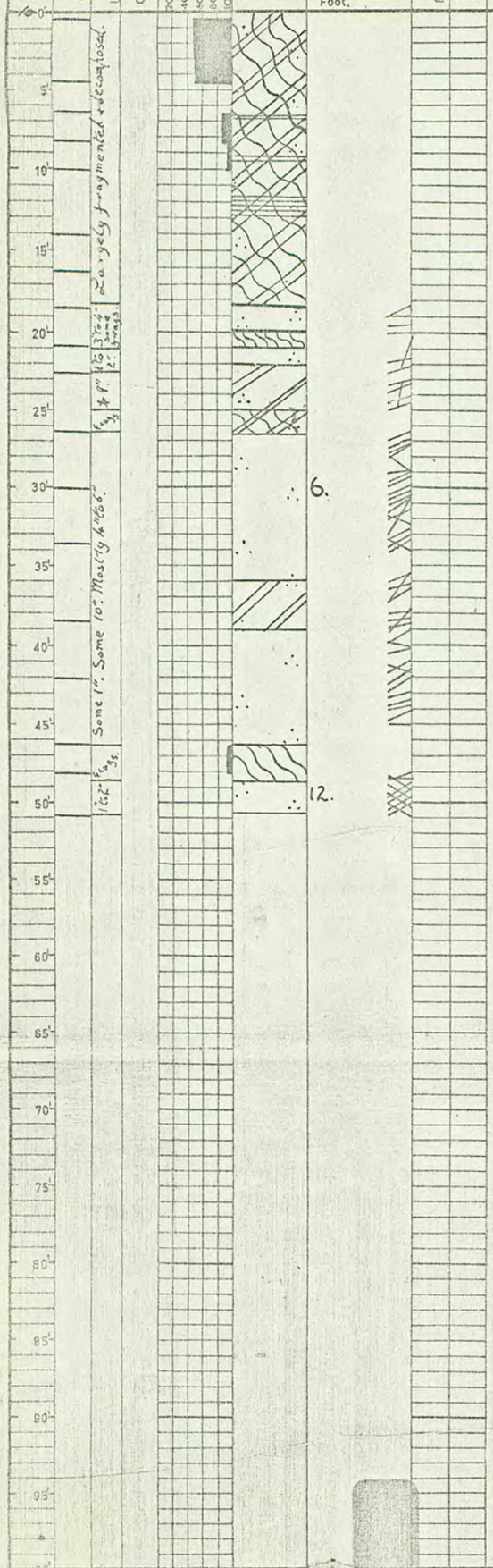
GEOLOGICAL PLAN: AS FOR:— SURVEY PLAN: A-126-912-19.

DATES (a) DRILLED: OCT-NOV'66. (b) WATER TABLE:

METHOD: DD. DIAMETER: NMLC.

SITE REMARKS: In 700' Bench to North of spur crest line.

POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5512.
	ON LINE:	BEARING:	AT CH:	
	A. STN:	BEARING:	DIST;	FILE No.
LEVEL.	SURFACE	COLLAR	WATER TABLE	
INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	SHEET 2. OF 2 SHEETS
	~~VERT./HOR./~~INC.	30°	040° approx	



REMARKS

92' to 126'-6". Grey or Buff, fine, silty, soft, fragmented and decomposed, clayey quartzites with several pure claystone Bands, as at 112'. Open joints seen in some complete lengths of a more quartzitic nature at 118'-4" to 120' + 121' to 122' pyrites filled to ± ⅛" thick.

Mineralization fills a longitudinal, open joint from 123' to 124½' with a dark green, flaky, crystalline chlorite and purple-Black haematite in the middle.

126'-6" to 150'-9". Light to dark grey, massive quartzite with oblique, wide, mostly open joints filled very thinly with iron oxide.

Slt decomposition from 136'6 to 139' with pyrites in the joint planes.
From 146' on, a Brown/Black, curved surface fracturing, light weight brittle, glassy lustred, translucent at chipped edges rock occurs at ± ¼" thick in some oblique joint planes. Possibly a baked clay, joint filling.

Overall the Bedding lies at ≈ 60° to axis of hole.

Hole completed 150'9".
Logged by D. Godfrey.
10.4.66.

(copy for Geology)

M.D.F./C.C.

G.E.3 CETHANA ROCKFILL DAMS II 15/12/66.

Attached is Mr. Boughton's report on Cethana Quarry together with an indication of the design requirements for three zones in the dam and the material properties required for each zone.

Testing results so far obtained (but not yet reported) show that well graded granular material will settle under load much less than poorly graded or uniform material. It will therefore be required that 3B material be as well graded as is possible to obtain economically. Quarrying techniques should be planned and developed to achieve this.

In my view there seems to be no reason to remove the fines from the 3A (bedding zone) material. With a well controlled, well graded 3B material acting as a filter to 3A material there can be no danger whatsoever of ~~Exifration~~ migration of fines in event of leakage. In addition removal of fines may well cause the 3A zone to settle under load by a significantly greater amount than if they were retained. This would be of little importance except around the periphery where everything possible should be done to reduce settlement adjacent to the plinth. Of course, the upper limit on fines should be that at which the compacted density and settlement under load is not affected by moisture content - say 2 to 3% passing a No. 200 sieve.

Another early indication from laboratory testing is that saturated surface dry material settles more under load than dry material. It is therefore likely that we will require complete wetting of the fill before, and as it is compacted. The water/rock ratio required will be about 0.5 by volume.

M.D. Fitzpatrick
DAMS II.

S.E.
C.C.E.
E.C.C. (2)
Geologist-in-Charge thru E.C.I.

I agree with above generally. 3A material if fines are included will need to be clean rock particles and thus selected from the best of the quarried rock. Also care will be needed to avoid segregation and areas of excessive fine material on the dam.

(Sgd.) W.R.M.
20/12/66

Geologist in charge
Thru ECI
for information

MINUTES OF DESIGN CONFERENCE ON CETHANA DAM

22ND DECEMBER, 1965

1. PRESENT

C.C.E., E.C.D., G.E.III, Messrs. M. D. Fitzpatrick, N.O.Boughton, S. Giudici, T. B. Liggins.

2. The conference had been called to review developments in the design of the dam since the design conference on 10th September 1965, when it was decided to retain the plan position of the dam, but excavate further into the left abutment to obtain adequate stability against sliding of the foundation.

3. Mr. Fitzpatrick reported that a new, deeper foundation profile had been determined using arch reactions from an arch shell on the original foundation profile. A new arch shell had been designed to suit the new profile, and stresses were acceptable at all points. However, a check on foundation stability with reaction from the new arch shell had given factors of safety much less than the value of 2.0 required for foundation stability.

Contributing factors to this low factor of safety were increased subtended angles of the dam arches for the new (and deeper) profile, with reactions consequently closer to the direction of failure, and re-distribution of arch abutment loads because of the change in the shape of the foundation profile.

It was agreed that the stability situation was little better than at the last conference, and that it was unlikely that significant improvement would result from a further deepening of the foundation excavation.

4. The following proposals for re-design of the dam were discussed:

4.1 Artificial Foundation: G.E.III noted that the reactions from the original shell gave satisfactory stability with the present excavation line. This could be achieved in practice by terminating the shell at the original profile and excavating and placing an artificial abutment in concrete. However, the additional cost could be of the order of £500,000.

4.2 Rotation of Present Shell: Mr. Fitzpatrick reported that stability calculations had been made for the present shell rotated 10° (upstream on left bank, downstream on right bank). However, this rotation had been insufficient to give the required factor of safety on the left abutment.

C.C.E. noted that the 20° rotation discussed at the previous conference had been satisfactory for stability and asked whether it should be re-considered.

G.E.III and Mr. Fitzpatrick recalled that some difficulty could be expected with obtaining acceptable stresses on the right abutment because of the long flat profile at the top, and that the dam could interfere with the power station.

4.3 Flatter shell with some Rotation: Mr. Boughton described a layout in which the upper arches of the shell were flattened by increasing the radii. Such a shell could be located so that it was in much the same position as the present shell on the right bank, but significantly further upstream on the left bank. A rotation of as much as 20° on the left bank might be possible without significant change to the right bank

Whether or not this proposal is feasible would be demonstrated by stress analyses at present in progress.

C.C.E. asked whether this layout would affect the cofferdam or diversion tunnel. In reply it was noted that the present cofferdam location was some distance from the main dam, being determined by the location of suitable abutments. The cofferdam was therefore likely to be unaffected. The extent to which the diversion tunnel would be affected could only be determined after the dam had been laid out, but the recent shift of the tunnel may have been enough to assure adequate cover.

4.4 Addition of Deadweight to Foundation: Mr. Fitzpatrick noted that some improvement of factor of safety could be obtained by filling in gullies below the left abutment cliffs with concrete, lightly prestressed to the rock if necessary. Use of heavy aggregate was also mentioned, although cost might be excessive.

4.5 Prestressing the Foundation: G.E.III asked whether a criterion such as "1.5 factor of safety without prestressing; 2.0 factor of safety with prestressing" would be acceptable.

C.C.E. and E.C.D. reaffirmed that the dam should be designed to stand by itself if at all possible and that foundation prestressing should only be considered as a last resort.

4.6 Removal of the bedding plane shears was raised, but it was agreed that the extent to which this would be necessary would make it a formidable operation.

4.7 Rockfill dam: This alternative was raised by C.C.E. but it was agreed that construction preparations were now too far advanced to consider it further.

5. The delay to the design programme caused by this development was the discussed. Mr. Fitzpatrick estimated that it could be at least 6 weeks before a satisfactory shell is developed. G.E.III noted that we have advised the U.S.B.R. that we will have data ready for trial-load analyses at the end of January, and that they should be informed that we will be late.

It was also noted that the Elliot 503 computer would not be available for some weeks after mid-January, when the extra store is due to be installed. Arrangements would have to be made to have programmes run on the 803 computer in Melbourne or perhaps on a 503 in New Zealand.

6. C.C.E. concluded that little further could be achieved at the conference. Work is to proceed on the most promising of the proposals listed in para. 4, namely, 4.1, 4.3 and 4.4. Some combination of these may provide the best solution.

NOB/NW

Notes prepared by N.O.Boughton
22.12.65.

Copy for Geology

FFF/GM.

Testing Engineer.

OHTHANA ACCESS ROAD TO NOMBE AREA - ROCK SLIP CHAINAGE 7000 FEET.

P.O. Kisale
8th December, 1965.

Reference E. & T. Requisition No. 1406 Dams 11.

LABORATORY RESULTS

Laboratory test results on samples of bedding plane filling material recovered from the rock slip at chainage 7000 feet are set out below.

					TRIAXIAL TEST-REMOULDED SAMPLE			
SAMPLE	S.G.	L.L.	P.L.	P.I.	C' p.s.i.	Tan ϕ	a	W/C
3883	2.73	20	10	10	2.5	0.7	127.0	11.5
3884	2.74	24	12	12	4.5	0	121.0	14.0

Copies of P.S.D. Curves and shear parameter plots are attached.

Insufficient material was available to check the effective stress parameters obtained from sample 3884, but it is considered that test sample 3883 values are appropriate for this soil type.

COMMENTS

1) Field measurements have shown the angle of slip plane to vary between 37° to 40° with the natural surface lying at about 35°.

2) Further slips are possible along joint planes steeper than 35°.

3) Where possible, drainage should be implemented above the slip planes to prevent ingress of water. (concrete table drains desirable along the present road).

F.F. FLETCHER

c.c. Dams 11
Roads
Geology
Mr. Fletcher

Tan ϕ' of 0.7 (35°) is a reasonable value for this type of soil. As rock on joints steeper than 35° is being held by cohesion, all efforts to keep water out should be made including sealing road, drain and shoulders.

Testing Engineer.

H.E. 932

TEST PLOT

SCHEME: M.F.P.D.

LOCATION: Cethana Rd. Slip

DATE OF TESTS: 20-8-1965

TEST DETAILS: Triaxial Test.

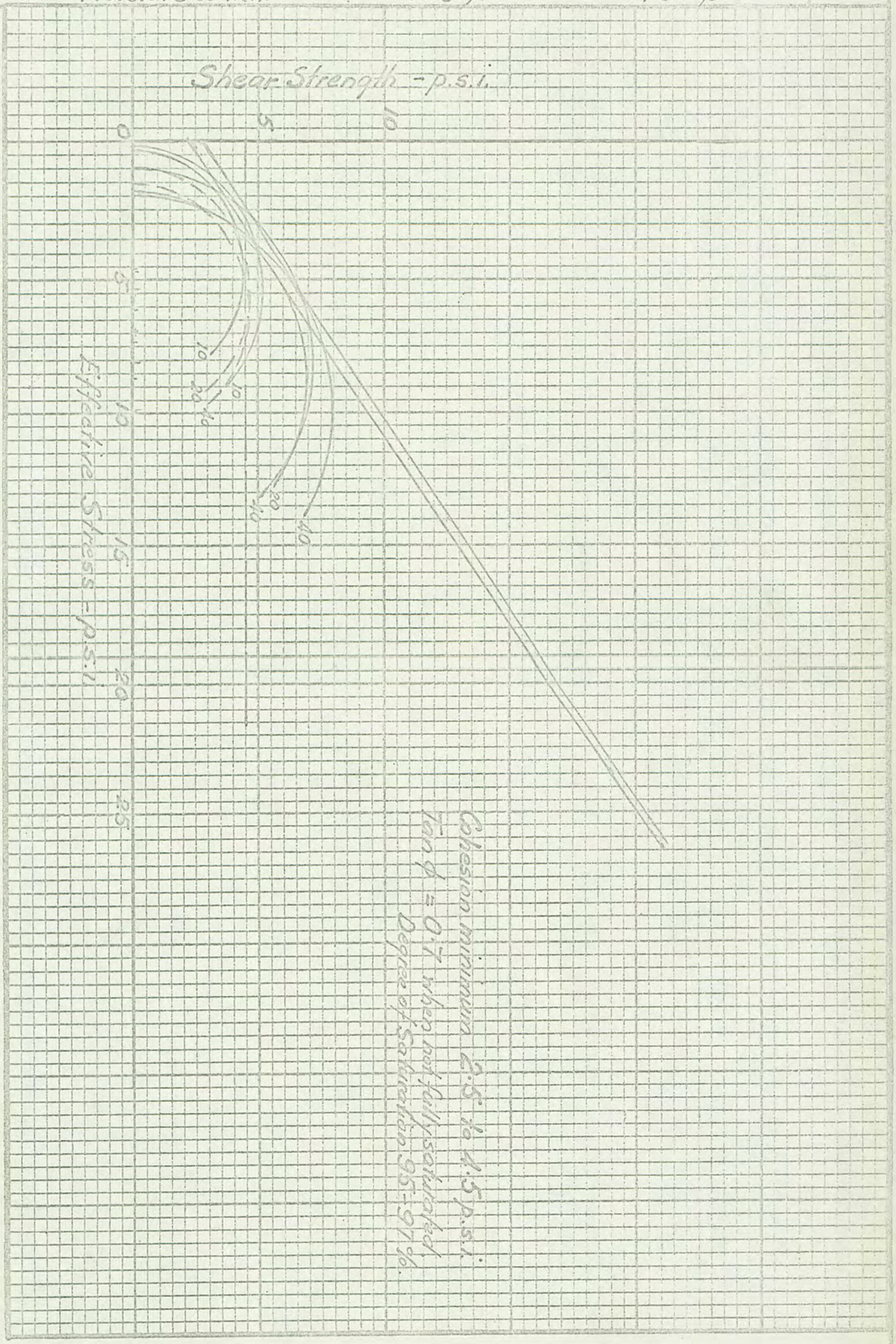
Material: Light grey plastic sandy (silty), easily ground into a rock flour.

Average Dry Density 127.0 lb/cu.ft for 3883 121.0 lb/cu.ft for 3884
-"- Moisture Content 11.5 % 14.0 %

HOLE No.	FILE No.

SAMPLE No.	SHEET OF SHEETS
3883 3884	

DEPTH



H.E. 930

PARTICLE SIZE DISTRIBUTION REPORT

SCHEME: M.F.P.D.

LOCATION: Cethana Rd. Slip

DATE: 4-8-1965

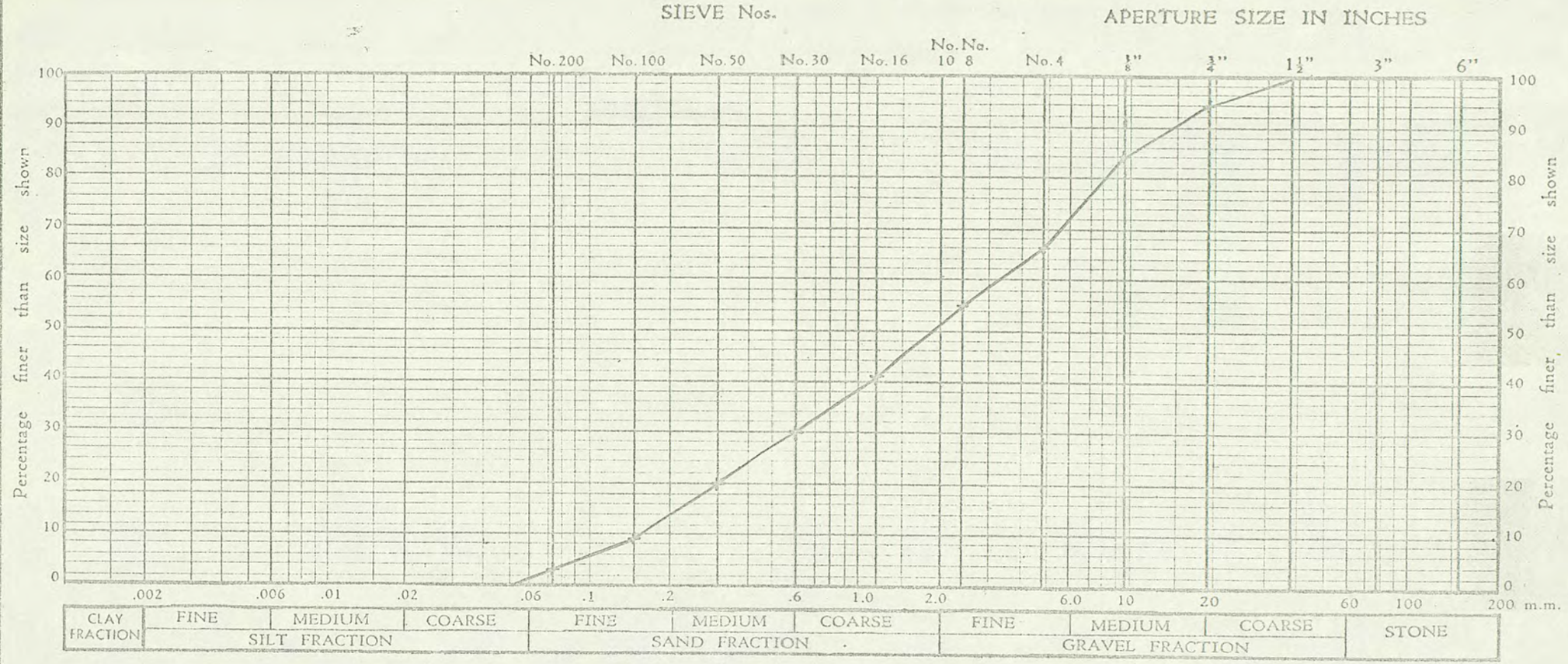
SAMPLE No. 3883

DEPTH:

HOLE No.

FILE No.

SHEET of SHEETS



Effective Size..... m.m. Uniformity Coefficient ..... Organic Matter..... %

Soluble Solids..... %

Remarks:

GRADING	%
Stone	0
Gravel	48
Sand	51
Silt	1
Clay	

SIEVE ANALYSIS					
Sieve	Per cent. Passing	Sieve	Per cent. Passing	Sieve	Per cent. Passing
6"		4	66	50	20
3"		8	55	100	9
1½"		10		200	3
¾"	94	16	41		
⅜"	84	30	30		

H.E. 930

PARTICLE SIZE DISTRIBUTION REPORT

SCHEME: M.F.P.D. SAMPLE No. 3884

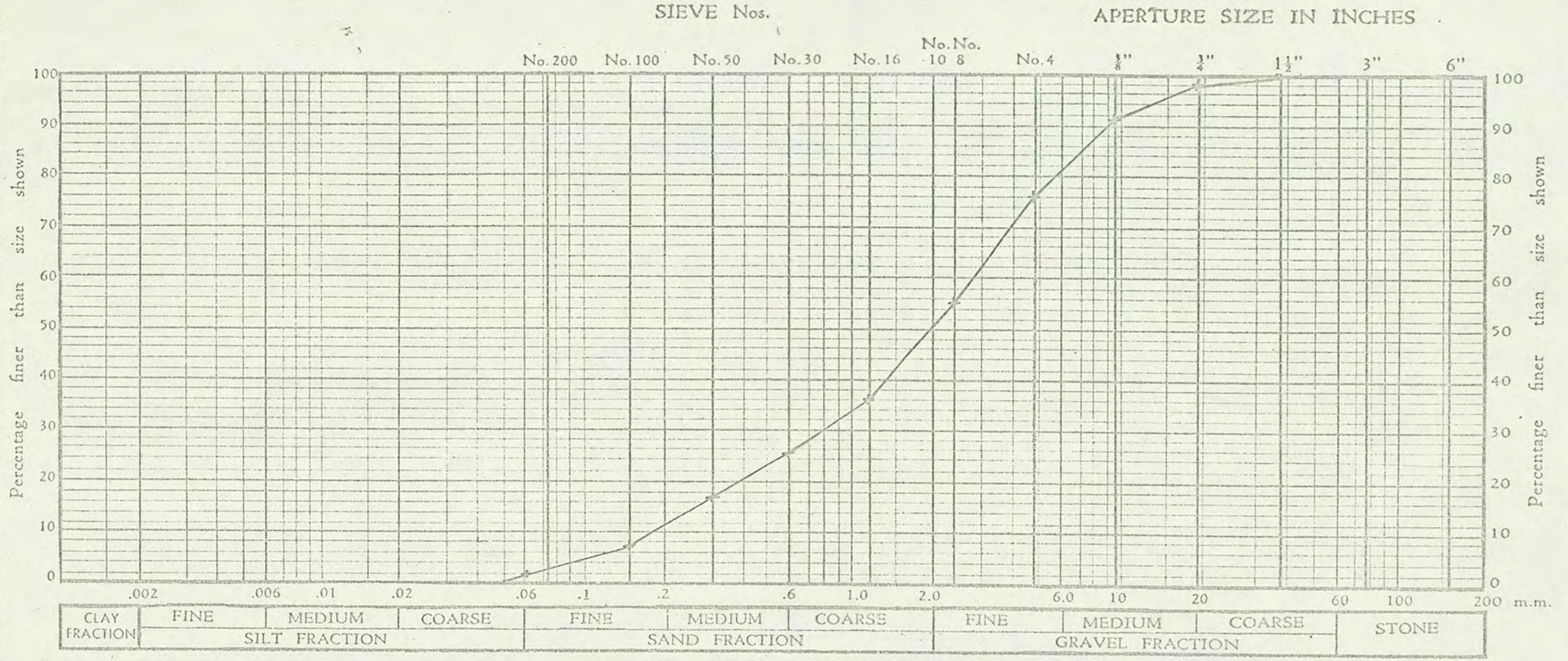
LOCATION: Cethana Rd. Slip DEPTH:

DATE: 4-8-1965

HOLE No.

FILE No.

SHEET of SHEETS



Effective Size ..... m.m. Uniformity Coefficient ..... Organic Matter ..... %

Soluble Solids ..... %

Remarks:

GRADING	%
Stone	0
Gravel	19
Sand	49
Silt	2
Clay	

SIEVE ANALYSIS					
Sieve	Per cent. Passing	Sieve	Per cent. Passing	Sieve	Per cent. Passing
6"		4	76	50	17
3"		8	55	100	7
1½"		10		200	3
¾"	98	16	36		
⅜"	91	30	25		

THE HYDRO-ELECTRIC COMMISSION

TASMANIA

MERSEY-FORTH POWER DEVELOPMENT

THE SEISMIC DETERMINATION OF YOUNG'S MODULUS AND POISSON'S RATIO AT CETHANA DAM - SITE

P. W. McDOWELL.

REPORT No. 644-126-2.
Accompanied by: B9162.

THE SEISMIC DETERMINATION OF YOUNG'S MODULUS AND POISSON'S RATIO FOR CETHANA DAM-SITE

I. INTRODUCTION.

A seismic survey was conducted in May 1965 to determine Young's modulus and Poisson's ratio at the proposed site of Cethana dam. The seismic 'spreads' were restricted to the adits because of the difficulty and danger of working on the steep sides of the valley. Also the work will provide a comparison between the dynamic elastic moduli obtained by the seismic method and the static elastic moduli from jacking tests in the adits. Further this information, and the geological 'mapping' of the adits, will enable the expensive jacking tests to be sited to best advantage.

Additional information was obtained by measuring the travel time of seismic waves from 'adit-to-adit' and from 'surface-to-adit'. In this way larger blocks of rock, less disturbed by the blasting necessary to drive the adits, could be investigated. Also the travel paths of seismic waves could be selected to investigate the anisotropy of the rock.

II. GEOLOGY.

The geological investigation report (644-Ceth-1) by G.E. Hale accompanied by plans: A11153, B8349, C4991, describes the geology of Cethana damsite and environs. Especial attention is drawn to the section VI Engineering Geology which describes the conditions of the fault zones and joints that traverse the site. At the damsite Ordovician quartzites and conglomerates of the Roland Conglomerate beds are encountered. Generally, these beds are massive and dip upstream at a shallow angle. There are however zones of shearing associated with some of the faults which contain broken fragments separated by rock flour, or chlorite, or chlorite weathered to clay. Apart from these 'zones' the effect of weathering on the rocks is slight. However considerable relaxation of joints close to the surface is attributed to physical weathering and stress relief due to erosion of the river valley.

III PRINCIPLES.

Elastic theory establishes the following relations among Poisson's ratio μ, Young's Modulus E, the compressional and shear velocities α and β and the density γ.

$$\mu = \left(\tfrac{1}{2}\alpha^2/\beta^2 - 1\right)\left(\alpha^2/\beta^2 - 1\right).$$

$$E = \gamma\alpha^2(1+\mu)(1-2\mu)/144g(1-\mu).$$

$$E = \gamma\beta^2(1+\mu)/72g.$$

where α, β, γ, and g are in ft. - lb.-sec. units and E is in lb/sq.in. Poisson's ratio is seen to depend only on the ratio of the seismic velocities. Evison discusses the importance of determining Poisson's ratio, rather than assuming a value for it to obtain a reliable estimate of Young's Modulus. For compact rocks, such as those at Cethana, variation in Poisson's ratio has little effect on the value of E but it was thought necessary to determine the value of μ for differing rock conditions at this dam-site.

It is difficult to evaluate the density of the in-situ rock through which the elastic wave has passed. Kudo et al describes a back-scattering gamma-ray density meter. The values of γ measured this way were found to be 10-15% smaller than those measured on corresponding cores from the same part of the rock. At present one density determination has been made on conglomerate and one on quartzite cores from Cethana dam-site. Except for the weathered shear-zones these values and published density determinations for quartzite are quite representative, when reduced by 15%, of the in-situ density.

IV. INSTRUMENTATION.

The S.I.E. - Dresser seismic refraction equipment and the M.D.I. shallow seismic equipment were both used to measure the travel times of seismic waves. The use of a travelling microscope enabled the seismic records from the former equipment to be read to $\frac{1}{2}$ of a millisecond or better and the M.D.I. can measure to $\frac{1}{4}$ of a millisecond.

The S.I.E. equipment was used almost exclusively, however, because the signal to noise ratio could be controlled and all the arrivals of seismic waves at each geophone could be recorded and preserved on photographic paper. Also 3-component geophones that record ground motion in three mutually perpendicular directions could be used with this apparatus.

Compressional and shear waves were produced by an explosive source but at two locations a swinging-weight source was used to produce directional shear waves.

V. RESULTS.

The measured velocities of seismic waves for travel paths, along the adits (see Plan) and the corresponding elastic moduli are shown together for each adit worked.

ADIT 7.

Portal (G3) to Bend in Adit (G6); α = 10,000 ft/sec.

Quartzite w. open joints μ = 0.33 (estimated)

γ = 155 lbs/cu.ft. E = 2.26×10^6 lbs/sq.in.

Bend in Adit (G3) to G2; α = 9,000 ft/sec.

Quartzite: sheared, with chlorite β = 4,300 ft/sec.

and clay between blocks. μ = 0.36

γ = 145 lbs/cu.ft. E = 1.5×10^6 lbs/sq.in.

G2 to end of adit.

U. Conglomerate w. closed joints. α = 16,000 ft/sec.

γ = 150 lbs/cu.ft. μ = 0.24 (est). E = 7.0×10^6 lbs/sq/in.

ADIT 6.

Portal to bend in adit (G3); α = 6,200 ft/sec.

Quartzite with open joints μ = 0.33 (est.)

γ = 155 lbs/cu.ft. E = 0.87×10^6 lbs/sq.in.

G3 to end of adit; α = 16,000 ft/sec.

Quartzite with closed joints μ = 0.24 (est.)

γ = 155 lbs/cu.ft. E = 7.3×10^6 lbs/sq.in.

ADIT 5.

Portal to bend in adit;

Quartzite w.open joints near portal

γ = 155 lbs/cu. ft.

α = 7,500 ft/sec.

β = 3,800 ft/sec.

μ = 0.33

E = 1.3×10^6 lbs/sq.in.

Bend in adit to end of adit;

Bedding planes in quartzite, open or clay filled in parts.

γ = 145 lbs/cu.ft.

α = 9,500 ft/sec.

μ = 0.33 (est.)

E = 1.9×10^6 lbs/sq.in.

ADIT 4.

Portal to G8(20' inside adit)

Lower Conglomerate, with open joints.

γ = 155 lbs/cu.ft.

α = 5,000 ft/sec.

μ = 0.33 (est.)

E = 0.57×10^6 lbs/sq.in

G8 to bend in adit

Lower Conglomerate, jointed and faulted.

γ = 155 lbs/cu.ft.

α = 8,000 ft/sec.

μ = 0.33 (est.)

E = 1.45×10^6 lbs/se.in.

Bend in adit to end of adit

Mainly conglomerate with closed joints.

γ = 155 lbs/cu.ft.

α = 15,000 ft/sec.

μ = .24 (est.)

E = 6.4×10^6 lbs/sq/in.

ADIT 3. Power Station Area.

Lower conglomerate, jointed & faulted.

γ = 155 lbs/cu.ft.

α = 10,000 ft/sec.

β = 5,000 ft/sec.

μ = 0.33

E = 2.26×10^6 lbs/sq.in

ADIT 3: G1 to G12.

G1 to G8:

Lower Conglomerate with closed joints.

γ = 155 lbs/cu.ft.

α = 12,000 ft/sec.

μ = 0.29 from comparison of travel times of compressional and shear waves over length of spread

E = 3.65×10^6 lbs/sq.in

G8 to G12;

Quartsite, sheared & jointed.

γ = 155 lbs.cu.ft.

α = 9,000 ft/sec.

μ = 0.29

E = 2.3×10^6 lbs/sq.in.

ADIT 3. offshoot.

Quartzite, sheared & jointed.

γ = 155 lbs/cu.ft.

α = 10,000 ft/sec

μ = 0.33 (est.)

E = 2.26×10^6 lbs/sq.in.

The velocities of compressional waves, and in some cases shear waves, for travel paths through relatively 'undisturbed' rock from 'adit to surface' and from 'adit to adit' are also shown on Plan B9162. All travel paths have been projected to the horizontal plane so a different convention has been adopted to distinguish these 'travel paths' from the 'travel paths' along the adits.

It is not valid to average the compressional wave velocities recorded in each 'block' because of the large range of the velocities. The range, for each 'block', of compressional wave velocity, and the corresponding range of Young's Modulus, have been calculated.

ADIT 1 to ADIT 7.

γ = 155 lbs/cu.ft. α ..... 10,000 - 11,600 ft/sec.

Upper Conglomerate in part; Mainly Quartzite
E ..... 2.68 - 3.62 x 10^6 lbs/sq.in.
μ = 0.27 (calculated).

ADIT 6 to ADIT 7.

In part Upper Conglomerate, mainly Quartzite.
α .....7,800 - 10,800 ft/sec.
E .....1.36 - 2.61 x 10^6 lbs/sq.in.
γ = 150 lbs/cu.ft. μ = 0.33 (est.)

Surface at D.H.5443 to Adit 6.

Mainly Quartzite,
α .....8,700 - 11,300 ft/sec.
E .....1.82-3.08 x 10^6 lbs/sq.in.
γ = 155 lbs/cu.ft. μ = 0.31 (calculated).

Surface D.H,5449 to Adit 5.

Mainly Quartzite partly Upper Conglomerate
α .....5,800 - 8,100 ft/sec.
E .....0.76-1.5 x 10^6 lbs/sq.in.
γ = 155 lbs/cu.ft. μ = 0.33 (calculated).

Surface at D.H. 5442 to Adit 5.

Mainly Quartzite
α .....5,700 - 10,300 ft/sec.
γ = 155 lbs/cu.ft. E .....0.78 - 2.54 x 10^6 lbs/sq.in.
μ = 0.31 (est.)

ADIT 3 toADIT 4.

Mainly Lower Conglomerate
α .....8,700 - 10,200 ft/sec.
E .....2.04 - 2.74 x 10^6 lbs/sq.in.
γ = 155 lbs/cu.ft. μ = 0.27 (est.)

Surface at D.H.5442 to Adit 4.

Mainly Lower Conglomerate
α .....5,100 - 8,000 ft/sec.
E .....0.59 - 1.45 x 10^6 lbs/sq.in.
γ = 155 lbs/cu.ft. μ = 0.33 (est.)

VI. CONCLUSIONS.

It is clear from the seismic velocities that the major factors influencing the variation in seismic wave velocity are 'jointing' and 'shearing' of the rocks. Laboratory work on rock specimens by M.R.J. Wyllie, A.R. Gregory and L.W. Gardner, confirms the statement that poor coupling of cracks in materials can cause great decreases in velocities. Open dry joints must persist to 20 ft. from the surface in Adit 4 and 30 ft. from the surface in Adit 6 because the low velocities of 5,000 ft/sec and 6,000 ft/sec were recorded. Closed joints and joints filled with clay or water are expected to be the cause of velocities between 8,000 and 12,000 ft/sec. Only in a few places was the laboratory determined value of 17,500 ft/sec.(which is also the expected velocity of seismic waves through fresh unfractured quartzite) recorded.

The extensive 'zones of shearing' in the Quartzite of Adits 4,5 and 7 have velocities between 7,500 and 9,500 ft/sec. - the clay and chlorite must provide seismic coupling between the blocks of quartzite. In the other areas of investigation geological faults appear to have little influence on seismic wave velocity.

The elastic moduli determined in this work are 'dynamic moduli' for rock subjected to very small stresses and elastic deformation. It is expected that static tests that cover joints opened by 'blasting' of 'Physical weathering' will yield low values of E initially through inelastic deformation but approach the dynamic values of E as these joints are closed.

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CETH-1.

Form No.H.E.10 GR/SM

THE HYDRO-ELECTRIC COMMISSION

TO	SUBJECT	FROM
Hyd. for. GEOLOGIST-IN-CHARGE. 8.9.65.	DETAILED GEOLOGICAL INVESTIGATION OF THE LEFT ABUTMENT OF CETHANA DAMSITE.	G. RAWLINGS. 8.9.65.

Detail investigation of Cethana left Abutment.

I. INTRODUCTION.

Detailed investigation has recently taken place of the abutments of Cethana Damsite to determine the location, extent and importance of the bedding plane shears and vertical joint systems known to be present. The work has entailed a re-examination of drill-cores, adits and surface exposures. Notes on the right abutment are in preparation and will be submitted shortly.

II. LEFT ABUTMENT.

1. Bedding Plane Shears.

(a) Bedding plane shears of three types have been mapped at the surface. Type (α) - major shears showing > 2" rock flour, fragmented rock and sheared quartzite. Type (β) - minor, shears showing < 2" rock flour, fragmented rock and sheared quartzite. Type (γ) showing small amounts of sheared rock and occasionally rock flour, planes generally open.

Continuous exposure allows some of these shears to be traced from the surface outcrop into the adits. In the unweathered state the shears are seen to be thicker and to contain a greater percentage of rock flour than their expression on the surface indicates. Consequently it may be anticipated that γ shears contain up to 1" of rock flour and fragments at depth, β shears at least this amount and α shears > 6". The α shears are particularly variable in thickness and may separate into two or more shears only to coalesce further along the bedding plane.

Unless drilled with mud, poor recovery of material in the sheared zones has been obtained. Noticeable core loss was obtained when drilling through α shears, and some fragmented and sheared rock was occasionally recovered e.g.(DH5438 30'-33'). Only sheared rock was obtained when drilling through β and γ shears.

(b) Two zones of shearing are present, they are referred to as Z1 and Z2 on the accompanying plan. Z1 extends from the base of the higher Conglomerate (ORU) approximately 50' down into the Quartzite (ORQ). Z2 extends from the base of Z1 to the top of the underlying lower Conglomerate(ORL).

Z1 shows an average shear plane spacing of one/4'. Three or four α shears have been mapped and are persistent through the zone. Most bedding planes show β shears which are well exemplified in DH5448.

Z2 shows only γ shears and these are best seen in adit 6, DH5445, DH5443 and DH5420. The rock is predominantly grey in colour and closer jointed than in Z1. The average shear plane spacing is one/19' in adit 6 but more shears appear towards the top of the zone.

(c) The bedding plane shears are not planar over the whole of the left abutment but locally for lengths up to 60' they may be considered to be so. e.g. Between DH5438 and a point 20' S. of adit 7 the bedding is uniform at 141°S.26° and shows only minor variations. Minor undulations occur throughout the sheared zones but only in the γ shears, and locally the β shears also, are these generally greater in amplitude than the thickness of the sheared zone.

2. Engineering Significance of Bedding Plane Shears.

(a) Bedding plane shears in Zone 1 are developed to the extent that it appears reasonable to assume failure with a shear strength equal to that of the filling material. They may be regarded as planar ~~area~~ critical sections of the dam foundation. Although slight offset may occur as the result of minor faulting, the shear plane spacing is too close for it to reduce the risk of failure.

For planar failure in Zone 1 a shear value intermediate between rock flour and rock fragments with a rock flour matrix can be assumed.

(b) In comparison with Zone 1 bedding plane shears in Zone 2 are poorly developed. It is considered that the shear strength assumed for the shears in this zone should be greater than the filling material for the following reasons: undulations of greater amplitude than the thickness of the sheared zone; poor general planarity; wide spacing of the shears; minor offsets due to disturbance by faults, veining etc.

For planar failure in Zone 2 a shear value intermediate between fragmented rock and solid rock can be assumed.

3. Vertical Joints.

(a) Two sets of vertical joints run parallel to the river and show not greater than 25° difference in strike and 15° variation in dip between them. At the surface these joints are generally open and are filled by mud or surface debris. At depth they are generally tight although they usually show discolouration due to percolating water. However drill cores and adit 7 show that rock flour may locally be present along these joint planes. The thickness of such rock flour is rarely up to $\frac{1}{2}$" and is possibly related to movement due to neighbouring faults.

(b) Two fault zones, approximately parallel to the above joint systems, have been located, one at 77' in adit 7 and the other in the vicinity of DH5447 (also found at 130' in DH5433). It is possible the cliff high on the left abutment may be related to the fault in adit 7. Such faults show that movement has occurred in the direction of the vertical joints and it is possible further faults may exist; core recovery and surface outcrop high on the L. abutment is locally poor.

(c) Generally the vertical joint systems are only locally planar and may run into or be truncated by each other. Within limits of 15-20° in strike and 15° in dip, they may show considerable variation. Continuous planar joint traces of 30' are rare. However although a fault such as that located in adit 7 could theoretically be planar the fault plane as seen in recent excavations shows a wide variation in dip.

4. Engineering Significance of Vertical Joint Sets.

(a) Although generally the vertical joint sets are not sufficiently planar, continuous or consistently filled to constitute failure surfaces with low shear strength it is considered that there may be individual continuous planes of weakness through the system. It can be assumed that the vertical joint system has a shear strength equal to that of solid rock and that the two faults have a shear strength at least equal to that of fragmented rock. It is unlikely other vertical faults are present over the critical areas of the dam foundation.

pp. for.
G. Rawlings.

c.c. - C.C.E.
E.C.D.
GL.III.
Dams II.

Accompanied by: A1239oB

Form No.H.E.10 GR/SM

THE HYDRO-ELECTRIC COMMISSION

TO	SUBJECT	FROM
GEOLOGIST-IN-CHARGE.	DETAILED GEOLOGICAL INVESTIGATION OF THE RIGHT ABUTMENT OF CETHANA DAMSITE.	G. RAWLINGS.

III. RIGHT ABUTMENT.

1. Bedding Plane Shears.

(a) α, β and δ shears may also be recognised on the right abutment and although the general pattern is similar, the precise location of the α shears differs from those on the left abutment. The zonation established previously can also be applied to the right abutment.

(b) Zone 1 shows three major α shears which are more prominent in outcrop than their counterparts on the left abutment and it may be assumed that in consequence they are thicker at depth. The lowest of these three shears has been taken as the base of Zone 1. Immediately downstream of the foundation the uppermost of these shears appears at the Upper Conglomerate/Quartzite boundary. As these shears are traced Westwards, down the limb of the anticline, they decrease in outcrop thickness. Most bedding planes in Zone 1 contain β or δ shears. The average shear plane spacing in Zone 1 is one/3'.

(c) As seen in Adit 8 the highest α shear consists of 18" of rock flour and rock fragments separated by thin beds of quartzite. The individual shears within the main shear may thicken up or coalesce with each other. The β shears are very variable in thickness and may locally show up to 2" of rock flour with few included rock fragments. The δ shears appear as thin seams of broken and sheared rock, rock flour and chlorite up to 1" thick.

(d) In the crest of the fold the rock is closely jointed and is traversed by several minor faults. These faults often contain rock flour, rock fragments, quartz and chlorite and where they intersect the bedding plane shears the latter are seen to thicken up and increase in rock flour content. This is well exemplified in adit 8 but also in DHs5430, 5435, 5436. The interaction of the faults (both normal and thrust) and the bedding plane shears has resulted in a closely jointed rock of comparatively low compressive strength especially in the area between adit 8 and fault IV.

(e) Due to their position on the fold (the left abutment is situated on the upstream flank of the anticline, the right abutment higher on the flank and on the crest) the bedding plane shears are less planar than those on the left abutment. A gradual swing in strike and reduction in dip of the bedding plane shears occurs towards the top of the dam foundation and in addition flexures of approximately 25' wavelength and 10' amplitude are characteristic of that area. However, bedding is locally reasonably planar for distances of up to 25' and permits consideration of planar shear failure.

(f) Minor faulting has produced offsets in the bedding plane shears but in places, especially where the offset is of the order of 1-2 feet, subsequent movement has taken place along the shear smoothing out the effects of the fault.

(g) Zone 2 shows entirely δ shears and is generally less closely jointed than Zone 2 on the left abutment. However DH5430 shows badly fragmented and veined rock for 40' above the lower conglomerate; this is believed to represent the Northward dipping thrust faults seen low on the right abutment.

2. Engineering Significance of Bedding Plane Shears.

(a) Bedding plane shears in Zone 1 are developed to the extent that it appears possible to assume failure with a shear strength intermediate between that of rock flour and fragmented rock. However it is considered unlikely that the bedding plane shears are generally sufficiently uniform in attitude or continuous over great enough distances to permit planar shear failure.

(b) Bedding plane shears in Zone 2 are poorly developed and a consideration of the various factors involved suggests that for planar failure the shear strength assumed for the shears should be greater than the shear strength of the filling material i.e. a shear strength of at least fragmented rock may be assumed, but it is considered that planar shear failure is unlikely.

3. Vertical Joints.

(a) Vertical joint sets comparable to those on the left abutment are present on the right abutment. They are generally open at the surface but are seen to be tight at depth. Suggestions of rock flour have been seen in the adits and drill cores but never to any significant development. Although tight they often show staining due to percolating water.

(b) No faults have been found parallel to the vertical joints but a suggestion of shearing along a joint between adits 4 and 5 indicates that movement may have occurred in that direction.

(c) General planarity is poor except for local distances of up to 30'. As on the left bank the joint systems coalesce, truncate each other or die out.

4. Engineering Significance of Vertical Joints.

(a) Due to the thin, discontinuous or absent filling and overall lack of planarity a shear value higher than the filling material can be assumed for planar shear failure along the vertical joint system on the right abutment. As a result of the spacing and intersection of the joints it is possible that failure could occur other than by planar shear, and failure by a step-wise shear must be considered as a possibility.

G. Rawlings.

G. Rawlings.

c.c. - C.C.E.
E.C.D.
GL.III.
Dams II.

Right Abutment
Investigation

LEFT ABUTMENT
CETHANA

LEFT ABUTMENT
CETHANA

THE HYDRO-ELECTRIC COMMISSION

TASMANIA

MERSEY-FORTH POWER DEVELOPMENT

GEOLOGICAL INVESTIGATION REPORT 644-Ceth-1

ON THE

CETHANA DAMSITE

BY

G. E. HALE

Accompanied by: A11153, B8349, C4991

C O N T E N T S

I. ABSTRACT.

This report contains the results of the investigation stage geological examination of the Cethana Scheme area. These results were obtained by field mapping, 24 diamond drill holes, 2 adits, 12 trenches and sluicing of the dam abutment area.

It is proposed to build a 350 ft. arch type dam and an underground power station close to it. The very narrow gorge and competent rocks make this site suitable for the proposed structures.

The rocks in this area are Ordovician quartzites and quartzite conglomerate of the Roland Conglomerate and quartzites, conglomerates, slates etc., of the Moina Sandstone Formation. The Cambrian metasediments which lie unconformably below these do not crop out but were reached by drilling. Talus, scree and soil mantle these rock types but have been removed from the abutments by sluicing.

The rocks occur in an anticlinal structure striking obliquely across the river and plunging to the west. The structure has been modified by thrust and normal faults, but the dam has been located to avoid the main fault zones.

Jointing dominates the other geological features and although the joints are open at the surface, they are normally tight a few feet from the surface. Very little clay material has been found in them, but they are limonite-coated as far as drilling has penetrated and it must be assumed that some leakage will occur along them.

Weathering has had little effect beyond weakening the bonds across joints near the surface and loosening the inter-grain bonds in the surface skin of the quartzites.

The conglomerates of the Roland and Moina beds have been suggested as aggregate and, if required, basalt could be obtained at several places downstream of the area.

II. INTRODUCTION.

1. General:

This report contains the results of the field mapping, drilling, sluicing, adit driving and trenching on the Cethana Damsite on the Forth River.

This dam is part of the Mersey-Forth Power Development. A thin arch dam 350 feet in height with an adjacent underground power station is proposed for this site.

2. Location and Access:

The damsite is located a little over 3 miles along the Lorinna Road from the Cethana Road junction, but vehicular access to the site is by a further 1½ miles of jeep track along the old Lorinna Road and down Tin Spur. Access may be gained to the camp downstream of the dam by means of the Cradle Mountain and Forestry Roads and a jeep track via Wilmot which is approximately eleven miles from the site.

3. Previous Work:

There have been no previous geological reports on the damsite, but several Department of Mines publications have covered the regional geology and the area to the west has been re-mapped by Mr. S.J. Paterson, H.E.C. geologist, as part of the investigation of the Wilmot Scheme.

3. Previous Work (contd.)

The latest Department of Mines publication covering the site is the regional map published in 1959 and designated - Geological Atlas, One Mile Series, Zone 7, Sheet No.37, Sheffield. The other publications are listed under references.

4. Method of Work:

Geology was plotted either directly onto photo-theodolite photographs or the plans produced from them. Sub-surface investigation was carried out by means of 24 diamond drill holes, sluicing, trenching, and 2 adits. A geophysical seismic survey to determine rock constants proved unsuccessful because of equipment failure.

A further programme of investigation of the dam and power station location is in progress by means of a further 17 drill holes and 5 adits.

This information is shown on plans A1153, B8349 and C4991.

III. PHYSIOGRAPHY.

1. Situation:

The damsite is located in the youthfully dissected Higher Coastal Surface (Davies 1959) just to the north of the Central Plateau boundary.

2. Nature of the River System:

The River Forth is an actively degrading river flowing in a fairly straight course from south to north and superimposed on folded Precambrian and Lower Palaeozoic rocks, which have a predominantly east-west structural trend.

The river in the dam locality shows an overall valley-in-valley structure with a youthful stream indicated by a steep, V-shaped section, fairly straight course, overlapping spurs, shoals, rapids, and a predominantly bedrock channel cut in a wider valley. The course of the river in this section is joint controlled.

There is no evidence of glacial activity in the Forth Valley near the dam, except for isolated pockets of gravels and sands which may be outwash material. Some of this type of material may be seen on the left bank opposite the mouth of Tin Spur Creek, and in the upper valley on the left bank half a mile downstream of the dam. It also occurred as pockets , which were sluiced off the bedrock on the right abutment area. The bedrock up to about 100 feet above present river level shows a stream-polished surface preserved by this lightly consolidated material.

In this gorge the rapid down-cutting by the river has outstripped its tributaries, all of which flow over waterfalls or steep rapids to reach the main stream.

At the damsite gorge the river has cut through the axis of a faulted anticlinal structure that strikes obliquely across the river. The rocks are Palaeozoic quartzites, sandstones and slates.

3. Stream Flow:

The average flow in the Forth at this point is 798 cusecs. The river at the site rises and falls rapidly in response to the rainfall on the Plateau.

4. Physiographic History:

The present River Forth has developed since the extrusion of the Tertiary basalts which split an older river system into two courses (the Mersey and the Forth) superimposed on the underlying folded rocks.

By the onset of the Pleistocene glaciation the River Forth at Cethana was entrenched to within less than a hundred feet of its present bed. There is no evidence of glaciation extending northward beyond Lorinna but the degree of infilling of the river by outwash material is unknown. There are no thick deposits such as are found in the Mersey Valley until the Paloona area is reached. It is possible that the river channel was filled completely and that the upper wide valley was cut by a meandering stream before the deeper narrow channel was exhumed.

The amount of downcutting in bedrock since the glaciation is not known but from the evidence from other areas it would seem reasonable to expect a deepening of rather less than one hundred feet.

IV. STRATIGRAPHY.

1. General:

The dam site is located on Lower Ordovician rocks, Moina Sandstone and Roland Conglomerate, but Cambrian metamorphic rocks were reached by drilling and occur in the storage upstream of the Devonian Dolcoath Granite. All these rocks are lightly covered by Recent scree and talus and perhaps some Pleistocene drift.

The proposed dam foundation is located entirely on the Roland Conglomerate, and the thin scree and talus (up to a maximum of about eight feet) has been removed by sluicing.

2. Cambrian:

Rocks considered to be of Cambrian age (Burns 1961, Jennings 1963) outcrop to the north of the dam area, near the Cethana camp site, and upstream of the Dolcoath Granite. Drilling in D.H.5407, 5411 and 5419 penetrated to these rocks under the dam area.

The downstream outcrop occurs as the upper plate of a thrust block and is entirely chert. As far as can be determined on poor exposures it lies unconformably below the Roland Conglomerate.

Upstream of the granite the Cambrian rocks are mainly porphyries, cherts, greywackes, siltstones, sandstones, conglomerates, and quartzites, and have been assigned by the authors quoted to either the Lorinna Greywacke (Jennings 1963) or the Bull Creek Formation (Burns 1961, Jennings 1963).

The drill cores contain dark grey to black greywacke siltstones, quartzites, quartzose conglomerates and quartz-chlorite rocks. All show a strongly developed cleavage parallel to the bedding. The rocks are often sheared parallel to the cleavage and the shear zones filled with chlorite, carbonates and pyrite. Pyrite and quartz veining are common throughout. The pebbles in the conglomerates are predominantly quartz, but some schist pebbles were noted.

2. Cambrian (contd.)

In the cores these rocks are found to be unconformably below the Roland Conglomerate, for the bedding in the younger rocks is nearly horizontal at the drill hole sites and the compositional banding of the Cambrian dips at 60° - 65°. However, in D.H.5411 the contact has been sheared and recemented by silica. Correlation with the formations cited above does not appear to be possible with the data available.

The rocks are fresh and the cores reveal no features likely to adversely affect the dam foundation. They occur at depths of 165 feet in D.H.5407, 225 feet in D.H.5411 and 257 feet in D.H.5419.

3. Ordovician:

(i) Roland Conglomerate

As described by Jennings (1958 and 1963), this Formation is "a dense recrystallised quartz conglomerate, generally but not invariably coloured pink, composed of sub-rounded fragments of quartz, quartzite and quartz-schist in a fine-grained siliceous matrix." Usually the matrix is subordinate and individual pebbles are in contact. The bedding is massive and rarely noticeable, fossils are absent, and no grading is apparent. It is regarded as a terrestrial deposit.

Although the Roland Conglomerate is predominantly coarse-grained with few quartzite beds, at Cethana 120 feet in the middle of the Formation is quartzite. Individual boulders up to about 2 feet in diameter can be seen but they are usually less than one foot in diameter with a preponderance of them about one inch in diameter. The pebbles show no regular variation in size but in the lower parts of the Formation more pebbles derived from the underlying Cambrian rocks occur e.g. at the bottom of the Conglomerate in D.H.5919.

The colour of the rocks is variable, being reddish to purple where haematite occurs in the matrix and has penetrated into pebbles, and lighter-coloured where quartz-veining, pyrite, carbonate and chlorite predominate. Many red-coloured pebbles are seen but are not always as significant (as a colouring agent) in the fresh rock as in the leached or weathered outcrops.

At the dam site these beds are approximately 500 feet thick and have three distinct members:

160'	Upper Conglomerate
120'	Quartzite and Conglomerate
200'	Lower Conglomerate

Because of the folding accurate thicknesses have not been measured, but because of local variations in thickness this is of little importance.

The bottom of the Lower Conglomerate is not exposed in this area, but elsewhere the contact is unconformable, as it appears to be in the bottom of holes 5407, 5411 and 5419. However, the contact in all cases shows signs of shearing, and decollement action between the two rock types is suspected.

These beds are well exposed on the dam abutments and river banks in the cliff faces rising from the water surface. They are massively bedded coarse conglomerates showing little matrix.

(i) Roland Conglomerate (contd.)

The rock fragments are mainly quartzite and are sub-rounded and fairly well sorted.

The upper part of the bed passes abruptly from conglomerate to quartzite and in most places the contact is well cemented.

The quartzite is more variable both in thickness and composition than the conglomerate beds, being mainly composed of silt-sized particles, but pebbles can be found throughout. Pebble beds occur at all levels but are especially common at the bottom and the top. At the top beds of quartzite and conglomerate interfinger along the contact.

The jointing and weathering pattern is different in the two types, and the quartzites are characterised by a thin, sandy soil cover and flatter slopes wherever they crop out.

The Upper Conglomerate is indistinguishable from the Lower Conglomerate in appearance and composition on most exposures. There is, however, a tendency for it to become finer and to contain more matrix towards the top, and there is a clear cut bedding plane separating it from the lowermost bed of the overlying Moina Formation. The outcrop of this bed is usually in cliff faces or steep rubble covered faces.

The colour of all these beds is variable from light-grey to purplish-green. Red colours are also common but have a patchy distribution. The quartzite beds are usually reddish in outcrop and the colour banding present often has the appearance of current bedding. However, no true current bedding has been detected here.

(ii) Moina Sandstone

The general picture of the formation has been described by Jennings (1958 and 1963) as follows: -

> "Generally speaking, the formation is fine-grained, dense and siliceous. It consists largely of quartzite and quartz sandstone with minor bands of shale, conglomerate and grit. The bedding planes are well developed and are accentuated by bedding plane slip during concentric folding. Individual beds are usually of the order of a foot or so thick and these, in conjunction with a strongly developed joint system, divide the rocks into a blocky form. Flaggy bedding occurs, particularly where the lithology is more variable".

As none of our major structures are located on these beds, no detailed account of them and their differences from the above general description will be attempted. Descriptions of all the rock types in the dam vicinity can be obtained from the logs of our drill holes 5421, 5422, 5424 and 5427.

Hornfelsing near the Dolcoath Granite and folding and faulting prevent the accurate matching of the sections through this Formation found near the dam site. But mapping and drilling downstream from the Roland Conglomerate outcrop indicate that the bottom of the Formation is predominantly quartzites, quartzite conglomerates and breccias. These pass upwards into quartzites highly leached to appear in a semi-indurated state, slates, conglomerates with sparse pebbles in a quartzitic matrix, and finally at the top of this sequence a thick tubicolar sandstone or quartzite of considerable thickness.

(ii) Moina Sandstone (contd.)

Many of the beds at all levels contain tubicolar casts which are considered to be fossilised worm burrows.

4. Quaternary:

Scree and Talus

As mentioned above the conglomerates usually occur in cliff faces or in steep faces covered with boulders of angular shape. The quartzites have flatter slopes with a thin sandy soil covering and fewer angular boulders. Large blocks of rock up to 20 feet across have fallen from the cliffs into these deposits or the river bed.

Trenching and sluicing have shown these deposits to be normally less than five feet in depth and unconsolidated.

Deeper deposits of scree consisting of loose, angular blocks of indigenous rock types up to about 1 foot across occur in the following places:

(a) R.H.S. - the gullies above D.H. 5914, above B.M.2577, and above Adit 3.

(b) L.H.S. - the gully behind the rock face above survey point 216 and along the river bank between D.H. 5412 and D.H. 5419.

All the gullies following faults contain some of this type of deposit.

The depression occupied by Fault IV has been sluiced but examination of trenches and observations during sluicing indicated depths of up to 10 feet of talus containing sub-rounded boulders rather than scree. Above the sluiced area the material remaining is a typical scree deposit.

It is possible that the lower and thicker parts of this deposit were laid down by river action and that this deposit, like the semi-consolidated gravels occurring in pockets on the polished bedrock in the right abutment area, may be much older than the scree and talus overlying them. Similar deposits occur in the vicinity of point XXIVB.

5. Igneous Rocks:

Dolcoath Granite

This granite occurs about $\frac{1}{2}$ mile upstream of the dam area and is of little importance from engineering considerations. It is usually cream to pink in colour and composed of plagioclase, orthoclase, quartz and biotite. It is too deeply weathered to be considered as a source of aggregate.

It has produced some baking effects in the Moina Sandstones and is the most probable source of minor mineralisation in the dam area. Tourmaline, dolomite, haematite, pyrite, arsenopyrite and some chalcopyrite have been introduced into both Cambrian and Ordovician rocks at the dam site. Gold, tin, molybdenite, bismuthinite and wolframite have been found in the locality.

5. Igneous Rocks:

Dolcoath Granite (contd.)

The granite has been intruded as a stock about 1 mile by 1½ miles in extent. Its boundary upstream is against Cambrian rocks and downstream against the Ordovician Moina Sandstone.

Dr. I. McDougall, of the National University, Canberra, has assigned it an Upper Cambrian to Lower Ordovician age on the basis of laboratory determinations, but the field evidence clearly indicates that it is of Devonian age.

V. STRUCTURE.

The whole of the dam area is in that part of the Round Mountain Synclinorium (Jennings 1958) called the Cockatoo Ridge Anticlinorium, a second order fold with a width of about 2000 feet. There are differences in detail from the scheme proposed by Jennings but they are not important from the engineering aspect. This anticlinorium lies between a thrust fault that crosses the Forth River in the old Cethana camp area, and the Dolcoath Granite.

The thrust fault dips at about 30° northwards and has carried the Cambrian cherts and Lower Conglomerate bed of the Roland Conglomerate over the grey tubicolar sandstone which is the highest bed of the Moina Sandstones present in the area.

Immediately south of this the Moina Sandstones are folded into 6 tight folds. Upstream of these the folds become wider as lower beds are exposed and the lowermost beds (the Roland Conglomerate) show the widest folds. Towards the granite the lower beds are again exposed and the folds become tighter. The folding is all of the inequant type and is broken by faulting and thrusting. The thrusting in the area may arise from a surface of decollement between the Cambrian and younger rocks but this cannot be proved.

The main construction area lies between survey points F1 and XXVII A, and the structure of this area only will be discussed in detail.

Between these two points, the Roland Conglomerate is folded into an anticline. But the simple anticlinal picture is upset by the disturbance called Fault I which is a thrust carrying the Upper Conglomerate bed and part of the Quartzite Member over the rest of the Quartzite and the Lower Conglomerate Member. This produces the effect of two anticlinal crests, one truncated below and the other truncated above the zone designated as Fault I.

Because of lack of exposure, it has not been possible to measure the displacement on Fault I but it does not seem to be more than tens of feet. It follows that the original structure was an asymmetrical anticline with a steep limb on the northern side. The thrust towards the south carried the crest of the fold back over the lower beds giving the final appearance of two crestal zones. The drag caused by the movement steepened the upstream limb of the upper plate but left the lower plate practically unchanged on the northern limb. In the lower plate the beds at the axis of the fold and southwards of it have been overturned towards the south. This is most clearly seen near B.M.2718 and in the Moina beds above point XXVIII A.

The alternative solution that the upper plate has been thrust from a fold beyond a syncline to the north eliminating the syncline seems unlikely on present evidence.

V. STRUCTURE (contd.)

Faults III and IV are normal faults neither of which has been traced into the upper plate, although there is sufficient breakage in that plate to fit them in a number of places. The overturning in the Moina beds above point XXVIII A, i.e. in the downthrown block of Fault IV, demonstrates that Fault I postdates Fault IV. The trace of Fault II shown on A11153 has been developed geometrically. There is sufficient field evidence to justify the location shown but its relationship to Fault I has not been established.

The folding is predominantly parallel and slippage has occurred on bedding planes, especially in the quartzite where bedding planes have been extensively slickensided. These movements may be traced as small fault zones following the bedding until they break through a bed to a higher bedding plane by means of thrusts with a displacement of about a foot or less. This movement displaces the higher bed towards the anticlinal crest. Jointing, particularly that at right angles to the fold axes, is very noticeable as it controls the river course and the direction and angle of cliff faces. Longitudinal, transverse and diagonal joints consistent with folded rocks are all represented as well as other systems complementary to the faults.

Although cleavage is well developed in the underlying Cambrian rocks, none is developed in the conglomerates or quartzites except near fault zones. In such places the shearing is indicated by chlorite-filled shears in the matrix of the conglomerates and shearing and chlorite replacement in the quartzites.

VI. ENGINEERING GEOLOGY.

The dam has been located to avoid the surface trace of the known faults. The topography of the site is acceptable and an advantage is that most of the foundation is on the southern limb of the main anticline.

1. Condition of Fault Zones:

(i) Fault I

The dip and rock conditions vary considerably along this thrust. Where it crosses the river the dip is nearly vertical and the zone is represented by two recemented crush zones in a closely jointed zone about 20 feet wide. The cement between the broken rock fragments is chlorite, and where the chlorite is unweathered there is a weak but water-tight bond present. In some places e.g. near D.H.5415 the chlorite has weathered to yield a very thin clay slick along the fault zone.

The dip of the fault zone flattens as it rises towards the south along the abutment areas, and although the fault zone can be seen in a few places only, especially on the left bank, the rock breakage appears to be confined to a fairly narrow zone and the chlorite cement is mostly unweathered.

The underground condition of this fault is unknown.

(ii) Fault II

In Adit 2 this fault appears as a thin zone of rock flour dipping towards the river at 40° and varying from about $\frac{1}{4}$" to 2" in width. The rock flour is damp, stained with limonite and is almost entirely silt-sized quartz particles; it has virtually no clay mineral and no coherence.

(ii) Fault II (contd.)

The rock between the fault and the adit portal is extensively jointed and carries water. The jointing to some extent is related to the fault but the general relaxation may be due also to the gorge-cutting process and release of stress. The joints below the fault plane are tight and dry for some distance beyond the fault.

(iii) Fault III

This fault occupies a scree-filled gully on the right bank. As far as can be seen the fault is vertical and has a down throw to the north of about 40 feet. The fault has been re-cemented mainly by quartz and appears to be tight. It has not been examined on the left bank or by any sub-surface exploration.

(iv) Fault IV

This fault has been revealed by sluicing from PY10 to PY K, but its trace has not yet been exposed on the left bank. It is a near vertical normal fault downthrowing to the north. The lack of marker beds makes it difficult to measure the throw but it seems to be in the order of 150 feet.

The fault zone is made up of about 30 feet of closely jointed sound rock, with a zone of rock flour about 2" - 4" wide following a fairly straight trace up the depression revealed by sluicing. However, the rock flour is not always confined to the one plane but follows branching and parallel zones in a few places.

On the river bank the fault was revealed by brecciated rock fragments recemented by silica. When the surface was broken the underlying rock flour, composed almost entirely of quartz, was found to be friable and easily dispersed by water.

The dam was moved downstream to avoid this fault but the Intake Structure and the upstream Coffer Dam are located on or near it.

(v) Faults similar to Fault II have been revealed in Adit 4 but progress to date is not sufficient to describe them. Like II their surface expression is negligible, but they contain thin bands of wet rock flour and are associated with considerable relaxation of the surface rock. As far as can be seen they do not cut any major part of the engineering structures.

(vi) Bedding Plane Faults

These faults initiated during folding are hardly distinguishable from the bedding or from jointing but there has been demonstrable movement in some places and slickensided surfaces are common along many beds.

The breaks are revealed as platy areas especially common in the Quartzite Member of the Roland Conglomerate. The plates are rock fragments cemented by chlorite material which breaks down to a clayey paste. In this weathered condition the bond between the particles is extremely weak and breaks down completely on wetting. This in turn leads to a blocky disintegration of the Quartzite beds as a whole.

(vi) Bedding Plane Faults (contd.)

These breaks can be seen clearly on the right abutment between PYA and the Quartzite boundary at PY17 and in many parts of the same bed along the whole of this abutment.

The corresponding beds on the left bank are broken in the same manner. The boundary between the Upper Conglomerate and the Quartzite is paralleled by a chlorite-cemented shear zone from Fault III to Fault IV, but weathering is fairly limited as far as can be seen and the zone is only a few inches thick.

A broken zone revealed in Adit 1, between the Lower Conglomerate and the Quartzite, is sheared but quite hard in outcrop, but in the adit in a wet condition it breaks down to rock fragments of small dimensions (2" x 2" x $\frac{1}{2}$") in a weak clay matrix, which is easily scraped out by a geological hammer. Where it was cut by the adit it is about 2 feet wide, but it becomes narrower along the drive in the downstream direction. This break follows the strike and dip of the beds and will be cut twice by the Diversion Tunnel, but this should not cause much difficulty; the adit is standing unsupported and there has been no excessive overbreak on this fault since it was opened up.

Further adits and drilling have been planned to examine these faults at dam foundation level on both banks.

(vii) Faults along river

No major fault has been located parallel to the river or in its bed. D.H.5414 has been drilled to explore this possibility but, although the core is broken, no major break was detected. However, the nature of the core is such that a number of small breaks could be postulated. Continuous rock bars at many places in the river bed and the general correlation of beds from one bank to the other also suggests that no major fault zone lies in the river bed.

2. Condition of Joints.

Jointing is universal and has determined the river course, and the shape and orientation of the cliff faces. It can be seen from the list of joint directions and the stereograms on Plan C4991 that a wide distribution of strikes and dips are present.

Many joints at the surface are open and are filled with rock fragments and soil supporting a heavy vegetation, and gaps several feet in width are visible. However, drill holes and the adits show that this is a surface phenomenon and that underground the joints are thin, limonite-stained, and usually tight, containing no clay or rock flour and are rough. But there are also many joints, fractions of an inch in width, which carry water and whose open nature is indicated by the presence of crystal faces on quartz and pyrite. These are seen throughout the Ordovician and some extend down into the Cambrian rocks.

2. Condition of Joints (contd.)

No harmful fillings have been seen in these joints and it is considered that normal washing out and grouting will be effective in preventing leakage through them.

Adits 2 and 4 show a considerable relaxation of the rock near the portals but this may be due in part to the faults revealed in them. Adits 1, 3 and 5 and most cliff faces show little surface relaxation on the joints.

In Adit 3 jointing in the Quartzite, and approximately parallel to the river and parallel to the bedding is most pronounced near the portal but becomes less in the Conglomerate. At the Power Station site only a few widely spaced heads parallel to the river are noticeable. Widely spaced mineralised zones nearly at right angles to the adit, and dipping mostly but not all away from the portal, are located towards the power station location. These are up to 3" wide. Near the portal the joints are wet and iron-stained but under greater cover most joint faces are dry and covered by pyrite. However, even at the greatest cover some joints carry water and deposit limonite on the adit walls.

3. Groundwater:

The occurrence of groundwater is controlled by the joint and fault pattern. Water under pressure is still flowing from D.H.5409, 5410 and 5404. This water has deposited limonite at the surface but analysis and concrete test blocks placed in the flow from D.H.5409 have revealed no deleterious constituents or effects.

It is considered that leakage at all depths under the dam will be possible and that control of this by grouting and drainage will be necessary and that some joints will lead water into the excavation for an underground power station.

Water pressure tests are being carried out on the drilling now in progress. The one hole completed (D.H.5429) showed very little water loss.

4. Weathering:

The effect of weathering is slight. Except for the chlorite along faults that breaks down to a clayey residue, the rocks have only a very thin weathered skin in which the quartzose matrix has been weakened leaving the rock with a rough, sandy surface. Pyrite in the rocks has been altered to limonite and leached from the exposed surfaces and deposited in the joints.

Physical weathering has resulted in a general relaxation of the joints close to the surface, and this has caused a blocky condition in the first few feet of the rocks over most of the area. The adits show that this does not persist at depth. The thin soil produced by weathering has been removed from the abutments by sluicing and it is considered that when the rock is excavated to dam foundation level the blocky surface will have been removed entirely.

However, some effect of the weathering of the chlorite-filled bedding plane faults may persist and this is being investigated by the drilling and the adits now in progress.

Adit 3 at dam foundation level shows sound jointed conglomerate with tight, iron-stained joints and bedding planes.

5. Landslides:

Despite the very steep side slopes along the Forth and its tributaries near Cethana, there is little sign of landslipping either on natural slopes or those influenced by road cuts or other excavations. Therefore except for the danger of occasional rock falls of small dimensions no difficulty in siting roads is expected.

In the vicinity of the dam there are many large blocks of rock up to 20 feet across that have fallen from cliff faces and are now more or less embedded in the talus and scree on the river banks. Sluicing has shown that these are not always easily displaced but they can easily be removed by the use of small amounts of explosives. It is thought that such boulders and the scree and talus will generally be removed during the early construction stages and will be no permanent threat to construction.

A greater problem is posed by large blocks of rock several tons in size which remain on the high cliffs above the site. These appear to be semi-detached from the main rock mass by joints and bedding planes.

Because of the clean nature of both joints and bedding planes it is not considered likely that these blocks will slip in the same manner as dolerite fails. However, some of them may be potentially dangerous. No satisfactory methods of determining which are dangerous have been developed and it seems that either none or a great many of the cliff faces should be scaled down before commencing construction. Because of the difficulty of reaching potential rock falls, and the uncertainty as to whether the removal of some blocks using explosives actually improves the overall safety of the cliffs or causes further deterioration, scaling down could become excessively expensive with no real gain in safety.

Attempts to remove small blocks of this kind above the portal of Adit 2 proved futile despite the use of explosives and all but a few superficial pieces are still in their original position.

6. Physical Properties of the Rock:

The following data, determined by the Testing Engineer, H.E.C. are all that are available at present. They were determined on diamond drill cores.

No.	Density lb/cu.ft.	Wave Velocity ft/sec.		Resonant Frequency	Dynamic Modulus lb/in^2 x 10^6	
		Longit.	Transv.		ASTM Method	Jap.Method
CD1	168	17500	14760	15080	11.0	8.5
CD2	182	17500	14500			9.2

CD1 is Conglomerate and CD2 is Quartzite from the Roland Conglomerates.

7. Materials for Construction:

It has been considered that a large part of the aggregate needed would be produced from the dam foundation excavation which is in the Roland Conglomerate and testing of this material has commenced. Pyrite, and difficulty in sorting out the chlorite-rich zones in the Quartzite Member, may prove troublesome in this.

Basalt is available near Cethana Village and along the valley sides south of the site but has not been examined.

Other areas of Roland Conglomerate, and quartzite and conglomerate beds of the Moina Sandstone outcrop nearby and have been suggested as quarry sites.

The massive pyroclastics of the Cambrian strata, and the Dolcoath Granite occur nearby but have not been examined seriously. The granite particularly is deeply weathered.

As the coffer dams are concrete structures no search for clays has been carried out. Thin talus deposits, weathered granite and basalt are likely sources for such materials.

8. Location of Engineering Structures:

(i) Dam.

As drilling and aditing now in progress will reveal the actual conditions at foundation level, no comment beyond that already made is of value at present; i.e. the dam is located clear of all known faults and on the Roland Conglomerate where it occurs dipping to the south on the upstream limb of the main anticline of the area. It is anticipated that the surface weathering effects will have disappeared at the proposed foundation level.

Rock bars with no obvious faults cross the river at about the proposed location. A few large fallen blocks of rock, some thin gravel and few potholes or deep spots may be found but no deep buried channel is anticipated in the river bed.

(ii) Coffer Dams.

The upstream coffer dam is located on the Roland Conglomerate on the left bank and a quartzite member of the Moina Sandstone on the right bank. Continuous outcrop across the river bed can be seen except where a few boulders obscure it. However, Fault IV crosses the river here and will be under the dam at about the centre of the river. Dental treatment will be needed on the crush zone associated with this fault.

The lower coffer dam abuts onto the Lower Conglomerate on both banks and this should be satisfactory. The river bed is covered by boulders, logs and gravel in this locality and has not been examined. However, it is thought that rock bars present near by indicate sound rock conditions generally in the area.

(iii) Diversion Tunnel.

This is located in the Roland Conglomerate and no great difficulty is considered likely because, except for the extensions of the bedding plane fault seen in Adit 1, the tunnel will be located in sound rock similar to that seen in Adits 1 and 3. The thin talus at the inlet portal should be removed before tunnelling is commenced. Hydraulic conditions call for the lining of this tunnel, but no support

(iii) Diversion Tunnel (contd.)

should be necessary except perhaps rock bolts where the fault is encountered.

(iv) Intake Shaft.

This is located in the blocky ground in the jointed fault zone along Fault IV. Further consideration of its location is needed following more drilling and field mapping. At present, it seems that the ground will be sound but broken in blocks a few inches across and that at least rock bolt and mesh, or perhaps greater support, will be needed during the excavation. A permanent lining of some kind will be necessary to keep the blocky rock in place and prevent the removal of fault gouge if this is encountered. D.H.5430 drilled down the shaft location shows decomposed quartzite between 66 and 86 feet.

(v) Power Station.

Adit 3 has reached the crown of the proposed power station but has not been logged. Indications are that the effect of jointing on the shape of the adit is slight; the rock appears to be a hard, sound, homogeneous conglomerate and shoots to good shape with no overbreak. Some widely spaced, near vertical joints cut diagonally across the power station axis but are clean and tight. The adit is at present dry but some joints close to the power station constantly drip water and deposit limonite.

It seems that the power station when excavated will be subject to groundwater but it is possible that pre-excavation grouting might prevent this if the expense of drilling can be justified.

(vi) Tailrace Tunnel.

This tunnel is in the same rock type, the Lower Conglomerate, as the power station and no difficulty in driving and supporting this tunnel is anticipated.

(vii) Road Access Tunnel.

This tunnel passes through the Roland Conglomerate and the rock should be sound. However, it crosses Faults III and II and passes close to Fault I, and although Fault III is recemented and should cause little concern, the rocks near Faults II and I are closely jointed. The joints have opened near the surface so that more overbreak is expected and more support may be required in this tunnel than in the others. The rock conditions in Adit 2 indicate that this should not be excessive and that a safe tunnel can be constructed in the location shown.

VII. WORK IN PROGRESS.

Adits and drill holes now in progress are designed to ascertain:

(i) if the dam is favourably located with regard to Fault IV and the bedding plane faults,

(ii) if the intake shaft should be re-located because of the broken rock associated with Fault IV,

(iii) if the power station has a favourable orientation with regard to the jointing pattern,

(iv) the rock conditions at depth in the proposed location of the main structure,

VII. WORK IN PROGRESS (contd.)

(v) water losses under water pressure testing.

VIII. CONCLUSIONS.

1. The foundation rocks at Cethana are adequate to carry the structures proposed.

2. In general the engineering layout is satisfactorily located with regard to the rock structures as far as they have been investigated, and it is thought unlikely that, except for the intake shaft, a major change will be required in the present proposals.

3. No reservoir problems are foreseen.

4. No major landslide problems seem likely in the reservoir or construction area. Local rock falls are likely.

IX. RECOMMENDATIONS.

1. Further investigation of the actual rock conditions particularly at the location of the subsidiary structures is still required for design details.

2. Further determination of rock properties by geophysics, in situ and laboratory testing, is desirable.

3. Further investigation of materials for construction is required.

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CETHANA

JOINT DIRECTIONS

R.H. BANK

Location 1.	008°W.64°
Quartzite	090°N.45°
(N.N.E. point 495)	046°E.45°
	005°W.75°
	084°N.31°
	163°N.14°
Location 2.	114°N.30°
Quartzite with thin	012°W.71°
bands of conglomerate	093°S.67°
	027°E.88°
	081°N.81°
	055°S.63°
	036°E.82°
	146°S.43°
	066°N.72°
	141°N.83°
	141°S.83°
	135°S.81°
Location 3.	028°E.79°
Conglomerate	023°W.76°
	063°N.82°
	084°S.38°
	062°vert.
	089°N.52°
	160°W.67°
	016°W.76°
	031°E.44°
	168°E.66°
Location 4.	024°E.81°
Conglomerate on	011°W.66°
track.	101°N.77°
	069°N.64°
	174°W.73°
	149°S.62°
	166°W.75°
	137°N.77°
	078°S.60°

L.H. BANK

Location 1.	012°W.83°
Quartzite	008°W.77°
	125°N.54°
	100°S.18°
	076°N.83°
	031°E.26°
	081°N.87°
	123°N.54°
Location 2.	086°N.48°
Quartzite	005°W.72°
	150°N.55°
	108°S.77°
	086°S.86°
	012°W.72°
	083°S.26°
	144°S.82°
Location 3.	018°W.86°
Quartzite	114°S.31°
	084°N.16°
	170°E.70°
	105°N.69°
	133°N.84°
	051°S.40°
	070°N.36°
	086°S.42°
	124°N.30°
Location 4.	004°W.76°
Quartzite	043°E.38°
	020°E.86°
	081°N.80°
	092°S.75°
	137°S.38°
	084°S.18°
	011°W.84°
	010°E.81°

FORM No H.E. 443

DRILLING RECORD

SCHEME:- MERSEY - FORTH

LOCATION:- CETHANA DAM SITE

POSITION PLOTTED ON DRAWING No.: Xs 544

DATES: (a) DRILLED: March '57 (b) WATER TABLE:

METHOD USED: D.D. DIAMETER: Nx: Bx: Ax:

SITE REMARKS:

POSITION	CO-ORDINATES:	E.	N.	HOLE No. 5401
	ON LINE: F1/VI	BEARING: 0° 00'	AT CH:	
	FROM STN.: F1	BEARING 335° 23'	DIST.: 96'	FILE No.
LEVEL.	SURFACE:	FORMATION:	WATER TABLE:	
	423			
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET 1 OF 2 SHEETS
	~~VERT/HOR~~/INC:	50°	150° Mag.	

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	0'						Conglomerate — pebbles (pink) 3/4"-1½" rounded: matrix quartz granules and quartz: pebbles mainly pink quartzite. Some signs of weathering in matrix.
	5'						Joints of 3" spacing, break pebbles.
	10'						36"-4'3" Joints with mica: some weathering: core broken.
	15'						haematite joints to 5'5" with fine crystal quartz. To 6'8" joints 60°: incipient and 2" apart.
							7'3"-7'10" open joints.
	20'						
	25'						Haematite cement replaces quartz matrix ordinary cement to 28"; thick haematite, chlorite, pyrite but smaller pebbles. Joints 60° 6" apart.
	30'						Broken core: haematite: open holes: weathered joints: quartz crystals, pyrite, etc. Conglomerate and large pebbles: less matrix: appears redder: haematite, pyrite in matrix: joints 60°+ up to 1' apart.
							34'-34'1" - joint open with pyrite and quartz crystals (weathered) - clean matrix
	35'						38' - " "
							35'-39' (Caving of hole - drillers log)
	40'						
							Joint: clay weathering: fine conglomerate from 41'
	45'						
							49'-54' fine conglomerate with less matrix from 50'
	50'						then quartz
							Joint up to 2"
	55'						more milky quartz from 54'→: matrix dark
	60'						all joints up to 2' apart.
	65'						68'10": 2' whitish conglomerate: then purple to 73'3"
							73': close joints: some vertical: some 50°
	70'						74' Weathered haematite boxwork.
	75'						Joints up to 6" apart, matrix leached out leaving purple veins.
	80'						
	85'						
					60/		open 60° joint: weathered with crystal quartz
	90'						92'-93' heavy pyrite + haematite along open joint with clay
	95'						from 13'-104': pyrite and haematite cement mineralisation: pebbles generally less than 1"
	100'						

FORM No. H.E. 443

DRILLING RECORD

SCHEME:- MERSEY - FORTH
LOCATION:- CETHANA DAM SITE
POSITION PLOTTED ON DRAWING No.: Xs 54A
DATES: (a) DRILLED: March 57 (b) WATER TABLE:
METHOD USED: DD DIAMETER: Nx: Bx: Ax
SITE REMARKS:

POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5401
	ON LINE: F1/V1	BEARING: 0° 00'	AT CH:	
	FROM STN.: F1	BEARING: 335° 23'	DIST.: 96	FILE No.
LEVEL	SURFACE:	FORMATION:	WATER TABLE:	
	423			
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET 2 OF 2 SHEETS
	~~VERT/HOR~~/INC:	50°	150° Mag.	

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.6 0.9 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	100'						Conglomerate - joints up to 3" apart
	5'						Conglomerate - black matrix milky quartz pebbles.
	110'						110' coarse pebbles: pyrite matrix matrix dark.
	15'						finer with better sorting: black matrix joints up to 2".
	120'						from 119' matrix red and coarser: some black slate? pebbles
	25'						reddish matrix: pebbles up to 2": appear to be beds of matrix 1" across and banded.
	130'						124': 2 joints with clayey material.
	35'						Joints rough with no mica or other minerals.
	140'						133'4" - 138' haematite matrix and joints.
	45'						134' Joint open with weathered mica and pyrite.
	150'						1140, 1143, 1144 } quartz veins at 45°
	55'						Joints here may be silica and not clay lined.
	160'						Core broken with haematite in vertical joints.
	65'						154'8" " rough open weathered joints.
	170'						From 164' - haematite cement with pyrite.
	75'						168'9": sp. haematite is fresh and black jointed up to 1', closed and usually haematite filled: some with yellowish material.
	180'						179-181' Very coarse conglomerate Series of 60° joints in big pebbles.
	85'						183'1" broken core with haematite and vertical joints.
	190'						187' " weathered joint with haematite and mica 188'9" : haematite gone: pits in haematite cement * pyrite. End of hole 189'3"
	95'						Logged G. Hale
	200'						

DRILLING RECORD

SCHEME:- MERSEY - FORTH

LOCATION:- CETNANB FARM SITE

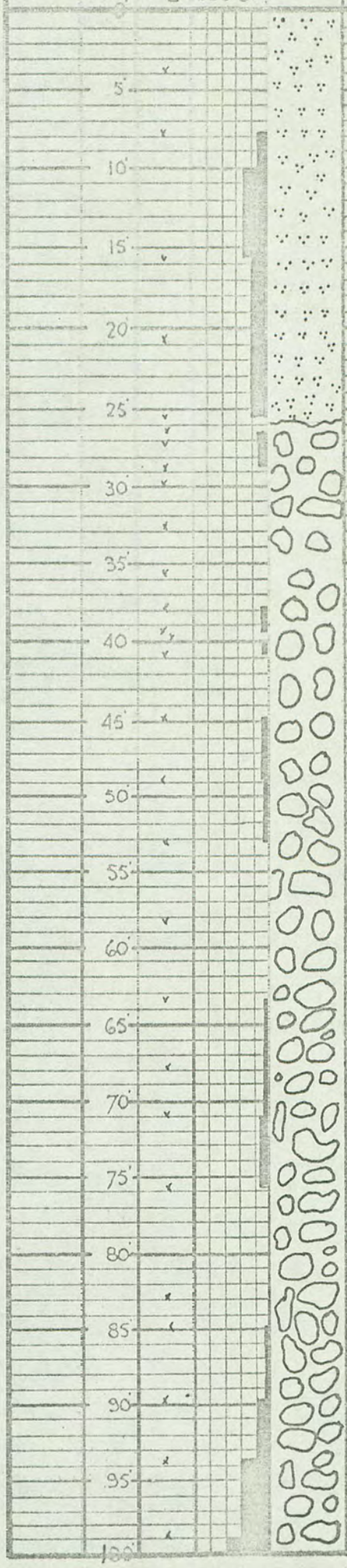
POSITION PLOTTED ON DRAWING No.: Xs 544

DATES: (a) DRILLED: April 54 (b) WATER TABLE:

METHOD USED: D.D. DIAMETER: Bx : Ax.

SITE REMARKS:

POSITION	CO-ORDINATES:	E.	N:	HOLE No. 5403
	ON LINE X1 / 1118	BEARING: 0° 00'	AT CH:	
	FROM STN.: X1	BEARING: 25° 02'	DIST.: 159'	FILE No.
LEVEL.	SURFACE:	FORMATION:	WATER TABLE:	
	430			
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET 1 OF 2 SHEETS
	VERT/~~HOR~~/INC.:			



REMARKS

Current-bedded fine quartzite: dark red colour open joints.

Joints to 25' are iron-stained (weathered)

26': Constant dip of 60°.
Clean straight bedding plane

Conglomerate—pebbles to 3": patchy matrix with smaller pebbles: haematite staining red oxide to 34': pyrite in haematite cement and along joints.
Joints at 30°, 45°, 60'-80°. Core breaks up to 18" lengths.

To 43'6": As above. Pebbles appear to be finer.
58'10": Fine grained; patchy.

Separated above and below by bedding planes at 10°: strikes differ.
70' - a 6" bed fine quartzite: bedding 20°
strikes vary.
71'6": 5" fine quartzite: bedding plane at 30°
73'9": Not as red as previously (both pebbles & matrix)
Conglomerate with pebbly matrix with many voids partly filled with clay material.

DRILLING RECORD

SCHEME:- MERSEY- FORTH

LOCATION:- CETHANA DAM SITE

POSITION PLOTTED ON DRAWING No.: Xs 544

DATES: (a) DRILLED: Apr/51 (b) WATER TABLE:

METHOD USED: D.O. DIAMETER: BX: AX:

SITE REMARKS:

POSITION

CO-ORDINATES:	E.	N:
ON LINE: X1 / 1118	BEARING: 0° 00'	AT CH:
FROM STN.: X1	BEARING: 25° 02'	DIST.: 159

LEVEL

SURFACE:	FORMATION:	WATER TABLE:
430		

INCL.

HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:
VERT/~~HOR/INC~~:		

HOLE No. 5403

FILE No. V

SHEET 2 OF 2 SHEETS

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0 0.2 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	10.6'						
	5'	x					
	110'	v					110': crystal filled open joint.
		x					Rust stained pyrite joints: haematite cement.
	15'	v					some clay in joints and matrix (to end of hole)
	120'	v					~~End of hole~~ 120'8"
	25'						Logged G. Holt
	30'						
	35'						
	40'						
	45'						
	50'						
	55'						
	60'						
	65'						
	70'						
	75'						
	80'						
	85'						
	90'						
	95'						
	00'						

DRILLING RECORD

SCHEME:- MERSEY - FORTH

LOCATION:- CETHANA DAM SITE

POSITION PLOTTED ON DRAWING No.: Ys 544

DATES: (a) DRILLED: April '57 (b) WATER TABLE:

METHOD USED: D.D. DIAMETER: NX : BX AX

SITE REMARKS:

POSITION	CO-ORDINATES:	E	N:	HOLE No. 5404
	ON LINE: F1/Y1	BEARING: 0° 00'	AT CH:	
	FROM STN.: F1	BEARING: 343° 16'	DIST.: 410'	FILE No.
LEVEL	SURFACE:	FORMATION:	WATER TABLE:	
	435			
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET 1 OF 2 SHEETS
	VERT/~~HOR~~INC:			

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY	GRAPHIC LOG	JOINTS	WATER	REMARKS
	0'						Purple conglomerate to 3'5"
	5'						current bedded sandstone (purple) to 25'6" all joints coated with quartz crystals; most with pyrite and mica (often weathered) Joints up to 1" apart: frequent quartz veins
	10'						
	15'						
	20'						
	25'						
	30'						Open joints and quartz crystals. Quartz sandstone or fine quartzite with thin conglomerate bands.
	35'						
	40'						
	45'						Joints open with chlorite, pyrite, quartz: haematite
	50'						
	55'						less jointing in region of 54'2"–63' Conglomerate.
	60'						
	65'						
	70'						
	75'						haematite nodules. bedding better developed.
	80'						
	85'						
	90'						Core more weathered – less haematite – joints with pyrite and chlorite – open.
	95'						
	100'						

Core jointed with joints 80°, 60°, 45°, 30°, 20° into 6" lengths

Joints fewer and pyrite lined

DRILLING RECORD

SCHEME:- MERSEY - FORTH

LOCATION:- CETHANA

POSITION PLOTTED ON DRAWING No.:

DATES: (a) DRILLED: (b) WATER TABLE:

METHOD USED: DIAMETER: Nx: Bx: Ax.

SITE REMARKS:

POSITION	CO-ORDINATES:	E.	N:	HOLE No. 540A
	ON LINE:	BEARING 0° 00'	AT CH:	
	FROM STN.:	BEARING:	DIST.:	FILE No.
LEVEL	SURFACE:	FORMATION:	WATER TABLE:	
	435			
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET 2 OF 2 SHEETS
	VERT ~~HOR/INC~~:			

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 2 4 6 0 0 0 8 0 1 0	GRAPHIC LOG	JOINTS	WATER
	100'					
	5'					
	110'					
	15'					
	120					
	25'					
	130'					
	35'					
	140'					
	45'					
	150'					
	55'					
	160'					
	65'					
	170'					
	75'					
	180'					
	85'					
	90'					
	95'					
	00'					

Jointing as above up to 1'

60°

REMARKS

Conglomerate: haematite cement with pyrite increasing from 101'

Tendency towards bigger pebbles set in a matrix of haematite with small pebbles giving a patchy rather than a uniform appearance.

Jointing less pronounced – open joints with pyrite chlorite and quartz.

Cement sometimes pyrite alone, sometimes haematite, or mixed: dark red colour.

Shearing: chlorite: open joints in haematite matrix

White current-bedded quartz. Then conglomerate as above with micaceous matrix and pyrite along beds. Red colouration.

Hole completed: 151'6".

LOGGED G. Hale.

DRILLING RECORD

SCHEME:- MERSEY - FORTH
LOCATION:- CETHANA DAM SITE
POSITION PLOTTED ON DRAWING No.: Ys 511
DATES: (a) DRILLED: April '57 (b) WATER TABLE:
METHOD USED: D.D DIAMETER: Bx : Ax.
SITE REMARKS:

POSITION: CO-ORDINATES: E. N: HOLE No. 5105
ON LINE: F1/Y1 BEARING: 0° 00' AT CH:
FROM STN.: F1 BEARING: 343° 31' DIST.: 416 FILE No.
LEVEL: SURFACE: FORMATION: WATER TABLE:
438
INCL.: HOLE DRILLED: DEPRESSION ANG.: INCL. BEARING: SHEET 1 OF 1 SHEETS
VERT/HOR/INC: -5° 30' 224° Mag

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY	GRAPHIC LOG	JOINTS	WATER	REMARKS
	0'						Current bedded quartzite sandstone or fine quartzite
	5'						Haematite stained joints: open with quartz and pyrite crystals
	10'						Haematite cement with odd pebbly bands.
	15'						Some beds whitish with irregular veins of haematite and pyrite.
							16'5" Carbonate pyrite and black material Specimen.
	20'						All typically fine with pebbles rounded and up to 1" diameter.
	25'						Dip of beds approximately 30° (dip not from axis)
	30'						Joint with carbonate pyrite quartz vein (Specimen)
	35'						
	40'						variable amounts of pebbles but generally finer with few pebbles and much quartz veining giving a white appearance.
	45'						
	50'						open joints mica (clay) or chlorite crystalline quartz and pyrite
	55'						
	60'						mixed stone conglomerate with haematite pebbles.
	65'				Joints break core into 2"-3" rough with pyrite, mica and quartz.		End of hole 66'
							fine bands of quartz give marble appearance and obliterate pebbles
	70'						Some carbonate or mica cement.
	75'						
	80'						LOGGED G. Hale
	85'						
	90'						
	95'						
	00'						

DRILLING RECORD

SCHEME:- Mersey - Forth

LOCATION:- Cethana Dam Site

POSITION PLOTTED ON DRAWING No.: Xs 544

DATES: (a) DRILLED: May 57 (b) WATER TABLE:

METHOD USED: D.D. DIAMETER: Ax.

SITE REMARKS:

POSITION	CO-ORDINATES:	E.	N.	HOLE No.
	ON LINE: X1/11B	BEARING: 0° 00'	AT CH:	5206
	FROM STN.: X1	BEARING: 25° 12'	DIST.: 162	FILE No.
LEVEL.	SURFACE:	FORMATION:	WATER TABLE:	
	434			
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET 1 OF 1 SHEETS
	~~VERT/HOR~~/INC:	3°	112° 15 Mag.	

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	0						Joints open - clay or chlorite quartz crystals: 45°-60° axis. Joints are clean breaks but strikes vary.
	5'						Dark red fine quartzite.
	10'						15': open weathered joints.
	15'						All core broken into pieces with maximum length of 6" by close jointing
	20'						xSp.
	25'						Core has many quartz veins - altered between 21'-44' giving a patchy appearence.
	30'						White spongy spots and areas of crushed quartz crystals in cavities (carbonate leached?)
	35'						Many open holes and joints with pyrite and quartz from 44' to bottom of hole.
	40'						End of hole 50'2"
	45'						
	50'						Logged G. Hale
	55'						
	60'						
	65'						
	70'						
	75'						
	80'						
	85'						
	90'						
	95'						
	100'						

ALL JOINTS UP TO 2-3" APART

FORM No. H.E. 443

DRILLING RECORD

SCHEME:- MERSEY - FORTH	POSITION	CO-ORDINATES:	E.	N:	HOLE No. 5407
LOCATION:- CETHANA DAM SITE		ON LINE: BM2577 XXVB	BEARING: 0° 00'	AT CH:	
POSITION PLOTTED ON DRAWING No.: Y5544		FROM STN. BM 2577	BEARING: 318° 46'	DIST.: 32	FILE No.
DATES: (a) DRILLED: May 57 (b) WATER TABLE:	LEVEL	SURFACE:	FORMATION:	WATER TABLE:	
METHOD USED: D.D DIAMETER:		430'			SHEET 1 OF 3 SHEETS
SITE REMARKS:	INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	
		VERT/HOR/INC:	-90°		

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS	OVERALL DESCRIPTION. 0-163'11"
	5'						0'-15'9" Haematite staining.	Quartzite conglomerate with pebbles up to 2" in diameter but av. size ½"
							39'-4' Zone of jointing with weathering and limonite.	
							0'-22'4" Sticks of core up to 4" but much is fragmentary and one stick is 15"	
	10'						5'6" Slickensiding & fragmentary core.	Mineralisation is present throughout especially on the joints.
							86"-90 Zone of weathering.	
	15'						16'6"-16'9" Zone of shearing and recementing.	
							19'6 Mineralisation and weathering	
	20'						25'4" Slickensiding	The rock is whitish-grey in colour with some well-defined haematite staining.
							26'0 Slickensiding.	
	25'						29'3"-33'0" Zone of shearing with mineralisation, Slickensides & chlorite(?) & carbonates	
	30'						36'9" : Carbonate	
							35'6"-37'0" Haematite staining	
	35'							
	40'						22'4"-134' Core good. Sticks up to 15" : av 6" : Some fragmentary	
							41'6"-44'6" Haematite stained	
	45'						46'6" Carbonate.	
							48'6"-49'6" Haematite staining	
	50'						55'6"-55'9 Slickensiding. Core fragmentary.	
	55'							
							60'0"-61'3" Haematite staining	
	60'						61'3" Carbonate zone.	
	65'						Pebble size in the conglomerate decreases with depth.	
	70'							
	75'							
	80'							
	85'							
	90'						S = Slickensiding	
							M. Mineralisation	
	95'						L = Limonite	
							C = Carbonate	
	100'						W = Weathering.	

X1

X2

DRILLING RECORD

80

SCHEME:- Mersey - Forth
LOCATION:- Cethana
POSITION PLOTTED ON DRAWING No.:
DATES: (a) DRILLED: May '57 (b) WATER TABLE:
METHOD USED: D.O. DIAMETER: • "
SITE REMARKS:

POSITION	CO ORDINATES:	E:	N:	HOLE No. 540T
	ON LINE:	BEARING: 0°·00'	AT CH:	
	FROM STN.:	BEARING:	DIST.:	FILE No.
LEVEL	SURFACE:	FORMATION:	WATER TABLE:	
	430			
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET 2 OF 3 SHEETS
	VERT/~~HOR/INC~~:	−90°		

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0·2 0·4 0·6 0·8 1·0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	100'						103': Fine jointing & recementation
	105'						} Zone of disturbance & shearing
							107'-112' Nomerous fine joints
	110'						110-118' Rock very quartzitic
							115'3"-116' Vertical joints, crossed at 115° @ 115'8"
	115'						118'6": Large 6" diameter quartz pebble with slickensiding.
							119'3"-121': Haematite stained.
	120'						
							126'3": Carbonate filled cavity.
	125'						128'6" Shatter zone plus carbonate.
	130'						133'11"-134'6": Shatter zone: slickensides: carbonate.
							136'-140': Core fragmentary: shear zone recemented with fine joints and slickensiding: @137'8" get cavity with quartz crystals - pyrite. also @ 138'9".
	135'						
	140'						142': Prominent joint filled with pyrite: ¼" thick.
							143'-147': Chips of core due to vertical jointing.
	145'						147'-163'11": Possible fault zone. Core is very broken ranging from chip size to 2". In this zone occurs recementing, weathering cavities, mineralisation and slickensiding. The cement material reacts with HCl to give H_2S.
	150'						
	155'						
	160'						163'11"-165' Predominantly quartzose blending towards slate at 165'. Small amounts of Limonite present.
	165'						165': Slaty phase of the Cambrian quartz chlorite commences.
	170'						165-212'4": Slaty quartz chlorite with occasional bands of finer slate than normal. Carbonates occurs throughout. Mineralisation is sparse: Shearing parallel to bedding plane occurs at 20° to core. Quartz abundant.
	175'						165'3": Joint with ¼" mineralisation
	180'						165'6"-171' Zone of fine joints with Carbonate
							172'3 Bands of fine slate.
	185'						172'4" - ¼" quartz vein
							173'3" ½" fine slate band.
							176'5"-177'9" Very fine slate bands ⅛" wide every ½"
	190'						177'9" - ½" quartz band.
							184'10"-185'3" Zone of slate bands cut by quartz at 20°
							189' Vertical fine slate bed.
	195'						195'6" ¾" finely banded slates at 20° with jointing along these bands and carbonation.
							196'8" fine slate band.
	200'						

X3 X4 X5

DRILLING RECORD

SCHEME:- MERSEY–FORTH
LOCATION:- CETHANA DAM SITE
POSITION PLOTTED ON DRAWING No.:
DATES: (a) DRILLED: May '54 (b) WATER TABLE:
METHOD USED: D.D. DIAMETER:
SITE REMARKS:

POSITION	CO-ORDINATES:	E.	N:	HOLE No. 5407
	ON LINE:	BEARING: 0° 00'	AT CH:	
	FROM STN.:	BEARING:	DIST.:	FILE No.
LEVEL.	SURFACE.	FORMATION:	WATER TABLE:	
	430			
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET 3 OF 3. SHEETS
	VERT/HORIZ.	-90°		

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY	GRAPHIC LOG	JOINTS	WATER	REMARKS
	200'						
		x					196'8'-212'4" Slaty phase continues with finer slate bands interspersed.
	205'						
		x					212'4"-216'3" Pebbles of quartz appear at 212'4" but slaty bands continue to 216'3".
	210'						
		x			-·- M.W.		
	215'						216'3" Conglomerate phase of the CAMBRIAN Quartz chlorite commences. Pebbles less than ¼" diameter and usually quartz. Carbonates present: matrix siliceous: Coring good.
		x					
	220'						
		x					221'8"-222'8" Impure quartz band with slate.
	225'	x					
							224'10"-235'5" Slaty phase recurs Jointing not common.
	230'	x					
							235'5"-237'6" Conglomerate phase.
	235'	x					237'6"-250' Slaty phase.
		x					239'11"-239'9" Vertical jointing with mineralisation and carbonation.
					M W L		
	240'	x					240'-240'6" Impure quartz + slate.
		x					241'9" Quartz band ½" wide: mineralisation and weathering.
	245'	x					
					S		242'-242'6" Quartz.
	250'				M.W.		End of hole 250'
							Logged by Gr. Hale 5/11/54 M. Craig
	55'						
	60'						
	65'						
	70'						
	75'						
	80'						
	85'						
	90'						
	95'						
	00'						

DRILLING RECORD

SCHEME:- MERSEY – FORTH
LOCATION:- CETHANA
POSITION PLOTTED ON DRAWING No.: Ys 544
DATES: (a) DRILLED: June '57 (b) WATER TABLE:
METHOD USED: DIAMETER:
SITE REMARKS:

POSITION — CO-ORDINATES: E. N: HOLE No. 5408
ON LINE BM2577 / XX48 BEARING 0° 00' AT CH:
FROM STN BM 2577 BEARING 323° 25' DIST.: 28 FILE No.
LEVEL — SURFACE: FORMATION: WATER TABLE:
431
INCL. — HOLE DRILLED: DEPRESSION ANG.: INCL. BEARING: SHEET 1 OF SHEETS
~~VERT/HOR~~/INC: 31° 173° 30' Mag

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	0'						
	5'						
	10'						
	15'						
	20'						
	25'						
	30'						
	35'						
	40'						
	45'						
	50'						
	55'						
	60'						
	65'						
	70'						
	75'						
	80'						
	85'						
	90'						
	95'						
	100'						

JOINTS: Hv V lengths; V m; V m; V m; Core lengths to 1' but usually less than 3"

30° Joints approx 2' intervals, 60°-45° joints 1' or less apart for whole core. Core broken by drilling rather than by close jointing.

Joint planes usually rough with iron-staining but no clay. Slickensiding & chlorite on 45° & flatter but not on steep joints.

Fresh core breaks through most pebbles but around some.

Hole completed 99'7" Logged G. Hale.

Roland Conglomerate pebbles ¼"-3" – little sandy matrix – purple colour to 58' then whitish to 87' with darker patches at 87'-88' and below 97'-6"

Much pyrite and haematite replacing the matrix and parts of some pebbles.

Rock is massive but some shearing and mineralisation on flat joints and on 45° joints.

97'-98' no. of flat white quartz veins cut pebbles and matrix

FORM No H.E. 443

DRILLING RECORD

SCHEME:- MERSEY - FORTH

LOCATION:- CETHANA DAM SITE

POSITION PLOTTED ON DRAWING No.: Xs 544

DATES: (a) DRILLED: June 57 (b) WATER TABLE:

METHOD USED: DIAMETER:

SITE REMARKS:

POSITION

CO-ORDINATES:	E.	N:
ON LINE: BM 2577 / XXVB	BEARING: 0° 00'	AT CH
FROM STN BM 2577	BEARING: 160° 19'	DIST.: 287

LEVEL

SURFACE:	FORMATION:	WATER TABLE:
428		

INCL.

HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:
VERT/~~HOR/INC~~:		

HOLE No. 5409

FILE No.

SHEET 1 OF 2 SHEETS

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	0'				2 CH / S		Whitish-grey quartzite: Jointed throughout
	5'						Longest piece 18": vein quartz throughout (45°)
							Slickensides at 90°: chlorite filled veins.
	10'						10' Arsenopyrite with radiating crystals.
							Joint 30°: open: quartz mica and Arsenopyrites.
	15'						Joint 45°: open: quartz: mica and Arsenopyrites
							in white pebbly conglomerate: pebbles 1" in diam: rounded 18"
	20'						19': Series of 45° pyrites (displaced)
							20'2": Rock massive: less chlorite & pyrite throughout.
	25'						12'4" Fine grey quartzite: 90° Joint: Slickensided
							transversely: chlorite and weathering.
	30'						
					1 S.		Abundant irreg. chlorite and quartz veining
	35'						32'-35': Thin conglomerate band.
					1 AP		35': Fine grey quartzite
	40'						40'-46': Fine grained quartzite (as above) but many
							irregular chlorite veins in recovered pieces.
	45'						46': Grey white quartzite (as above)
							49'-51': Near Vertical Joints causing core loss (?)
	50'				1 Quartz 1 Chl		53': Red colouration increasing downwards.
							58': Variably coloured greenish and reddish
	55'					x Sp.	specimen: with weathered quartz veins
							61'-69' Conglomerate. White pebbles Red
	60'						matrix
	65'						67'9": Chlorite increasing: cavities along joints (45°)
							bedding 60°: chlorite increasing
	70'						69' Fine white Quartzite with chlorite veining (6")
							70'6"-71' Mottled quartzite.
	75'						6" Conglomerate
							71'6" Mottled quartzite
	80'						75'2": Conglomerate: Reddish pebbles: Green
							chlorite or Carbonate cement. Pebbles up
	85'						to 3". Colour purplish with greenish matrix
							82'6": Fine grained greenish: 6"
	90'						83' Conglomerate
	95'						
	100'						

FORM No HE. 443

DRILLING RECORD

SCHEME:- MERSEY - FORTH	POSITION	CO-ORDINATES:	E.	N:
LOCATION:- CETHANA.		ON LINE:	BEARING 00° 00'	AT CH:
POSITION PLOTTED ON DRAWING No.:		FROM STN.:	BEARING:	DIST.:
DATES: (a) DRILLED: June '57 (b) WATER TABLE:	LEVEL	SURFACE:	FORMATION:	WATER TABLE:
METHOD USED: DIAMETER:		428		
SITE REMARKS:	INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:
		VERT/~~HOR~~/~~INC~~:		

HOLE No. 5409

FILE No.

SHEET 2 OF 2 SHEETS

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	100'						
	5'						
	110'						Coarse quartz conglomerate with haematite and pyrite. Purplish colour. Greenish carbonate or chloritic cement in places. Joints at 45° and 60° common.
	15'						
	120'						
	25'						
	130'						
	35'						
	140'						
	45'						
	150'						
	55'						
	160'						
	65'						
	170'						End of hole 171'4"
	75'						Logged G.H.ale
	80'						
	85'						
	90'						
	95'						
	200'						

DRILLING RECORD

SCHEME:- MERSEY - FORTH
LOCATION:- CETHANA
POSITION PLOTTED ON DRAWING No.: Ys 544
DATES: (a) DRILLED: July '57 (b) WATER TABLE:
METHOD USED: DIAMETER:
SITE REMARKS:

POSITION — CO-ORDINATES: E.: N.: HOLE No. 5410
ON LINE: BM2577 - XXVB BEARING: 0°00' AT CH:
FROM STN.: BM 2577 BEARING: 161° 05' DIST.: 287 FILE No.
LEVEL — SURFACE: FORMATION: WATER TABLE:
431
INCL. — HOLE DRILLED: DEPRESSION ANG.: INCL. BEARING: SHEET 1 OF 1 SHEETS
~~VERT HOR~~ INC: 7°40' 98°30' Mag

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY (INCHES) 0 6 12 18 24	GRAPHIC LOG	JOINTS	WATER
	0'					
	5'					
	10'					
	15'					
	20'					
	25'					
	30'					
	35'					
	40'					
	45'					
	50'					
	55'					
	60'					
	65'					
	70'					
	75'					
	80'					
	85'					
	90'					
	95'					
	99'					

ALL JOINTED

REMARKS

0'-3'6" Core shattered: longest stick 12"
Numerous joints 45°: 70°: 10°: 30°
Massive quartzite: greyish-white.
12'11"-14' Reddish band
White quartz veins throughout.
irregular black streaks
11' chlorite veins at 70°

23': Quartz crystals in vug
Joints usually open & lined with Quartz crystals.
25': Quartz and tourmaline in vug.
26': Thin chloritic bed @ 70°
Core broken
Core reddish: sheared with green chlorite throughout. Common parting at 70° on chlorite.
33'11": Massive whitish quartzite, less chlorite.
35'4": chlorite parting at 70°
Jointing at 45°
End of hole 44'9" Becomes reddish and highly fractured
bedding at 60°: capped by chlorite bands.
Quartzite and chlorite.
44' Whitish grey: joints with pyrite to end of hole
47' Core shattered on 45° & 60°. Joints cut by chlorite.

Logged by G. Hale.

DRILLING RECORD

SCHEME:- MERSEY - FORTH
LOCATION:- CETHANA
POSITION PLOTTED ON DRAWING No.: Xs 54A
DATES: (a) DRILLED: July '57 (b) WATER TABLE:
METHOD USED: DIAMETER:
SITE REMARKS:

POSITION
CO-ORDINATES: E: N:
ON LINE: BM 2577 XXV B BEARING: 00° 00' AT CH:
FROM STN. BM 2577 BEARING: 54° 23' DIST.: 117

LEVEL
SURFACE: FORMATION: WATER TABLE:
4371

INCL.
HOLE DRILLED: DEPRESSION ANG.: INCL. BEARING:
VERT/~~HOR/INC~~:

HOLE No. 5A11
FILE No.
SHEET 1 OF SHEETS

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	0						Coarse whitish - grey conglomerate with haematite staining : pebbles up to 2" : pyrite through out : rusted joints to 13'2" Clay often leached from matrix in joints to show pits : open joints : some joints slickensided
	5'						
	10'						
	15'						
	20'						18'8" Cavity 1" lined with pyrite + purplish mineral
							21' joint 1/4" with weathered mica
	25'						25' open joint filled with fine muscavite + pyrite
							Joints break 45° + 60° : core in pieces up to 12"
	30'						
	35'						
	40'						42'8" patch of Dolomite
							Conglomerate as above but finer, better packed: haematite + pyrite nodules : joints lined with pyrite, chlorite : reddish where haematite predominates in cement greenish where pyrite + dolomite. Joints generally tighter than above 30' : core in lengths up to 24". No joints above 60°
	45'						
	50'						
	55'						
	60'						Core whitish - grey below 60'
	65'						
	70'						
							73' joint 80°
	75'						
	80'						
							85' - 88'6" rusty marks
	85'						
	90'						88'6" - 91' shattered core
							Matrix pyrite + dolomite (?) : some joints show signs of slickensides 45°
	95'						Quartz pebbles predominate.
	100'						

DRILLING RECORD

SCHEME:- MERSEY - FORTH
LOCATION:- CETHANA
POSITION PLOTTED ON DRAWING No.:
DATES: (a) DRILLED: (b) WATER TABLE:
METHOD USED: DIAMETER:
SITE REMARKS:

POSITION	CO-ORDINATES:	E.	N:	HOLE No. 5411
	ON LINE:	BEARING 00°00'	AT CH:	
	FROM STN.:	BEARING:	DIST.:	FILE No.
LEVEL	SURFACE:	FORMATION:	WATER TABLE:	
	437			
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET 4 OF 5 SHEETS
	VERT/HOR/INC:			

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	100'						
	5'						106' Very coarse conglomerate : boulders up to 8" : light-grey : pyrite + dolomite cement.
	110'						core loss on vertical joint , other joints still present : core up to 24"
	15'						
	120'						
	25'						Shearing + near Vertical joints increase from 100' : core in pieces up to 3" : joints show openings + slickensides to 147'3"
	130'						
	135'						
	140'						
	45'						Core up to 18" : no near vertical joint or joint over 60°
	150'						
	55'						Increase in number of pebbles other than Quartz
	160'						
	65'						165' rust stained along closed joint
	170'						Small holes and open joints to 184'2"
	75'						
	180'						
	85'						188' Conglomerate pebbles up to 5" to 6" (Stretched ?) increased amount of strongly sheared mixed stone matrix cemented with dolomite , chlorite + some pyrite : joints + shearing approx 60° some 45° all broken joints slickensided
	190'						
	95'						
	200'						

DRILLING RECORD

SCHEME:- MERSEY- FORTH
LOCATION:- CETHANA
POSITION PLOTTED ON DRAWING No.:
DATES: (a) DRILLED: (b) WATER TABLE:
METHOD USED: DIAMETER:
SITE REMARKS:

POSITION: CO-ORDINATES: E.: N.:
ON LINE: BEARING: 00°00' AT CH:
FROM STN.: BEARING: ° ' DIST.:
LEVEL: SURFACE: FORMATION: WATER TABLE:
437
INCL.: HOLE DRILLED: DEPRESSION ANG.: INCL. BEARING:
VERT/HOR/INC:

HOLE No. 5411
FILE No.
SHEET 3 OF 5 SHEETS

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	200'	x					
	5'						
	210'	x					209' 6" of recemented fault breccia
	15'	x					210'-214' fault breccia 12" silicification evident
		x					
	220'	x					
		x					222' Rock sheared brecciated 6" on 45°
		x					225'6" CAMBRIAN : slate dark grey
	25'	x					slatey cleavage 60° ; dolomite +
		x					pyrite veins ll to cleavage
	230'						Black slate continues to 245'
		x					Schistocity + bedding 65° ; joints
	35'	x					filled with pyrite, carbonate, chlorite.
							x Sp
	240'	x					245' Fine Quartzite (Jennings: Qtz Chloritic rock):
	45'	x					Sand bands interbedded with thin slate bands
							x Sp. to 256'
	250'	x					
	55'	x					Coarser white mottled rock with irregular
	260'	x					chloritic cleavages at 60°
		x					Massivly bedded
	65'						x Sp.
		x					
	270'						269'3" joint filled with pyrite, hole
		x					Qtz pebbles + pyrite increase to 273':
	75'						shearing less: grades into finer at
		x					275' less pebbles : shearing more
	280'						intense : cleavage filled with chlorite
		x					+ carbonate : approx 80° : open
	85'						dolomitic box work at 279 : re-cemented
		x					FAULT ZONE (?)
	290'						xsp
		x					Vertical jointing slickensides in near
	95'	x					vertical joint at rt ∠ to core
							Joint at 45° : cemented with carbonate
	300'	x					298' Quartz pebbles coarser

DRILLING RECORD

SCHEME:- MERSEY - FORTH

LOCATION:- CETHANA

POSITION PLOTTED ON DRAWING No.:

DATES: (a) DRILLED: (b) WATER TABLE:

METHOD USED: DIAMETER:

SITE REMARKS:

POSITION	CO-ORDINATES:	E.	N.	HOLE No. 5A-11
	ON LINE:	BEARING 00°00'	AT CH:	
	FROM STN.:	BEARING:	DIST. 117	FILE No.
LEVEL	SURFACE:	FORMATION:	WATER TABLE:	
	437			
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET A OF 5 SHEETS
	VERT ~~HOR/INC~~			

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	300'						302' open joint 80°: pyrite, carbonate (?), red silica, calcite, with core loss
	5'	x					Epidote (?) Pyrite filling along steep cleavages. Fine grained from 303' pyrite
	310'	x					XSp. throughout. Sheared quartzite (?) Fine grained
	15'	x					Qtz coarser towards 325'
		x					XSp cleavage 80° cut by qtz + pyrite veins at 45°
	320'						319' qtz pyrite vein : chalcopyrite (?), chlorite
		x					322' qtz pyrite vein with holes 45° displaces
	25'						shearing : steep mineralised joint 80°
		x					325'-327' Nearly complete replacement with Qtz.
	330'						327'-329' Fine Quartzite
		x					329'-329'8" Coarse " "
		x					Qtz vein to 332' with chlorite, muscavite, pyrite
	35'	x					334-342 Coarse blebs of qtz.: core almost
		x					completly replaced by qtz.
	340'	x					340' bedding at 60°
							342'-344' Coarse qtz rock : qtz vein 45°
	45'	x					346' Conglomerate of predominantly qtz pebbles:
							mineralised matrix : abundant qtz veins :
	350'	x					some schist pebbles.
							351' to 359'7" Fine grained qtzite : bedding + cleavage 60°
	55'	x					351'5" Qtz vein mineralised :
							Rock replaced by qtz mineralised
	360'	x					362'8" shearing at 45° at 362'
		x					362'8"-367'4" Fine grained quartzite with abundant
	65'						qtz.
		x					367'4"-374' Rock replaced by quartzite : mineralised
	370'						374-382 Fine grained qtz rock : some
							scattered qtz veins
	75'						377 Country Rock for 12'
		x					380 Mineralised zone with open cavities.
	380'						382- Fine qtzite dk grey : massivly bedded :
							small qtz blebs + veins with green mineralized
	85'						vein 60° bedding 80° with variably coloured
		x					blebs of pyrite + coarser appearance through-out.
	390'						397' Mineralized zone : Green + pyrite
							397'6" 45° joint : pyrite
	95'						398' 45° joint : pyrite
		x					398'6" joint : qtz
	400'						

FORM No. H.E. 443

DRILLING RECORD

SCHEME:- MERSEY - FORTH

LOCATION:- CETHANA

POSITION PLOTTED ON DRAWING No.: Xs 544

DATES: (a) DRILLED: (b) WATER TABLE:

METHOD USED: DIAMETER:

SITE REMARKS:

POSITION — CO-ORDINATES: E: N: HOLE No. 5411

ON LINE BM 2577 XXV B BEARING 00° 00' AT CH:

FROM STN. BM 2577 BEARING 54° 23' DIST.: 117 FILE No.

LEVEL — SURFACE: FORMATION: WATER TABLE:

437

INCL. — HOLE DRILLED: DEPRESSION ANG.: INCL. BEARING:

VERT/~~HORIZ~~: SHEET 5 OF 5 SHEETS

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0-2 2-6 6-8 8-10	GRAPHIC LOG	JOINTS	WATER	REMARKS
	400'						404' Quartzite with thin white qtz veins increasing distinct vein at 60°
	5'						406' Quartz chloritic rock (Jennings) : dark + light grey banding at 80° : light areas irregular boundaries with pyrite. Heavily impregnated with pyrite + greenish grey with dark grey banding at 80° Fine dark banding : bedding replaced by pyrite + qtz filled : joints 45° + 60°
	410'	x					
	15'						
	420'	x					
	25'						421' Quartz vein with openings : banding less distinct : heavy pyrite impregnation
	430'	x					427' Change from green to blackish on 80° : green vein on 80° at 430' with distinct qtz banding below
	35'						433' 8" quartz vein
	440'	x					437 Rock replaced by green chlorite qtz : much pyrite : qtz for 8" with voids + pyrite at 436'
	45'						437-442 Dark grey quartzite with irregular qtz, chlorite, pyrite blebs.
	450'	x					442 Dark grey quartzite : occasional pyrite veins and blebs.
	55'						
	60'						Hole Completed 448'
	65'						Logged C. Hale
	70'						
	75'						
	80'						
	85'						
	90'						
	95'						
	00'						

DRILLING RECORD

SCHEME:- MERSEY- FORTH
LOCATION:- CETHANA
POSITION PLOTTED ON DRAWING No.: Xs 514
DATES: (a) DRILLED: Aug '57 (b) WATER TABLE:
METHOD USED: DIAMETER:
SITE REMARKS:

POSITION — CO-ORDINATES: E: N: HOLE No. 5412
ON LINE: BM 2577 XXYB BEARING: 00° 00' AT CH:
FROM STN BM 2577 BEARING: 52° 06' DIST.: 119 FILE No.
LEVEL — SURFACE: 439 FORMATION: WATER TABLE:
INCL. — HOLE DRILLED: DEPRESSION ANG.: INCL. BEARING:
VERT/HOR/INC: 30° 193° SHEET 1 OF 1 SHEETS

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0-2 2-4 4-8 8-10	GRAPHIC LOG	JOINTS	WATER	REMARKS	Overall Description
	0						0'-12'6": Numerous weathering cavities with associated Limonite espec. from 10'6"-12'3" Pebble size av. 1/8"-1/4"	0'-15'6" Haematite stained conglomerate with pebble size up to 1½" but average 1/8" to 1/4". Limonite occurs on all joints but mineralisation slight.
	5						0-15'6" Haematite stained.	
	10						@ 15' Carbonate + shearing.	
	15						15'6"-22'6" mainly quartzose with a little mineralisation and weathering	15'6"-22'6" Predominantly quartz with vertical jointing Some limonite and mineralisation
	20					weathering		
	25						22'6"-50'6" Haematite stained.	
	30							
	35						@ 37' Zone of pyrite mineralisation	
	40							22'6-50'6" As for 0-15'6"
	45							50'6"-55'9" Quartz conglomerate with haematite absent and mineralisation occurring at junction of pebbles and matrix. Some Carbonation.
	50						51'10-53 Mineralised.	
	55						50'6-53'6" Quartzose. 53'9" Slickensiding 53'6"-63' Haematite stained. 65'10" Dolomite film.	
	60						65'10-79'2" Haematite staining absent.	55'9"-63' As above but haematite stained
	65						73'3" Slickensiding with Carbonate present.	63'-79'2" As above but haematite absent.
	70							
	75						Core:	
	80						0-57'3: Core shattered with av. length of sticks 1-2" and longest stick 10" (@ 54")	
	85						57'3"-58'2" Core fragmentary.	
	90						58'2"-79'2" Core better with sticks up to 15".	
	95						M = Mineralisation C = Carbonate L = Limonite W = Weathering	
	100						Logged 1-11-57 Cr. Hales M. Craig.	

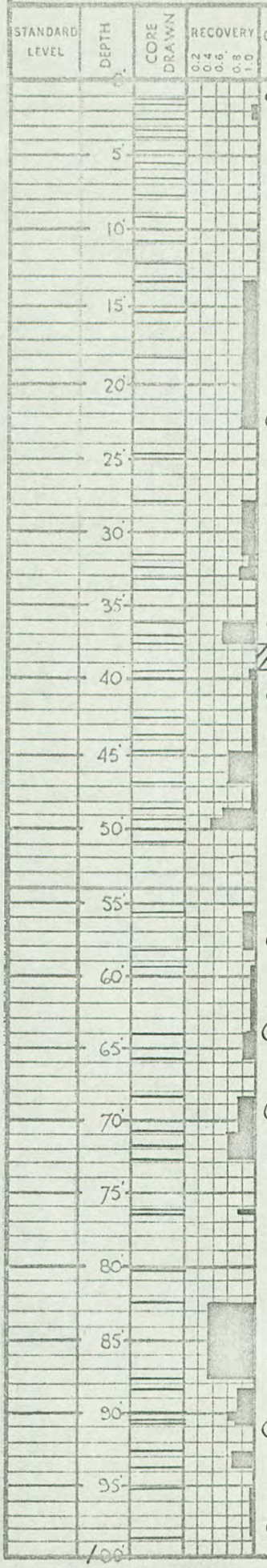
x1 x2 x3

FORM No H.E. 443

DRILLING RECORD

SCHEME:- MERSEY - FORTH	POSITION	CO-ORDINATES:	E	N:
LOCATION:- CETHANA		ON LINE: BM2577 / XXV8	BEARING 00° 00'	AT CH:
POSITION PLOTTED ON DRAWING No.: Ys 54A		FROM STN BM 2577	BEARING 56° 13'	DIST.: 113
DATES: (a) DRILLED: SEPT, '57 (b) WATER TABLE:	LEVEL	SURFACE:	FORMATION:	WATER TABLE:
METHOD USED: D.D. DIAMETER: Ax.		437		
SITE REMARKS: Approx 18' above water level	INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:
		~~VERT~~/~~HOR~~/INC:	47°	81° 30'

HOLE No 5413 | FILE No. | SHEET 1 OF 2 SHEETS



REMARKS Overall Description.

0-13'3" Sticks of core up to 9" | Competant quartz conglomerate with a siliceous matrix cementing pebbles up to 2" in diameter.

13'3"-34' longest stick 12" but av. length 1"-2".

0'-3'6": weathered zone with numerous small cavities and joints but rock competant.

Occasional staining by haematite but this is generally absent.

24'8" joint cavity + pyrites.

28'8" slickensiding.

32' } Joint cavity + pyrite
36½'-37' } Broken core.

34'-36' core sticks less than 1" but drill near gap in rock.

Weathering common for first 3' but thereafter sparse x1

Exit
Drill passing through gap in rock.
Re-entry

Mineralisation occurs throughout especially at joints

@39'6" Chert wedge at joint with slickensiding.

39'6"-44' longest stick 6" with av = 2"

Colour of the rock — whitish grey

65'-73': Haematite staining more obvious.

@67'9" Recemented Shear (?) x2

@94': Carbonate Cement (?)

DRILLING RECORD

SCHEME:- MERSEY - FORTH.

LOCATION:- CETHANA.

POSITION PLOTTED ON DRAWING No.:

DATES: (a) DRILLED: SEPT '57 (b) WATER TABLE:

METHOD USED: D.D. DIAMETER:

SITE REMARKS:
Approx 18' above water level.

POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5413
	ON LINE:	BEARING: 00° 00'	AT CH:	
	FROM STN.:	BEARING:	DIST.:	FILE No.
LEVEL	SURFACE:	FORMATION:	WATER TABLE:	
	437			
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET 2 OF 2 SHEETS
	~~VERT~~ / HOR / INC:			

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER
	100'				C	
	105'					
	110'					
	115'					
	120'				H M M	
	125'					
	130'					
	35'					
	40'					
	45'					
	50'					
	55'					
	60'					
	65'					
	70'					
	75'					
	80'					
	85'					
	90'					
	95'					
	00'					

REMARKS

100'6" : Quartz band.

102'6" : Weathering Cavities + mineralisation &.

121'6" : 1" Quartz band X2

End of hole 128'4" X4

L = Limonite

S = Slickenside

H = Haematite

W = Weathering

M = Mineralisation.

Q = Quartz

Logged 1-11-57
G. Hale & M. Craig

DRILLING RECORD

SCHEME:- MERSEY - FORTH.	POSITION	CO-ORDINATES:	E.	N:
LOCATION:- CETHANA.		ON LINE ~~BM 2577 / X X VB~~	BEARING: 00° 00'	AT CH:
POSITION PLOTTED ON DRAWING No.: Xs 544		FROM STN BM 2577	BEARING 160° 26	DIST.: 67
DATES: (a) DRILLED: Oct: 57 (b) WATER TABLE:	LEVEL	SURFACE:	FORMATION:	WATER TABLE:
METHOD USED: D.D. DIAMETER:		416		
SITE REMARKS:	INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:
		~~VERT/HOR~~ INC:	-40°	222° Mag

HOLE No. 5414 | FILE No. | SHEET 1 OF 2 SHEETS

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS	Overall description.
	0'						0-4'6" Core shattered with sticks up to 1": mainly quartz weathered with limonite.	Competant quartz conglomerate of a whitish grey colour.
	5'						2'1" Weathered zone + mineralisation.	
	10'						4'6"-22'8" Sticks of core up to 6"	Mainly quartz up to 4'6" thence haematite stained up to 26'.
	15'						0-8' : Limonite occurs on all joints: sparsely after 8'	
	20'						11'4" : weathering of pyrites	There after rock remains whitish grey in colour Pebbles range from 1/8" → 2" in diameter and are cemented by a quartose material (rarely by a carbonate
	25'						22'8"-34'5" : Core broken with sticks up to 1"	
	30'						34-34'5" : small quartz and calcite filled veins	
	35'						34'5"-39' Sticks less than 1"	
	40							
	45'						46'-46'9" Prominent vertical jointing.	Calcite is absent.
	50'						49'-52' Slight brecciation recemented Slickensides.	Pyrite mineralisation occurs throughout especially on joint faces.
	55'						58'6"-58'9" Weathered + Dolomite	
	60'					W	39'-100' Sticks up to 12"	
	65'							
	70'				Xcpc joints		69' : Joint 20° with finer bed for 1".	
							69'4" : Dolomite.	
	75'						70'4"-70'9" Zone of 45° joints with limonite.	
	80'							
	85'							
	90'							
	95'						94' : Calcite.	
	100'							

DRILLING RECORD

SCHEME:- MERSEY - FORTH.	POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5414
LOCATION:- CETHANA.		ON LINE:	BEARING 00° 00'	AT CH:	
POSITION PLOTTED ON DRAWING No.: A		FROM STN.:	BEARING:	DIST.:	FILE No.
DATES: (a) DRILLED: Oct: '57 (b) WATER TABLE:	LEVEL.	SURFACE:	FORMATION:	WATER TABLE:	
METHOD USED: O.D. DIAMETER:		416			
SITE REMARKS:	INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET 2 OF 2 SHEETS
		~~VERT/HOR~~ INC:	−40°	222° Mag	

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	100'				101'11" = 10°		Core up to 9" in length
	105'				104'6" = 0 104'6" = 45		100'-114': Core slightly haematite stained
	110'				110'6" = 45		110'-111'11" Zone of jointing: joints at 45°
	115'				114'6" = 30 114'9" = 45 116'10" = 35 117' = 45		114'-120'6": Core haematite stained. 120'6"-146': Core lightly stained.
	120'				122' = 45		146'-152'8": Core haematite stained.
	125'						
	130'						128'6": 1½" core removed for slide.
	135'						
	140'				139'1" = 45		
	145'						145'6": 4" core removed for slide.
	150'				152' = 45 153' = 60 154' = 70		152'8"-179'8": Core becomes whiter especially after 173'.
	155'				156'4" @ 30° clay filled J @ 45°		156'5": 1" core removed for slide.
	160'						Suspected recemented shear zones at 156'5": 166'9": 179'
	165'						Core broken by joints into pieces 18" long
	170'						
	175'				176'8" = 30		176'8" = slickensides
	180'				179'8" = 45		End of Hole 179'8"
	85'						
	90'						Logged G Hale & M. Craig.
	95'						
	00'						

FORM No. H.E. 443

DRILLING RECORD

SCHEME:- MERSEY - FORTH

LOCATION:- CETHANA DAM SITE

POSITION PLOTTED ON DRAWING No.: Ys 544

DATES: (a) DRILLED: Nov. 57 (b) WATER TABLE:

METHOD USED: D.D. DIAMETER:

SITE REMARKS:

POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5415
	ON LINE: 1X/11A	BEARING 00° 00'	AT CH:	
	FROM STN. 1X	BEARING 262° 01'	DIST. 90	FILE No.
LEVEL	SURFACE:	FORMATION:	WATER TABLE:	
	523			
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET 1 OF 2 SHEETS
	VERT/~~HOR/INC~~:	— 90°		

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	0'				Core breaks up to 1' Iron stained.		0 - 23'3" purplish quartzite with conglomerate bands and colour banding.
	5'						Bedding obscure - one side of the core is about 30°, the other 80°.
	10'						
	15'						
	20'						
	25'						Purplish Roland Conglomerate
	30'						Core carries pyrite and some haematite throughout.
	35'						
	40'						
	45'						
	50'						52'6" Fine band 6"
	55'						
	60'				Jointed as above, iron stained to 77'9"		Chlorite filled joints.
	65'						
	70'						71' - 75' Quartzite (fine)
	75'						Slickensided on chlorite 77'9" - 78'3" dip approximately 60°. 81' - 82' Slickensiding on chlorite filled joints.
	80'						
	85'				88' Fa 60°		
	90'						
	95'						
	96'						

DRILLING RECORD

SCHEME:- MERSEY – FORTH

LOCATION:- CETHANA DAM SITE

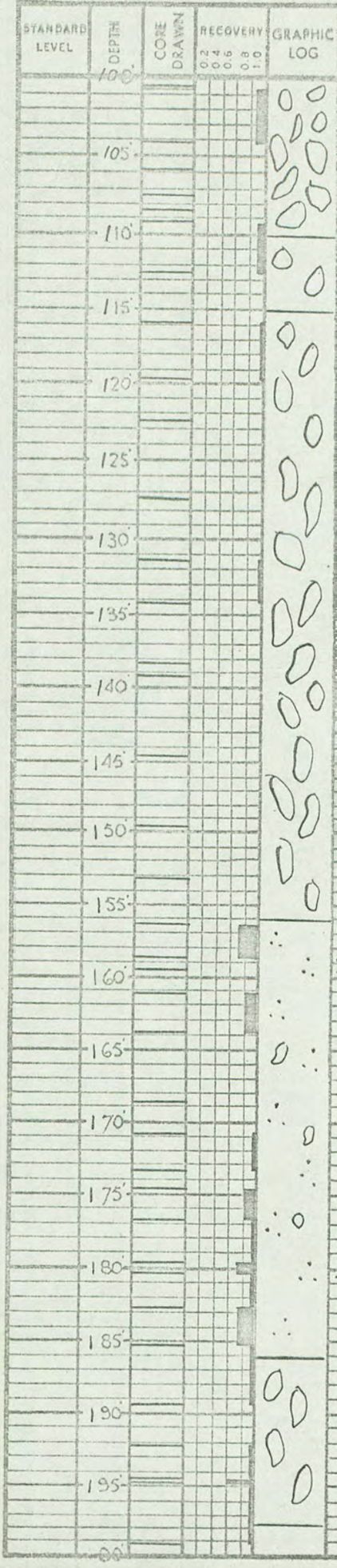
POSITION PLOTTED ON DRAWING No.: Xs 544

DATES: (a) DRILLED: Nov 1957 (b) WATER TABLE:

METHOD USED: D.D. DIAMETER:

SITE REMARKS:

POSITION	CO-ORDINATES:	E.	N:	HOLE No. 5415
	ON LINE: IX/11A	BEARING 00° 00'	AT CH:	
	FROM STN.: 1X	BEARING 262° 01'	DIST.: 90'	FILE No.
LEVEL.	SURFACE:	FORMATION:	WATER TABLE:	
	523			SHEET 2 OF 2 SHEETS
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	
	VERT/~~HOR~~/INC.:	-90°		



REMARKS

104' 60° Slickensided.

110' - 115' Zone of silicification - less pebbles. may be fine band with few pebbles. joints show slickensides Roland Conglomerate with pyrite

Common jointing at 30° haematite sealed.

X Sp.

Roland Conglomerate with occassional parts showing more matrix than usual.

light coloured.

Silicified conglomerate with joints at 30° and 45° filled with arsenopyrite.

158' - 185' Conglomerate or quartzite silicified difficult to distinguish pebbles or matrix.

172' Irridescence on arsenopyrite.

180' Joint at 75° cuts mineralised joints.

185' Normal conglomerate, reddish colour.

187' Some leaching apparent.

End of hole 199'1" Logged G. Hale

FORM No. H.E. 443

DRILLING RECORD

SCHEME:- MERSEY – FORTH

LOCATION:- CETHANA

POSITION PLOTTED ON DRAWING No.: Xs 544

DATES: (a) DRILLED: NOV: '57 (b) WATER TABLE:

METHOD USED: D.D. DIAMETER:

SITE REMARKS:

POSITION	CO-ORDINATES:	E.	N:	HOLE No. 5416
	ON LINE: IX/IIA	BEARING: 00° 00'	AT CH:	
	FROM STN.: IX	BEARING 255° 26'	DIST.: 90	FILE No.
LEVEL	SURFACE:	FORMATION:	WATER TABLE:	
	524			
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET 1 OF 1 SHEETS
	~~VERT/HOR~~/INC:	27°	114° Mag	

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	0'						The core is quartzite conglomerate bound by a siliceous matrix cementing pebbles up to 1" in diameter. It is haematite stained throughout. The majority of pebbles are quartz. Limonite and chlorite occur frequently especially at joints.
	5'						0'-1'6": Conglomerate.
	10'						1'6"-4'6": Fine quartzite.
	15'						4'6"-7'0": Conglomerate.
	20'						7'0"-42': Quartzite.
	25'				Jointed.		13'2"-13'6": Zone of slickensiding.
	30'						14'7"- Slickensiding.
	35'						25': Blue tourmaline plus limonite on a 45° joint.
	40'						25'2": Open joint + pyrite.
	45'				All		33'7": Weathering cavities.
	50'						42'-60'7": Conglomerate.
	55'						Below 40' the occurrence of free quartz increases and the core becomes more fragmentary.
				Qtz			44'3"-44'6": Quartz vein.
	60'						47'-55': Weathering cavities with mineralisation, joints: quartz and limonite especially 47'-48'.
	65'						56'10"-57'1": Quartz vein.
	70'						59'6"-59'9": Slickensiding.
	75'						End of hole 60'7"
	80'						Logged: G. Hale
	85'						: M. Craig
	90'						15th Dec: 1957.
	95'						
	100'						

DRILLING RECORD

SCHEME:- MERSEY – FORTH
LOCATION:- CETHANA
POSITION PLOTTED ON DRAWING No.: X. 544
DATES: (a) DRILLED: Nov. 57 (b) WATER TABLE:
METHOD USED: D.D. DIAMETER:
SITE REMARKS:

POSITION — CO-ORDINATES: E. N.
ON LINE: 1X / 11A BEARING: 0°0' AT CH:
FROM STN.: 1X BEARING: 1°55' DIST.: 311

LEVEL — SURFACE: FORMATION: WATER TABLE:
424

INCL. — HOLE DRILLED: DEPRESSION ANG.: INCL. BEARING:
VERT/~~HOR~~/~~INC~~:

HOLE No. 541Y
FILE No.
SHEET 1 OF 2 SHEETS

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	0						
	5'				Joints break core 3 pieces 10'		Reddish quartzite to 8'3"
	10'						Joints filled with quartz vugs, clay, pyrite, haematite, White-grey quartzite, no iron staining below 12'.
	15'						
	20'						
	25'				Joints up to 1' from 23' down. at 70°-60°, 45°, 89° and		
	30'						
	35'						Becomes redder at 33'10", with pebble conglomerate at 38'11"
	40'						Conglomerate is dark purplish red with a varying amount of matrix.
	45'						
	50'						Thin white quartzite band 51'-51'8"
	55'				Jointing up to 1', but less than usual.		
	60'						
	65'						Colour banding with less pebbles from 66'
	70'						
	75'						Quartzite becomes less pebbly and develops into a soft massive purple quartzite which is almost a slate, the bedding being near parallel to the core axis. at 80', to 60° at 88', and 45° at 98'
	80'						Near vertical joints break core from 74'-80'
	85'						
	90'				Jointing less severe. Carbonate and pyrite filled.		Joint 45° at 93' Leached vug with quartz and pyrite.
	95'						
	98' 60° //						98'3" Joints with carbonate and pyrite.
	100'						

FORM No. H.E. 445

DRILLING RECORD 60

SCHEME:- MERSEY-FORTH.

LOCATION:- CETHANA.

POSITION PLOTTED ON DRAWING No.:

DATES: (a) DRILLED: Dec. 57 (b) WATER TABLE:

METHOD USED: DIAMETER: BX and AX

SITE REMARKS:

POSITION	CO-ORDINATES:	E.	N:	HOLE No. 5417
	ON LINE:	BEARING:	AT CH:	
	FROM STN.:	BEARING:	DIST.:	FILE No.
LEVEL	SURFACE:	FORMATION:	WATER TABLE:	
				SHEET 2 OF 2 SHEETS
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	
	VERT/~~HOR/INC~~:	90°		

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	100'						
	105'				Joints break core to pieces up to 1". No joints above 60°		104' Purplish conglomerate with holes, clay patches and leached joints.
	110'						As above, with decrease in clayey material below 129'.
	115'						
	120'						
	125'						
	130'						
	135'				Shearing on 45° joints.		
	140'						
	145'						
	150'						
	155'						
	160'						
	165'						As above to 189'
	170'						
	175'						
	180'				Joints as above.		Breccia ¼" wide at 75°. Pyrite and haematite present.
	185'						
	190'				Irregular breaks through vugs.		mineralised and silicified vuggy conglomerate which has a reddish colour.
	195'						
	200'						Hole completed 200'6". Logged G Hale

DRILLING RECORD

SCHEME:- MERSEY-FORTH.

LOCATION:- CETHANA.

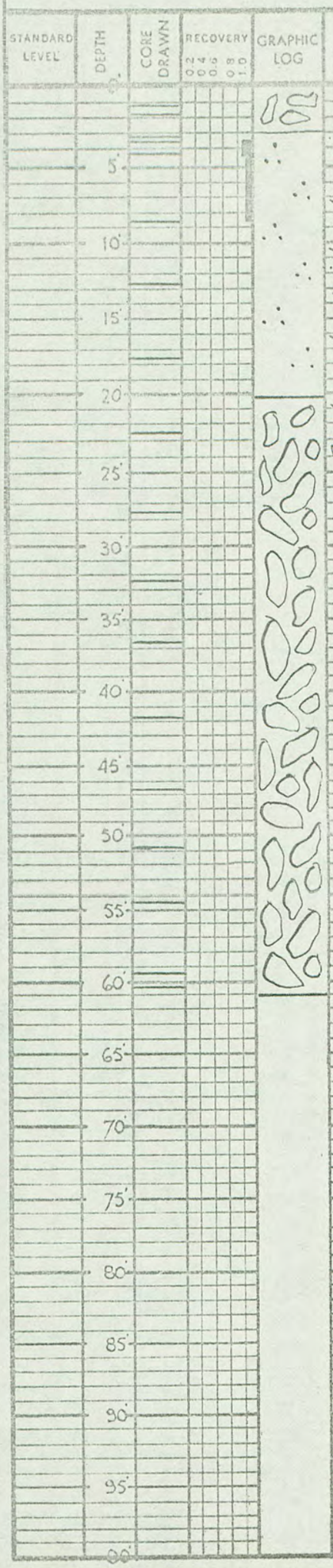
POSITION PLOTTED ON DRAWING No.: Xs 544

DATES: (a) DRILLED: DEC. 57 (b) WATER TABLE:

METHOD USED: D.D. DIAMETER: BX and AX

SITE REMARKS:

POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5418
	ON LINE: 1X / 11A	BEARING: 0°0′	AT CH:	
	FROM STN.: 1X	BEARING: 0°57′	DIST.: 311	FILE No.
LEVEL.	SURFACE:	FORMATION:	WATER TABLE:	
	428			
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET 1 OF 1 SHEETS
	~~VERT~~/~~HOR~~/INC:	20°	222°	



REMARKS

Coarse, reddish Roland Conglomerate to 3′.

Finer, whitish quartzite to 20′. Carbonate and chlorite present.

15′ leached zone. Joints at 45° and 70°

23′ joint fillings of quartz.

Reddish Roland Conglomerate - jointing less pronounced. Less breakage from 30′. Pebbles mainly quartz.

Hole completed 60′5″.

Logged M. Craig & G. Hale.

DRILLING RECORD

SCHEME:- MERSEY - FORTH.

LOCATION:- CETHANA.

POSITION PLOTTED ON DRAWING No.: Xs 544

DATES: (a) DRILLED: Dec-57. (b) WATER TABLE:

METHOD USED: DIAMETER: BX . AX

SITE REMARKS:

POSITION

CO-ORDINATES:	E.	N:
ON LINE BM2577 / XXVB	BEARING: 0°0	AT CH:
FROM STN. BM 2577	BEARING 357°40'	DIST.: 398

LEVEL

SURFACE:	FORMATION:	WATER TABLE:
424		

INCL.

HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:
VERT/~~HOR/INC~~:	90°	

HOLE No. 5419

FILE No.

SHEET 1 OF 3 SHEETS

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER
	0'				Joints break core into 2" fragments.	
	5'					
	10'					
	15'					
	20'					
	25'					
	30'					
	35'					
	40'					
	45'					
	50'					
	55'				Jointing mainly 45° and 60° not weathered - some leaching.	
	60'					
	65'					
	70'					
	75'					
	80'					
	85'				Pieces up to 14" long	
	90'				70°	
	95'					
	99'					

REMARKS

Fine white closely jointed quartzite. Joints iron stained with some leaching.

Number of quartz pebbles increasing.

52'- 59' Conglomerate band, joints pyritised.

Dark purplish conglomerate.

65' Bedding appears to be approximately 20°

69'- 73'9" Finer conglomerate with unsheared pebbles, but matrix

Conglomerate with less matrix from 78'.

DRILLING RECORD

SCHEME:- MERSEY – FORTH.

LOCATION:- CETHANA.

POSITION PLOTTED ON DRAWING No.:

DATES: (a) DRILLED: Jan. 58 (b) WATER TABLE:

METHOD USED: DIAMETER: BX - AX

SITE REMARKS:

POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5419
	ON LINE:	BEARING:	AT CH:	
	FROM STN.:	BEARING:	DIST.:	FILE No.
LEVEL.	SURFACE:	FORMATION:	WATER TABLE:	
				SHEET 2 OF 3 SHEETS
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	
	VERT/~~HOR/INC~~:	90°		

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	100						As above, with patches of haematite staining in parts giving a deep red colouration.
	105						
	110						
	115						
	120						
	125						
	130						
	135				Joints as above.		
	140						
	145						
	150						
	155						
	160						159' Unleached carbonate patches.
	165						
	170						
	175						
	180				Joints break core to 4" pieces which are clean and rough.		Core loss due to jointing. Pyrite and some carbonate present.
	185						
	190						As above.
	195						190'-202' As above, ie. whitish conglomerate, heavily silicified containing pyrite and carbonate. Some leaching apparent but no iron staining.
	200						

DRILLING RECORD

SCHEME:- MERSEY - FORTH
LOCATION:- CETHANA
POSITION PLOTTED ON DRAWING No.:
DATES: (a) DRILLED: JAN. 58 (b) WATER TABLE:
METHOD USED: DIAMETER: BX - AX
SITE REMARKS:

POSITION: CO-ORDINATES: E: N: | ON LINE: BEARING: AT CH: | FROM STN.: BEARING: DIST.:
LEVEL: SURFACE: FORMATION: WATER TABLE:
INCL.: HOLE DRILLED: DEPRESSION ANG.: INCL. BEARING: | VERT/~~HOR/INC~~:

HOLE No. 5419
FILE No.
SHEET 3 OF 3 SHEETS

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	200'						
	205'				Joints as above - usually tight and filled with carbonate and pyrite.		Conglomerate as above - silicified and mineralised
	210'						
	215'						
	220'						
	225'						
	230'						
	235'						235' Haematite enriched fine band 10"
	240'						237' - 257' White conglomerate, silicified with few quartz pebbles in much fine matrix. Carbonate increased in the joints towards 257'
	245'						
	250'				Core up to 2'9" pieces few joints at 30° and 45°.		
	255'						
	260'						A gradual increase of slatey pieces with brecciation to whitish clay slate with joints at 65° and 55°. Bedding plane cleavages at 15° and dips 75°.
	265'						Contact is tight but broken so that the dip is concealed.
	270'						Gradual change to white quartzite at 269' 5" for 12".
	275'				Joints tight and not noticeable. Core to 3' lengths.		
	280'						Greenish grey slate to the end of hole, mineralised with pyrite stringers and joint fillings. All joints tight with some carbonate.
	285'						
	290'						Cleavage or bedding or both at 28°
	295'						
	300'						Hole completed 301' 6". Logged G. Hale

DRILLING RECORD

SCHEME:- MERSEY - FORTH
LOCATION:- CETHANA.
POSITION PLOTTED ON DRAWING No.: X.S 544
DATES: (a) DRILLED: Jan. 58 (b) WATER TABLE:
METHOD USED: DIAMETER: BX
SITE REMARKS:

POSITION — CO-ORDINATES: E: N: HOLE No. 5620
ON LINE: BM2577 / XXV B BEARING: 0°0 AT CH
FROM STN.: BM 2577 BEARING: 358° 19' DIST.: 400 FILE No.
LEVEL. — SURFACE: FORMATION: WATER TABLE:
426
INCL. — HOLE DRILLED: DEPRESSION ANG.: INCL. BEARING: SHEET 1 OF 1 SHEETS
~~VERT~~/~~HOR~~/INC: $12\frac{1}{2}°$ 28c°

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER
	0					
	5'					
	10'					
	15'					
	20'					
	25'					
	30'					
	35'					
	40'					
	45'					
	50'					
	55'					
	60'					
	65'					
	70'					
	75'					
	80'					
	85'					
	90'					
	95'					

Joints iron stained; break core into 2" pieces. 80°, 80°

Joints less pronounced. Iron stained. 45°, 60°/70°

10°, 45°/70°, 60°

45°/70° Fe

80°/60°

REMARKS

White jointed quartzite with chlorite filled cracks to 9'9".

Purplish quartzite to 16'9"

White jointed quartzite as above with some redder bands to 65'8".
Joints parallel to core axis dominate – most weathered.
Gradational changes from white or grey to red and purplish coloured rock is gradual, having no clear cut boundary.

All the core is fine quartzite with no fossils.

Core broken by joints at 45° - lengths up to 9".

Fine red quartzite to end of hole.

70' 0" End of hole.

Logged C. Hale.

FORM No. H.E. 443

DRILLING RECORD

SCHEME:- MERSEY - FORTH.
LOCATION:- CETHANA.
POSITION PLOTTED ON DRAWING No.: X₅ 539
DATES: (a) DRILLED: JAN. 58. (b) WATER TABLE:
METHOD USED: DIAMETER: BX
SITE REMARKS:

POSITION: CO-ORDINATES: E: N: HOLE No. 5421
ON LINE: XY / XYA BEARING: 0°0' AT CH
FROM STN.: XX BEARING: 333°53' DIST.: 133 FILE No.
LEVEL: SURFACE: FORMATION: WATER TABLE:
402
INCL.: HOLE DRILLED: DEPRESSION ANG.: INCL. BEARING: SHEET 1 OF SHEETS
~~VERT~~/~~HOR~~/INC: 35° 235°

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0-25% 25-50% 50-75% 75-100%	GRAPHIC LOG	JOINTS	WATER	REMARKS
	0'				Many joints at 0°, 45° and 60°		DARK reddish brown, hard granule conglomerate with numerous haematite blebs. Lighter colour from 9'. mixed rock types in granules. Rock broken by jointing into fragments up to 15" long. Joints iron stained.
	5'						
	10'						
	15'						
	20'						
	25'						
	30'						
	35'				less jointing. 45°		37' Granule conglomerate and sandstone quartzite is finer than above, having more matrix and less haematite.
	40'						
	45'						
	50'						
	55'				45°		55' Jointing, with quartz veins and leached — dark colour again with more haematite and rock fragments
	60'				60°		61' vertical joint.
	65'						66' Broken by jointing and leached.
	70'						
	75'				Very minor jointing.		
	80'						
	85'						
	90'						Core loss prevents determination of contact. Slate is light green-grey with slatey cleavage at 70°, cut by chlorite filled joints at 80°. Cleavage less pronounced from 97', and core gradually goes darker grey. Bedding is parallel to cleavage. Joints tight and iron filled.
	95'						
	100'						

DRILLING RECORD

SCHEME:- MERSEY – FORTH

LOCATION:- CETHANA

POSITION PLOTTED ON DRAWING No.: Xs 539

DATES: (a) DRILLED: Feb. 28. (b) WATER TABLE:

METHOD USED: DIAMETER:

SITE REMARKS:

POSITION

CO-ORDINATES:	E:	N:
ON LINE: XX / XYA	BEARING: 0°00	AT CH:
FROM STN.: XX	BEARING: 333°53'	DIST.: 133

LEVEL

SURFACE:	FORMATION:	WATER TABLE:
402		

INCL.

HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:
~~VERT~~/~~HOR~~/INC:	35°	235° Mag

HOLE No. 5421

FILE No.

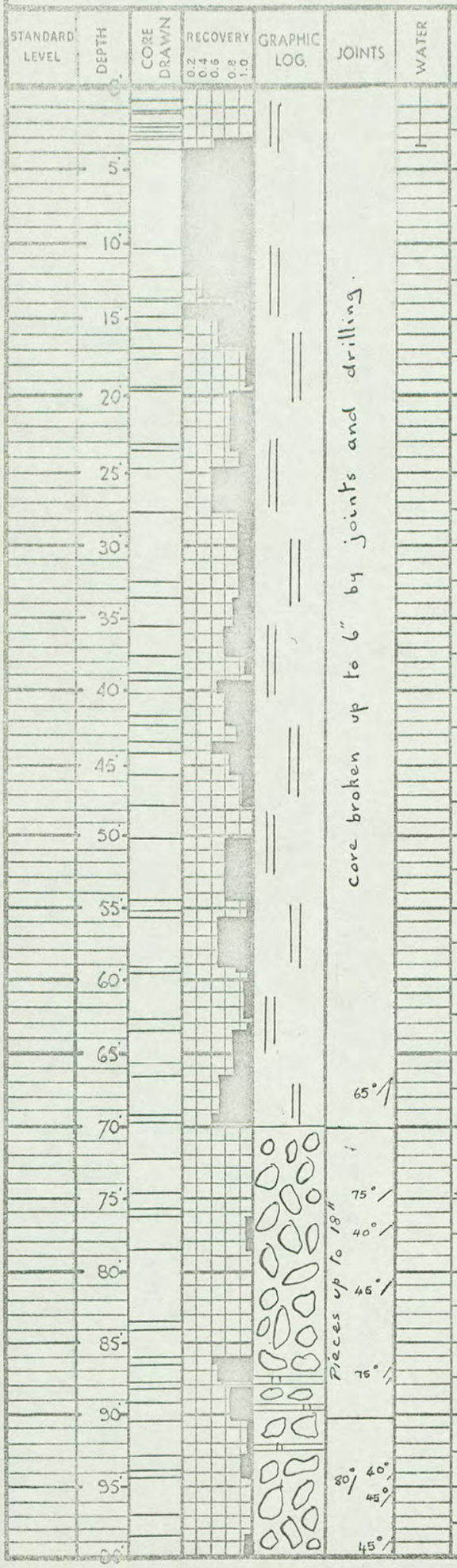
SHEET 2 OF 2 SHEETS

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	10'						Dark grey slate with sandy nodules filled with pyrite.
	5'				60°/ 70°/		
	110'						Joints at 60° and 45° displace one another. Bedding approximately 55° with cleavage parallel.
	15'				V/		
	120'				45°/ 10°/		
	25'				10° 60°/ 50° 10°		Iron filled joints tight. 60° joint displaced 10° joint.
	130'				7°///		
	35'				45° Fe 10° 45°		Interbedded ; disturbed bedding with small green nodules.
	140'				10° Fe V/		rock grey - bedding 52°. The cleavage has not the same strike as the bedding and less dip (36°). Cleavage is cut at 50° (this is not parallel to bedding)
	45'				46° Fe Xsp. 30°		150'7" Hole completed.
	150'						Logged G. Hale.
	55'						
	60'						
	65'						
	70'						
	75'						
	80'						
	85'						
	90'						
	95'						
	200'						

DRILLING RECORD

SCHEME:- MERSEY-FORTH
LOCATION:- CETHANA
POSITION PLOTTED ON DRAWING No.: X3539
DATES: (a) DRILLED: Feb.'58 (b) WATER TABLE:
METHOD USED: D.D. DIAMETER:
SITE REMARKS:

POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5422
	ON LINE: ~~XX~~ XYA	BEARING: 0°00'	AT CH:	
	FROM STN.: XX	BEARING: 341°57'	DIST.: 242	FILE No.
LEVEL	SURFACE:	FORMATION:	WATER TABLE:	
	395			
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET 1 OF 2 SHEETS
	~~VERT/HOR~~ INC.:	36°	92° Mag	



REMARKS

0 - 3'6" mid-grey slate with tubicles.

3'6" - 10' No record.

10' - 24'9" white tubicolar quartzite.
pyrite abundant.

24'9" - becomes more slaty.
dark grey slates with lighter sandy patches and tubicolar horizon

Bedding 35° at 32'0" on tubicolar bed in slate.

66' Bedding and cleavage 35°
69'10" Joints at 65° and 70°

Greenish-white pebble or granule conglomerate. Pebbles ¼" diameter.
Milky quartz - red quartz grains, haematite and purple chert fragments.
From 72' haematite very abundant and colour purplish - patchy colouration.
Slaty band at 86'7" and 89'1" and 92'
Dip 35° on slate band at 90'4"
leached zone (clay) gives holes in core at 91'

lighter colour from about 98' and finer grained.

DRILLING RECORD

SCHEME:- MERSEY - FORTH

LOCATION:- CETHANA

POSITION PLOTTED ON DRAWING No.:

DATES: (a) DRILLED: Feb. 58. (b) WATER TABLE:

METHOD USED: D.D. DIAMETER:

SITE REMARKS:

POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5422
	ON LINE:	BEARING:	AT CH:	
	FROM STN.:	BEARING:	DIST.:	FILE No.
LEVEL	SURFACE:	FORMATION:	WATER TABLE:	
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET 2 OF 2 SHEETS
	~~VERTHOR~~/INC:			

STANDARD LEVEL | DEPTH | CORE DRAWN | RECOVERY 0.2 0.4 0.6 0.8 1.0 | GRAPHIC LOG | JOINTS | WATER

Core to 6" lengths.

	REMARKS
100	Quartzite purplish and sandy down to 109'6"
105	104' - about 12" purple with white spots - coarse sandstone.
	Bedding dip 45°.
110	109'6" - 127' White quartzitic sand-
115	stones with some finer bands.
	112' - 114' pitted and leached - iron stained.
120	From 119' white mottled. appearance but
	Thin greenish slate, dip 45°. same grainsize.
125	122' 65° joint slickensided - 30°.
	Develops into grey tubicolar sandstone
130	and quartzite.
	133'9" Cavity with clay, tourmaline, chalcopyrite.
135	
140	
145	
150	
	Friable sandy patch - yellowish colour and
155	pits 153' - 156'.
	Last 6" yellowish colour.
160	End of hole 159'7".
65	
	Logged G. Hale
70	
75	
80	
85	
90	
95	

DRILLING RECORD

SCHEME:- MERSEY - FORTH.

LOCATION:- CETHANA.

POSITION PLOTTED ON DRAWING No.: X 3 544

DATES: (a) DRILLED: Feb. 58 (b) WATER TABLE:

METHOD USED: D.D. DIAMETER:

SITE REMARKS:

POSITION	CO-ORDINATES:	E.	N:	HOLE No. 5423
	ON LINE: XX III A / 1 B	BEARING: 0°00'	AT CH:	
	FROM STN. XX III A	BEARING: 66°38'	DIST.: 28	FILE No.
LEVEL	SURFACE:	FORMATION:	WATER TABLE:	
	593			
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET 1 OF 3 SHEETS
	VERT/~~HOR/INC~~:			

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG.	JOINTS	WATER	REMARKS
	0'						
	5'						Fine red quartzite with white quartz veins and colour banding. Cleavages at about 45°
	10'						
	15'						17' Colour banding, 10° dip.
	20'				Core up to 15" Joints at 60° and 45° mainly.		20' Iron joint 70°. Several quartz veins parallel.
	25'						21'-22' Core with parallel 45° quartz veins banding at 10°.
	30'						26' Joint 45° green chlorite and slickensides
	35'						36'6" 45° joint, chlorite, slickensides.
	40'						
	45'						
	50'						
	55'						
	60'						
	65'						
	70'				Core up to 8".		
	75'						
	80'						
	85'						
	90'						
	95'						
	99'						

FORM No. H.Q. 443

DRILLING RECORD

SCHEME:- MERSEY-FORTH
LOCATION:- CETHANA
POSITION PLOTTED ON DRAWING No.:
DATES: (a) DRILLED: Feb. 58. (b) WATER TABLE:
METHOD USED: D.D. DIAMETER:
SITE REMARKS:

POSITION — CO-ORDINATES: E: N: | ON LINE: BEARING: AT CH: | FROM STN.: BEARING: DIST.:
LEVEL — SURFACE: FORMATION: WATER TABLE:
INCL. — HOLE DRILLED: DEPRESSION ANG.: INCL. BEARING: | VERT/~~HOR/INC~~:

HOLE No. 5423
FILE No.
SHEET 2 OF 3 SHEETS

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	100'				Pieces up to 8", Joints at 80°, 70°, 60°, 45°, 20°.		As above to 107'
	105'						
	110'						
	115'						Massive red quartzite with quartz veins, fresh joints and colour banding.
	120'						
	125'						
	130'						
	135'						
	140'						
	145'						
	150'						Red quartzite.
	155'						153' pebbles of milky quartz in band, dip 25°-30°
	160'				Joints at 45°, 60° and near vertical. Break core up to 8" pieces.		156'
	165'						157'6" - 160' grey quartzite
	170'						160' - 163' pebbles in quartzite with much matrix, i.e. pebbly quartzite.
	175'						Bedding approximately 30°.
	180'						Purply red quartzite to 173', then increase in the number of pebbles to conglomerate at 175'.
	185'						Coarse purplish-whitish conglomerate with quartz veins.
	190'						186' - 187' grey sandstone with pebbles cleavage nearly parallel to bedding at 60° dip.
	195'				upto 12" but closed.		Conglomerate to 193'
	200'						purple slatey rock cleavage at 50°, bedding approximately 58°.

DRILLING RECORD

SCHEME:- MERSEY-FORTH

LOCATION:- CETHANA

POSITION PLOTTED ON DRAWING No.:

DATES: (a) DRILLED: Mar. 58 (b) WATER TABLE:

METHOD USED: D.D DIAMETER:

SITE REMARKS:

POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5423
	ON LINE:	BEARING:	AT CH:	
	FROM STN.:	BEARING:	DIST.:	FILE No.
LEVEL	SURFACE:	FORMATION:	WATER TABLE:	
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET 3 OF 3 SHEETS
	VERT/~~HOR/INC.~~			

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	20						Purple slate
	205						Coarse conglomerate, pebbles 2", glassy quartz, arsenopyrite and pyrite.
	210						END of hole 213' 8"
	215						Logged G. Hale
	20						
	25						
	30						
	35						
	40						
	45						
	50						
	55						
	60						
	65						
	70						
	75						
	80						
	85						
	90						
	95						
	00						

DRILLING RECORD

SCHEME:- MERSEY - FORTH
LOCATION:- CETHANA.
POSITION PLOTTED ON DRAWING No.: Xs 539
DATES: (a) DRILLED: MAR.'58. (b) WATER TABLE:
METHOD USED: D.D. DIAMETER:
SITE REMARKS:

POSITION: CO-ORDINATES: E. N: HOLE No. 5424
ON LINE: XX/XVA BEARING: 0°0' AT CH:
FROM STN.: XX BEARING: 344°02' DIST.: 247 FILE No.
LEVEL: SURFACE: FORMATION: WATER TABLE:
398'
INCL.: HOLE DRILLED: DEPRESSION ANG.: INCL. BEARING: SHEET 1 OF 1 SHEETS
~~VERT/HOR~~/INC: 16° 273° Mag

STANDARD LEVEL | DEPTH | CORE DRAWN | RECOVERY 0.2 0.4 0.6 0.8 1.0 | GRAPHIC LOG | JOINTS | WATER

6" pieces largest.
Core up to 20"

REMARKS

0 - 15'8" White quartzitic sandstone with tubicles
Joints 65° and 45° at 6'.

mid grey slates with tubicles.
cleavage 70° - 80°.
bedding 70° - 80°.

41' Brownish white sandy quartzite, few quartz pebbles.
46' Greenish gray slate with disturbed bedding.
51'6" - 52' whitish sandy bands - ½" thick

55'7" whitish sandy bands ¼" thick
55'7" - 62' white sandy quartzite.

62' - 65'7" Greenish-grey slate with tubicles.
Dip 70°, cleavage 70°
65'7" - 67' brownish white pebbly quartzite.
67' End of hole.

Logged C. Hale.

DRILLING RECORD

46

SCHEME:- MERSEY - FORTH.

LOCATION:- CETHANA.

POSITION PLOTTED ON DRAWING No.: X s 544

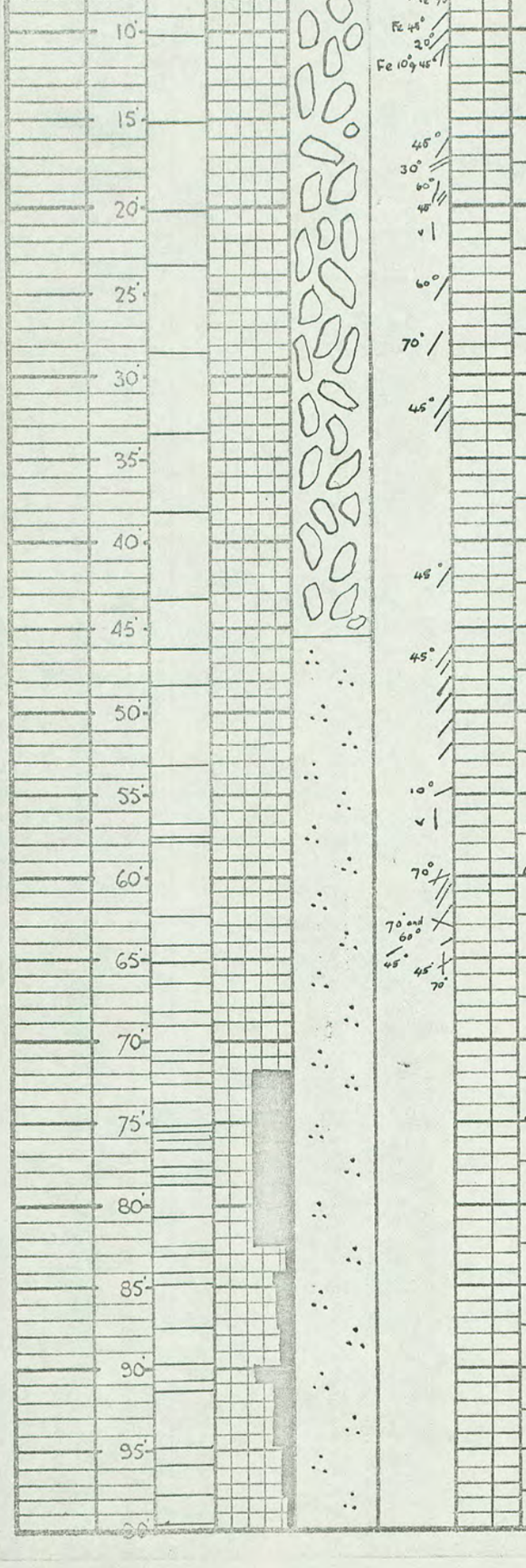
DATES: (a) DRILLED: March '58 (b) WATER TABLE:

METHOD USED: D.D. DIAMETER:

SITE REMARKS:

POSITION	CO-ORDINATES:	E:	N:	HOLE No. 6425
	ON LINE: F1/V1	BEARING: 0°00'	AT CH:	
	FROM STN.: F1	BEARING: 349°48	DIST.: 285	FILE No.
LEVEL	SURFACE:	FORMATION:	WATER TABLE:	
	411			
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET 1 OF 2 SHEETS
	~~VERT/HOR~~/INC:	87°	285° Mag.	

STANDARD LEVEL | DEPTH | CORE DRAWN | RECOVERY 0.2 0.4 0.6 0.8 1.0 | GRAPHIC LOG | JOINTS | WATER



REMARKS

0 - 45'4"

Conglomerate - white pebbles, purple matrix. pebbles to 3" diameter with fine pebbles in matrix. Carbonate, sulphide and clay replacing matrix, some leaching. Slickensides at 10'. Core jointed, but lengths up to 2'6" obtained. Slickensides on 30°.

Mineralised zone on joint.

45'4" - 100' Purple quartzite dips 35°. Shearing and cleavage in thin chlorite bands, dip 50° - 60°

Core broken on near vertical joint. Jointing at 45° and 70° cuts core cleanly.

Core broken in drilling - joints as above but core in lengths up to 2" only. Mineralised vugs leached out and are not iron stained.

DRILLING RECORD

SCHEME:- MERSEY - FORTH

LOCATION:- CETHANA.

POSITION PLOTTED ON DRAWING No.:

DATES: (a) DRILLED: Mar. '58 (b) WATER TABLE:

METHOD USED: D.D. DIAMETER:

SITE REMARKS:

POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5425
	ON LINE:	BEARING:	AT CH:	
	FROM STN.:	BEARING:	DIST.:	FILE No.
LEVEL	SURFACE:	FORMATION:	WATER TABLE:	
				SHEET 2 OF 2 SHEETS
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	
	~~VERT/HOR~~ INC:			

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	100'				60°		Purple quartzite to 135'
	105'				70° 45°		dip of colour banding and shearing - chlorite
					60° 45°		filled partings 50°-60°.
	110'				60° 45° 30°		Vugs filled with fine carbonate.
	115'				60° 60°		Core up to 12" lengths
	120'				30° 70°		
					60° 70°		
	125'				60° 70°		
	130'				70° 30°		132' Vug with fine sandstone.
	135'				60° 45°		End of hole 135'.
	40'						Logged G.Hale
	45'						
	50'						
	55'						
	60'						
	65'						
	70'						
	75'						
	80'						
	85'						
	90'						
	95'						
	96'						

DRILLING RECORD

SCHEME:- MERSEY - FORTH

LOCATION:- CETHANA.

POSITION PLOTTED ON DRAWING No.: Xs 544

DATES: (a) DRILLED: MAR. 58. (b) WATER TABLE:

METHOD USED: D.D. DIAMETER:

SITE REMARKS:

POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5426
	ON LINE: F/~~V~~/L	BEARING: 0°00'	AT CH:	
	FROM STN.: F1.	BEARING: 350°47'	DIST.: 287	FILE No.
LEVEL	SURFACE:	FORMATION:	WATER TABLE:	
	413			
INCL.	HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:	SHEET 1 OF 1 SHEETS
	~~VERT/HOR~~/INC:	20°	278° Mag	

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY: 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER
	0				Fe 10° /	White
	5				/ 60° // 60° /	
	10				45° / 45° / 60° / 70° / 10° / 70° / 45° /	
	15					
	20				45° /	
	25				45° / 45° //	
	30				10° / 45° / 60° / Fe 40°	
	35				/ 30° 20° / 45°	
	40				30° / 45° / 60° / 60°	
	45					
	50				60° / 48° /	
	55				46° // 60°	
	60					
	65					
	70					
	75					
	80					
	85					
	90					
	95					
	96					

REMARKS

0 - 60' 3" Roland Conglomerate

purplish matrix.

leached, pebbles 2" - 3", pebbly matrix.

leached carbonate vugs

35' - 36' core broken on series of joints 45°, 60° and vertical.

45' Carbonate filled vugs in matrix.

End of hole 60' 3"

Logged G. Hale

DRILLING RECORD

SCHEME:- MERSEY - FORTH

LOCATION:- CETHANA

POSITION PLOTTED ON DRAWING No.: Xs539

DATES: (a) DRILLED: Mar. '58 (b) WATER TABLE:

METHOD USED: D.D. DIAMETER:

SITE REMARKS:

POSITION

CO-ORDINATES:	E.	N:
ON LINE: ~~XX~~ XVA	BEARING: 0°0'	AT CH:
FROM STN.: XY	BEARING: 331°40'	DIST.: 126

LEVEL

SURFACE:	FORMATION:	WATER TABLE:
403		

INCL.

HOLE DRILLED:	DEPRESSION ANG.:	INCL. BEARING:
~~VERT/HOR~~/INC:	25°	56° Mag

HOLE No. 5427

FILE No.

SHEET 1 OF 2 SHEETS

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER	REMARKS
	0				45° / 60°	Red	0-12' granule conglomerate with haematite pebbles, glassy quartz and purple haematite staining in some beds. Dip 20°-26° becomes finer down-wards to sandstone (banded current-bedded) from 12'-14'5"
	5				20° / 70°		
	10				70° /	White	
	15				70° / 60°		14'5"-14'8" grey granule conglomerate. 14'8"-21' light greenish-grey glassy quartzite with yellow chloritic partings and pebble bands at 17' and 19'.
	20				60° / 45°		21'-24' Coarse sandstone quartzite (light grey, some glassy bands).
	25				V / 60°		24'-33' Fine sandstone quartzite (some glassy) light greenish grey - disturbed bedding. Marbled appearance - tubicolar.
	30				V / 60°		
	35				45° / 80° / 20°		33'-36' Slightly coarser quartzite, sandgrains of quartz. no disturbances
					45° /		36'6"-37' disturbed bedding quartzite.
	40				60° / 45°		37'-38' glassy quartz with sandgrains. Grey quartzite (sandy) disturbed bedding at top dies out downwards.
	45				85° / 30° / 60°		
	50				70° / 60° / 75° /		49' disturbed bedding for 8", then sandy quartzite to porous medium sandstone from 53'6"-55'.
	55				44° / 60° / V		8" disturbed bedding, 2" fine quartzite, then sandstone, porous and leached rugs to 60'
	60				40° / 10°		60'-69' glassy light grey quartzite with white quartz grains and sandy patches. Some disturbed bedding.
	65				60° /		
	70				30° / 45° / 30°		2" grey slaty rock then green porous ruggy sandstone. to 70'3". 70'3"-71' Dark grey blotchy quartzite.
	75						71' Yellowish weathered rock with slate fragments
							72'8"-75' Driller reports making water dark grey tubicolar quartzite (disturbed).
	80						75'-79' Fine yellowish-grey sandy quartzite. Green chloritic partings - spotty at top.
	85						79'-92'6" glassy quartzite - chloritic partings.
	90						92'6"-94' disturbed bedding - dark grey sandy quartzite.
	95						Becomes glassy quartzite, changing from light grey to greenish light grey to 106'6".
	100						

DRILLING RECORD

SCHEME:- MERSEY-FORTH
LOCATION:- CETHANA
POSITION PLOTTED ON DRAWING No.:
DATES: (a) DRILLED: MAR. '58 (b) WATER TABLE:
METHOD USED: D.D. DIAMETER:
SITE REMARKS:

POSITION: CO-ORDINATES: E: N: | ON LINE: BEARING: AT CH. | FROM STN.: BEARING: DIST.:
LEVEL: SURFACE: FORMATION: WATER TABLE: | 403
INCL.: HOLE DRILLED: DEPRESSION ANG.: INCL. BEARING: | ~~VERT/HOR~~/INC:

HOLE No. 5427
FILE No.
SHEET 2 OF 2 SHEETS

STANDARD LEVEL	DEPTH	CORE DRAWN	RECOVERY 0.2 0.4 0.6 0.8 1.0	GRAPHIC LOG	JOINTS	WATER
	100'					White
	105'					
	110'					
	115'					
	120'					
	125'					
	130'					
	135'					
	140'					
	145'					
	150'					
	55'					
	60'					
	65'					
	70'					
	75'					
	80'					
	85'					
	90'					
	95'					
	200'					

REMARKS

Dark grey, disturbed bedding.
Spotty green-grey with yellow blotches in glassy quartzite to 113'.
113'-114' dark grey pebbly quartzite.
114'-122' glassy quartzite with yellowish bands.
122'-124'9" pebbly dark grey quartzite, white quartz grains of diameter $\frac{1}{8}$th inch.
124'9"-128' glassy quartzite.

128'-129'3" white quartz grains in quartzite.

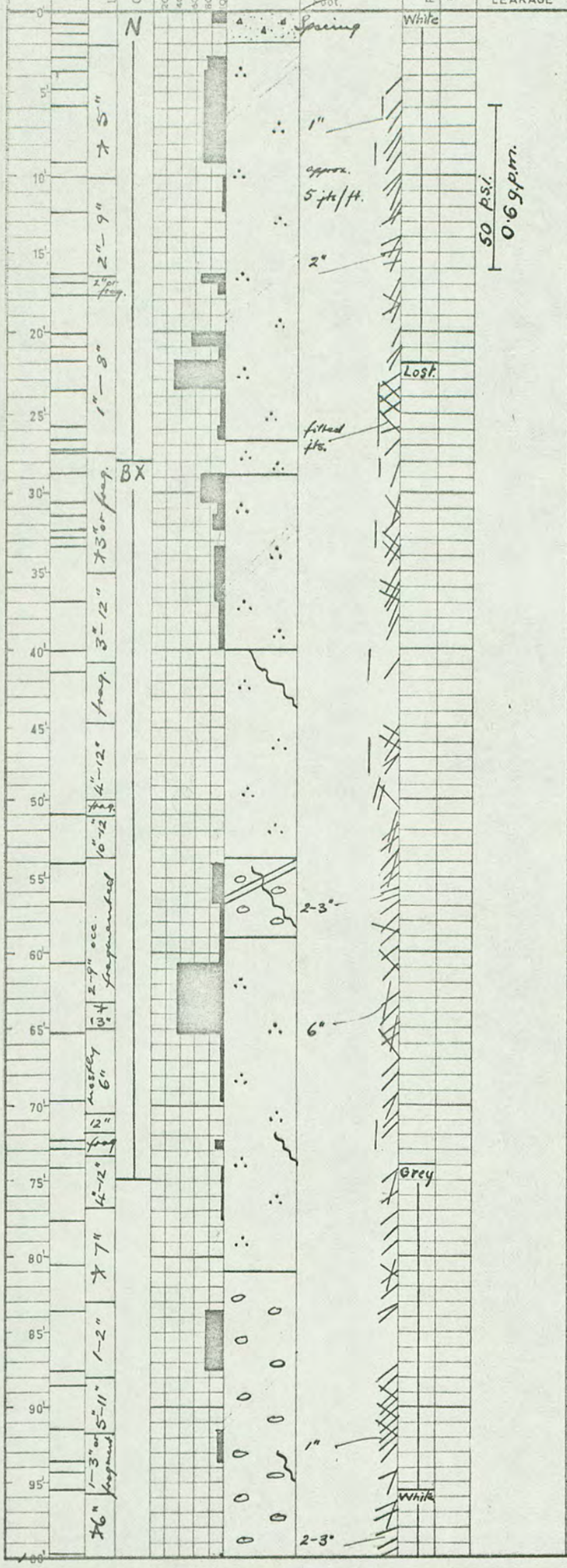
129'3"-136'5" Fine grained white quartzite.
136'5" White quartzite conglomerate, pebbles white and quartz 1" diameter and rounded. Chloritic partings and pebbly quartz matrix.
147'9" Reddish pebbles at bottom.
End of hole 147'9".

Logged G. Hale.

FORM No. H.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5428
LOCATION: CETHANA DAMSITE		ON LINE: HA849 XXIX B	BEARING: 0°00'	AT CH:	
GEOLOGICAL PLAN: A11153 SURVEY PLAN: S4120 8911		AT STN: XXIX B	BEARING: 41°43'	DIST: 70'	FILE No.
DATES (a) DRILLED: July '64 (b) WATER TABLE:	LEVEL	SURFACE	COLLAR	WATER TABLE	
METHOD: D.D. DIAMETER: NX, BX, BMLC.		674			SHEET 1 OF 5 SHEETS
SITE REMARKS: Thin scree slope high on right abutment.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
		VERT./~~HOR./INC.~~	90°		



REMARKS

0–2' Angular fragments of hard, grey, jointed quartzite.

2'–26'8" Light grey – light purple, hard, close or very closely jointed quartzite. Rock fresh with weathered joints. Occasional shear zones and much quartz veining seen. Joints open, tight or cemented.

2'9" Sheared quartzite.
6'6" Quartz veining

16'6" Quartz veining.

20'6" Dip of bedding 40°

26'8"–28'10" Well banded, hard, purple–grey quartzite dipping at 20°

28'10"–40'1" Grey, becoming purple below, hard jointed quartzite with occasional banding. Joints open, tight and filled.

34' Iron pyrites common.

40'1"–53'9" Hard, grey, closely jointed quartzite with occasional pebbles. Some joints weathered others tight or filled.

Ordovician Quartzite and Conglomerate.

53'9"–59' Hard, grey/purple, conglomerate with small patches of quartzite. Quartz veining common rock badly weathered at 56' where development of pyrites occurs.

59'–81' Grey – slightly pink, closely jointed, fine grained, uniform quartzite showing less weathering along joints than above. Joints open, tight or filled by quartz and pyrite, less jointed than above.

81'–168' Hard, purple–grey conglomerate with occasional pockets of quartzite. Rock fresh, closely jointed. Some joints weathered, most open some filled. Pyrites common. Mimic seen in many joints.

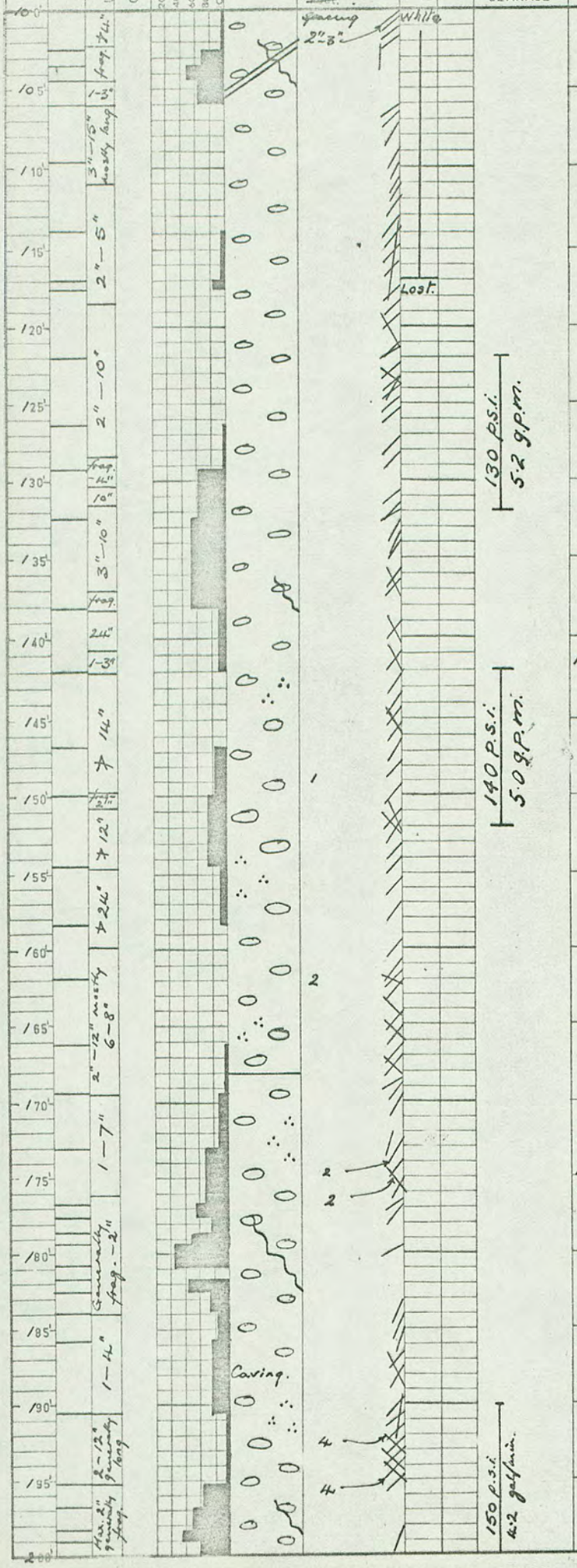
94'2"–96'2" Quartzite

FORM No. H.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT
LOCATION: CETHANA DAMSITE.
GEOLOGICAL PLAN: SURVEY PLAN:
DATES (a) DRILLED: July '64 (b) WATER TABLE:
METHOD: D.D. DIAMETER: NX, BX, BMLC
SITE REMARKS: Thin scree slope high on right abutment.

POSITION	CO-ORDINATES:	E:	N:	HOLE No. 54.28
	ON LINE:	BEARING:	AT CH:	
	AT STN:	BEARING:	DIST:	FILE No.
LEVEL.	SURFACE	COLLAR	WATER TABLE	
				SHEET 2 OF 5 SHEETS
INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
	VERT./HOR./INC.	90°		



100'4" – 104'4" Rock badly weathered.

138'6" – 139'6" Much hydrothermal pyrite. Rock greyer down to 151'

Ordovician Quartzite and Conglomerate.

168' – 292'6" Hard, grey – purple conglomerate with pockets of quartzite more common than previously. Rock well jointed, occasionally sheared; joints open, sealed by quartz & pyrite & very occasionally weathered. Quartz veining seen and rock flour and/or chlorite present along some joints. Quartzite lenses became fewer below. Pockets may be largely apparent representing large boulders in the conglomerate.

FORM No. H.E. 443

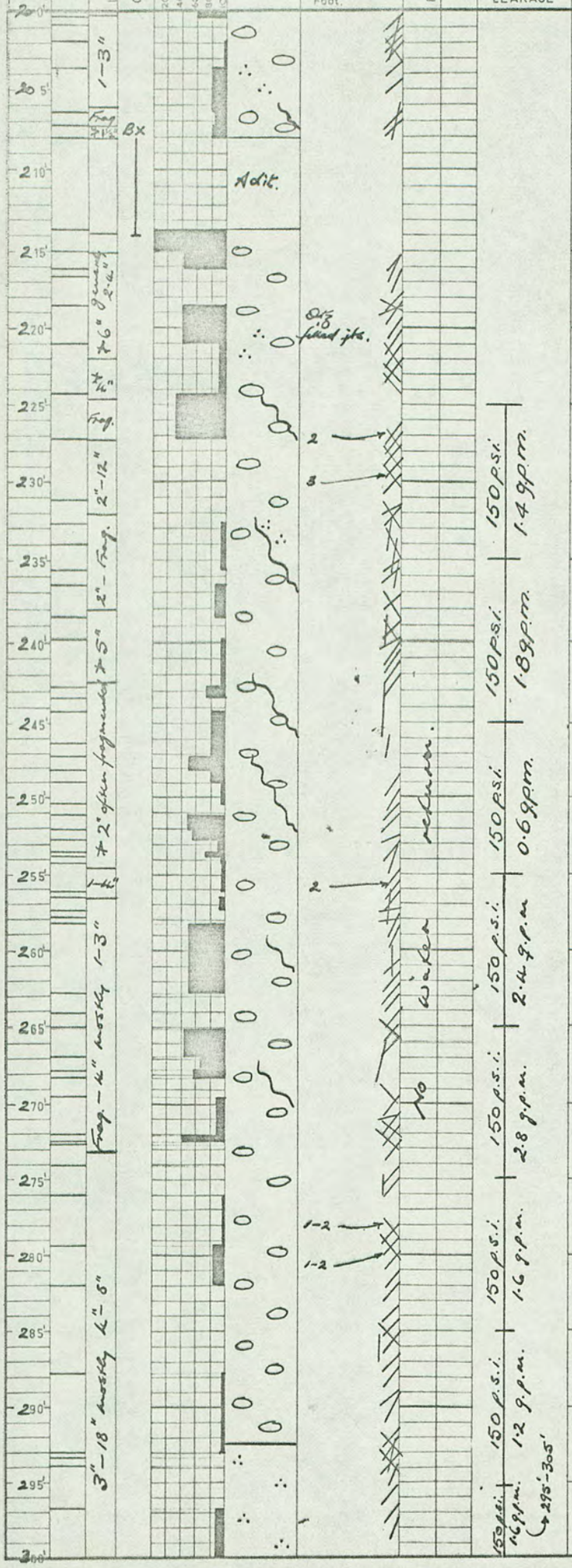
DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E:	N:
LOCATION: CETHANA D.S.		ON LINE:	BEARING:	AT CH:
GEOLOGICAL PLAN: SURVEY PLAN:		AT STN:	BEARING:	DIST:
DATES (c) DRILLED: July '64 (b) WATER TABLE:	LEVEL.	SURFACE	COLLAR	WATER TABLE
METHOD: D.D DIAMETER: NX, BX, BMLC				
SITE REMARKS: Thin loose slope high on right abutment.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
		VERT/~~HOR~~/~~INC~~	90°	

HOLE No. 5428

FILE No.

SHEET 3 OF 5 SHEETS



FORM No. H.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT
LOCATION: CETHANA D.S.
GEOLOGICAL PLAN: SURVEY PLAN:
DATES (a) DRILLED: July 64 (b) WATER TABLE:
METHOD: D.D. DIAMETER: NX, BX, BMLC.
SITE REMARKS: Thin scree slope high on right abutment.

POSITION

CO-ORDINATES:	E:	N:
ON LINE:	BEARING:	AT CH:
AT STN:	BEARING:	DIST:

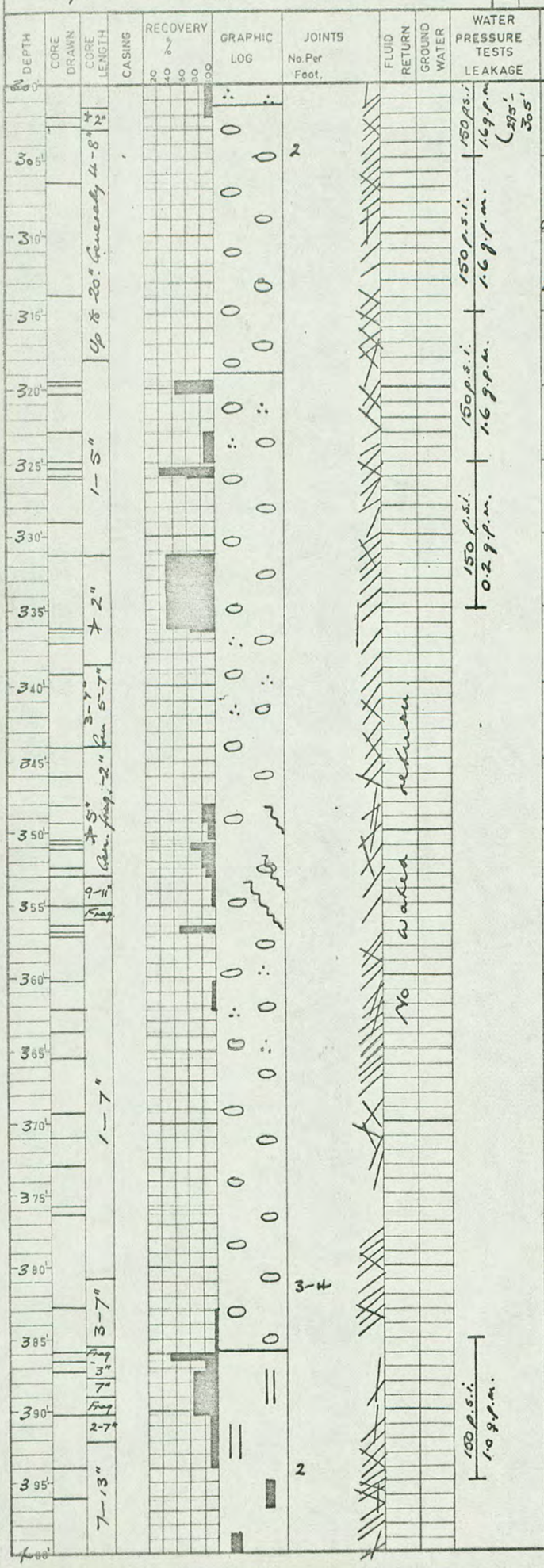
LEVEL.

SURFACE	COLLAR	WATER TABLE

INCL.

HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
VERT/~~HOR.~~/~~ING.~~	90°	

HOLE No. 5428
FILE No.
SHEET 4 OF 5 SHEETS



REMARKS

30'6" – 319' Hard, purple-grey, strongly jointed quartz conglomerate. Joints fresh, tight and filled, quartz veins common. Joints and pebble margins often show fine-grained filling – chlorite, rock flour & carbonate. Slight evidence of movement suggested by angular quartz particles. Galena and pyrite present.

319' – 385'10" Light & dark grey quartz conglomerate/quartzite. Joints tight or showing fillings as above. Pebbles generally difficult to distinguish perhaps due to recrystallization. Matrix generally chloritic often sheared at pebble margins. Veined by quartz, chlorite, pyrite, galena and tourmaline.

Ordovician Quartzites and Conglomerates.

382'10" Thin veins of galena.

385'10" – 401' Light or dark grey & black relatively hard quartzose slate or phyllite with strong development of arsenopyrites often showing euhedral crystals. Joints fewer than above, occasionally open, usually filled by pyrites or chlorite.

Foliation 65-70° to vertical.

Cambrian Slate & Phyllite

FORM No. H.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT

LOCATION: CETHANA D.S.

GEOLOGICAL PLAN: SURVEY PLAN:

DATES (a) DRILLED: July '64 (b) WATER TABLE:

METHOD: D.D. DIAMETER: NX, BX, BMLC.

SITE REMARKS: Thin scree slope high on right abutment.

POSITION				HOLE No.
	CO-ORDINATES:	E:	N:	DH28
	ON LINE:	BEARING:	AT CH:	
	AT STN:	BEARING:	DIST:	FILE No.
LEVEL.	SURFACE	COLLAR	WATER TABLE	
				SHEET 5 OF 5 SHEETS
INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
	VERT. / ~~HOR~~ / ~~INC.~~	90°		

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0										Hole completed 401'
										Logged by R. E. Rawlings 29/9/64.
5										
10										
15										
20										
25										
30										
35										
40										
45										
50										
55										
60										
65										
70										
75										
80										
85										
90										
95										
100										

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION: CO-ORDINATES:	E:	N:	HOLE No. 5429
LOCATION: CETHANA DAMSITE	ON LINE: HA849 XXIX B	BEARING: 0°00'	AT CH:	
GEOLOGICAL PLAN: A11153 SURVEY PLAN: S41208911	AT STN: XXIX B	BEARING: 233°38'	DIST: 172'	FILE No.
DATES (a) DRILLED: July – Aug. '64 (b) WATER TABLE:	LEVEL: SURFACE	COLLAR	WATER TABLE	
METHOD: D.D. DIAMETER: NX	756			SHEET 1 OF 1 SHEETS
SITE REMARKS: Site excavated in weathered quartz conglomerate high on right bank.	INCL.: HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
	VERT./~~HOR.~~/~~INC.~~	90°		

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No Per Foot	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE
0'		Frag.	NX			Joint Spacing	White		
5'		+ 10"				¼"	Grey		
10'		Fragmented				2"			50 p.s.i. 0.8 g.p.m.
15'		12"							
		Frag.							
20'		+ 7"							50 p.s.i. 0.0 g.p.m.
25'		up to 24"				6"			
30'		Frag.					Brown		
35'		+ 14"							50 p.s.i. 0.0 g.p.m.
40'		1" – 11"				7"			
45'		3" or frag.							50 p.s.i. 0.2 g.p.m.
50'		up to 18" occasionally 2"							
		1" – 2"					Grey		
55'		+ 8" occ. fragments				5"			50 p.s.i. 0.2 g.p.m.
60'									
65' – 100'									

REMARKS

0 – 1'6" grey to light brown fragmented conglomerate, strongly jointed.

1'6" – 26'0" light grey to light brown jointed conglomerate. Joints mostly open showing iron oxide and occasionally dousy quartz.

26'0" – 35'6" Grey – purple conglomerate with strong joints, occasionally open and weathered, often sealed by quartz and/or pyrite.

35'6 – 60'4" well bedded, purple – dark grey jointed quartzites. Joints, open, closed or cemented often showing shear zones, occasionally quartz/pyrite veining. Much bedding plane shear.

35'6" – 37'4" Bedding 20° with much shearing.

Bedding planes generally open suggesting slight clay loss. Bad limonite staining down to 47'7", slight staining below but not so marked. Traces of clay seen at 36'5", 40'2", 49'2" and 49'9"

55'4" dark banding showing sedimentary structures.

Hole completed 60'4"

Logged by G.E. Rawlings

20/8/64

FORM No H.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT
LOCATION: CETHANA D.S.
GEOLOGICAL PLAN: A11153 SURVEY PLAN: S4120 8911
DATES (a) DRILLED: July – Aug. '64 (b) WATER TABLE:
METHOD: D.D. DIAMETER: NX, NMLC
SITE REMARKS: Site excavated in 2' talus overlying weathered conglomerate high on right bank.

POSITION

CO-ORDINATES:	E:	N:	HOLE No
ON LINE: HA802 HA849	BEARING: 0°00'	AT CH:	5430
AT STN: HA849	BEARING: 219°37'	DIST: 420'	FILE No.

LEVEL

SURFACE	COLLAR	WATER TABLE
731		

INCL.

HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
VERT./HOR./INC.	90°	

SHEET 1 OF 4 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY %	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0'			NX							0–15' Hard, grey, weathered quartz conglomerate. Joints open and weathered & cemented. Rock broken up due to open joints at some horizons. Occasional quartz veins present.
5'		Rock fragmented on joints up to 18" generally 2–6"				2				
10'							Grey		10'–20' 50 p.s.i. No loss.	
15'										15'–17'8" Purple quartz conglomerate much veined by quartz & showing occ. joints. Rock much weathered with limonite filling its & round pebbles.
20'		4–14" occ. 3–4"								17'8"–72'6" Light grey, weathered, jointed quartz conglomerate with occasional patches of quartzite. Quartz veins common. Joints generally open and weathered, occasionally recemented.
25'									20'–32' 50 p.s.i. 0.4 gals/min.	
30'		7" 1–2"				2				
35'		7" occ. frag.				1			29'–39' 50 p.s.i. 0.2 gals/min.	
40'										
45'		8"–12" generally							39'–52' 50 p.s.i. 0.4 gals/min.	
50'		3"–14" generally				2	Grey			
55'							Brown		50'–60' 60 p.s.i. 0.4 gals/min.	
60'		12"				4–5	Grey			
65'									59'–69' 70 p.s.i. 0.4 gals/min.	68'11"–80'8" Rock fragmented. Conglomerate fragments down to 72'6", quartzite fragments below. Much core loss – represents fault zone.
70'		3" often frag.				3				
75'									69'–79' 80 p.s.i. 0.6 gals/min.	72'6"–187'5" Grey to slightly purple well jointed quartzite with occasional quartz veins. Joints show less weathering below 83' but are still open. Pyrites common; rock becomes more grey below.
80'		1–7"								
85'						3				
90'		Fragmented occ. 8"								91'6" Joints fresh & weathered but iron seen to be oxidised.
95'						4–5				
100'										

DRILLING RECORD

AREA: HERSEY FORTH POWER DEVELOPMENT

LOCATION: CETHANA D.S.

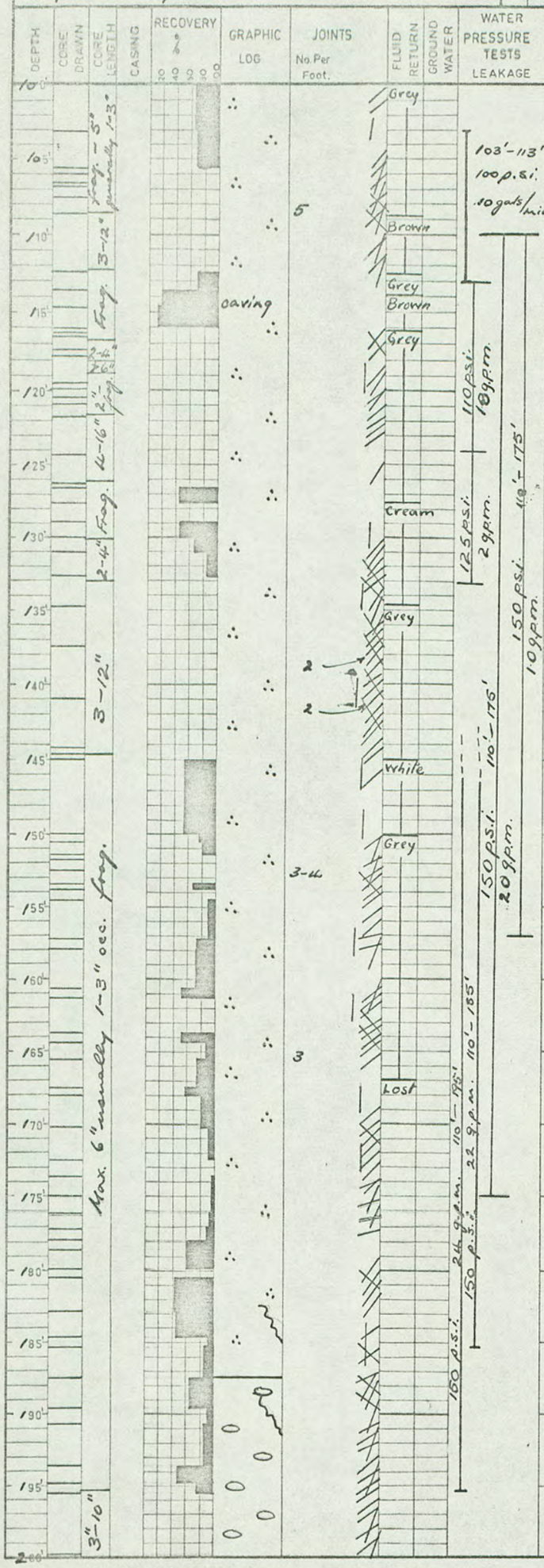
GEOLOGICAL PLAN: SURVEY PLAN:

DATES (a) DRILLED: July - Aug '64 (b) WATER TABLE:

METHOD: D.D. DIAMETER: NX, NMLC, BX.

SITE REMARKS: Site excavated in 2' talus overlying weathered conglomerate high on right bank

POSITION			
CO-ORDINATES:	E:	N:	HOLE No. 5430
ON LINE:	BEARING:	AT CH:	
AT STN:	BEARING:	DIST:	FILE No.
LEVEL. SURFACE	COLLAR	WATER TABLE	
INCL. HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	SHEET 2 OF 4 SHEETS
VERT./~~HOR./INC.~~	90°		



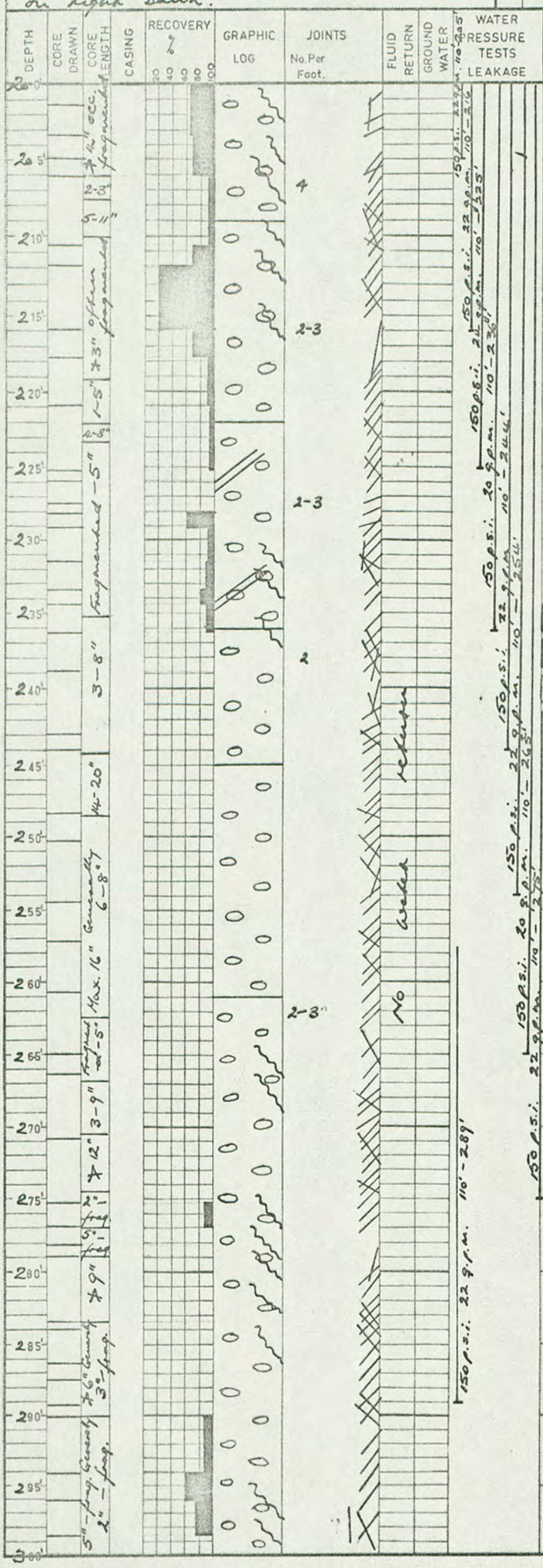
DRILLING RECORD

AREA: HERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E:	N:
LOCATION: CETHANA D.S.		ON LINE:	BEARING:	AT CH
GEOLOGICAL PLAN: SURVEY PLAN:		AT STN:	BEARING:	DIST:
DATES (a) DRILLED: July – Aug. '64 (b) WATER TABLE:	LEVEL.	SURFACE	COLLAR	WATER TABLE
METHOD: D.D. DIAMETER: NX, NMLC, BX				
SITE REMARKS: Site excavated in 2' talus overlying weathered conglomerate high on right bank.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
		VERT./~~HOR./INC.~~	90°	

HOLE No. 5430

FILE No.

SHEET 3 OF 4 SHEETS



DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT

LOCATION: CETHANA D.S.

GEOLOGICAL PLAN: SURVEY PLAN:

DATES (a) DRILLED: July – Aug. '64 (b) WATER TABLE:

METHOD: D.D. DIAMETER: NX, NMLC, BX.

SITE REMARKS: Site excavated in 2' talus overlying weathered conglomerate high on right bank.

POSITION			
	CO-ORDINATES:	E:	N:
	ON LINE:	BEARING:	AT CH:
	AT STN:	BEARING:	DIST:

LEVEL.			
	SURFACE	COLLAR	WATER TABLE

INCL.			
	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
	VERT./~~HOR./INC.~~	90°	

HOLE No. 5430

FILE No.

SHEET 4 OF 4 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE
300 0'									
305'	5" – Frag. Gravel 2" – Frag.								
310'									
315'		2'–8"					No water return.		150 p.s.i. 24 g.p.m. 110'–320'.
	Frag. –1"								
320'									
325'									
330'									
335'									
340'									
345'									
350'									
355'									
360'									
365'									
370'									
375'									
380'									
385'									
390'									
395'									
400'									

REMARKS

Hole completed 320'

Logged by G.E. Rawlings

17/9/64.

FORM NO. H.E. 443

DRILLING RECORD

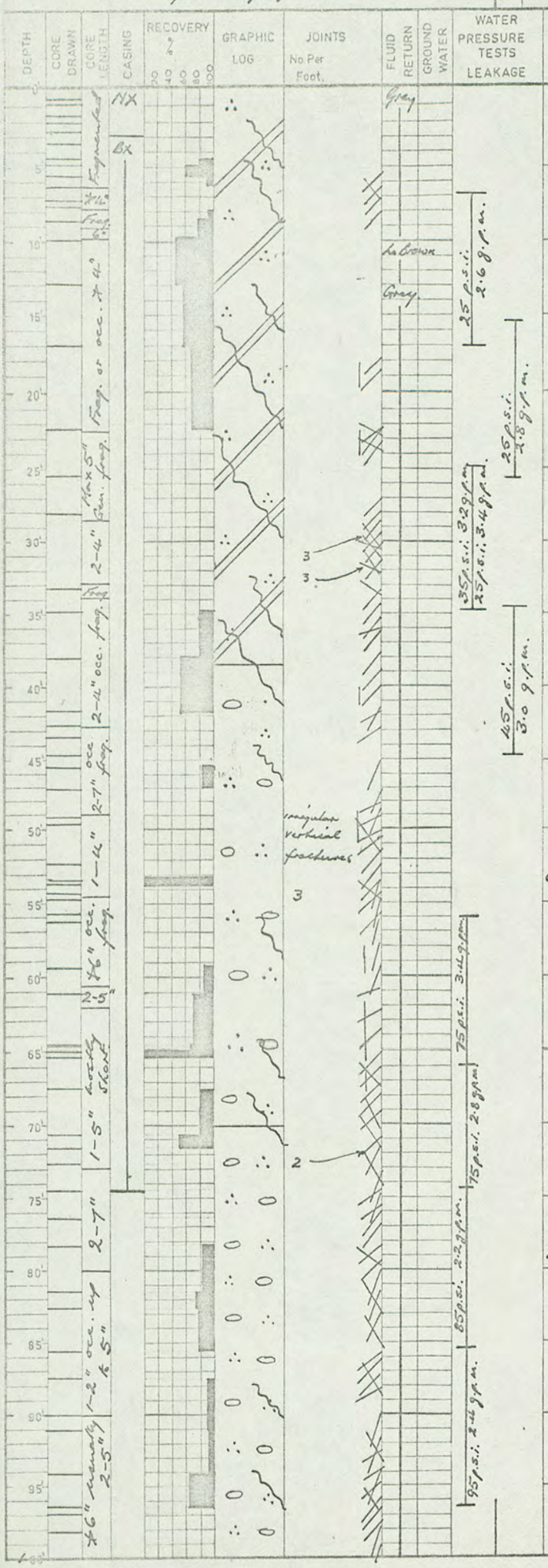
AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5431
LOCATION: CETHANA D.S.		ON LINE: HA802 HA849	BEARING: 90° 00'	AT CH.	
GEOLOGICAL PLAN: A11153 SURVEY PLAN: S4120891		AT STN: HA849	BEARING: 166° 24'	DIST: 134'	FILE No.
DATES (a) DRILLED: July 1964 (b) WATER TABLE:	LEVEL.	SURFACE	COLLAR	WATER TABLE	
METHOD: D.D. DIAMETER: NX		448			SHEET 1 OF 1 SHEETS
SITE REMARKS: Site on solid quartzite low on right bank downstream of adit.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
		~~VERT~~/~~HOR~~/INC.	55°	116° T	

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
G.L. 0'		1-2' frag					Grey			0–41' Hard, grey, weathered, well jointed quartzite. Many joints open and showing limonite, others tight or recemented by quartz and chlorite. Rock occasionally fragmented. Slickensides seen along some open joints. Pyrites present.
5'		4" – fragments					Brown Grey			
10'						4				
15'		4' 6"					L. Grey		9'1" – 19'1" 50 p.s.i. 2·8 gals/min.	
20'		7" partly frag.				3				
25'		Frag. 4'-5"			Caving				19'1" – 29'1" 50 p.s.i. 2·2 gals/min.	
30'		4' 10"				3				
35'		Frag.			Caving.		White		31'10" – 40'6" 20 p.s.i. 4·6 g/min.	
40'		4' 8" occ. frag					Brown		40 p.s.i. 9·8 gals/min.	
45'		3-4"				2	White		40'6" – 50' 25 psi. 2·8 g/min 50 p.s.i. 5 gals/min.	41'–60' light grey – purple jointed quartz conglomerate. Joints open and weathered or tight and/or recemented. Pyrited cavities. Joints often limonite stained.
50'		Good sticks 4'5" occ.							50'–60' 30 p.s.i. 4·2 gals/min 60 p.s.i. 8·6 gals/min.	
55'		Frag.				2	Lost			
60'		4'5"					White			Hole completed 60'. Logged by G. E. Rawlings 20/8/64.
65'										
70'										
75'										
80'										
85'										
90'										
95'										
100'										

FORM No. H.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5432
LOCATION: CETHANA D.S.		ON LINE: HA849 HA802	BEARING: 000° 00'	AT CH:	
GEOLOGICAL PLAN: A111153 SURVEY PLAN: S4120 8911		AT STN: HA849	BEARING: 196° 31'	DIST: 129'	FILE No.
DATES (a) DRILLED: Aug. '64 (b) WATER TABLE:	LEVEL	SURFACE	COLLAR	WATER TABLE	
METHOD: D.D. DIAMETER: NX		494			SHEET 1 OF 2 SHEETS
SITE REMARKS: Core in solid quartzite immediately N. of fault.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
		~~VERT~~/~~HOR~~/INC.	55°	160° T	



0-38'6" Light grey, weathered, well jointed quartzite. Rock generally much broken up, occasionally completely fragmented. Quartz veins occasionally present, pyrites common. Joints generally open and weathered, occasionally tight.

38'6"-70' Irregularly fractured and broken quartz conglomerate and quartzite showing 'crazed' appearance. Pyrite veins and fillings common, dark filling to irregular fractures associated with them. Joints generally open and weathered but also tight and/or sealed. Quartz veins very common often grading into quartzite. Pebbles often obscured by recrystallization.

70'0"-133'4" Hard grey conglomerate with much associated quartzite. Open joints weathered down to 80' other joints tight or filled. Pyrites common filling joints, occasional quartz veins. Proportion of pebbles: quartzite increases below. Pebbles still somewhat obscured.

FORM No H.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT
LOCATION: CETHANA D.S.
GEOLOGICAL PLAN: SURVEY PLAN:
DATES (a) DRILLED: Aug 64 (b) WATER TABLE:
METHOD: D.D. DIAMETER: NX, NMLC.
SITE REMARKS: Site in solid quartzite immediately N. of fault.

POSITION				HOLE No.
	CO-ORDINATES:	E:	N:	5432
	ON LINE: HA802 HA849	BEARING: 0°00'	AT CH:	
	AT STN:	BEARING: 196°27'	DIST: 430	FILE No.
LEVEL.	SURFACE	COLLAR	WATER TABLE	
	495'			
INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	SHEET 2 OF 2 SHEETS
	~~VERT./HOR.~~/INC.	55°	160° T	

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
10 0							Grey			
10 5		7 6" mainly 2-5"				2-3			105 p.s.i. 5.6 g.p.m.	
10		5" often frag.								
15									115 p.s.i. 4.2 g.p.m.	
20		7" occ. frag.				2-3				
25		2-5" occ. frag.							125 p.s.i. 2.8 g.p.m.	125'-129'5" Quartz veining and strong development of pyrite
30		5-11" frag.				2-3				
35		4-5" often fragmented							135 p.s.i. 3.0 g.p.m.	133½"-160'1" Grey - slightly purple quartz conglomerate. Pebbles easier to distinguish than above. Rock fresh and jointed; joints generally tight or sealed, occasionally open. Occasional quartz veins and much pyrites.
40		8"				1-2				
45		frag. 8"				1-2			145 p.s.i. 3.4 g.p.m.	
50									150 p.s.i. 3.6 g.p.m.	
55		1-5" occ. fragmented on top 8"				4-5				
60									150 p.s.i. 2.8 g.p.m.	Hole completed 160' Logged by G. E. Rawlings 18/9/64
65										
70										
75										
80										
85										
90										
95										
96										

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5433
LOCATION: CETHANA D.S.		ON LINE: HA 849 HA 802	BEARING: 000° 00'	AT CH:	
GEOLOGICAL PLAN: A11153 SURVEY PLAN: SA120 8911		AT STN: HA 849	BEARING: 115° 28'	DIST: 398	FILE No.
DATES (a) DRILLED: Aug/Sept 1964 (b) WATER TABLE:	LEVEL	SURFACE	COLLAR	WATER TABLE	
METHOD: D.D. DIAMETER: NX, BX, EMLC		639			SHEET 1 OF 2 SHEETS
SITE REMARKS: Site on L. bank in solid conglomerate.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
		~~VERT./HOR.~~/INC.	51°	302° T	

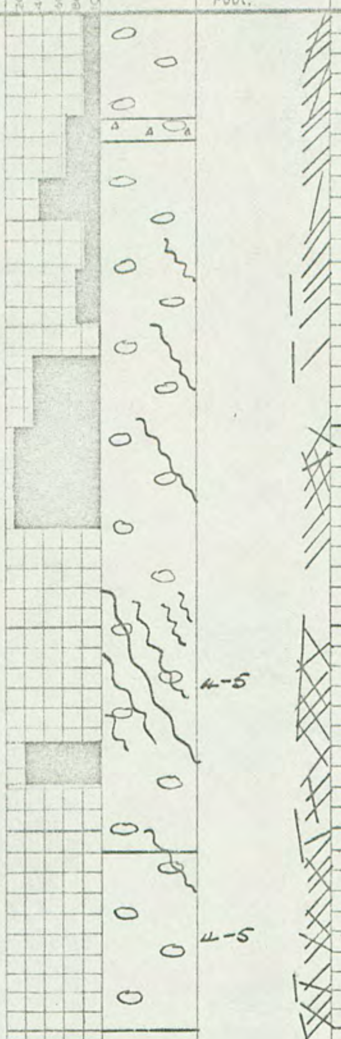
DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY %	GRAPHIC LOG	JOINTS No. Per Foot	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0	NX	4'5" Thin Frag.	NX				White			0–23'3" Weathered grey – slightly purple jointed quartz conglomerate. Joints open and weathered, occ closed.
5'	BX		BX							
10'		Occasionally 1–3"								
15'		7'10"				2				23'3"– 56'6" Fresh grey – slightly purple jointed quartz conglomerate. Joints show weathering in the form of iron staining, occasionally tight.
20'		1'3"				2			18'–28'5" 50 p.s.i. 6·8 gal/min.	
25'		1'4"								
30'		9"				2-3			28'5"– 37'8" 50 p.s.i. 6·4 gal/min	31'6" 35° joints + 2" separation 31'7"–34'4" 90° and 25° joints together produce broken core.
35'		3" Occ. Frag.								
40'		6"							37'8"– 49'5" 50 p.s.i. 6·8 gal/min	39'9"–44'6" 11" Solid conglomerate recovered 60° and 40° joints.
45'		1'5" Frag.				1–2				44'6"–47'2" Sub-angular pebbles of weathered conglomerate recovered. Core loss due to weathering and/or jointing.
50'		2'7"							49'–58' 60 p.s.i. 4·4 gal/min	
55'		Frag. 3" Frag.								
60'		1'7" Frag				1-2			58'– 69'8" 70 p.s.i. 3·2 gal/min.	56'6"–76'0" Dark grey – purple quartz conglomerate. Well jointed, joints open tight and recemented. Open joints show weathering and iron staining. Matrix occasionally badly weathered. Iron pyrites present. Core loss probably due to weathered matrix. 66' 55° joint 1–6" separation.
65'		1'5"								
70'		5'15"				3-4			69'8"– 80'6" 70 p.s.i. 4·4 gal/min.	76'–80'0" Pocket of light purple quartzite. Rock strongly jointed, broken up and somewhat weathered. 76'0" 45° joint + 1½" separation.
75'		Frag 4"								
80'		1'3"							80'6"– 90'1" 90 p.s.i. 8·4 gal/min.	80'0"–106'3" Light grey, fresh, well jointed quartz conglomerate becoming purple – dark grey below 85'. Joints generally tight but occasionally open and weathered. Pyrites present. Conglomerate becomes less distinct below 98'. No obvious reason for high water loss 80'–90'.
85'		Frag– 4'2"				Rock strongly jointed.				
90'		12" Frag							90'–100' 100 p.s.i. 2·8 gal/min.	
95'		2'0" Frag				2.				
100'		11'6" Frag								
		15"								
		7'12" Occ. down to 1"								

FORM No. H.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E:	N:	HOLE No 5433
LOCATION: CETHANA D.S.		ON LINE:	BEARING:	AT CH:	
GEOLOGICAL PLAN: SURVEY PLAN:		AT STN:	BEARING:	DIST:	FILE No.
DATES (a) DRILLED: Aug./Sept. '64 (b) WATER TABLE:	LEVEL	SURFACE	COLLAR	WATER TABLE	
METHOD: D.D. DIAMETER: NX, BX, BMLC.					SHEET 2 OF 2 SHEETS
SITE REMARKS: Site on L. bank in solid conglomerate.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
		~~VERT~~/~~HOR~~/INC.	51°	302° T	

Columns: DEPTH | CORE DRAWN | CORE LENGTH | CASING | RECOVERY % | GRAPHIC LOG | JOINTS No. Per Foot | FLUID RETURN | GROUND WATER | WATER PRESSURE TESTS LEAKAGE | REMARKS



Depth scale: 100, 105, 110, 115, 120, 125, 130, 135, 140, 145, 150, 155, 160, 165, 170, 175, 180, 185, 190, 195, 200

Core length: ±5" Gen. 2" - frag. ; 9" ; Frag. ; 3½" 2" frag. ; 9" ; Max. 8" Gen. 4" - fragmented ; Fragmented occ. up to 3" ; 2 – 6" ; Frag. – 4" ; 1 – 7"

Joints No. per foot: 4-5 (c. 130'–135'); 4-5 (c. 145')

Fluid return: No return

Water pressure tests leakage	Remarks
100'–110' 100 p.s.i. 2·8 gal./min.	105'3" – 106'3" Massive limonite(?) filling joint cavity above 1' of strongly jointed (brecciated ?) conglomerate.
110'–120' 120 p.s.i. 1·4 gal./min.	106'3" – 141'0" Grey-purple jointed conglomerate in which pebbles are indistinct. Much very chalk, galena, rock often strongly broken up. Joints generally tight, occasionally weathered. 108'–110' Weathered jointed conglomerate. 116'–125' No indication of why core lost. Slight trace of clay (rock flour?) along 20° joint. Core would probably have been recovered by BMLC bit (125' onwards was drilled by BMLC bit).
120'–130'4" 130 p.s.i. 5·4 gal./min	130'4" Joints filled by tourmaline?
130'4" – 140'6" 140 p.s.i. 5·2 gal./min.	130'4" – 135'4" Strongly fractured quartzite, also brecciated and weathered. Many surfaces show rock flour. Good recovery obtained. 134' 20° joints, 2" separation.
140'6" – 150' 150 p.s.i. 10·8 gal/min.	141'0" – 150' Dark grey jointed quartzite conglomerate. Pebbles becoming more distinct than above. Joints usually tight and fresh but occasionally weathered. Pyrite occasionally weathered to give cavities. 145° 45° joints & 1" separation.

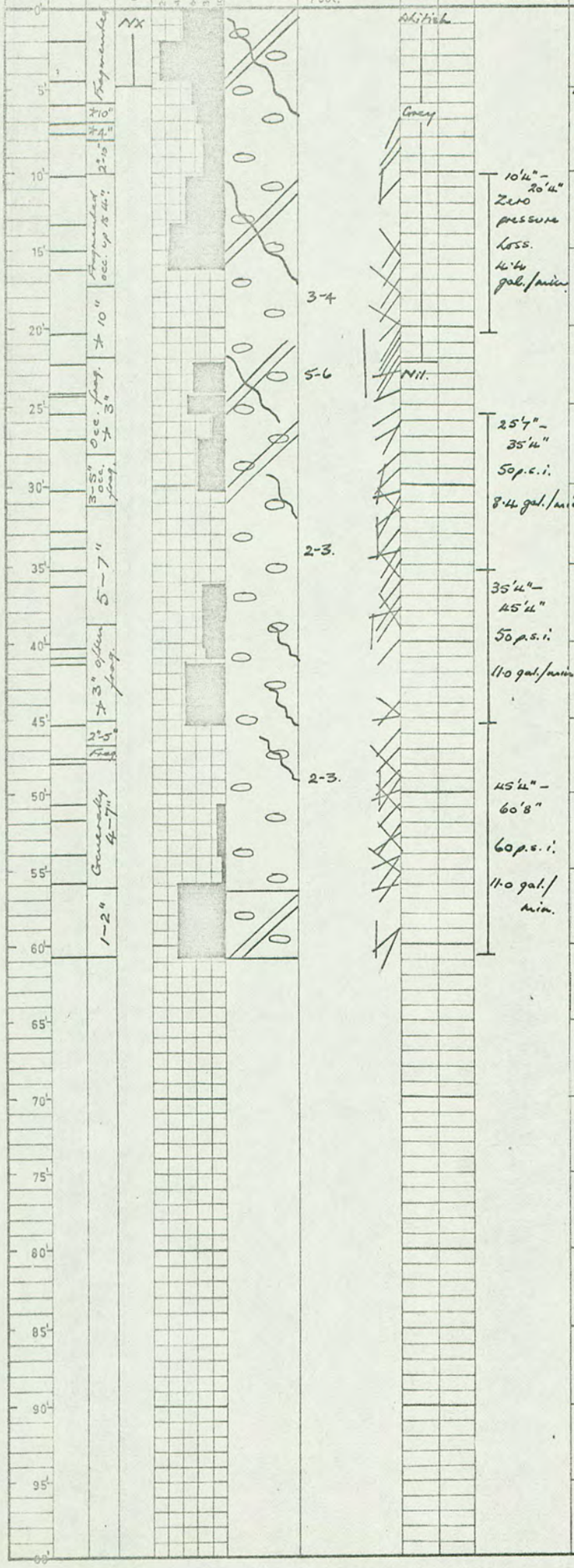
Hole completed 150'0"

Logged G.E. Rawlings 1/10/64.

Major weathering to 73', weathered fault (?) zones below.

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5434
LOCATION: Cethana D.S.		ON LINE: HA849 HA802	BEARING: 0°00'	AT CH:	
GEOLOGICAL PLAN: A11153 SURVEY PLAN: 34120 8911		AT STN: HA849	BEARING: 119°48'	DIST: 382'	FILE No.
DATES (a) DRILLED: Sept 1964 (b) WATER TABLE:	LEVEL	SURFACE	COLLAR	WATER TABLE	
METHOD: D.D. DIAMETER: NX. NMLC.		593			SHEET 1 OF 1 SHEETS
SITE REMARKS: Site high on left bank in solid conglomerate.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
		~~VERT./ HOR./~~ INC.	57°	281° T	

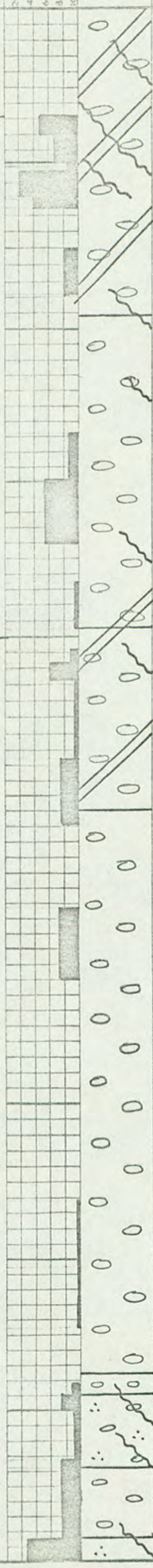


REMARKS
0 – 56'4" light purple & light grey quartz conglomerate. Rock weathered with open joints but also showing tight joints, often well broken up. Below 31' joints still open and weathered but rock less broken up and fresher. Pyrites often seen along shallow joints. Steep joints show clay fillings down to 20'4"
20'6" 75° joints ± ½" apart.
33'10" 38° joints ± 3" apart, slightly weathered.
39'0" 80° joints ± ½" apart
49'0" 45° weathered joint 50'7" 30° joints, 4½" apart.
51'6" Bedding 30°? Slight shears seen along similar planes. (Measured from perpendicular to core axis).
56'4" – 60'8" Dark purple weathered conglomerate, partly ground up, large core loss. Shows strong system of vertical joints (i.e. joints parallel to core axis.) Is much iron stained, matrix shows strong hematite development. Hole completed 60'8".
Logged by G.E. Rawlings 1/10/64
55'0" 45° joints 4-6" apart, slightly weathered
Major weathering down to 31'. Slightly weathered surfaces to 56'4", bad weathering 56'4" – 60'8". No obvious reason for core loss and/or water loss, probably due to close jointing.

FORM No. H.E. 443

DRILLING RECORD

AREA: Mersey Forth Power Development		POSITION — CO-ORDINATES:	E:	N:	HOLE No. 5435
LOCATION: Cethana D.S.		ON LINE: HR 849 / HR 802	BEARING: 0°00	AT CH:	
GEOLOGICAL PLAN: A11153	SURVEY PLAN: S 41208911	AT STN: HR849	BEARING: 212°47'	DIST: 445	FILE No.
DATES (a) DRILLED: August/Sept. '64	(b) WATER TABLE:	LEVEL — SURFACE	COLLAR	WATER TABLE	
METHOD: D.D.	DIAMETER: NX, BX.	748			SHEET 1 OF 2 SHEETS
SITE REMARKS: Site on L. bank in solid conglomerate.		INCL. — HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
		VERT./~~HOR.~~/INC.	66°	188° T	



DEPTH	CORE LENGTH	CASING	JOINTS No. Per Foot	FLUID RETURN	WATER PRESSURE TESTS LEAKAGE
0'–5'	≯10" occ. frag.	NX		Grey; Brown; Grey	
6'–12'	Gen. frag. or up to 2".	BX			
10'–19'					9'–19' 50 p.s.i. 4 gal./min
12'–14'	≯4"		3-4	Yellow	
14'–17'	2"–1'			Grey	
17'–18'	Frag.				
18'–23'	up to 15" occ. 2"		2-3	Brown; Pink; Grey	19'–29' 50 p.s.i. 8 gal./min.
23'–30'	1"–6"			Pink	
30'–35'	Frag.–2"		2-3	Pink/Brown	29'–39' 50 p.s.i. 6 gals./min
35'–38'	≯5" also frag.			Pink; Grey; Pink/Brown	
38'–39'	2–5				
39'–43'	≯2"			Grey	
43'–58'	Generally 2–4"		3-4	Pink/Brown	43'–53' 55 p.s.i. 4 gals./min.
52'–58'				Grey; Pink; Grey	53'–62' 60 p.s.i. 6 gals./min.
58'–62'	≯7"				
62'–67'	6–14"		2-3		62'–72' 75 p.s.i. 6.7 gals/min.
67'–69'	≯8"				
69'–70'	15"				
70'–88'	Good core ≯13" occ. 1–5"		1-2	Brown; Grey	72'–84' 85 p.s.i. 8.3 gals./min.
88'–93'	≯3" occ. frag.				84'–98' 100 p.s.i. 12 gals/min.
93'–98'	5–6" occ. 1–2"			Brown; Lost	

REMARKS

0–19'2" Hard, massive, weathered quartz conglomerate. Generally well jointed, joints both open and tight. Grey in colour down to 15' becoming more purple below. Core often fragmented.

17'10"–18'5" Completely fragmented.

19'2"–39'7" Hard, massive, purple (occasionally grey or reddish) quartz conglomerate showing occasional quartz veins. Joints generally tight or slightly open often showing slight weathering or iron staining.

39'7"–51' Recrystallized, occasionally weathered, veined and sheared grey-pink quartz conglomerate. Rock much fractured pebbles often difficult to distinguish. Many fractures filled by iron or chlorite.

51'–87'6" Grey-purple-pink hard jointed quartz conglomerate. Joints generally tight but occasionally open and weathered. Pyrite fills many joints. Pebbles rounded to sub-rounded usually of quartz or quartzite. Rock becoming more fractured below 80' with the incoming of quartz veins. Occasional lenses of quartzite (with pebble constituent) occur as at 80' and 87'. Hematite present in conglomerate matrix.

87'6"–89' Fragmented core shows vein quartz and one 3" stick of conglomerate.

89'–93'10" Short sticks of grey quartzite with occasional quartz pebbles, becoming more conglomeratic below. Quartz veins common.

93'10"–98'6" Grey quartz conglomerate, somewhat weathered with open joints & strong quartz veining at 98'

FORM No. H.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT
LOCATION: Cethana S.S.
GEOLOGICAL PLAN: SURVEY PLAN:
DATES (a) DRILLED: Sept. '64 (b) WATER TABLE:
METHOD: D.D. DIAMETER: NX. BX
SITE REMARKS: Site on R. bank in solid conglomerate

POSITION
CO-ORDINATES: E: N:
ON LINE: HA849 HA802 BEARING: 0°00' AT CH:
AT STN: BEARING: 212°47' DIST: 445'

LEVEL.
SURFACE: 748 COLLAR: WATER TABLE:

INCL.
HOLE DRILLED: VERT./~~HOR.~~/INC. ANGLE FROM HORIZONTAL: 66° DIRECTION:

HOLE No. 5435
FILE No.
SHEET 2 OF 2 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY %	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0										98'6" – 159'10" Dark - light grey, occasionally reddish, quartzite. Rock above much broken, slightly weathered and with quartz veining. Joints generally tight but occasionally open and weathered and often filled by pyrite. Rock uniform but shows much fracturing at 137', 151'7" – 153' and 156' – 158'.
5									98' – 112' 110 p.s.i. 11.7 gals/min	
10										
15									112' – 124' 125 p.s.i. 11.7 gals/min.	
20										
25		3" often fragmented or short							124' – 136' 130 p.s.i. 11.7 gals/min.	125' Bedding 65° (measured from perpendicular to core axis)
30		5" often fragmented or short								
35									134' – 144' 150 p.s.i. 11.7 gals/min.	
40										
45									144' – 159'10" 150 p.s.i. 11.7 gals/min.	
50										
55		3 – 12"								
60		2½" Rig								Hole completed 159'10" Logged by G.E. Rastings 9/10/64.
65										
70										
75										
80										
85										
90										
95										
100										

FORM No. H.E. 443

DRILLING RECORD

AREA: HERSEY FORTH POWER DEVELOPMENT
LOCATION: Cotkana D.S.
GEOLOGICAL PLAN: A11153 SURVEY PLAN: S4120 8911
DATES (a) DRILLED: Oct. 1964 (b) WATER TABLE:
METHOD: D.D. DIAMETER: NX, BX, BMLC
SITE REMARKS: Site on right bank in solid conglomerate.

POSITION
CO-ORDINATES: E: N: HOLE No. 5436
ON LINE: HA849 HA802 BEARING: 0°00' AT CH.
AT STN: HA849 BEARING: 212°12' DIST: 386' FILE No.

LEVEL
SURFACE: 680 COLLAR: WATER TABLE:

INCL.
HOLE DRILLED: VERT/~~HOR~~/INC. ANGLE FROM HORIZONTAL: 55° DIRECTION: 140° T

SHEET 1 OF 1 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY %	GRAPHIC LOG	JOINTS No. Per Foot	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0			NX							0–24'5" Hard, well jointed, grey-purple weathered quartzite conglomerate. Joints generally open, occasionally tight or showing iron staining and breakdown of matrix. Keporkian pebbles: matrix variable eg. at 14' more matrix than usual. Occasional quartzite pockets and quartz veining. Core breaks into much shorter sticks during BX drilling.
5'			BX			2-3		Grey		
10'		6" to 1'4" occ. 3-4"						Brown		
15'		Frag.				3-5				
20'		3'10" occ. 2'1" frag.						Pink		
25'						½-1		Grey		24'5"–39'2" Rock largely as above but pebbles stand to be smaller and more common, the rock darker overall and joints fewer. Mineralization (mainly pyrite) and quartz veining common.
30'		2" — Frag.							25'-35' 50 p.s.i. 1.2 gal/min	
35'						1-2			35'-45' 50 p.s.i. 10 gal/min	39'2"–41'2" Medium grained quartz sand obtained from water return — probably represents fault zone.
40'								Yellow Pink White		41'2"–62' Hard, purple-grey, fine to medium grained quartzite in which banding is occasionally seen especially where beds are red. Shearing not uncommon, rock moderately jointed. Joints usually tight but also open and weathered, occasionally with chlorite present. Quartz veins and pyrites present.
45'								Grey	45'-55' 50 p.s.i. 6.2 gal/min.	
50'		1'-4"				1-2				
55'		12"							55'-65' 60 p.s.i.	
60'		Max. 4" occ. frag.							10.2 gal/min.	62'–89'7" Hard, dense, fine grained quartzite, grey-pink in colour. Rock strongly jointed (bedding?), joints generally tight, occasionally showing chlorite or iron staining. Below 78' rock joints show chlorite although very little weathered. Rock generally banded, pyrites and occasional quartz veins present.
65'						8-9			65'-75' 70 p.s.i. 5.6 gal/min.	
70'										
75'						3-4			75'-89' 80 p.s.i. 5.2 gal/min.	
80'		Max. 8" occ. 1-3" or frag.								
85'						4-5				
90'										Hole completed 89'7" Logged by G.E. Rawlings 3.11.64
95'										
100'										

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT		POSITION: CO-ORDINATES: E: N:	HOLE No. 5437
LOCATION: Cethana D.S.		ON LINE HA849 HA802 BEARING 0°00' AT CH:	
GEOLOGICAL PLAN: A11153	SURVEY PLAN: S4120 8911	AT STN: HA849 BEARING: 155°12' DIST: 83'	FILE No.
DATES (a) DRILLED: Sept. '64	(b) WATER TABLE:	LEVEL: SURFACE / COLLAR 431 / WATER TABLE	
METHOD: D.D.	DIAMETER: NX, BX.		SHEET 1 OF 2 SHEETS
SITE REMARKS: Low on right abutment in weathered quartzite.		INCL.: HOLE DRILLED VERT/HOR/INC. — ANGLE FROM HORIZONTAL 73° — DIRECTION 120° T	

DEPTH	CORE LENGTH	CASING	JOINTS No. Per Foot	FLUID RETURN	WATER PRESSURE TESTS LEAKAGE	REMARKS
0'	Max 5" Gen. fragmented	NX		Grey		0 - 35'3" Hard, grey - brown uniform quartzite, well weathered usually along joints but occasionally allowing rock to break up. Many joints tight, some open. Pyrites seen occasionally along joint planes.
5'	15"	BX				
10' – 19'	Max. 6" occasionally slightly fragmented		6-7		7'4" - 19'4" 25 p.s.i. 4.8 gals/min.	19' Bedding 60°? (Measured from perpendicular to core axis)
20' – 30'	Fragmented – 1½"	AX			23'2" - 33'2" 50 p.s.i. 5 gal./min.	
30' – 35'	7¼" occ. fragmented				32'6" - 42'6" 50 p.s.i. 3.8 gal./min.	35'3" - 65'11" Fresh, hard, grey uniform jointed quartzite with weathered joints. Joints generally tight, occasionally open as at 42'6". Pyrites present along many joints.
40'	Up to 17"		1-2		39'6" - 49'6" 50 p.s.i. 4.2 gals/min.	40' Bedding 50°? (measured from perpendicular to core axis)
45'	2-4"		3-4			
50' – 55'	Maximum 15" often 5-6"				48' - 69' Unable to test as water bypasses packer.	
60' – 70'	Maximum 7" Gen. 1-3"					65'11" - 96'8" Fresh, hard, grey jointed quartzite with sporadic quartz/quartzite pebbles, often recrystallized and difficult to see. Joints generally tight or filled, occasionally open and weathered. Most prominent joints show iron staining. Pyrite occupies many of filled joints.
75'	Max. 21" Gen. 4-9"				73' - 78' 80 p.s.i. 0.2 gals./min.	
80'	7-10" occ. 1-3"		1-2		79' - 89' 90 p.s.i. 2.5 gals./min.	83' Bedding 40°? (measured from perpendicular to core axis)
85'	11-16"		4-5.			
88'	3-5"					
90'	4"				90' - 100' 100 p.s.i. 8.6 gals./min.	
92'	11"					
95' – 100'	1-5" occ. up to 8"					96'8" - 113'1" Light to dark grey quartzite with occasional pebbles becoming more weathered than above. Some joints open

FORM No. H.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT.

LOCATION: Cethana S.S.

GEOLOGICAL PLAN: A11153 SURVEY PLAN: SA120 8911

DATES (a) DRILLED: Sept. '64 (b) WATER TABLE:

METHOD: D.D. DIAMETER: NX, BX.

SITE REMARKS: Low on right abutment in weathered quartzite.

POSITION			
CO-ORDINATES:	E:	N:	HOLE No. 5437
ON LINE: HA802 HA849	BEARING: 200° 00'	AT CH:	
AT STN: HA849	BEARING: 155° 12'	DIST: 83'	FILE No.

LEVEL.			
SURFACE	COLLAR	WATER TABLE	
431			

INCL.			
HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	SHEET 2 OF 2 SHEETS
~~VERT.~~/~~HOR.~~/INC.	73°	120° T	

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0'		12-20"	AX				Grey.		99'-109' 110 p.s.i: 9.0 gal/min.	and badly weathered, others light or recemented. Quartz veins begin to appear at 100'4". Pyrites common.
5'		3-8"								.
10'		6-12"							109'-119' 120 p.s.i: 9.8 gal/min.	113'1"- 119'7" Weathered jointed quartzite showing slight mineralization, well broken up towards base.
15'		Maximum 5' usually less.				3-4				
20'							Hole making much water.		116'-126' 125 p.s.i. 9.6 gal/min.	119'7"- 130'5" Occasional angular fragments of quartzite. Water return showed very abrasive quartz sand. Rock offered no resistance to drilling— fault zone.
25'										
30'										Hole discontinued at 130'5"
35'										Logged: G. E. Rawlings. 9/10/64.
40'										
45'										
50'										
55'										
60'										
65'										
70'										
75'										
80'										
85'										
90'										
95'										
100'										

FORM No. H.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E:	N:
LOCATION: CETHANA D.S.		ON LINE: HA849 HA802	BEARING: 0°00'	AT CH:
GEOLOGICAL PLAN: A11153 SURVEY PLAN: S4120 8911		AT STN: HA849	BEARING: 113°15'	DIST: 276'
DATES (a) DRILLED: Sept./Oct. '64 (b) WATER TABLE:	LEVEL:	SURFACE	COLLAR	WATER TABLE
METHOD: D.D. DIAMETER: NX, BX			495	
SITE REMARKS: Site on left bank in solid quartzite.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
		~~VERT.~~/~~HOR.~~/INC.	51°	316°

HOLE No. 5438

FILE No.

SHEET 1 OF 2 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY %	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0'		Fragmented occ. 6"	NX				Brown			0-5' Weathered and broken up, hard grey-purple, well jointed quartzite with occasional quartz veins.
5'		1-4"	BX			3-4	Grey			5-15' Fresh, hard, grey-purple well jointed quartzite with occasional quartz veins. Joints generally tight although slightly weathered and maybe occasionally open. Grey/purple banding often prominent but is probably secondary. Pyrites often present, slight shearing along some planes probably bedding.
10'		3-8"							9'9"–19'10" 50 p.s.i. 4.2 gal/min	
15'						3-4				
20'		Max. 5" occ. fragmented								15'-148' Fresh, hard grey, well jointed quartzite occasionally becoming very fragmented. Chlorite and rock flour seen along many joints especially in fractured zone, also brecciation perhaps due to recrystallization (as at 72'6"). Joints generally tight but often showing slight degrees of weathering. Shearing still present along some planes.
25'		1-9"				5-6			19'10"–29'10" 50 p.s.i. 4.4 gal/min	
30'		Max. 5" often fragmented								21'-23' Shearing along 45° planes
35'						5-6				29'10"-33'5" Fragmented rock resulting from close jointing.
40'		3-8"								37' Shearing more intense along 45° planes.
45'		5"-frag.							39'-49' 50 p.s.i. 0.4 gal/min.	
50'		6-8" Frag. 4" 2-7"							49'-58'7" 60 p.s.i. 1.4 gal/min	55' 55° Joints, 1-3" separation. 56'4"-60'4" Rock fragmented and somewhat weathered. Tourmaline present.
55'		Frag.								
60'		Max. 9" Gen. 2-5"							58'7"-69'4" 60 p.s.i. 1.2 gal/min	Core noticeably more broken up when size reduced at 69'4"
65'		1" or frag				5-6				66'6"-81' Rock often fragmented. 64'-76' Core broken up partly due to mineralization. Steeply dipping joints 70°-90° & 4" separation
70'		12" 6"							69'4"-83'1" 80 p.s.i. 1.0 gal/min.	
75'		Frag. 8"								
80'		2"-frag. occ. 4" & 6"				3-4				
85'									83'1"-94'3" 90 p.s.i. 0.4 gal/min.	89'4" Iron stained joint at 45°
90'		1-5"								89'9" Iron stained joint at 45°
95'		12" 6" 4"				5-6.			94'3"-103'7" 100 p.s.i. 0.4 gal/min.	94'0" 70° joints, 3-4" separation
100'		4-9" occ. 2"-frag.								

FORM No. H.E. 443

DRILLING RECORD

AREA: HERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5W38
LOCATION: CETHANA D.S.		ON LINE: HA849 HA802	BEARING: 0°00'	AT CH:	
GEOLOGICAL PLAN: SURVEY PLAN:		AT STN: HA849	BEARING: 113°15'	DIST. 276'	FILE No.
DATES (a) DRILLED: Sept. / Oct. '64 (b) WATER TABLE:	LEVEL.	SURFACE	COLLAR	WATER TABLE	
METHOD: D.D. DIAMETER: NX, BX		495			SHEET 2 OF 2 SHEETS
SITE REMARKS: Site on left bank in solid quartzite.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
		VERT./~~HOR.~~/INC.	51°	316° T	

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY %	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
100'							grey			104'8" 45° joints. ½"-2" Separation.
105'		Frag 3'6"							103'7"- 113' 110 p.s.i. 1·8 gal./min.	108'0" 70° joints, 1" Separation, slightly weathered.
		Frag 5'7"				3-4				
110'		Frag 3'								
115'		Frag 4'6"				3-4			113'- 123'9" 120 p.s.i. 1·6 gal./min.	116'-118' Broken core shows much pyrites
120'		2" Frag								120'6"-121' Broken core shows much pyrites.
		Nx 7" often Frag								124'6" 45° joints, 2" Separation.
125'		Frag. occ. 3"							123'9"- 132'10" 130 p.s.i. 2·0 gal./min.	132'10" Chalcopyrite and pyrite.
130'		2-5"							132'10"- 143'6" 140 p.s.i. 2·6 gal./min.	134'0"-143'6" Broken core lengths resulting from less jointed rock.
135'		4-13"								141'0"-143'6" 45° joints, ¼"-6" Separation Surfaces slightly weathered.
140'		2" Frag				3-4				
145'		1'6" occ. Frag.							143'6"- 154'5" 150 p.s.i. 1·8 gal./min.	148'-161'4" Fresh hard banded quartzite, generally grey becoming purple below 157'2". Banding maybe Secondary colour banding. Joints usually tight but occasionally showing slight weathering. Colour banding (probably bedding) 40°.
150'		2-9" occ. Frag.								
155'									154'5"- 161'4" 160 p.s.i. 8·4 gal./min.	161'0" Rock flour and pyrite along 70° joint.
160'										Hole completed 161'4"
165'										Logged by G.E. Rawlings 4/11/64.
170'										
175'										No apparent reason for high water loss, in fact rock looks fresher and tighter than elsewhere in drill hole. (at base of hole) Joints slightly weathered throughout, pyrite often weathered out. No major decomposition or clay seen.
180'										
185'										
190'										
195'										
200'										

FORM No. H.E. 443

DRILLING RECORD

AREA: HERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E:	N:
LOCATION: CETHANA D.S.		ON LINE: HA849 HA802	BEARING: 000° 0'	AT CH:
GEOLOGICAL PLAN: A11153 SURVEY PLAN: 54120811		AT STN: HA849	BEARING 203° 52'	DIST: 306'
DATES (a) DRILLED: Oct. 1964 (b) WATER TABLE:	LEVEL.	SURFACE	COLLAR	WATER TABLE
METHOD: D.D. DIAMETER: NX, BX,		601		
SITE REMARKS: Site in solid quartzite on downstream edge of right abutment.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
		~~VERT./HOR.~~/INC.	55°	122° T

HOLE No. 5439

FILE No.

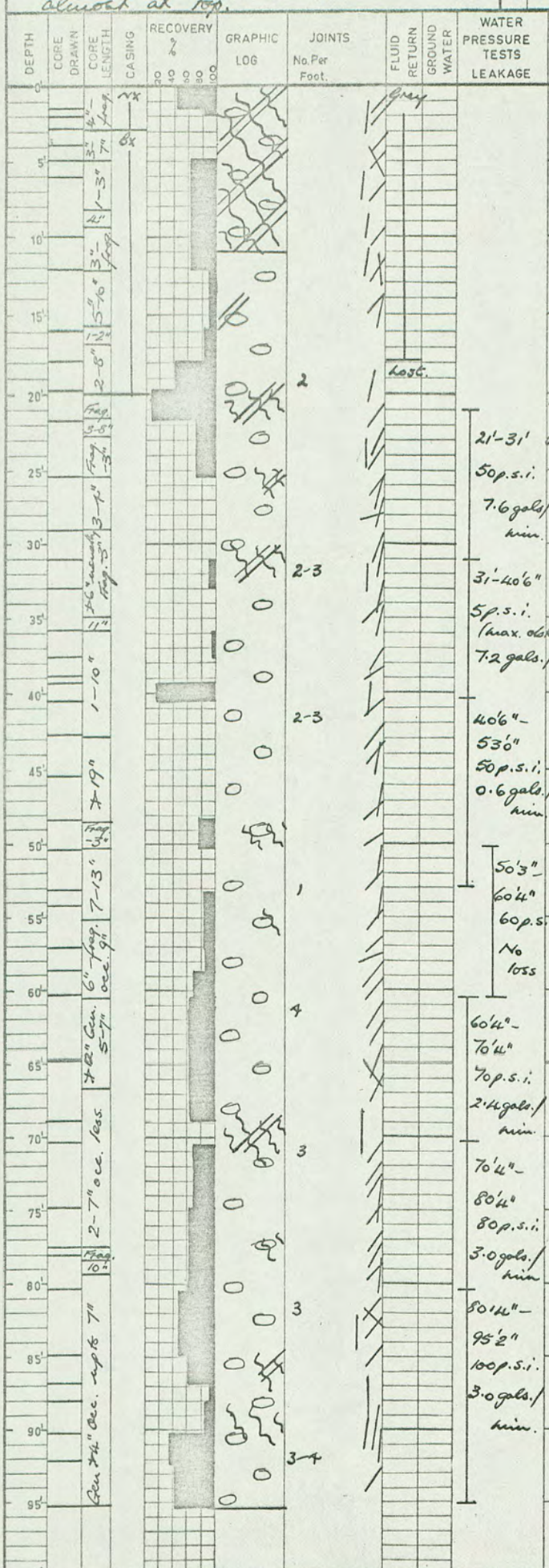
SHEET 1 OF 1 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY %	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0	NX						Grey			0-6'11" Weathered hard grey jointed quartzite with occasional quartz veins. Rock often much broken up, joints open and weathered.
5	BX	3" occ. frag.					White			6'11"-20'0" Hard, pink-grey, banded, jointed quartzite showing occasional quartz veins and much broken up in part. Slight shearing along bedding. Joints open and weathered, occasionally with chlorite, tight or filled.
10		6" occ. frag.				3-4	Grey			
15		2-4" Frag.					White			
20		Frag.								20'0"-32'5" Hard grey quartzite, strongly jointed and showing marked quartz veining. Occasional pebbles appear towards base. Joints as above often showing more marked weathering, chlorite seen occasionally.
25		2-6"				5			25-35' 50 p.s.i. 4.2 gal/min.	
30		Frag.					Grey			32'5"-46'8" Hard, grey, jointed quartzite with patches of conglomerate or occasional scattered pebbles. Joints generally open and showing iron staining, occasional shearing as at 36'9". Conglomerate patches at 32'5"-35'6" and 41'-42'7".
35		6-11" 1-3" 11"							35-45' 50 p.s.i. 3.8 gal/min.	
40		1-4" occ. frag. 10" 2-5" occ. 11"				3-4				
45		6-9" 3" frag. 12" 1-3"							45'-60' 60 p.s.i. 4.2 gal/min.	46'8"-60'0" Hard grey, jointed, quartzite with occasional pebbles. Thick quartz veins (±4") common. Joints open and well weathered, more prominent than above. Limonite staining common below 54'8". Some joints tight or filled by quartz or pyrite. Fragmented below 57'6".
50		7" occ. 1" or frag. 12" 1" frag.				4-5				
55										
60										Hole completed 60'0" Logged by G.E. Rawlings 16/11/64.
65										
70										
75										
80										
85										
90										
95										
98										

FORM No. H.E. 443

DRILLING RECORD

AREA: HERSEY FORTH POWER DEVELOPMENT.	POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5440
LOCATION: Cetkana D.S.		ON LINE: HA849 HA802	BEARING: 0°00'	AT CH:	
GEOLOGICAL PLAN: A 11153 SURVEY PLAN: SA 120 8911		AT STN: HA849	BEARING: 120°30'	DIST: 570	FILE No.
DATES (a) DRILLED: October 1964 (b) WATER TABLE:	LEVEL.	SURFACE	COLLAR	WATER TABLE	
METHOD: D.D. DIAMETER: NX, BX, BMLC		743			SHEET 1 OF 1 SHEETS
SITE REMARKS: Site in weathered conglomerate on upstream edge of left abutment almost at top.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
		~~VERT.~~/~~HOR.~~/INC.	62°	294°	



REMARKS

0-11'0" light grey quartz and quartzite conglomerate composed of rounded - sub-rounded pebbles ±1½" in diameter set in siliceous cement. Rock badly weathered and broken up.

11'0"-95'2" lithology as above but rock fresher. Joints limonite stained down to 20', usually open occasionally tight and showing slight weathering. Matrix becomes green-grey below 33'; micaceous shale seen locally.

Below 58'8" pebbles became larger - pebbles 2-3" diameter common. Quartz veins appear.

81'8"-86'8" Rock becomes very dark, contains much pyrite and is well broken up.

Hole completed 95'2"

Logged by G.E. Rawlings 17/12/64.

FORM No. H.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT

LOCATION: CETHANA D.S.

GEOLOGICAL PLAN: A11153 SURVEY PLAN: SA1208911

DATES (a) DRILLED: OCT. 1964 (b) WATER TABLE:

METHOD: D.D. DIAMETER: NX, BX.

SITE REMARKS: Site on right bank in solid quartzite.

POSITION

CO-ORDINATES:	E:	N:	HOLE No.
ON LINE: HA849 HA802	BEARING: 0°00'	AT CH:	54441
AT STN: HA849	BEARING 211°38'	DIST: 276'	FILE No.

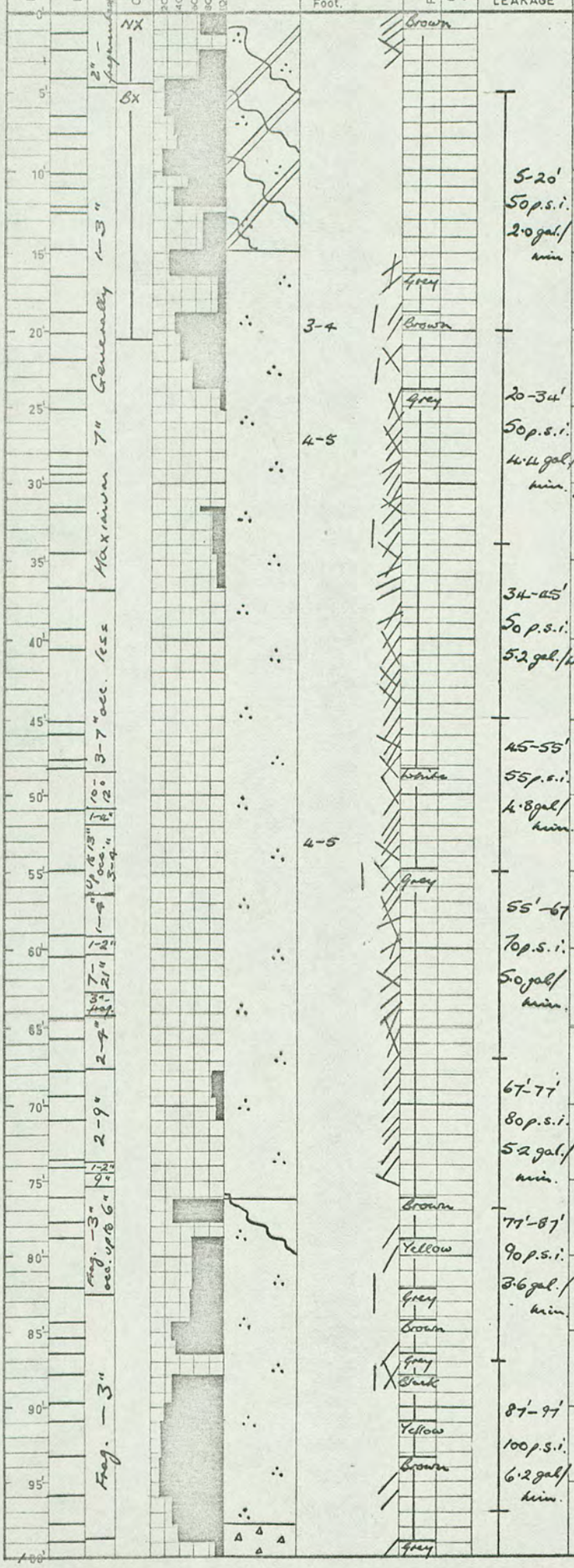
LEVEL.

SURFACE	COLLAR	WATER TABLE
594		

INCL.

HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
~~VERT./HOR.~~/INC.	55°	118°

SHEET 1 OF 2 SHEETS



REMARKS

0-14'9" Hard, weathered, light grey, quartzite, well jointed and often much broken up.

14'9"-76'1" Hard, light grey, well jointed quartzite showing occasional quartz veins and pyrite mineralisation. Joints both tight and open. Open joints often weathered and show shearing, vein quartz and chlorite. Chlorite seen along many joint planes especially 34-45'

76'1"-97'8" Veined, fractured and partially recrystallized quartzite. Joints as above. Fractures and joints usually filled by chlorite and/or pyrite.

97'8"-103'4" Brecciated quartzite — angular to sub-rounded fragments of quartzite set in grey-black matrix.

FORM No H.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E:	N:
LOCATION: CETHANA D.S.		ON LINE: HA 849 HA 802	BEARING: 0°00'	AT CH:
GEOLOGICAL PLAN: A 11153 SURVEY PLAN: SA 120 8911		AT STN: HA 849	BEARING: 211°38'	DIST: 276'
DATES (a) DRILLED: Oct. 1964 (b) WATER TABLE:	LEVEL	SURFACE	COLLAR	WATER TABLE
METHOD: D.D. DIAMETER: NX, BX.		594		
SITE REMARKS: Site on right bank in solid quartzite.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
		~~VERT.~~/~~HOR.~~/INC.	55°	111°

HOLE No. 5441

FILE No.

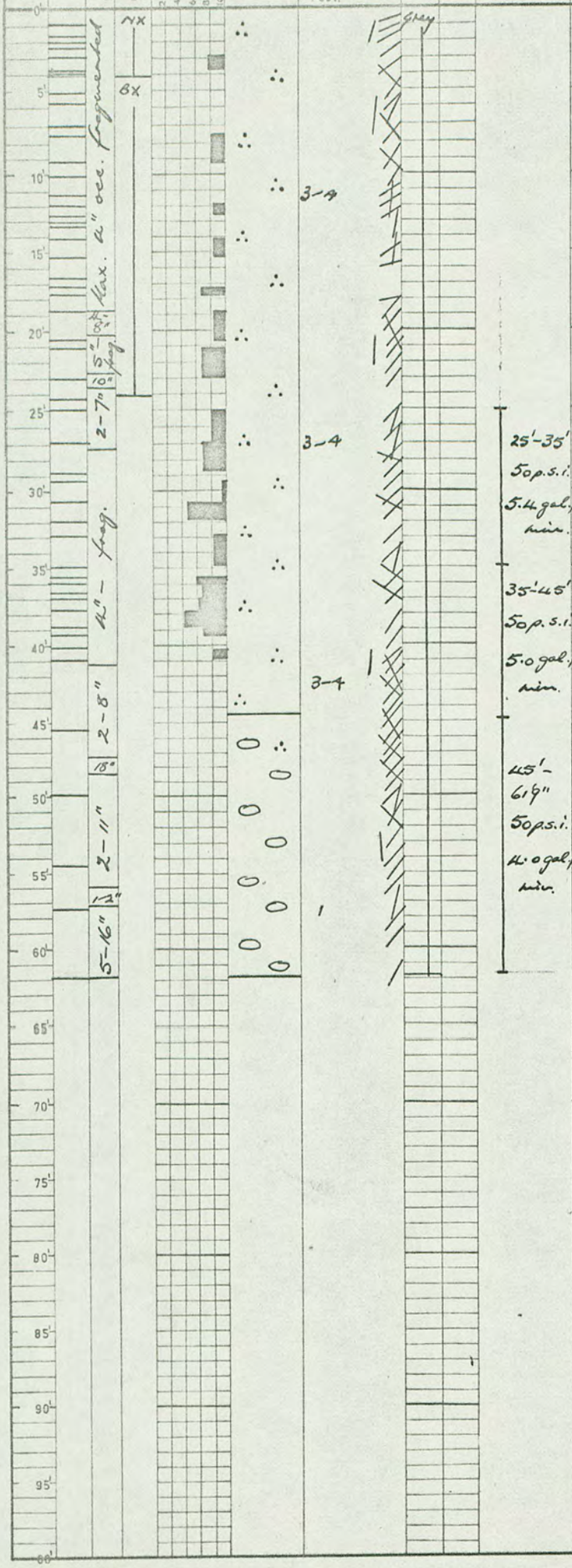
SHEET 2 OF 2 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0							Grey.			
5'		3-4" occ. 1-2'							97'-112' 120 p.s.i. 6.4 gal/min.	103'4" - 124'7" light to dark grey, jointed conglomerate, strongly veined and recrystallized down to 108'. Pebbles sparse above but increasing in quantity and perhaps size also, below. Chlorite specks and veining common. Joints generally tight, occasionally slightly weathered but not appreciably so. Pyrites present.
10'		Frag. - 1-2"								
15'		1-5"								
20'		2-6" Core. 4-6"							112'- 124'7" 125 p.s.i. 7.4 gal./min.	
25'		6-12"								
30'										Hole completed 124'7"
35'										Logged by G. E. Rawlings 5/11/64
40'										
45'										
50'										
55'										
60'										
65'										
70'										
75'										
80'										
85'										
90'										
95'										
100'										

FORM No. M.E. 445

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION: CO-ORDINATES:	E:	N:	HOLE No. 5442
LOCATION: CETHANA D.S.	ON LINE: HA849 HA802	BEARING: 000° 0'	AT CH:	
GEOLOGICAL PLAN: A111153 SURVEY PLAN: S41208911	AT STN: HA849	BEARING: 196° 25'	DIST: 239'	FILE No.
DATES (a) DRILLED: Oct. 1964 (b) WATER TABLE:	LEVEL: SURFACE	COLLAR	WATER TABLE	
METHOD: D.D. DIAMETER: NX, BX	543.0			SHEET 1 OF 1 SHEETS
SITE REMARKS: Site in solid quartzite at downstream edge of right abutment	INCL.: HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
	~~VERT~~/~~HOR~~/INC.	55°	119°	



REMARKS
0-44'5" Hard red-grey banded quartzite with prominent quartz veins (filled joints.?). Rock closely jointed, joints usually tight maybe slightly open and showing occasional iron staining. Occasional pebbles begin to appear at 23'.
44'5"-61'9" Hard, dark grey, occasionally reddish quartzite conglomerate. Junction with above quartzite rather indistinct due to gradual passage and recrystallization. Pockets of quartzite appear at top of conglomerate. Joints less common than in quartzite and maybe tight or slightly open usually showing slight weathering. Pyrites common.
Hole completed 61'9" Logged by G. E. Rawlings. 17/11/64.

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT				HOLE No.
LOCATION: CETHANA D.S.	POSITION	CO-ORDINATES:	E:	N:	5443
GEOLOGICAL PLAN: A 11153 SURVEY PLAN: SA 1208911		ON LINE: HA849 HA802	BEARING: 0°00	AT CH:	
DATES (a) DRILLED: Oct – Nov. 1964 (b) WATER TABLE:		AT STN: HA849	BEARING: 111°32	DIST: 206'	FILE No.
METHOD: D.D. DIAMETER: NX, BX, AXT.	LEVEL.	SURFACE	COLLAR	WATER TABLE	
SITE REMARKS: Site in solid quartzite on upstream edge of left abutment.		,, 427	Location approximate area covered with rubble		SHEET 1 OF 2 SHEETS
	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
		~~VERT./HOR./~~INC.	73°	294°	

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY %	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0			NX				Grey.			0–13' Hard grey jointed quartzite, fairly well weathered, fragmented down to 1'4". Joints generally open and badly stained by limonite. Faint banding seen.
5						4				
10		2–6" occ. up to 10"	BX						9'–19' 50 p.s.i. 3.2 gals/min.	13'–53'4" Hard, grey-slightly purple jointed quartzite, most joints tight although some open and often stained by limonite. Occasional patches of conglomerate as at 23'. Only very slight iron staining along joints below 33'7". Joints occasionally filled by pyrite.
15		1–3" occ. frag. 2–6"								
20		3–11" 13"							20'–30' 50 p.s.i. 4.4 gals/min.	
25		Frag. 5–9" Frag. 8–16"				3				25'5" 25° joint 10" separation.
30		14" 1" frag. 12" 4" frag.							29'10"– 39'10" 50 p.s.i. 5.0 gals/min.	34'6" 40° joint 6" separation – slight shear. 40° joint 1½" separation. 37'0"–38'0" Rock fragments show core loss to be due to breaks along weathered joints.
35		2–7" 2" frag.								
40		2–6"				5			40'1"– 50'1" 50 p.s.i. 6.2 gals/min	
45			AX				Not getting full return below 47'			45'9" 25° joints, 2" separation 45'9"–50'0" loss due to weathered jointed rock, limonite staining seen.
50		3"–frag. 1–7"							50'–60' 60 p.s.i. 8.0 gals/min.	53'7" Pyrite developed at quartzite/conglomerate junction.
55		14" 17"				2				53'7"–152'3" Hard, grey-purple jointed quartzite conglomerate composed of sub-angular – rounded pebbles of quartz and quartzite set in a purple or grey matrix. Joints generally tight, although occasionally open and showing traces of limonite. Matrix occasionally becomes greenish as at 81'3" and 85' due perhaps to presence of chlorite – especially present near cave. Pyrite present. Rock becomes more fragmented below 140'11".
60		Gen. 7–10" occ. 2–3'								
65		2"–frag. 10"								
70		1–3" occ. frag. 3' 5½"							59'8"– 69'8" 70 p.s.i. 7.4 gals/min.	69'8" 70° joint shows rock flour and weathered chlorite.
75		1–2" 13"				---				67'5" Sheared conglomerate.
80		2–8" mostly 3.5"			Caving.	75'– 120' >1½' between similar joints.				69'4" Shearing along joints 40° and 70° – iron stained.
85		24"							79'2"– 89'2" 90 p.s.i. 9.2 gals/min.	63'0–73'0. Core loss due to weathered and sheared conglomerate 71'0" 35° joints, 7" separation.
90		4–8"								91'11" 50° shear plane.
95		1–3" occ. up to 6"							89'8"– 99'8" 100 p.s.i. 1.6 gals/min.	
100		+9"								

DRILLING RECORD

AREA: MERSEY FORTH RIVER DEVELOPMENT
LOCATION: CETHANA DS.
GEOLOGICAL PLAN: A11153 SURVEY PLAN: SA120 8911
DATES (a) DRILLED: Oct. – Nov. 1964 (b) WATER TABLE:
METHOD: D.D. DIAMETER: NX, BX, AXT.
SITE REMARKS: Site in solid quartzite on upstream edge of tipped abutment.

POSITION

CO-ORDINATES:	E:	N:
ON LINE: HA849 HA802	BEARING: 0°00'	AT CH:
AT STN: HA849	BEARING: 111°32'	DIST: 206'

LEVEL

SURFACE	COLLAR	WATER TABLE
427	Location approximate area covered with rubble	

INCL.

HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
~~VERT./HOR.~~ INC.	73°	294°

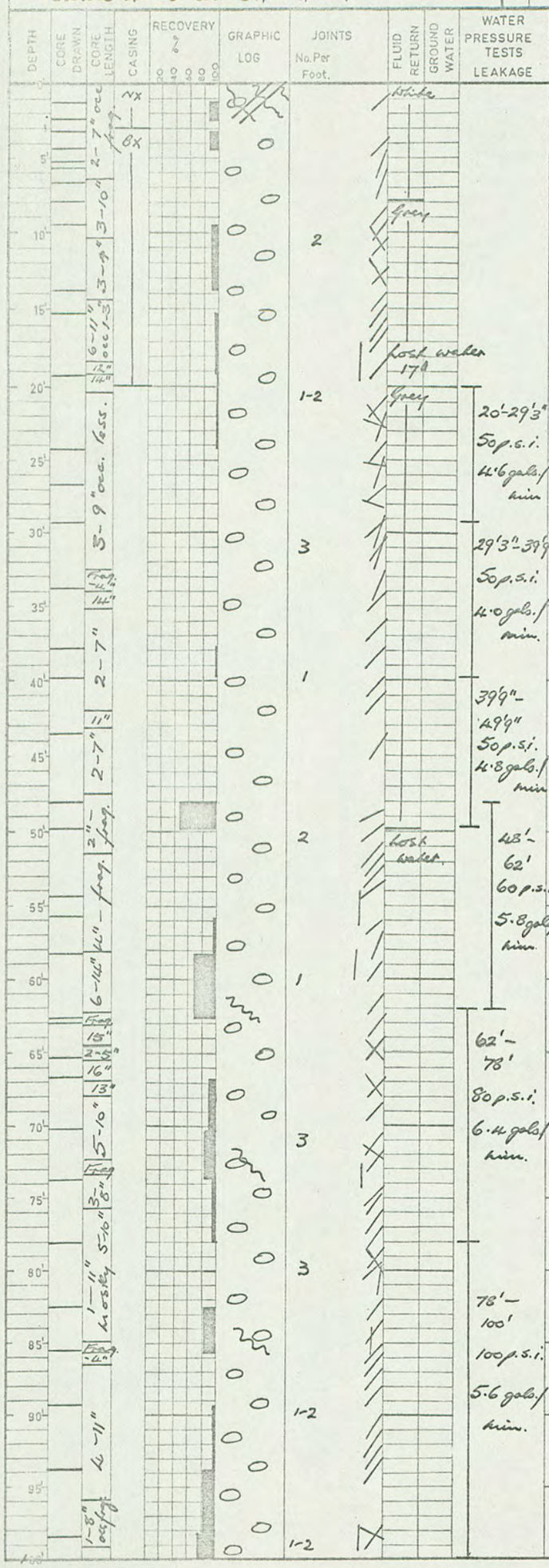
HOLE No. 5WL3
FILE No.
SHEET 2 OF 2 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
100'		1-2"	AX						100'7"– 110'7" 110 p.s.i 1.8 gals/min	
105'		± 9" occ.								
110'		2'-1" frag.			Caving			Grey		Below 111'7" core more broken due to AX drilling.
115'		2-6"								
120'		6-18"							120'–130' 130 p.s.i. 1.8 gals/min.	122' 30° joint 12" separation
125'		1-2" 2"				3-4				
130'		2-7"							130'10"– 140'10" 140 p.s.i. 2.4 gals/min.	
135'		6–12" + occ. 1–3"				½				137'6" weathered chlorite in matrix.
140'		± 6"							140'10"– 150'10" 150 p.s.i. 4.4 gals/min	143'0"–150'10" Conglomerate becomes darker and broken up – much loss. No definite indication of a fault. Higher water losses probably due to jointing.
145'		2"-frag.								
150'		12" 3"– frag.				1				152'3"–158'4" Grey quartz and quartzite conglomerate. Rock slightly weathered and much broken up into very short lengths. Joints rare but generally tight.
155'		1-5"							153'7"– 163'7" 150 p.s.i. 4.8 gals/min	
160'		2'-8" 3"								158'4"–200'1" Purple occasionally grey, hard, quartzite and quartz conglomerate. Rock contains much pyrite and joints often filled and matrix often permeated by it.
165'		± 8" Gen. 1-4"				2			161'9" 171'9" 150 p.s.i. 4.4 gals/min	
170'		15"								Joints generally tight, often filled occasionally slightly open and showing slight staining.
175'		4-8"							170'4"– 185'4" 150 p.s.i. 4.8 gals/min	159'6" 45° joint, 3" separation.
180'		20" 21"								161'0" 60° pyrite vein. 162' 15° pyrite vein. 180'6" 65° pyrite vein 180' 45° joint, 18" separation.
185'		1-5"				filled				
190'		6-14"				2			182'8"– 192'8" 150 p.s.i. 3.6 gals/min	Badly weathered joints down to 34' Elsewhere joints show slight weathering also often tight. Water losses directly linked to incidence of joints.
195'		3'-frag. 24"								Hole completed 200'1"
200'		1-8"				filled.			190'1"–200'1" 150 p.s.i. 3.8 gals/min.	Logged by G. E. Rawlings 5/12/64

FORM No. H.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5
LOCATION: CETHANA D.S.		ON LINE: HA 849 HA 802	BEARING: 0°00'	AT CH:	
GEOLOGICAL PLAN: A 11153 SURVEY PLAN: SA 120 80 11		AT STN: HA 849	BEARING: 120°22'	DIST: 576'	FILE No.
DATES (a) DRILLED: Oct.-Nov. '64 (b) WATER TABLE:	LEVEL.	SURFACE	COLLAR	WATER TABLE	
METHOD: D.D. DIAMETER: NX, BX, BWLC.		746			SHEET 1 OF 2 SHEETS
SITE REMARKS: Strike in solid conglomerate at top of left abutment. Same strike as DH SH40.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
		~~VERT./HOR.~~/INC.	5°	315° T	



WATER PRESSURE TESTS LEAKAGE	REMARKS
	0–12'11" Generally light grey, occasionally dark grey, quartz and quartzite conglomerate, weathered down to 2'6". Joints open or tight, occasionally filled, usually showing slight weathering. Matrix often grey-green in colour and occasionally weathered. Pebbles quite well cored usually ± 1½" diameter. Rock shows zones of strong limonite staining as at 23'10", 53'–54'4" & 68' due to film of iron surrounding pebbles and filling cracks. Rock occasionally very slightly weathered making pebbles indistinct.
20'-29'3" 50 p.s.i. 4.6 gals./min	
29'3"–39'9" 50 p.s.i. 4.0 gals./min.	
39'9"–48'9" 50 p.s.i. 4.8 gals./min.	
48'–62' 60 p.s.i. 5.8 gals/min.	6' Carbonate along joint.
62'–78' 80 p.s.i. 6.4 gals/min.	Below 71' core becomes more severely discoloured by limonite perhaps due to oxidation of Pyrite (seen at 81' and 94'6") Chloride occasionally present in the matrix
78'–100' 100 p.s.i. 5.6 gals/min.	

FORM No. H.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT		POSITION	CO-ORDINATES:	E:	N:
LOCATION: CETHANA D.S.			ON LINE:	BEARING:	AT CH:
GEOLOGICAL PLAN:	SURVEY PLAN:		AT STN:	BEARING:	DIST:
DATES (a) DRILLED: Oct.–Nov. '64	(b) WATER TABLE:	LEVEL	SURFACE	COLLAR	WATER TABLE
METHOD: D.D.	DIAMETER: NX, BX, BMLC.				
SITE REMARKS: Site in solid conglomerate at top of left abutment. Same site as DH 5440.		INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
			~~VERT./HOR./~~ INC.	5°	315° T

HOLE No. 5444

FILE No.

SHEET 2 OF 2 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
100' – 114'		A 14" with occ. zones 2"-frag. (?)				2-3			100'–121' 120 p.s.i. 5.8 gals/min.	
115'		3–7"								
		15"								
120' – 124'		1–8"				2-3.				Hole completed 124'4" Logged by G.E. Rawlings 16/12/64.

Depth scale: 100', 105', 110', 115', 120', 125', 30', 35', 40', 45', 50', 55', 60', 65', 70', 75', 80', 85', 90', 95', 00'

FORM No. H.E. 443

DRILLING RECORD

AREA: HERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E:	N:
LOCATION: CETHANA D.S.		ON LINE: HA 849 HA 802	BEARING: 0°00'	AT CH:
GEOLOGICAL PLAN: A11153 SURVEY PLAN: SA1208911		AT STN: HA 849	BEARING: 123°02'	DIST: 250'
DATES (a) DRILLED: Oct 1/64 (b) WATER TABLE:	LEVEL	SURFACE	COLLAR	WATER TABLE
METHOD: D.D. DIAMETER: NX, BX.		453		
SITE REMARKS: Site in solid quartzite at downstream edge of left abutment.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
		~~VERT~~/~~HOR~~/INC.	57°	305° T

HOLE No. 5445

FILE No.

SHEET 1 OF 1 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY %	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE
0'		6"–frag.	NX				Grey		
5'		9"–frag.							
		7"–frag.	BX						
10'						3-4			
15'									15-25' 60 p.s.i. 3.6 gals/min.
20'		6–11" occ. shorter				3			
25'									25'-32' 60 p.s.i. Nil
30'		2–7" occasionally fragmented				4-5			
35'									32'-43' 60 p.s.i. 3.6 gal./min
40'		1–4" occasionally fragmented				4-5			
45'									43'-53' 60 p.s.i. 2.4 gal./min.
50'		7"				7			
55'		3"–frag.							53'10"–60' 1.6 gal./min.
60'									
65'									
70'									
75'									
80'									
85'									
90'									
95'									
100'									

REMARKS

0–9'5" Hard weathered grey quartzite. Joints generally open but occasionally tight, although rock iron stained. Slight mineralisation and faint banding present. 4'8"–5'7" fragmented.

9'5"–60' Hard light grey to light purple banded quartzite. Joints generally tight although some still open. Many joints show iron staining and some decomposed chlorite.

7'0" 45° joint, 1" separation
85° joint, 2" separation.
15'6" 55° joint, 5-8 separation
12'6" 55° joint, very stained
14'0" 55° joint, stained and sheared.
30'8" 90° joint, very iron stained.
35'6" 80° joint, 1" separation
34'10"–37'6" No indication why core lost, rock flour along 45° joint.
24'0"–43'0" Joints all strongly stained by iron. Rock well jointed, core more broken up than above. No indication that 25'–32' zone is more waterbright.
43'0" 75° joint
30° joint, 3" separation.
59'6"–60'0" Quartz veined rock – core ground up, hence loss.

Hole completed 60'0"

Logged by G.E. Rawlings 4/11/64.

Iron stained joints to 43', slightly weathered joints to base of hole.

FORM No H.E. 443

DRILLING RECORD

AREA: HERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5446
LOCATION: CETHANA D.S.		ON LINE: HA 802 HA 849	BEARING: 0° 00'	AT CH:	
GEOLOGICAL PLAN: A 11153 SURVEY PLAN: SA 120 89 11		AT STN: HA849	BEARING: 153°57'	DIST: 82'	FILE No.
DATES (a) DRILLED: Oct./Nov. 1964 (b) WATER TABLE:	LEVEL.	SURFACE	COLLAR	WATER TABLE	
METHOD: D.D DIAMETER: NX, BX, BMLC.		432			SHEET 1 OF 4 SHEETS
SITE REMARKS: Site in solid quartzite on upstream edge of right abutment. Same site as DH 5437	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
		~~VERT./HOR.~~/INC.	70°	320° T	

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0'	2'-Frag	Frag	BX.				Grey			0-16' Hard, light grey to light brown jointed quartzite, mostly strongly weathered and often broken up. Joints open but also tight and mostly iron stained. Faint banding below.
5'	1-6"	Frag								
10'	Frag	1-6"								
15'	Frag	9"							15'-25' 50 p.s.i. 5·2 gals/min	16'-22'2" Hard. light grey, banded, jointed quartzite. Joints open and weathered but also tight Rock occasionally fragmented.
20'	1-5" occ. frag									
25'	1-10" occ. frag	2-9"							25'-35' 50 p.s.i. 2·8 gals/min.	22'2"-290'4" Light grey, greenish grey, dark grey or purple quartz and quartzite conglomerate. Rock generally fresh although many joints show slight traces of weathering. Joints occasionally tight but mostly open and showing slight weathering. Pyrites and occasionally hematite seen along joints. Pebbles large (+5"), occasionally undisturbed but often outlined by pyrites.
30'										
35'	Frag	5-11" occ. frag							35'-45' 50 p.s.i. 6·4 gals/min.	
40'	22'	2-11"				7-8				
45'	Frag	7-10"							45'-55' 55 p.s.i. 5·8 gals/min.	
50'	Frag	4"				1-2				54'-56' Rock stained purple and shows much pyrite.
55'	Frag	4"								
60'	1-5" occ. 8"	4-10"							55'-65' 60 p.s.i. 4·2 gals/min	
65'	1" frag	5-9"				4				
70'	1-4"								65'-75' 70 p.s.i. 3·4 gals/min.	68'4" Open joint, very strongly weathered.
75'	Frag	1-5" occ. 8"				4				
80'	Frag.								75'-85' 100 p.s.i. No loss.	83'4" 14" Quartzite boulder.
85'	2-4" Frag	6-18" occ. Less				5			85'-95' No loss	87'4" 5" pebble 'spotted' gtte.
90'										
95'	Frag 3"	4-9"				4			95'-105' 100 p.s.i. 1·2 gals./min.	
100'										

FORM No. H.E. 443

DRILLING RECORD

AREA: HERSEY FORTH POWER DEVELOPMENT

LOCATION: CETHANA D.S.

GEOLOGICAL PLAN: SURVEY PLAN:

DATES (a) DRILLED: Oct. Nov. 1964 (b) WATER TABLE:

METHOD: D.D. DIAMETER: NX, BX, BMLC.

SITE REMARKS: Site in solid quartzite on upstream edge of right abutment.

POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5 of 6
	ON LINE:	BEARING:	AT CH:	
	AT STN:	BEARING:	DIST:	FILE No.
LEVEL	SURFACE	COLLAR	WATER TABLE	
				SHEET 2 OF 4 SHEETS
INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
	~~VERT./HOR.~~/INC.	70°		

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0'		27"					Grey		95'-105' 100 p.s.i. 1.2 gal./min.	104' Pyrite filled joints ¼" wide.
10'		4'-9" occ. 1-3"				3			105'-115' 115 p.s.i. 0.8 gal./min.	100'-150' Joints still open and somewhat weathered – many also tight or sealed by pyrite.
15'		24"								
20'		4'-16" occ. less Frag.-2"				2			115'-125' 125 p.s.i. 1.0 gal./min.	120'-128' Iron pyrites and occasionally chalcopyrite strongly developed along joints and around pebble margins.
25'		2'-6"							125'-135' 135 p.s.i.	127'-138' Tendency for pebbles to become smaller, more uniform and more tightly packed.
30'		Frag.				3			1.8 gal./min	
35'		1'-5" 4"-8"							135'-145' 145 p.s.i.	
40'		Frag. 2'-5" Frag.							0.6 gal./min.	
45'		1" 4" Frag.-8"				5			145'-155' 150 p.s.i.	
50'		Frag. 1'-6" occ. Frag.				4-5			3.2 gal./min.	150'-200' Some joints still open and showing slight weathering.
55'		9" 13"							155'-165' 150 p.s.i.	
60'		1'-7"				2			2.8 gal./min	
65'		Frag.							165'-175' 150 p.s.i.	166'-174½' Hematite and pyrite well developed.
70'		Frag. 6" 4"-Frag.							3.4 gal./min.	
75'		Frag.-3" occ. 5"-8"				3			175'-185' 150 p.s.i.	
80'									5.6 gal./min.	Below 181' pebbles increase in size and more recrystallization occurs – pebble margins less obvious.
85'		1'-8"				4-5			185'-195' 150 p.s.i.	
90'		Frag.-6"							6.4 gal./min.	
95'		4'-12"				3			195'-205' 150 p.s.i.	
100'									10.2 gal./min.	

FORM No. H.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E:	N:
LOCATION: CETHANA D.S.		ON LINE:	BEARING:	AT CH:
GEOLOGICAL PLAN: SURVEY PLAN:		AT STN:	BEARING:	DIST:
DATES (a) DRILLED: Oct./Nov. '64 (b) WATER TABLE:	LEVEL.	SURFACE	COLLAR	WATER TABLE
METHOD: D.D. DIAMETER: NX. BX. CALC				
SITE REMARKS: Site in solid quartzite on upstream edge of right abutment.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
		~~VERT./HOR.~~/INC.	70°	

HOLE No. 5446

FILE No.

SHEET 3 OF 4 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
200'	1'2"	1'3"				2			195'-205' 150 p.s.i. 10.2 gal./min	200'-290'4" joints generally became tight but open pyrite or carbonate filling. Pebbles up to 4" diameter.
205'									205'-215' 150 p.s.i.	
210'		Good shells 4'-14° occ. 1'-2°				4-5			1.8 gal./min	
215'									215'-225'	
220'		8"				2			150 p.s.i. 2.2 gal./min.	219' 3" angular fragment of dark pyritous quartzite.
225'		3'-9°							225'-235'	
230'	1'2"	1'3"				2			150 p.s.i. 1.6 gal./min	
235'		mostly 5"-15" occ. 2" frag.							235'-245'	
240'		3° frag.				3			150 p.s.i. 1.6 gals./min.	
245'		4'-9°							245'-255'	
250'	1'7"	1'2"				1			150 p.s.i. 2.6 gals./min.	Below 253' pebbles again became distinct.
255'	11"	7"							255'-265'	
260'	6"	4'-6"							150 p.s.i. 1.8 gals./min.	258'9" - 259'9" Sheared quartzite conglomerate. 262'-263'7" Rock completely fragmented. Break-up appears to be due partly to brittle rock, strong jointing, presence of pyrite & green matrix. 264'7" - 265'7" Similar break-up to above
265'	Frag.	12"							265'-275'	
270'		8"-20" occ. less.				1-2			150 p.s.i. 1.4 gals./min.	Below 265'7" quartzite boulders up to 12" in diameter appear. Often strongly jointed.
275'									275'-285'	
280'	6"-Frag.	6"-24" occ. less.				1			150 p.s.i. 1.8 gals./min.	
285'									285'-303'	
290'		1'-5"				2			150 p.s.i. 1.8 gals./min	290'4" - 290'6" Sheared Cambrian/Ordovician junction dipping at 15° actual junction plane at base of conglomerate rather open & irregular. Junction shows sheared and slightly brecciated rock. 290'6" - 291'2" Sheared grey-green argillite. 291'2" - 303'3" Well foliated grey-green argillite
295'		3-12" occ. 1-2°								
300'						2-3.				

FORM No. H.E. 443

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E:	N:
LOCATION: CETHANA D.S.		ON LINE:	BEARING:	AT CH:
GEOLOGICAL PLAN: SURVEY PLAN:		AT STN:	BEARING:	DIST:
DATES (a) DRILLED: Oct/Nov. '64 (b) WATER TABLE:	LEVEL.	SURFACE	COLLAR	WATER TABLE
METHOD: D.D. DIAMETER: NX, BX, BMLC.				
SITE REMARKS: Site is solid quartzite on upstream edge of right abutment.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION
		~~VERT./HORT.~~ INC.	70°	

HOLE No. 5LL6

FILE No.

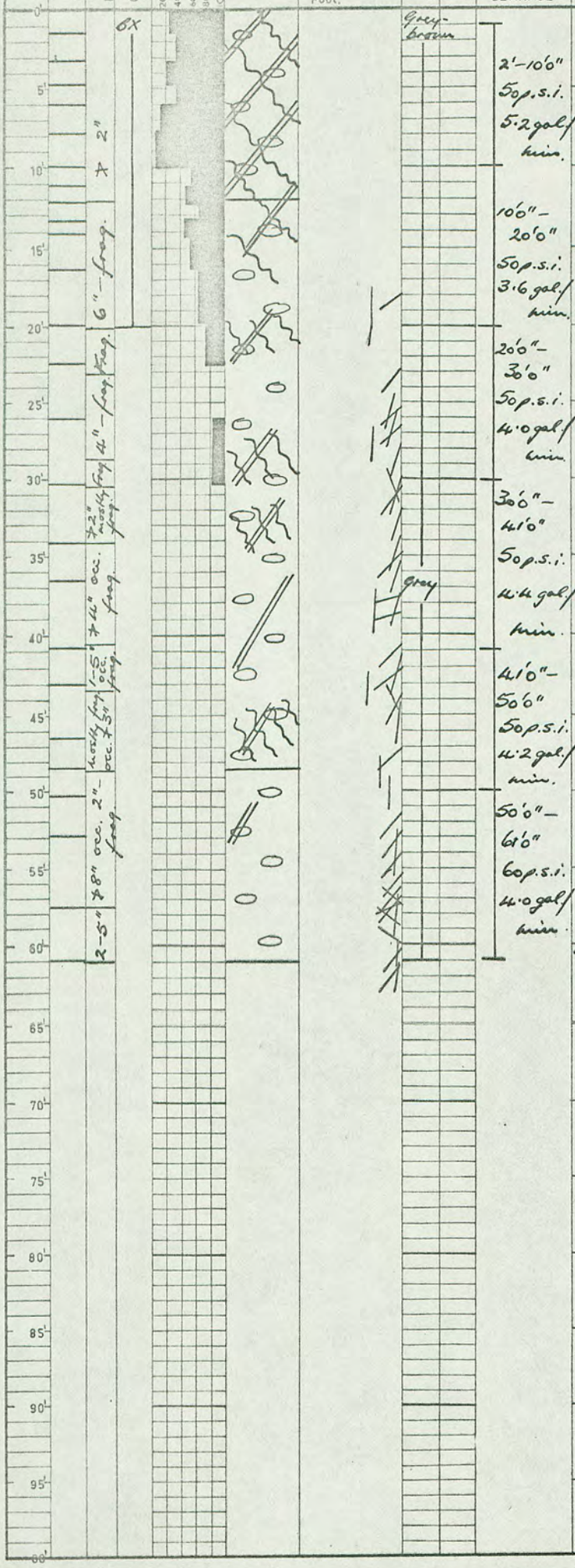
SHEET 4 OF 4 SHEETS

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
30 0'		3-12" 0.8-1.2'			∴ ‖ ‖ ∴					or slate becoming rather quartzitic below 295'6". Foliation at low angle (30°) near contact but becomes vertical at 295' and is often folded below. Joints usually filled by quartz, pyrite or limonite and tight although occasionally slightly open. Shear planes and foliation show ± 1/8" limonite, pyrite and arsenopyrite common. Occasional slight movement seen along joints.
5'										
10'										
15'										
20'										
25'										
30'										
35'										
40'										
45'										
50'										
55'										
60'										
65'										
70'										
75'										
80'										
85'										
90'										
95'										
303'3"										Hole completed 303'3' Logged by G. E. Rawlings 16/12/64.

FORM No. H.E. 443

DRILLING RECORD

AREA: HERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E:	N:	HOLE No. SM47
LOCATION: CETHANA D.S.		ON LINE: HA 849 HA 802	BEARING: 0° 00'	AT CH:	
GEOLOGICAL PLAN: A11153 SURVEY PLAN: SA120 8911		AT STN: HA 849	BEARING: 119° 50'	DIST: 511	FILE No.
DATES (a) DRILLED: Nov. '64 (b) WATER TABLE:	LEVEL.	SURFACE	COLLAR	WATER TABLE	
METHOD: D.D. DIAMETER: NX, BMLC.		712			SHEET 1 OF 1 SHEETS
SITE REMARKS: Site in gulley on downstream edge of left abutment.	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
		~~VERT./HOR./~~INC.	62°	300° T	



REMARKS

0–12' Angular to sub-angular fragments of quartz and quartzite conglomerate showing weathered joint surfaces – weathered & badly broken up bedrock.

12'–48'6" Weathered light grey to light brown quartz and quartzite conglomerate. Joints generally open and weathered and showing carbonaceous material. Rock occasionally completely fragmented.

Steep joints show the worst weathering.

48'6"–61'0" Light to dark grey, locally also pink and green, quartz and quartzite conglomerate, fresher than above but still showing many open weathered joints down to base of hole. Rock takes on greenish tinge due to matrix (presence of chloride?) Pocket of pyrites at 53'6" producing weathered rock.

Hole completed 61'0"

Logged by G.E. Rawlings

17/12/64.

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION: CO-ORDINATES:	E:	N:	HOLE No. 5448
LOCATION: CETHANA D.S.	ON LINE: HA849 / HA802	BEARING: 0°00'	AT CH:	
GEOLOGICAL PLAN: A11153 SURVEY PLAN: S4120811	AT STN: HA849	BEARING: 117°55'	DIST: 324'	FILE No.
DATES (a) DRILLED: Dec. '64 (b) WATER TABLE:	LEVEL: SURFACE	COLLAR	WATER TABLE	
METHOD: D.D. DIAMETER: NX BMLC	569			SHEET 1 OF 1 SHEETS
SITE REMARKS: Site in centre of left abutment. Hole drilled with mud from 30'	INCL.: HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
	VERT./~~HOR./INC.~~	90°		

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0'			BX				grey			0–54'4" Hard, slightly weathered, (occasionally more strongly) quartzite conglomerate. Pebbles rounded & sub-rounded occasionally sub-angular. Rock jointed, joints both open and tight occasionally showing slight weathering. Rock devitrified sporadically.
5'		3–14"								
10'		frag.					brown			
15'					Caving					
20'		3" – frag.			Caving					
25'		2–3"								
30'						2	Vole clay			
35'		1–9"								
40'		3" – frag.				4				
45'		1–4"								
50'		3–5" frag.				4				50' Small pocket of red quartzite. 50'–51'1" Rock fragmented.
55'		3" – frag.								54'4"–100' Purple-grey banded quartzite showing close joints often open. Thin clay seams are recovered at some horizons along planes dipping at low angle. Slight shearing and evidence of clay at conglomerate/quartzite junction.
60'		4" – frag.				4				56'10" Thin clay seam + 1/16" with vein quartz and sheared rock.
65'		2–4"								63'7" Thin clay seam and sheared rock + 1/4"
70'		3" – frag.				4				65'1" 1/8" clay.
75'										69'8" 3–4" desilicified quartzite – quartz grains set in sandy matrix with associated fragments of mudstone (breccia?)
80'		2–7" occ. fragmented				4				71'8" Saucy quartz.
85'										72'6" Evidence of thin clay.
90'						2				89' Sheared bedding planes.
95'		± 10' occ. ~3"								Rock becomes greyer and shows pyrites towards base of hole.
100'						5				Hole completed 100' Logged by G.K. Rawlings 6/1/65

DRILLING RECORD

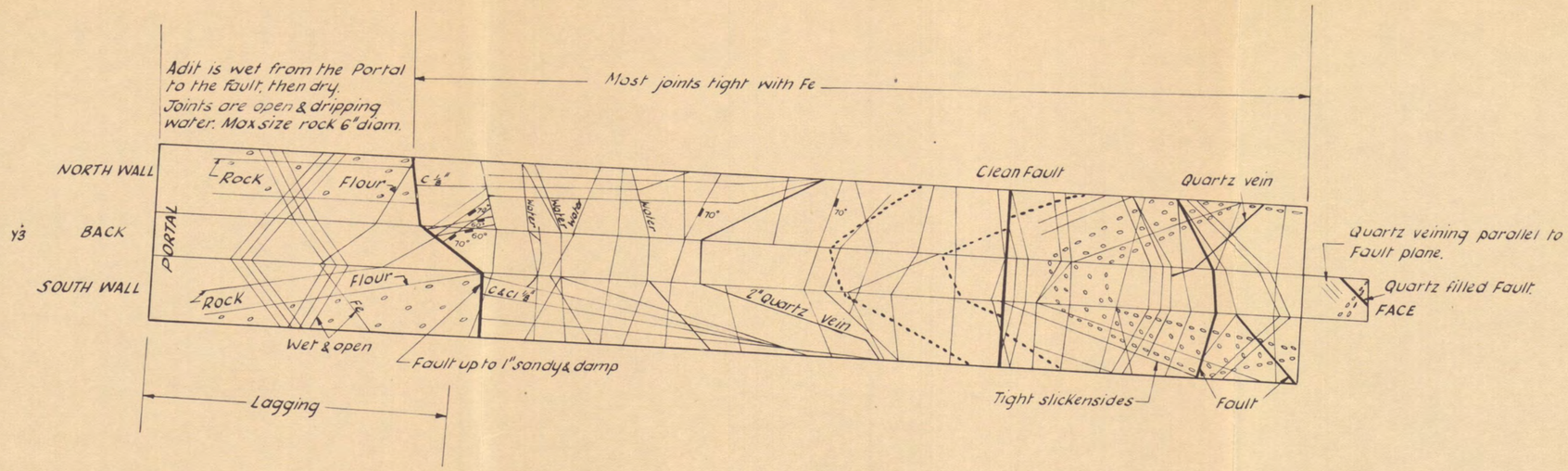
AREA: MERSEY FORTH POWER DEVELOPMENT	POSITION	CO-ORDINATES:	E:	N:	HOLE No. DH9
LOCATION: CETHANA D.S.		ON LINE: HAB49 / HAB02	BEARING: 0°00'	AT CH:	
GEOLOGICAL PLAN: A11153 SURVEY PLAN: SA120811		AT STN: HAB49	BEARING: 209°30'	DIST: 414'	FILE No.
DATES (a) DRILLED: Dec. 64 (b) WATER TABLE:	LEVEL.	SURFACE	COLLAR	WATER TABLE	
METHOD: D.D. DIAMETER: NX; BMLC.		623			SHEET 1 OF 1 SHEETS
SITE REMARKS: Site on path in centre of right abutment. Hole drilled with mud from 10'0"	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
		VERT./~~HOR./INC.~~	90°		

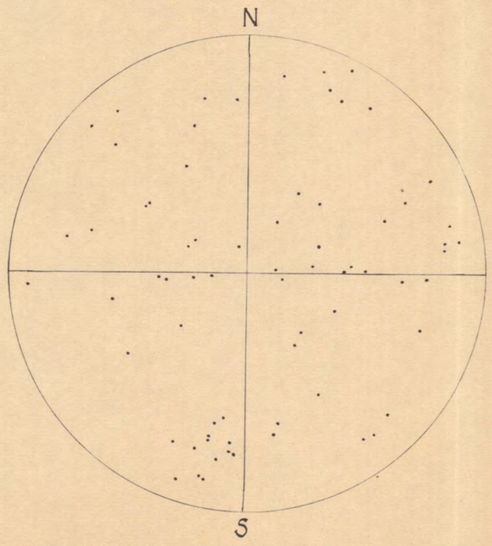
DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY % (20 40 60 80 100)	GRAPHIC LOG	JOINTS No. Per Foot	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0'		3'10" occ. frag.	NX				Grey			0–24'9" light & dark grey conglomerate composed of well rounded to sub-angular quartzite pebbles set in fine grained siliceous matrix. Pebbles less common than usual in Top Conglomerate and often not in contact. Large pockets of quartzite occur eg. 13'6" – 15'. Base of conglomerate is strongly broken up with a large core loss. Rock generally fresh, open joints down to 11'0 Driller reports 3' of sand between 5'6" and 10'0".
5'		2" – frag.					Brown			
10'		7'8" occ. 1" or less					Yellow clay.			
15'										
20'										
25'		3" frag.								24'9" – 60' Dark & light purple banded quartzite. Shear zones parallel to bedding, often with associated clay, common. Joints generally tight but maybe slightly open and showing slight weathering
30'		3" – 9" occasionally shorter.								33'10" – 34'8" three shear planes with suggestions of clay (not recovered)
35'						bedding				39'9" 1½" clay, broken and sheared rock.
40'										Quartzite immediately below junction shows sheared rock, chlorite and pyrite.
45'										
50'										
55'		1'4"								57'11" ½" sheared and broken rock with trace of clay.
60'		2'10" occ. frag.								60' Sheared rock.
65'										Hole completed 60'0"
70'										Logged by G.E. Rawlings 6/1/65
75'										
80'										
85'										
90'										
95'										
100'										

DRILLING RECORD

AREA: MERSEY FORTH POWER DEVELOPMENT.	POSITION	CO-ORDINATES:	E:	N:	HOLE No. 5450
LOCATION: CETHANA D.S.		ON LINE: HA 849 / HA 802	BEARING: 0°00'	AT CH:	
GEOLOGICAL PLAN: A11.63 SURVEY PLAN: 54120 8011		AT STN: HA 849	BEARING: 210°00'	DIST: 408'	FILE No.
DATES (a) DRILLED: Dec. '64 (b) WATER TABLE:	LEVEL.	SURFACE	COLLAR	WATER TABLE	
METHOD: D.D. DIAMETER: NX, BMLC.		691			SHEET 1 OF 1 SHEETS
SITE REMARKS: Same site as DH 5449	INCL.	HOLE DRILLED	ANGLE FROM HORIZONTAL	DIRECTION	
		VERT./~~HOR./INC.~~	90°		

DEPTH	CORE DRAWN	CORE LENGTH	CASING	RECOVERY %	GRAPHIC LOG	JOINTS No. Per Foot.	FLUID RETURN	GROUND WATER	WATER PRESSURE TESTS LEAKAGE	REMARKS
0'		4"-[illegible]					White			0-25'1" Dark - light purple & grey quartzite conglomerate. Pebbles rounded & sub rounded occasionally not in contact with each other. Rock jointed, joints open down to 10'6". Occasional patches of reddish-grey quartzite exist as at 11'6". Quartz veins ± ¼" occur below 17'6". Core much fragmented below 22' with consequent loss - loss believed to be broken rock rather than clay
5'		± 6"				2				
10'		½" - 4"					Yellow clay			
15'		± ½" occ. [illegible]				3				
20'		2"-[illegible]								
25'		± 10"				5				25'1"-60' Purple - grey banded sst - quartzite showing occasional joints and much shearing along the bedding. Occasional clay zones seen generally accompanied by shearing. Joints usually tight perhaps showing slight staining.
30'		1-8"								
35'		± 4"				2				26'2" 2-3" broken rock and clay. 33'6" Sheared rock 34'2" " " 34'7" " "
40'		3-12"								37'4"-37'7" " " 37' ± ½" Sheared rock and clay & quartz
45'		18"				0				47'10" 1" clayey quartzite. 51'3"-51'9" Broken rock
50'		± 6" often less.								
55'						3-4				57'4" 6" of clay and rock fragments much ground up, also 1" bedded (?) clay. 60' 1" Sheared rock and quartz.
60'										Hole completed 60'0" Logged by G.E. Rawlings 17/1/65.
65'										
70'										
75'										
80'										
85'										
90'										
95'										
00'										





Stereogram of joint-systems at Cethana damsite.
Readings taken from eight locations.

N

ORDOVICIAN

Roland Formation Quartzite

- Conglomerate band
- Quartz pebble band
- Fault
- Joint
- C Carbonate
- Cl Clay
- Fe Iron stain

To accompany Geological Report 644-126-1

A11153 Geology

Reference

THE HYDRO-ELECTRIC COMMISSION TASMANIA

MERSEY FORTH POWER DEVELOPMENT

CETHANA

PLAN OF EXPLORATORY ADIT No. 2

Plotted	B.W.H.	Traced	B.W.H. 16/1/68	Checked	G.E.H.	SCALE
Geologist: G. Hale			Geologist in Charge: G Hale			10 Feet to 1 Inch

C4991

Please leave

E412 KYDS
E200FT
E400FT
E600FT
E800FT
N2200FT
N891KYDS
2000FT
N1800FT
N1600FT

ORDOVICIAN

Om Moina Sandstone

Roland Conglomerate

Oru Upper Conglomerate

Orq Quartzite

Orl Lower Conglomerate

FORTH RIVER

ADIT 1

ADIT 3

ADIT 4

ADIT 5

ADIT 6

ADIT 7

DH5443

DH5442

DH5449

10,000 Seismic compressional wave velocity ft/sec

←8500→ Travel path along adit

8500 Travel path between adits or between adits and surface

To accompany report 644-126-2

A11153 - Geology

THE HYDRO-ELECTRIC COMMISSION TASMANIA

MERSEY FORTH POWER DEVELOPMENT

CETHANA SCHEME

SEISMIC INVESTIGATION

Plotted	P.W. McD	Traced		Checked	P.W. McD.	SCALE
Geophysics by: P.W. McDowall		Geologist in Charge				40 Feet to 1 Inch

B9162

THE HYDRO-ELECTRIC COMMISSION

TASMANIA

MERSEY-FORTH POWER DEVELOPMENT

THE SEISMIC DETERMINATION OF YOUNG'S MODULUS AND POISSON'S RATIO AT CETHANA DAM - SITE

THE HYDRO-ELECTRIC COMMISSION

TASMANIA

MERSEY-FORTH POWER DEVELOPMENT

THE SEISMIC DETERMINATION OF YOUNG'S MODULUS AND POISSON'S RATIO AT CETHANA DAM - SITE

P. W. McDOWELL.

REPORT No. 644-126-2.
Accompanied by: B9162.

THE SEISMIC DETERMINATION OF YOUNG'S MODULUS AND POISSON'S RATIO FOR CETHANA DAM-SITE

I. INTRODUCTION.

A seismic survey was conducted in May 1965 to determine Young's modulus and Poisson's ratio at the proposed site of Cethana dam. The seismic 'spreads' were restricted to the adits because of the difficulty and danger of working on the steep sides of the valley. Also the work will provide a comparison between the dynamic elastic moduli obtained by the seismic method and the static elastic moduli from jacking tests in the adits. Further this information, and the geological 'mapping' of the adits, will enable the expensive jacking tests to be sited to best advantage.

Additional information was obtained by measuring the travel time of seismic waves from 'adit-to-adit' and from 'surface-to-adit'. In this way larger blocks of rock, less disturbed by the blasting necessary to drive the adits, could be investigated. Also the travel paths of seismic waves could be selected to investigate the anisotropy of the rock.

II. GEOLOGY.

The geological investigation report (644-Ceth-1) by G.E. Hale accompanied by plans: A11153, B8349, C4991, describes the geology of Cethana damsite and environs. Especial attention is drawn to the section VI Engineering Geology which describes the conditions of the fault zones and joints that traverse the site. At the damsite Ordovician quartzites and conglomerates of the Roland Conglomerate beds are encountered. Generally, these beds are massive and dip upstream at a shallow angle. There are however zones of shearing associated with some of the faults which contain broken fragments separated by rock flour, or chlorite, or chlorite weathered to clay. Apart from these 'zones' the effect of weathering on the rocks is slight. However considerable relaxation of joints close to the surface is attributed to physical weathering and stress relief due to erosion of the river valley.

III PRINCIPLES.

Elastic theory establishes the following relations among Poisson's ratio μ, Young's Modulus E, the compressional and shear velocities α and β and the density γ.

$$\mu = \left(\tfrac{1}{2}\alpha^2/\beta^2 - 1\right)\left(\alpha^2/\beta^2 - 1\right)$$

$$E = \gamma\alpha^2(1+\mu)(1-2\mu)/144g(1-\mu)$$

$$E = \gamma\beta^2(1+\mu)/72g$$

where α, β, γ, and g are in ft. - lb.-sec. units and E is in lb/sq.in. Poisson's ratio is seen to depend only on the ratio of the seismic velocities. Evison discusses the importance of determining Poisson's ratio, rather than assuming a value for it to obtain a reliable estimate of Young's Modulus. For compact rocks, such as those at Cethana, variation in Poisson's ratio has little effect on the value of E but it was thought necessary to determine the value of μ for differing rock conditions at this dam-site.

It is difficult to evaluate the density of the in-situ rock through which the elastic wave has passed. Kudo et al describes a back-scattering gamma-ray density meter. The values of γ measured this way were found to be 10-15% smaller than those measured on corresponding cores from the same part of the rock. At present one density determination has been made on conglomerate and one on quartzite cores from Cethana dam-site. Except for the weathered shear-zones these values and published density determinations for quartzite are quite representative, when reduced by 15%, of the in-situ density.

IV. INSTRUMENTATION.

The S.I.E. - Dresser seismic refraction equipment and the M.D.I. shallow seismic equipment were both used to measure the travel times of seismic waves. The use of a travelling microscope enabled the seismic records from the former equipment to be read to $\frac{1}{2}$ of a millisecond or better and the M.D.I. can measure to $\frac{1}{4}$ of a millisecond.

The S.I.E. equipment was used almost exclusively, however, because the signal to noise ratio could be controlled and all the arrivals of seismic waves at each geophone could be recorded and preserved on photographic paper. Also 3-component geophones that record ground motion in three mutually perpendicular directions could be used with this apparatus.

Compressional and shear waves were produced by an explosive source but at two locations a swinging-weight source was used to produce directional shear waves.

V. RESULTS.

The measured velocities of seismic waves for travel paths, along the adits (see Plan) and the corresponding elastic moduli are shown together for each adit worked.

ADIT 7.

Portal(G3) to Bend in Adit (G6); α = 10,000 ft/sec.

Quartzite w. open joints μ = 0.33 (estimated)

γ = 155 lbs/cu.ft. E = 2.26×10^6 lbs/sq.in.

Bend in Adit (G3) to G2; α = 9,000 ft/sec.

Quartzite: sheared, with chlorite β = 4,300 ft/sec.

and clay between blocks. μ = 0.36

γ = 145 lbs/cu.ft. E = 1.5×10^6 lbs/sq.in.

G2 to end of adit.

U. Conglomerate w. closed joints. α = 16,000 ft/sec.

γ = 150 lbs/cu.ft. μ = 0.24 (est). E = 7.0×10^6 lbs/ sq/in.

ADIT 6.

Portal to bend in adit(G3); α = 6,200 ft/sec.

Quartzite with open joints μ = 0.33 (est.)

γ = 155 lbs/cu.ft. E = 0.87×10^6 lbs/sq.in.

G3 to end of adit; α = 16,000 ft/sec.

Quartzite with closed joints μ = 0.24 (est.)

γ = 155 lbs/cu.ft. E = 7.3×10^6 lbs/sq.in.

ADIT 5.

Portal to bend in adit;

Quartzite w.open joints near portal

γ = 155 lbs/cu. ft.

α = 7,500 ft/sec.

β = 3,800 ft/sec.

μ = 0.33

E = 1.3×10^6 lbs/sq.in.

Bend in adit to end of adit;

Bedding planes in quartzite, open or clay filled in parts.

γ = 145 lbs/cu.ft.

α = 9,500 ft/sec.

μ = 0.33 (est.)

E = 1.9×10^6 lbs/sq.in.

ADIT 4.

Portal to G8(20' inside adit)
Lower Conglomerate, with open joints.

γ = 155 lbs/cu.ft.

α = 5,000 ft/sec.

μ = 0.33 (est.)

E = 0.57×10^6 lbs/sq.in

G8 to bend in adit
Lower Conglomerate, jointed and faulted.

γ = 155 lbs/cu.ft.

α = 8,000 ft/sec.

μ = 0.33 (est.)

E = 1.45×10^6 lbs/se.in.

Bend in adit to end of adit
Mainly conglomerate with closed joints.

γ = 155 lbs/cu.ft.

α = 15,000 ft/sec.

μ = .24 (est.)

E = 6.4×10^6 lbs/sq/in.

ADIT 3. Power Station Area.
Lower conglomerate, jointed & faulted.

γ = 155 lbs/cu.ft.

α = 10,000 ft/sec.

β = 5,000 ft/sec.

μ = 0.33

E = 2.26×10^6 lbs/sq.in

ADIT 3: G1 to G12.

G1 to G8:
Lower Conglomerate with closed joints.

γ = 155 lbs/cu.ft.

α = 12,000 ft/sec.

μ = 0.29 from comparison of travel times of compressional and shear waves over length of spread

E = 3.65×10^6 lbs/sq.in.

G8 to G12;
Quartsite, sheared & jointed.

γ = 155 lbs.cu.ft.

α = 9,000 ft/sec.

μ = 0.29

E = 2.3×10^6 lbs/sq.in.

ADIT 3. offshoot.
Quartzite, sheared & jointed.

γ = 155 lbs/cu.ft.

α = 10,000 ft/sec

μ = 0.33 (est.)

E = 2.26×10^6 lbs/sq.in.

The velocities of compressional waves, and in some cases shear waves, for travel paths through relatively 'undisturbed' rock from 'adit to surface' and from 'adit to adit' are also shown on Plan B9162. All travel paths have been projected to the horizontal plane so a different convention has been adopted to distinguish these 'travel paths' from the 'travel paths' along the adits.

It is not valid to average the compressional wave velocities recorded in each 'block' because of the large range of the velocities. The range, for each 'block', of compressional wave velocity, and the corresponding range of Young's Modulus, have been calculated.

ADIT 1 to ADIT 7.

γ = 155 lbs/cu.ft. α ..... 10,000 - 11,600 ft/sec.

Upper Conglomerate in part; Mainly Quartzite
E ..... 2.68 - 3.62 x 10^6 lbs/sq.in.
μ = 0.27 (calculated).

ADIT 6 to ADIT 7.

In part Upper Conglomerate, mainly Quartzite.
α .....7,800 - 10,800 ft/sec.
E .....1.36 - 2.61 x 10^6 lbs/sq.in.
γ = 150 lbs/cu.ft. μ = 0.33 (est.)

Surface at D.H.5443 to Adit 6.

Mainly Quartzite,
α .....8,700 - 11,300 ft/sec.
E .....1.82-3.08 x 10^6 lbs/sq.in.
γ = 155 lbs/cu.ft. μ = 0.31 (calculated).

Surface D.H,5449 to Adit 5.

Mainly Quartzite partly Upper Conglomerate
α .....5,800 - 8,100 ft/sec.
E .....0.76-1.5 x 10^6 lbs/sq.in.
γ = 155 lbs/cu.ft. μ = 0.33 (calculated).

Surface at D.H. 5442 to Adit 5.

Mainly Quartzite
α .....5,700 - 10,300 ft/sec.
γ = 155 lbs/cu.ft. E .....0.78 - 2.54 x 10^6 lbs/sq.in.
μ = 0.31 (est.)

ADIT 3 toADIT 4.

Mainly Lower Conglomerate
α .....8,700 - 10,200 ft/sec.
E .....2.04 - 2.74 x 10^6 lbs/sq.in.
γ = 155 lbs/cu.ft. μ = 0.27 (est.)

Surface at D.H.5442 to Adit 4.

Mainly Lower Conglomerate
α .....5,100 - 8,000 ft/sec.
E .....0.59 - 1.45 x 10^6 lbs/sq.in.
γ = 155 lbs/cu.ft. μ = 0.33 (est.)

VI. CONCLUSIONS.

It is clear from the seismic velocities that the major factors influencing the variation in seismic wave velocity are 'jointing' and 'shearing' of the rocks. Laboratory work on rock specimens by M.R.J. Wyllie, A.R. Gregory and L.W. Gardner, confirms the statement that poor coupling of cracks in materials can cause great decreases in velocities. Open dry joints must persist to 20 ft. from the surface in Adit 4 and 30 ft. from the surface in Adit 6 because the low velocities of 5,000 ft/sec and 6,000 ft/sec were recorded. Closed joints and joints filled with clay or water are expected to be the cause of velocities between 8,000 and 12,000 ft/sec. Only in a few places was the laboratory determined value of 17,500 ft/sec.(which is also the expected velocity of seismic waves through fresh unfractured quartzite) recorded.

The extensive 'zones of shearing' in the Quartzite of Adits 4,5 and 7 have velocities between 7,500 and 9,500 ft/sec. - the clay and chlorite must provide seismic coupling between the blocks of quartzite. In the other areas of investigation geological faults appear to have little influence on seismic wave velocity.

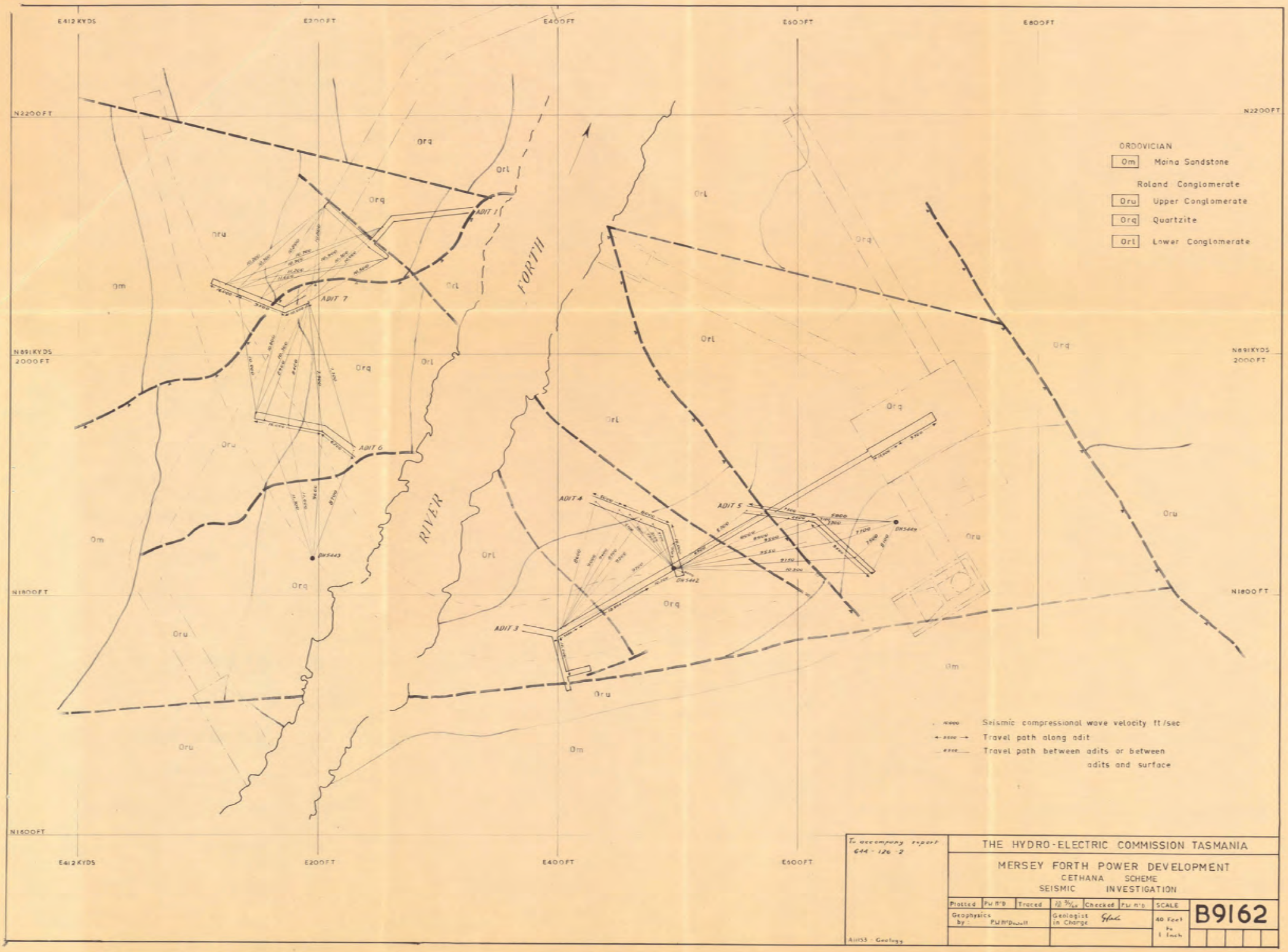
The elastic moduli determined in this work are 'dynamic moduli' for rock subjected to very small stresses and elastic deformation. It is expected that static tests that cover joints opened by 'blasting' of 'Physical weathering' will yield low values of E initially through inelastic deformation but approach the dynamic values of E as these joints are closed.

VII. REFERENCES.

'The Seismic determination of Young's Modulus and Poisson's Ratio for rocks in-situ'. F.E. Evison, Geotechnique 1956.

'Dynamic Investigation of Foundation rocks in-situ'. T.F. Onodera. Proc. 5th Symp. on Rock mechanics 1962.

'Elastic wave velocities in heterogeneous and porous media' M.R.J. Wyllie, A.R.Gregory and L.W. Gardner, Geophysics Vo.XXI. Jan. 1956.



To accompany report 644-126-2

THE HYDRO-ELECTRIC COMMISSION TASMANIA

MERSEY FORTH POWER DEVELOPMENT
CETHANA SCHEME
SEISMIC INVESTIGATION

Plotted	P.W. M°D	Traced		Checked	P.W. M°D	SCALE
Geophysics by: P.W. M°Donnell			Geologist in Charge			40 Feet to 1 Inch

B9162

A1953 : Geology

TMB/RMN

[redacted] NAVEN.

G. E. I

CETHANA TAILRACE

HYDRAULICS
23rd August, 1967

Reference: Cethana Tailrace - Minutes Meeting 25/7/67.

The following comments are made using the paragraph numbers of the reference.

Para. 4.6

The levels set out in Table 1 are confirmed.

Para. 4.7

All spoil deposited in the river bed must be removed over the length of the river improvements and 800 feet beyond.

Para. 4.8

1. Velocities of Jet on Impact

The head loss in Cethana Spillway chute has been calculated as 29 ft. Subtracting this from head available between reservoir surcharge level and jet impact position gives an available potential head of 330 ft. and an impact velocity of 146 ft. per sec. A recommendation has already been made in the Cethana Dam Spillway Model Studies that part of the river wall in the jet impact area be trimmed off in order to expose sound rock if possible, and to facilitate the passage of the water in getting away cleanly and with the least amount of splash. When this material is removed there will still be 50 ft. of rock, measured horizontally, between the rock face at the toe of the cut and the projection of the outside edge of the access road. (See Figure 1 attached). With this in mind and providing the uncovered rock face is good unweathered material it is considered that no concrete protection will be needed in this area. If the material is found to be badly weathered or friable then a skin of concrete should cover it. If it is jointed but not weathered then rock bolting is suggested between river bed level and S.L.425 over the area outlined in Figure 1.

2. Extent of Spray Area

This is not clearly defined by the model studies because of surface tension effects. However, from a study of where drops of water did land in the model it would seem that the areas shown hatched on the accompanying Figure 2 could be thoroughly drenched by spray during the operation of the spillway at high discharges. No installations susceptible to moisture should be placed in this area. Attention should be given also to providing first class drainage of the access road in this area.

3. Debris in River Valley

The water from the jet after impact sweeps up on the right bank for considerable distance downstream. All loose material should be removed from this area to prevent its accumulation in the river valley further downstream. The area that should be cleared is shown in Figure 2 crosshatched.

An inspection should be made of the exposed rock mentioned in Para. 1 above to decide what protection is needed.

Sluicing of the area shown on Figure 2 crosshatched should be done down to the end of the river improvements.

Para. 4.10

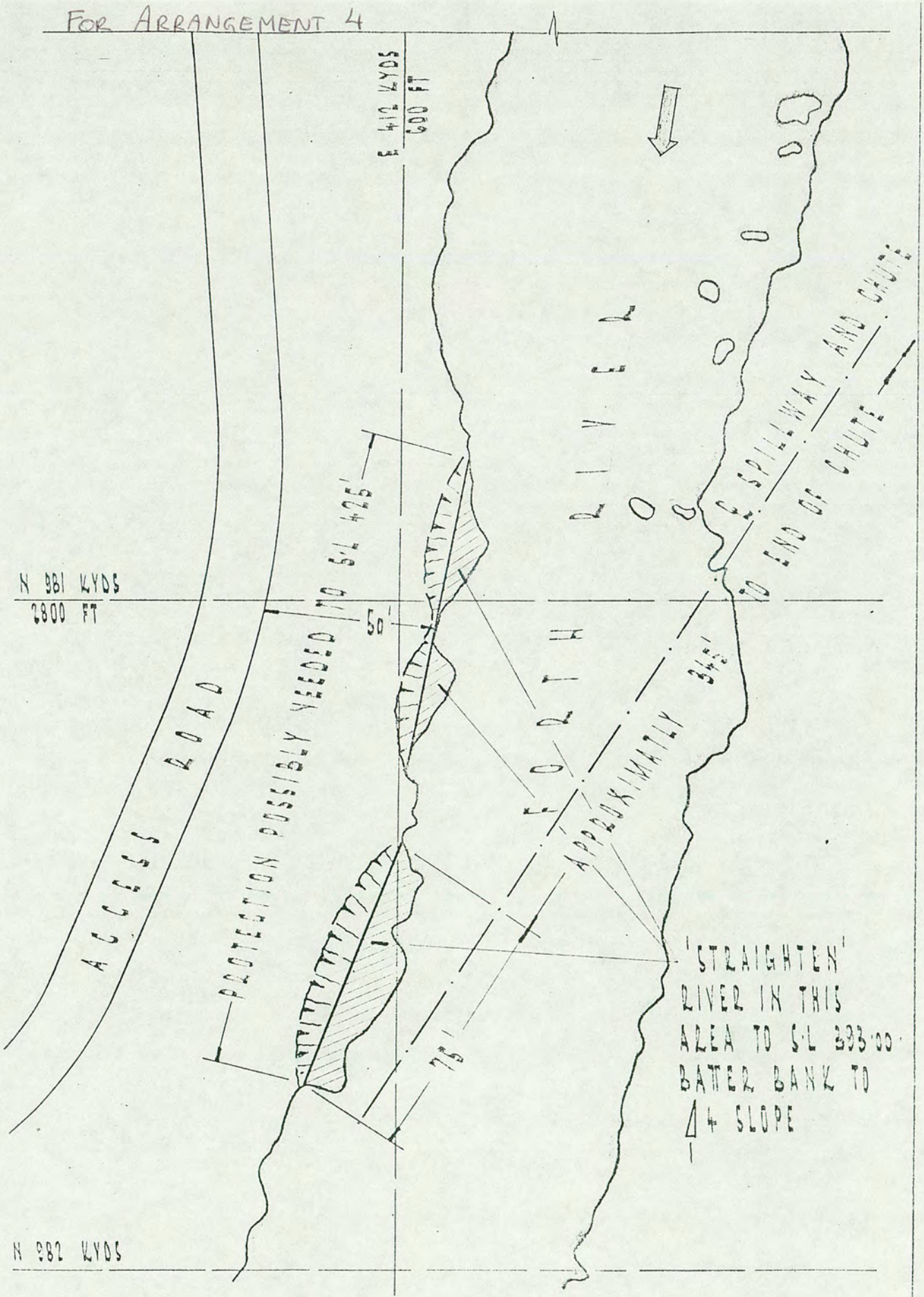
It is not economic to line the tailrace tunnel invert. The cost of lining is about $12,000 and we can afford to pay only $6,000 for this work on value of head gained.

However, material say 2" size and under will be eroded and may cause minor problems in the improved river until the first flood occurs. It is desirable to grade the floor only for maintenance purposes not hydraulic considerations.

B. L.

for Hydraulics.

c.c.
Penstocks
G.E.III
Gates and Valves
W.F. Nevin



CETHANA DAM SPILLWAY

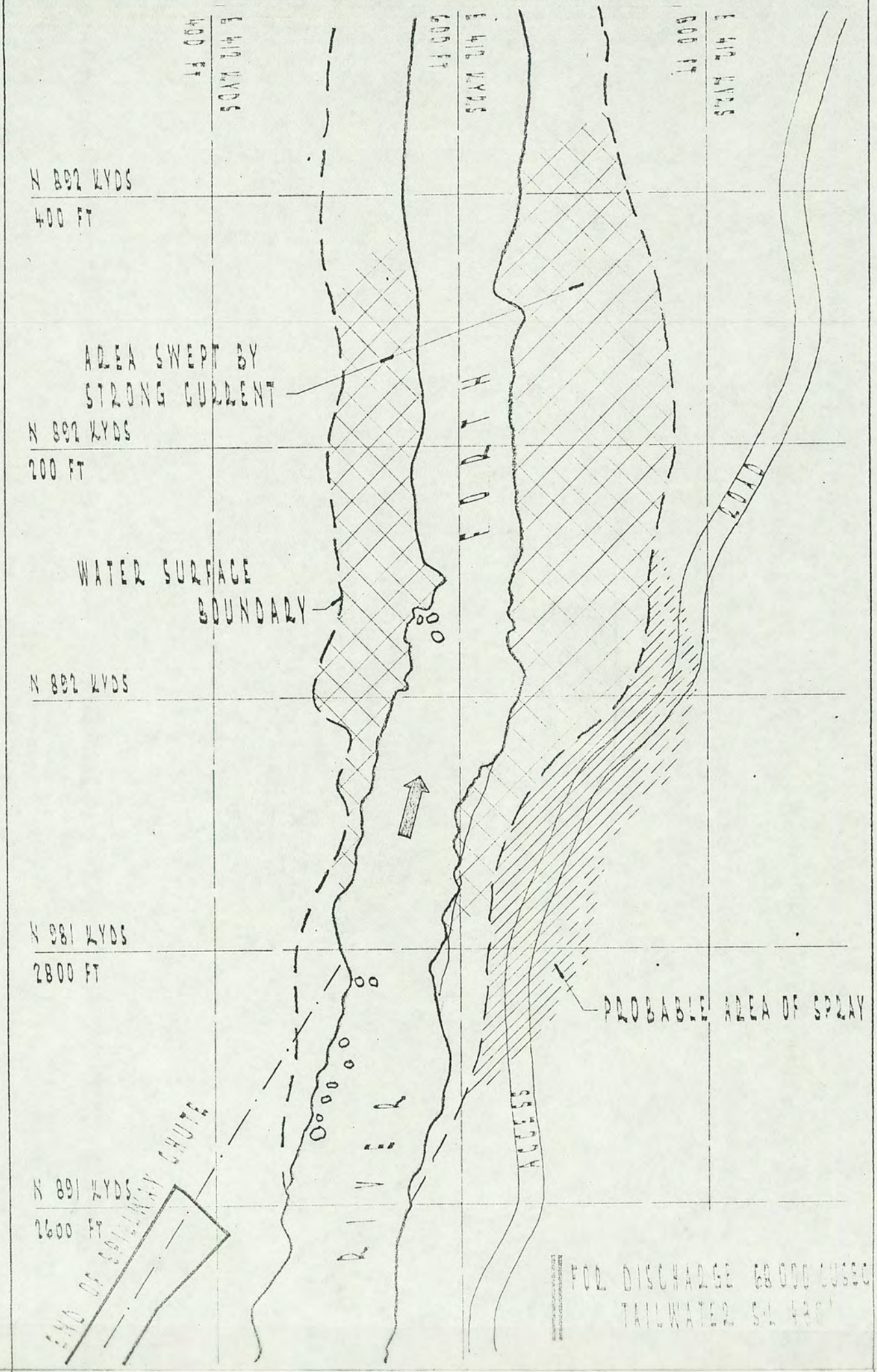
MODEL STUDIES

EXCAVATION IN JET IMPACT AREA

FIG. 1

DRAWN : W.O.K.	CHECKED : G.T.R.	SCALE : 1" = 40'-0"	15 5 63

FOR ARRANGEMENT 4



CETHANA DAM SPILLWAY

MODEL STUDIES

CONDITION WITH SPILLWAY DISCHARGING

FIG 2

DRAWN : W.C.K.	CHECKED W.A.H.	SCALE : 1" = 100'-0"	18-8-67

No. 3407

INSPECTION REPORT

Name of Structure .....:		CETHANA DAM
Date .....:		23rd and 24th April, 1968.
Inspection By .....:		N. O. Boughton, G.E.A. Hale.
Field Engineers Present .....:		G. Bolt, S. Patterson, F. Sarno.
Purpose .....:		Inspection.
Items Inspected:-	(1)	Spillway excavation below S.L.610.
	(2)	
	(3)	

Remarks by Inspecting Engineer:-

(1) Poor rock in face of bench at S.L.591 is caused by intersections of diagonal faults and horizontal fault. Excavation below S.L. 605 to be adjusted to allow for concreting whole face if necessary with strips 10 ft. high, stressing cables @ 8' c/c horizontally.

~~Action Taken:-~~

Immediate action is to cut present bench to S.L.589, with wall batter set back about 6 ft. so that 2 ft. thick concrete will lie behind 3H:1OV line from chute floor corner. (Sketch supplied, drawing to follow). Depending on nature of rock exposed, concreting on this berm may be required to be about 15 ft. and forms should be ordered accordingly.

~~Action Required:-~~

Full concrete and stressing treatment required on face above S.L.589 between spillway chainages 752 and 897. Between spillway chute and ch. 752, badly faulted rock to be excavated by hand and covered with 1 ft. minimum thickness concrete, and bolted to sound rock adjacent.

Geologists to map as much as possible of area while concreting and stressing in progress, as advance information. Treatment at each level to be decided after inspection by Designs.

Mortar pads to be set on vertical joints above excavation to check on movements.

N. Boughton

26/4/68.

No. 3408

INSPECTION REPORT

Name of Structure .....:		CETHANA DAM.
Date .....:		24th April, 1968.
Inspection By .....:		N. Boughton, G. Hale.
Field Engineers Present .....:		G. Bolt.
Purpose .....:		Inspection.
Items Inspected:-	(1)	Dam plinth foundation adjacent to blocks 19 p1, 19 p2.
	(2)	
	(3)	

Remarks by Inspecting Engineer:-

(1) Field proposal to place concrete, upstream of plinth, in order to retain the road, is approved, provided the concrete does not encroach on the plinth foundation.

~~Action Taken:-~~ Plinth foundation in this area is quite sound, and extension of plinth to provide longer leakage path would not be required.

N. Boughton.

26/4/68.

Chief Geologist – for information

No. 65

INSPECTION REPORT

Name of Structure ..... :		Parangana Dam.
Date ..... :		24th April 1968.
Inspection By ..... :		N. Boughton, G.E.A. Hale.
Field Engineers Present ..... :		T. Lee.
Purpose ..... :		Inspection.
Items Inspected:-	(1)	Riprap on dam embankment.
	(2)	Spillway downstream from lined section of chute.
	(3)	

Remarks by Inspection Engineer:-

(1) Present method of placing riprap by placing large rocks in contact and then chinking voids with smaller particles is very good.
If it is not possible to obtain enough broken rock within specification size by selection from adjacent rockfill or other sources, it is preferable to use +4" rounded cobbles (aggregate reject) than -3" broken rock for chinking.

(2) Apart from a small area adjacent to the chute cut-off, no rock downstream from the chute could be ripped. Schist appears hard and tight. Some erosion of the left channel wall could occur, but floor and right wall erosion should be slight.

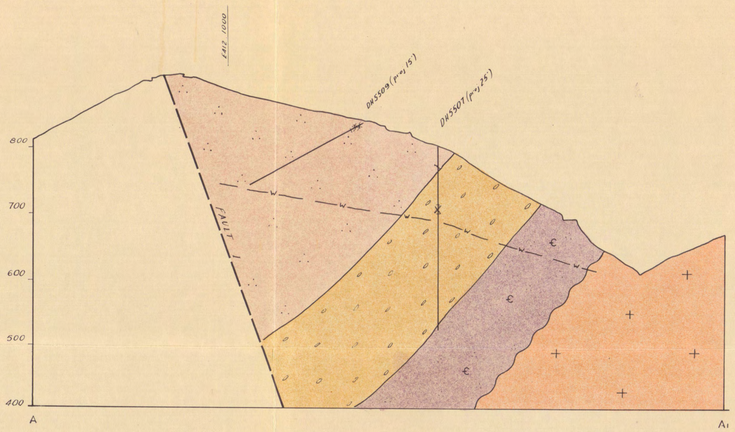
No requirement for concrete lining downstream from the end of the lined chute.
However trench for cut-off wall below chute floor should be taken down as far as possible without explosives.

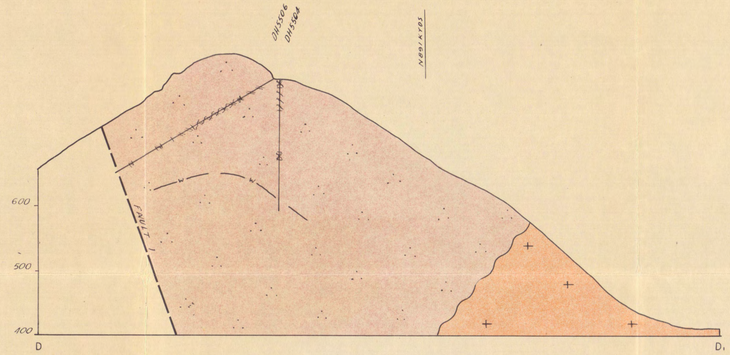
N. Boughton.

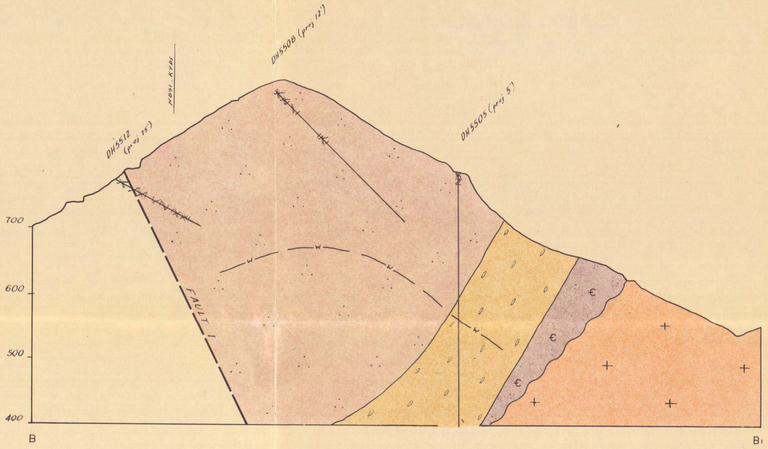
26/4/68

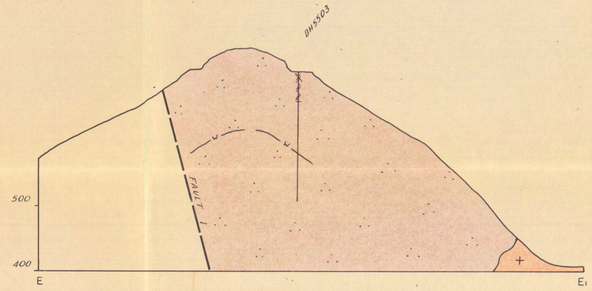
THE HYDRO-ELECTRIC COMMISSION TASMANIA			
MERSEY FORTH POWER DEVELOPMENT CETHANA QUARRY GEOLOGY			
Drawn G.E.R.	Traced	Checked G.E.R.	SCALE
Geology by: G.E.Rawlings	Geologist in Charge		100 Ft to 1 inch 1:1200

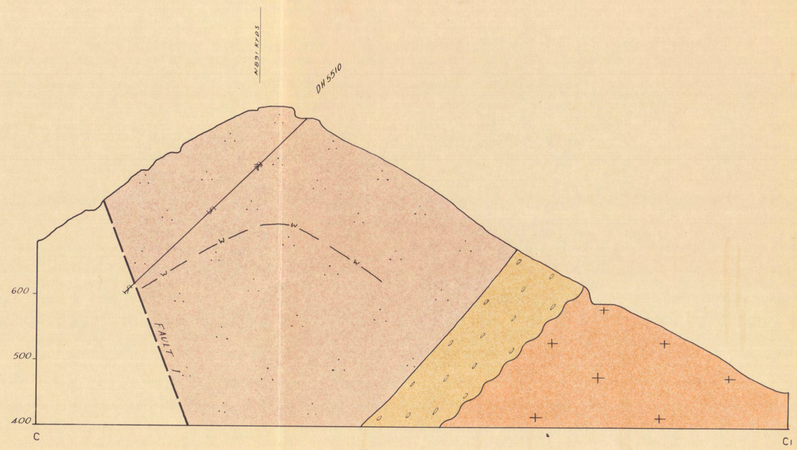
A14022

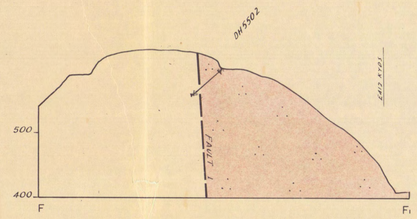












DEVONIAN

Granite

ORDOVICIAN

Moina Sandstone

Roland Conglomerate

CAMBRIAN ?

Quartzite

Geological Boundary

Unconformity

Fault

Water Table as indicated by weathering along joints

DH5503 Drill Hole

weathered rock

broken rock

Rock to North (left) of Fault 1 mainly deeply weathered quartzites

To Accompany: Memo to G.M.C. Nov '66

Ref. Drwgs:

A14022 - Geology

THE HYDRO-ELECTRIC COMMISSION TASMANIA

MERSEY FORTH POWER DEVELOPMENT

CETHANA QUARRY

GEOLOGICAL SECTIONS A - F

Drawn	G.E.R.	Traced		Checked	G.E.R.	SCALE	A14062
Geology by G.E. Rawlings		Geologist in Charge				100 Ft to 1 Inch 1:1200	


HAULAGE ROAD
ACCESS ROAD
OLD DOZER TRENCH
COVERED BY SPOIL
WEATHERED AND DECOMPOSED
SLOPE COVERED BY TALUS AND SPOIL
BEDS EXTRAPOLATED
OBSCURED BEDS EXTRAPOLATED
DECOMPOSED AND WEATHERED
PARTIALLY WEATHERED TO FRESH
SERIES 1
SERIES 3
SERIES 4
SERIES 5
SERIES 6
SERIES 7
SERIES 8
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
SECTION E-E
SECTION F-F
SECTION G-G
SECTION G'-G'
DOZER TRENCH
DH5503
DH5504
DH5505
DH5506
DH5507
DH5508
DH5509
DH5510
DH5512
DH5516
GF238
GF238D
GF238E
FORTH RIVER
E 1000 ft
E 0800 ft
E 0600 ft
E 0400 ft
E 0200 ft
DEVONIAN
Ddlgr GRANITE
ORDOVICIAN
MOINA SANDSTONE
Om QUARTZITE —FRESH
Om QUARTZITE —DECOMPOSED AND WEATHERED
Om QUARTZITE —DECOMPOSED AND WEATHERED WITHIN A FRESH QUARTZITE SERIES
ROLAND CONGLOMERATE
Or ROLAND CONGLOMERATE
CAMBRIAN?
€ QUARTZITE
BEDDING DIPPING
BEDDING HORIZONTAL
SURVEY STATION
FORMATION BOUNDARY
BOUNDARY BETWEEN FRESH AND DECOMPOSED — WEATHERED QUARTZITE
CONCEALED BOUNDARY BETWEEN FRESH & DECOMPOSED— —WEATHERED QUARTZITE
NORTHERLY BOUNDARY OF QUARRYABLE QUARTZITE
OUTLINE OF ORIGINAL QUARRY BOUNDARY
SERIES 2 etc., SEE EXPLANATORY NOTES ATTACHED
ANTICLINE
SYNCLINE
DRILL HOLE WITH DIRECTION & DIP
To Accompany:
Ref. Drwgs.
THE HYDRO-ELECTRIC COMMISSION, TASMANIA
MERSEY–FORTH POWER DEVELOPMENT
CETHANA SCHEME
QUARRY
Drawn N.H.H. GODFREY
Traced N.H.H. GODFREY
Checked
SCALE 1:40
Geology by: G.E. RAWLINGS & N.H.H. GODFREY
Geologist in Charge
A14659

E412 KYDS

E413 KYDS

N892 KYDS

N891 KYDS

FORTH RIVER

Claude Creek

Proposed Access Road without Diversion

CETHANA DAMSITE A11153

CLAUDE CREEK SYNCLINORIUM

COCKATOO RIDGE ANTICLINORIUM

N

ORDOVICIAN

Om Moina Sandstone

Roland Conglomerate

Oru Upper Conglomerate

Orq Quartzite

Orl Lower Conglomerate

CAMBRIAN

€

Geological Boundary

Unconformity Plan

Unconformity Section

Fault Normal

Fault Thrust

Anticline

Syncline

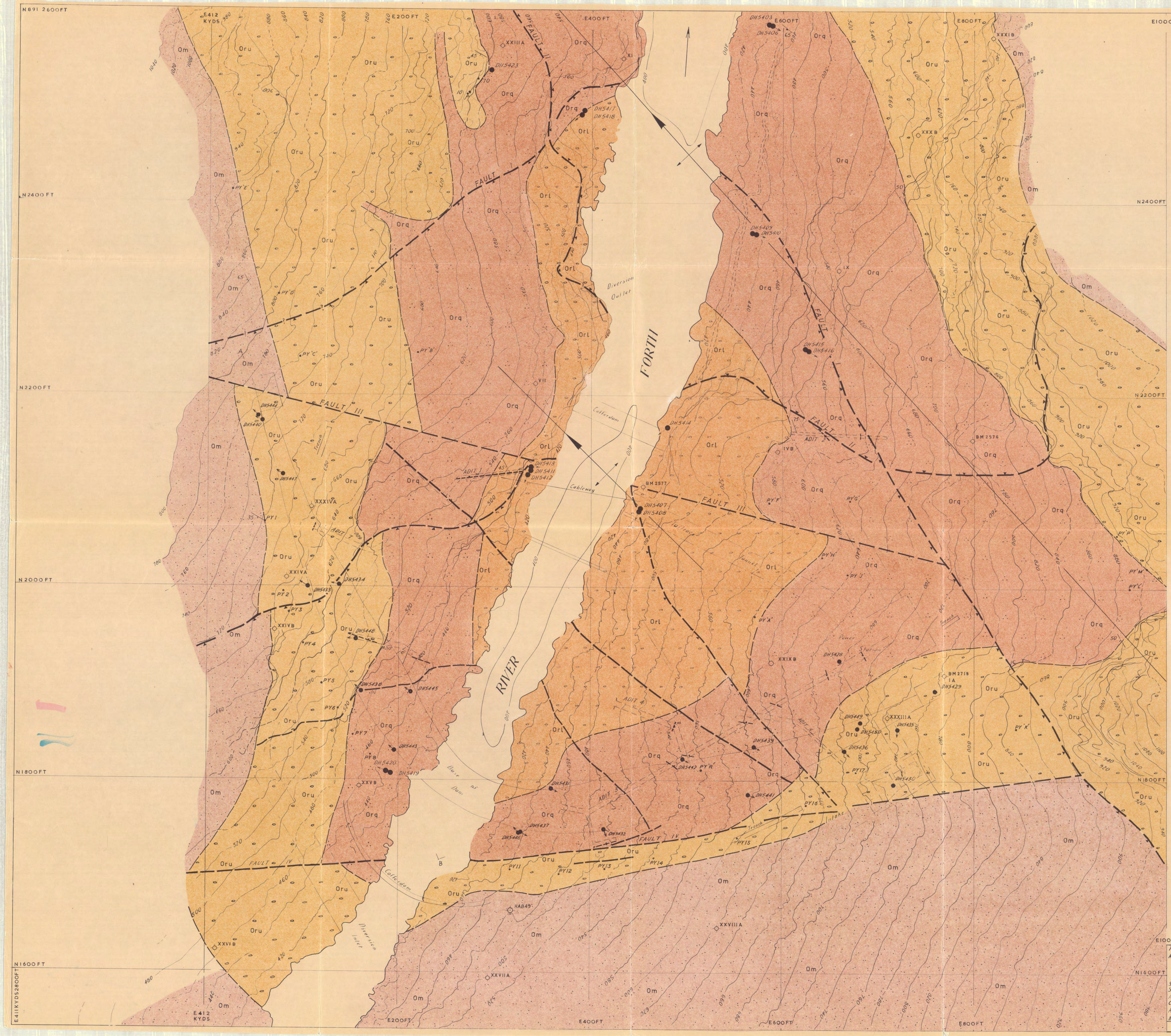
Strike & Dip of Beds

Projection of left bank geology

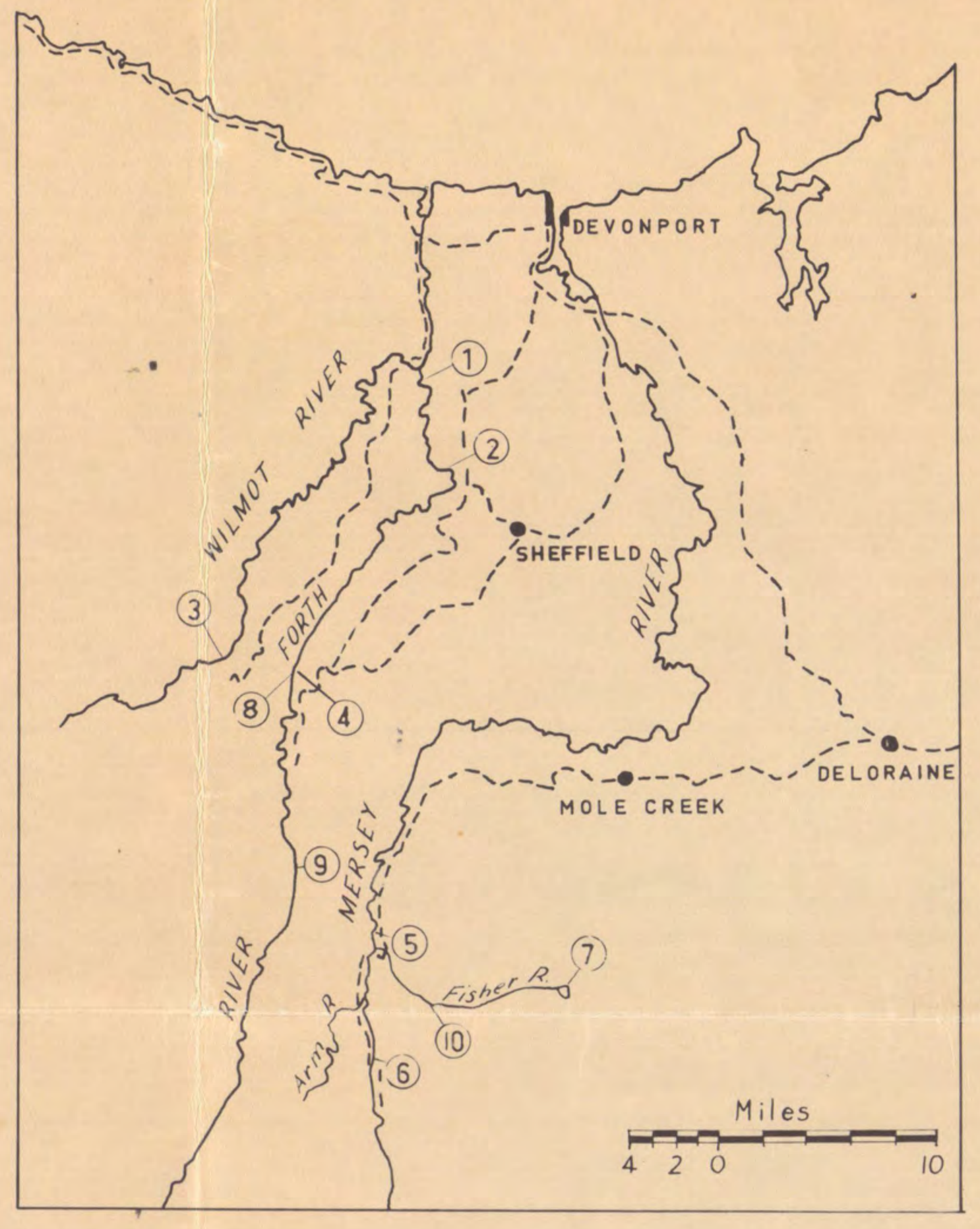
Claude Ck

To Accompany: Geological Report 64A-Ceth-1	THE HYDRO-ELECTRIC COMMISSION TASMANIA				
	MERSEY FORTH POWER DEVELOPMENT				
	CETHANA SCHEME				
Ref. Drawings S4-410890	REGIONAL GEOLOGY				
	Plotted	Traced	Checked	SCALE	B8868
	Geology by G.E. Hale, K.D. Corbett and C.E. Rawlings	Geologist in Charge		400 FT TO 1 IN	

ORDOVICIAN
Om Moina Sandstone
Roland Conglomerate
Oru Upper Conglomerate
Orm Middle Conglomerate
Orq Quartzite
Orl Lower Conglomerate
Geological Boundary - established
Geological Boundary - approximate
Fault – Normal
Fault – Reverse or Thrust
Fault – Adit position
Bedding Plane Shear
Anticline with Plunge
Dip of Bedding
Dip of Joint
Vertical Joint
Drill Hole with direction & angle
N
RIVER
FORTH
Proposed Diversion Tunnel
FAULT IV
C Redrawn
To Accompany: Geological Report 644 - Cetn - 3
Ref. Drwgs
XS 759 - Survey
A10845 Adits 1,4,5 & 7
A12227 Adit 3
B9203 Diversion Tunnel
B9523 Adit 6
C5963 Adit 8
THE HYDRO-ELECTRIC COMMISSION TASMANIA
MERSEY FORTH POWER DEVELOPMENT
CETHANA DAMSITE
GEOLOGY
Drawn
Traced
Checked G.E.R.
Geology by: G.E. Rawlings
Geologist in Charge
SCALE 20 Feet to 1 Inch 1:240
A12390



LOCALITY PLAN



1. Upper Paloona
2. Devils Gate
3. Wilmot
4. Cethana
5. Parangana
6. Rowallan
7. Lake Mackenzie

POWER STATION & PENSTOCK

8. Wilmot
9. Lemonthyme
10. Fisher

N

ORDOVICIAN

Om	Moina Sandstone
	Roland Conglomerate
Oru	Upper Conglomerate
Orq	Quartzite
Orl	Lower Conglomerate

Joint — Vertical
Joint — Dipping (60)
Bedding Dipping (75)
Geological Boundary
Fault Thrust
Fault Normal
Fault adit position
Anticline
Drill Hole (DH5406)
Survey Control Station (XX)
Survey Point (PY1)

To accompany Geological Report 6.44-126-1

S41208911 } Survey
S41208912 }
A12227 - Adit 3
C4991 - Adit 2
A10845 - Adits 1,4,5,6 & 7
B8349 - Section

Reference

THE HYDRO-ELECTRIC COMMISSION TASMANIA

MERSEY FORTH POWER DEVELOPMENT

CETHANA DAMSITE
GEOLOGY

Plotted	G.E.H. P.R.P.	Traced	7/4/65	Checked	G.E.H.	SCALE
Geology by:	G.E. HALE	Geologist in Charge	G Hale			40 Feet to 1 Inch

A 11153